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Attention Functioning Among Adolescents With Multiple Learning, Attentional, Behavioral, and Emotional Difficulties

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Abstract

Attention-deficit/hyperactivity disorder (ADHD) is characterized by high levels of inattention, hyperactivity, and impulsivity; however, these symptoms can result from a variety of reasons. To obtain a comprehensive understanding of the various difficulties of individuals with ADHD, especially when co-occurrence difficulties are present, it is essential to combine neuropsychological and subjective assessment tools. In the present field study the authors investigated a group of adolescents with multiple deficits (MD) using neuropsychological and subjective measures. Teachers' ratings verified extremely high levels of symptoms of oppositional behavior, inattention, hyperactivity-impulsivity, social problems, and emotional problems in this group. As expected, MD group participants showed decreased abilities to maintain attention on task for a long period of time, focus attention and effectively inhibit adjacent distractors, and resist conflicting irrelevant information. Importantly, although significant differences in the attention measures were observed at the group level, not all MD participants displayed deviant performance. Thus, we conclude that the heterogeneous group of adolescents with MD comprises individuals with primary attention deficits as well as those with other nonattentional deficits that show equivalent behavioral symptoms. Using neuropsychological tools can be useful in differentiating between different core deficits and in guiding appropriate interventions.

Keywords

learning difficulties, ADHD, behavioral problems, emotional problems, adolescents, neuropsychological measures

Attention plays a major role in different types of learning in various contexts (Petersen & Posner, 2012). In light of the substantial role that attention plays in acquiring and managing important skills in everyday life, and given the fact that inattention symptoms can result from various problems (Feldman & Reiff, 2014; Nigg, 2005; Pritchard, Nigro, Jacobson, & Mahone, 2012), in the present study we wished to investigate attention functioning in a group of adolescents with various disabilities who could not be retained in general education schools. Investigating attention functioning in such a sample can be a great challenge; in the present study many participants suffered from emotional, social, and academic problems that could explain behavioral symptoms of inattention, hyperactivity, and impulsivity. Thus, under such circumstances in particular, direct assessment of attention can disentangle between primary attention deficits and secondary attention deficits and contribute to understanding the core deficits that impair the ability of these individuals to adaptively behave in school settings as well as in other settings.

While symptoms of inattention may be present in various situations and syndromes they are perhaps mostly associated with attention-deficit/hyperactivity disorder (ADHD), which is characterized by inappropriate levels of inattention and/or hyperactivity-impulsivity. It is one of the most prevalent childhood chronic behavioral disorders, with an estimated prevalence of 5% to 10% in children (Scahill & Schwab-Stone, 2000). In adolescence, ADHD strongly correlates with substance abuse (Molina & Pelham, 2003), low academic achievement (Barkley, Fischer, Edelbrock, & Smallish, 1990; Weyandt & Dupaul, 2008), and risk-taking behavior (McNamara, Vervaeke, & Willoughby, 2008). In the United States, ADHD is considered to be a major public health problem, with large-scale

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implications for society and individuals (Chacko, Kofler, & Jarrett, 2014; Ferguson, 2000; Pritchard et al., 2012).

ADHD is not necessarily present in isolation and is frequently accompanied by other comorbidities such as disruptive behavior disorders (oppositional defiant disorder or conduct disorder; Bird, Gould, & Staghezza-Jaramillo, 1994; Jensen et al., 2001), anxiety disorders (Biederman, Newcorn, & Sprich, 1991; Jensen et al., 2001), and learning disabilities [LDs] (Pastor & Reuben, 2008). Furthermore, comorbidity is so prevalent that researchers of a large-scale U.S. survey found that 4% of children met the criteria for both LD and ADHD (Pastor & Reuben, 2008).

Learning disabilities was recently redefined in the fifth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (*DSM-5*) (American Psychiatric Association [APA], 2013) as a Specific Learning Disorder. This general diagnostic category refers to deficits that affect academic achievement and encompasses difficulties in different academic fields such as reading, mathematics, and written expression (Tannock, 2013). LD is a frequently occurring disorder, with an estimated prevalence of 7.5% among children and adolescents (Boyle et al., 2011). All of the previously mentioned comorbid disorders (as well as others) can display similar behavioral symptoms such as inattention, restlessness, and difficulties in withholding inappropriate responses, to name a few. Thus, it is imperative to rule out other causes for behavioral and emotional symptoms in order to reach accurate assessment of ADHD. Failure to do so will impede the obtainment of effective treatment and improvement in the functioning of individuals with ADHD (Chacko et al., 2014; Feldman & Reiff, 2014; Pritchard et al., 2012).

Until recently, most of the theoretical frameworks for developmental disorders such as ADHD and LD emphasized single-deficit models, which assume that each syndrome has its own distinct environmental and genetic source (Pennington, 2006). However, such "simple" models have been criticized by many researchers (e.g., Frith, 2003; Morton, 2004; Nigg, 2005; Pennington, 2006; Willcutt et al., 2010). A major point of weakness in single-deficit theories is their inability to explain cognitive impairment subtypes. For instance, a large amount of evidence has indicated heterogeneity of cognitive profiles among individuals with ADHD (Nigg, 2005; Sonuga-Barke, Bitsakou, & Thompson, 2010; Tsal, Shalev, & Mevorach, 2005). Moreover, the admittedly high prevalence of comorbidity between some syndromes (as in the case of ADHD and LD) implies at least partial contingency between allegedly independent processes. Therefore, from a cognitive point of view, ADHD is best conceptualized using a multiple pathways model referring to several different etiologies that may lead to similar behavioral manifestations (e.g., Nigg, 2005; Pennington, 2006; Tsal et al., 2005; Willcutt et al., 2010; Willcutt, Sonuga-Barke, Nigg, & Sergeant, 2008). The theoretical framework of the present study is a multiple pathways model that treats attention as a multifaceted construct (Tsal et al., 2005).

Indeed, contemporary theories in cognitive neuroscience characterize the human attentional system as composed of several distinct attention networks (Parasuraman, 2000; Petersen & Posner, 2012; Posner & Petersen, 1990; Tsal et al., 2005). Tsal and his colleagues (2005) described a model derived from Posner and Petersen's (1990) influential theory of attention networks that refers to four distinct functions within the attention regime: (a) sustained attention—the ability to allocate attentional resources to a nonattractive task over time while maintaining a relatively constant level of performance, (b) selective (spatial) attention—the ability to focus attention on a relevant target while ignoring adjacent distracters, (c) orienting attention—the ability to direct attention over the visual or auditory field according to sensory input and to disengage and reorient efficiently, and (d) executive attention—the ability to resolve conflicts of information and/or responses. These four functions of attention act as separate (at least to a certain extent) cognitive modules. Based on the concept of attention as a multifaceted system, these researchers assessed each of its distinct components within a group of children diagnosed with ADHD who displayed different clusters of attention deficits (Tsal et al., 2005). Such findings are in line with a growing body of evidence that validates the idea of attention as composed of distinct networks (Fan, McCandliss, Sommer, Raz, & Posner, 2002; Shalev & Algom, 2000; Shalev, Mevorach, & Tsal, 2008; Tsal et al., 2005). One prominent benefit of a multidimensional approach to attention in the context of ADHD is that it breaks down the somewhat vague concept of "inattention" into specific well-defined core deficits (i.e., difficulty in maintaining attention on a given task for a long period of time, difficulty in focusing attention on a restricted area of the perceptual field, difficulty in inhibiting a response to an irrelevant aspect of an attended object) that may underlie certain difficulties in a variety of everyday functioning. For example, in a recent study with adolescents with and without ADHD, Stern and Shalev (2013) found that sustained attention played a major role in reading comprehension, although none of the participants with ADHD suffered from a reading disorder.

Arguably, these previous studies suggest that any attempt to assess attention deficit and its comorbidities at the cognitive level should consider attention in a multidimensional fashion. However, the clinical diagnosis procedure of ADHD does not treat attention as composed of different functions. Instead, it is based on subjective observations of behaviors that in many cases are common among other syndromes, such as LDs, anxiety, depression, and conduct disorders (APA, 2000; Nigg, 2005; Pritchard et al., 2012). In addition, such subjective evaluations can be biased and contingent on the observer's point of view (Sims & Lonigan, 2012). Interestingly, although cognitive neuropsychology contributed significantly to current theory of ADHD (Koziol & Stevens, 2012; Pritchard et al., 2012), it offered limited, if any, contribution to the behavioral measures used for diagnosis (Lezak, Howieson, Loring, Hannay, & Fischer, 2004). Furthermore, neuropsychological assessment tools do not always provide a clear criterion that can differentiate between performance of individuals with ADHD versus those without ADHD in various tasks (Nigg, Willcutt, Doyle, & Sonuga-Barke, 2005; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). Therefore, while ADHD is seemingly a steady behavioral construct with three different and partially distinct subtypes (predominantly inattentive, predominantly hyperactive/impulsive, combined inattentive and hyperactive/impulsive) (see *Diagnostic and Statistical Manual of Mental Disorders*, fourth edition [*DSM-IV*]; APA, 2000) or presentations (see *DSM-5;* APA, 2013), neuropsychological assessment reveals a more complex picture.

One group whose members suffer the most from the implications of ADHD is adolescents. Within this group, in addition to common comorbidity rates, there are risks such as smoking and substance abuse or dependency (Horner & Scheibe, 1997; Milberger, Biederman, Faraone, Chen, & Jones, 1997). In addition, adolescents are exposed to competition, anger, violent behavior, and different sources of anxiety (Feindler, 1995; Ommundsen & Vaglum, 1991), not to mention age-related behavioral patterns such as risk taking, increased conflicts with adults, aggression, and so forth (Spear, 2000). The coexistence of so many behavioral risk factors makes it difficult, perhaps virtually impossible, to distinguish according to behavioral symptoms; that is, cases with a distinct, real syndrome from those representing the "standard" problems of adolescence. Adolescents with ADHD show deficient social comprehension and social problem solving (Miller & Hinshaw, 2010), form fewer friendships and close friends, and quite frequently have to cope with peer rejection (Hoza et al., 2005; Wehmeier, Schacht, & Barkley, 2010). Adolescents and young adults with ADHD are prone to be dangerous drivers, to be involved in car accidents, and to encounter more severe injuries while driving (Barkley & Cox, 2007; Weiss & Murray, 2003). Clearly, adolescents with ADHD are highly susceptible to a variety of adverse effects and therefore should be treated carefully.

The Current Study

The experimental group in the current study included a group of 9th- and 10th-graders from a single high school that can be described as the very last station before complete school dropout. The school's students come from low socioeconomic status, some of them come from broken families, many of them experience learning difficulties, and the academic achievements of *all of them* are well below the norm. Many of these adolescents are characterized by attention deficits and/or behavior problems; others suffer from social and/or emotional problems. Not surprisingly, the teachers of these adolescents rated them (on the group level) as demonstrating extremely high levels of symptoms of oppositional behavior, inattention, hyperactivity-impulsivity, and social and emotional problems (see Table 2 in the Results section). Thus, these individuals suffer from various severe problems, all of which impair significantly their ability to learn. We call this group the multiple deficits (MD) group hereafter. From a methodological point of view, investigation of such a sample poses substantial constraints. However, in light of the vast negative implications of ADHD in adolescence that were briefly described above, and given the similar presentations of symptoms of inattention, hyperactivity, and impulsivity in a variety of psychopathologies, examining the attention functioning of adolescents with multiple academic, behavioral, and emotional problems is of great importance and may shed light on the core deficits. Moreover, this investigation tests the feasibility of neuropsychological tools to differentiate between individuals with primary attention deficits and individuals who have other primary deficits that may produce inattention, hyperactivity, and impulsivity symptoms. Such assessment may be useful in guiding appropriate interventions and in adjusting efficient teaching techniques (Pritchard et al., 2012).

Thus, in the present research, our aim was to measure attention functioning using neuropsychological tools derived from the four functions of the attention model as well as subjective evaluations of behavioral symptoms, in extremely severe cases of disadvantaged adolescents at high risk for juvenile delinquency and with high levels of symptoms of various behavioral syndromes (as detailed above). In a previous study, Tsal et al. (2005) found that most children with ADHD were characterized by a deficit in sustained attention and that approximately half of the participants with ADHD demonstrated deficits in selective (spatial), orienting, and executive attention. Importantly, the attention tasks that Tsal and his colleagues designed to assess the attention functioning of children with ADHD produced large effect sizes (Cohen's d > 1.0; Stern & Shalev, 2013; Tsal et al., 2005). In addition, in a very recent study (Mazor-Karsenty, Parush, Bonneh, & Shalev, 2015), the Location-Direction task—which we used in the present study to assess executive attention—differentiated between young adults with ADHD and young adults with sensory modulation disorder, a disorder characterized by behavioral symptoms that overlap with ADHD (distractibility, impulsiveness, disorganization, and hyperactivity). Moreover, the Conjunctive Continuous Performance Task (CCPT) that was developed to assess sustained attention (Shalev, Ben-Simon, Mevorach, Cohen, & Tsal, 2011) produced strong correlations with reading and reading comprehension among adolescents with and without ADHD (Stern &

Shalev, 2013), demonstrating the relevance of this task to the academic functioning of adolescents with and without ADHD. In the present study we therefore used three of the four neuropsychological tools that Tsal and his colleagues had used. The data for the participants in the MD group were collected in the school and were compared with data of age- and gender-matched control participants (the control group), who were assessed in their homes. Thus, the data of all the participants in the present study were collected in the field, where the conditions are much noisier than in lab settings.

Method

Tel Aviv University and the Ministry of Education Ethics Committees approved the experimental protocol. The authors obtained relevant informed consent from participants and parents/guardians.

Participants

The total number of participants in this study was 76. Of these, 38 (19 girls) were students at a single high school in Tel Aviv, Israel. This was a school for adolescents on the verge of dropping out. All students in the school are of normal intelligence and are from various socioeconomic backgrounds. All students failed to meet the minimal academic requirements of general education high schools. Thus, the academic level of the school is rather low, and all students can be basically defined as having learning difficulties. Most students exhibit behavioral problems, including conduct disorder, oppositional disorder and other undefined problems. In addition, the students in this school are likely to also have emotional problems, attention problems, and LDs.

Unfortunately, most of the students had not been assessed for a didactic or psychiatric diagnosis previously. Thus, in this study we relied on standard symptoms rating scales completed by the school's teachers (PsychTech LTD, 2003). These 38 participants were assigned to the MD group. Nine participants in the MD group were regularly treated pharmacologically (with psychostimulants), and they took their medicine as usual during the time they were participating in the study.

The remaining participants were 38 students (23 girls) from various general education high schools, with medium to high socioeconomic status, and were assigned to the control group.

The Home Version of DuPaul's *ADHD Rating Scale* (DuPaul et al., 1998) was used to confirm low levels of ADHD symptoms in the control group. In cases where the ratings exceeded the 80th percentile, the control group participant was excluded from the study. Other exclusion criteria for the control group were having a LD, behavior disorders, or neurological diseases. All participants had been determined to have a typical IQ since all of them were attending general education schools and none of them had ever been referred to a special education school.

All of the participants in the study had normal or corrected to normal vision. Participants were included in the study only if they displayed reasonable cooperation during the testing session (e.g., sat quietly, completed the task).

Measures

Sustained attention task. A CCPT was used to assess sustained attention (Shalev et al., 2011; Stern & Shalev, 2013). Participants were presented with a sequence of color drawings of geometric shapes that appeared in the center of the screen. The size of each stimulus ranged from 2.5 to 2.7 cm in height and from 2.6 to 3.0 cm in width. There were 16 possible stimuli resulting from the factorial combinations of square, circle, triangle, or star appearing in red, blue, green, or yellow. Participants were instructed to respond by pressing the space bar with their preferred index finger as soon as a target (red square) appeared and to withhold responses to all other stimuli. The target appeared in 30% of the trials. In 17.5% of the trials a differently colored square appeared, on 17.5% of the trials a red nonsquare geometric shape appeared, and on 35% of the trials a nontarget shape that shared neither identity nor color with the target appeared. Each stimulus was presented for 100 milliseconds (msec) and was separated from the next by an interval of 1,000; 1,500; 2,000; or 2,500 msec. The various stimulus types and interstimulus intervals were randomly intermixed. The task consisted of a single block of 320 trials preceded by 15 practice trials and lasted approximately 12 min. Reaction time (RT) (in msec) and accuracy (in percentages) were recorded. The task reliabilities derived from the present study are reported below.

Selective (spatial) attention task. A conjunctive visual search test (CVST), previously employed by Tsal et al. (2005), was used to assess selective (spatial) attention. Participants were required to search for a target defined as a specific conjunction of color and shape. The target was a blue square (1.1 cm in width and height) appearing among an equal number of red squares (1.1 cm in width and height) and blue circles (1.1 cm in diameter). There were four display set sizes of 4, 8, 16, or 32 items, which were equally frequent and randomly intermixed within a block. The items were randomly positioned within a 7 × 6 matrix 9.5 cm in width and 8 cm in height. Half of the displays contained a target. Each trial began with the presentation of a small, white central cross (0.6 cm in width and height) for 1,000 msec, which was immediately followed by the onset of the search display, which remained on until response. The intertrial interval, from response to the presentation of the fixation point, was 500 msec. Participants were required to respond with their right index fingers to the presence of the target and with their left index fingers to its absence. There were four 40-trial blocks, preceded by 10 practice trials. RT (in msec) and accuracy (in percentages) of each condition were recorded. The task reliabilities based on the present study are reported later.

Executive attention task. A location-direction Stroop-like task (LDST) previously used by Tsal et al. (2005) was used to assess executive attention. Participants were presented with a single stimulus varying along two dimensions that could elicit conflicting responses. A white arrow 1.5 cm in height and 0.6 cm in width, pointing either up or down, appeared either 1.2 cm above or below the center of the screen along the vertical meridian. Participants responded "up" with their right index fingers and "down" with their left index fingers. The task was composed of two subtasks: location judgments and direction judgments. In the location subtask, participants were required to respond "up" or "down" to the location of the arrow (above or below the center of the screen) while ignoring its direction. In the direction subtask participants were required to respond "up" or "down" to indicate the direction to which the arrow was pointing while ignoring its location. Half of the trials within each block were congruent (e.g., an arrow above the center of the screen pointing upward) and 50% were incongruent (e.g., an arrow above the center of the screen pointing downward). These two types of trials were randomly intermixed within each block. Each display was preceded by a 1,000 msec white, central fixation cross. The stimulus was presented for 150 msec. The time for response was unlimited. The intertrial interval was 1,500 msec. Participants were presented with two 40-trial location blocks followed by two 40-trial direction blocks. Each subtask was preceded by 10 practice trials. RT (in msec) and accuracy (in percentages) in each of the conditions were recorded. The task reliabilities derived from the present study are reported later.

Conners' Teacher Rating Scale. The Hebrew translation of the teacher version of the *Conners' Teacher Rating Scale–Revised* (CTRS-R; Conners, 2001) was used to evaluate ADHD symptoms as well as symptoms of oppositional behavior and social and/or emotional problems in the MD group. Five of the established factors of the rating scale were used in this study: *DSM-IV* inattention factor, *DSM-IV* hyperactivity-impulsivity factor, social problems, emotional lability, and oppositional behavior.

Procedure

Data collection. Data for MD participants were collected during a school day in a quiet room within the school designated for this purpose. Data for control participants were collected in a quiet room at the home of each participant. Each participant performed the three attention tasks in a single session, with breaks between them. The sustained attention task was always administered first, and the order of the selective and executive attention tasks was counterbalanced across participant.

Data trimming, missing data, and outliers. For each participant, all RTs shorter than 100 msec or longer than 3,000 msec were removed prior to analysis. RTs deviating more than 2 standard deviations (for the selective attention task and the executive attention task) or 3 standard deviations (for the CCPT—the sustained attention task) from the participants' means (separately for each task and each condition) were also removed. This resulted in exclusion of no more than 10% of trials in each condition of each task, and the number of excluded trials did not differ between control and MD participants.

Certain task runs were missing for some participants due to time constraints, loss of motivation, or technical problems (CCPT: data of 2 control participants were missing; CVST: data of 2 MD participants and 1 control participant were missing; LDST: data of 5 MD participants and 3 control participants were missing). Additionally, at the group level, RT and accuracy measures exceeding the group mean by 3 standard deviations led to an exclusion of the participants' data from the analysis of the corresponding task (CCPT: data of 2 MD participants and 2 control participants excluded, CVST: data of 4 MD participants excluded; LDST: data of 2 MD participants excluded; all cases excluded due to poor performance). This procedure resulted in the following final number of participants per task: 36 MD participants and 34 control participants in CCPT, 32 MD participants and 37 control participants in CVST, and 31 MD participants and 35 control participants in LDST. For the CTRS-R, missing item responses were replaced by the personal mean score of the relevant factor (Peyre, Lepiege, & Coste, 2011).

Reliability estimates of the attention measures. Reliability estimates were calculated using a permutation approach—the reliability estimate was obtained from the mean of 100,000 split-half estimates, each computed from a unique random split of the data at the level of trial type (MacLeod et al., 2010). The reliability computations were based on the whole sample of the current study. Reliabilities of RT data were very high for all tasks (.96 for CCPT, .90–.91 for CVST, and .95–.96 for LDST), while reliabilities of accuracy data were very high (.93) for CCPT, very low (.09–.28) for CVST, and medium to high (.75–.83) for the LDST task.

Attention measures and statistical analysis

Sustained attention. Four measures were extracted from CCPT: means and standard deviations for RTs in responding to targets (M-RT and SD-RT, both were recorded in msec), percentage of omission errors (omission of target stimulus), and percentage of commission errors (identification of a non-target stimulus as a target). Two-tailed independent samples *t* tests with Bonferroni corrections were applied to these four measures to compare performances of MD participants and control participants. Effect sizes were estimated with Cohen's *d* (Cohen, 1998).

Selective (spatial) attention and executive attention. RT and accuracy data for CVST (trials including a target stimulus only since the performance on trials without target is influenced by nonattentional factors) and for LDST were submitted to repeated measures ANOVAs. In CVST the within-subjects factor was set size (4, 8, 16, or 32 items). In LDST the within-subjects factors were subtask (location vs. direction judgments) and congruency (congruent vs. incongruent stimuli). The Greenhouse-Geisser correction was applied in cases when the assumption of sphericity for within-subjects factors was violated. Bonferroni correction was applied in cases where multiple post hoc tests were performed. Effect sizes of the ANOVAs were estimated with partial η^2 (Cohen, 1988).

In cases wherein significant interactions of group and any of the within-subjects variables were obtained, difference measures were computed (i.e., in CVST, the RT difference between 8-item displays and 4-item displays; in LDST, the RT difference between congruent and incongruent trials). These difference measures reflect the effect of attentional load on performance and serve as specific measures of selective/executive attention. Subsequently, these measures were categorized using K-means cluster analysis with a two-cluster solution predefined. A chi-square test was used to examine the relationship between group membership (MD or control) and cluster membership (low- or high-attention functioning).

For participants in the MD group, correlations between the attention measures and the CTRS-R factors (as discussed in the Measures section) were calculated. To cope with multiple correlations testing, we applied the Benjamini-Hochberg correction (Benjamini & Hochberg, 1995).

Results

Sustained Attention Task (CCPT)

The MD group differed significantly from the control group in three of the CCPT measures (see Table 1). MD participants committed more omission and commission errors and had larger variability in RTs. In all three measures, effect sizes were large (Cohen's *d* between 0.8 and 0.95). Figure 1 shows the performance distributions for each group in each of these measures, depicting larger intersubject variability in the MD group.

Table 1. Sustained Attention Task (CCPT) - A Comparison Between Groups.

Measure	Control	Multiple deficits	*t* value	Cohen's *d*
SD-RT	61.5 (13.0)	78.3 (26.6)	3.34*	0.80
M-RT	421.6 (46.6)	446.0 (55.2)	2.00	0.48
Omissions	0.6% (1.1%)	5.1% (7.7%)	3.44*	0.82
Commissions	0.9% (1.0%)	4.4% (5.1%)	3.86**	0.95

Note. SD-RT = standard deviation of reaction times; M-RT = mean of reaction times.
*$p < .005$. **$p < .001$ (Bonferroni corrected).

Subjecting the data of SD-RT for cluster analysis using K-means with a two-cluster solution predefined revealed that 9 of the 36 MD participants and 2 of the 34 control participants were classified into the low-functioning cluster. The rest of the participants (i.e., 27 and 32 participants from the MD and the control groups, respectively) were classified to the high-functioning cluster. These results show that there was a significant relationship between the groups and the level of sustained attention functioning, $\chi^2(1) = 4.83$, $p < .05$.

Selective (Spatial) Attention Task (CVST)

Analysis of RTs in the CVST revealed a significant main effect of group, $F(1, 67) = 48.04$, $p < .001$, $\eta^2 = 0.42$, with MD participants slower than control group participants, and a main effect of set size, $F(3, 201) = 204.46$, $p < .001$, $\eta^2 = 0.75$, with responses to larger set displays being slower than responses to smaller displays (4-item displays: 697 msec; 8-item displays: 752 msec; 16-item displays: 840 msec; 32-item displays: 965 msec). Crucially, the increase in RTs in accordance with the set size was steeper in the MD group than in the control group, as indicated by a significant interaction between group and set size, $F(3, 201) = 9.22$, $p < .001$, $\eta^2 = 0.12$ (see Figure 2A).

Post hoc tests revealed that the increase in mean RT in 16-item displays compared to 8-item displays was significantly larger for participants in the MD group than for participants in the control group (MD: $M = 113$ msec, $SD = 89$; Control: $M = 68$ msec, $SD = 50$; $t(47.39) = 2.53$, $p < .05$). A similar trend was obtained when comparing 32-item displays with 16-item displays and 8-item displays with 4-item displays, although the differences were not significant: 32 vs. 16: MD $M = 148$ msec, $SD = 123$; Control $M = 105$ msec, $SD = 84$, $t(53.76) = 1.66$, $p = .103$; 8 vs. 4: MD $M = 69$ msec, $SD = 89$; Control $M = 42$ msec, $SD = 54$, $t(49.67) = 1.50$, $p = .14$. These findings demonstrate a specific attentional difference between groups, with MD participants more susceptible to increases in the demand on selective attention. An analogous analysis of the accuracy data was not performed for this task due to low reliability coefficients

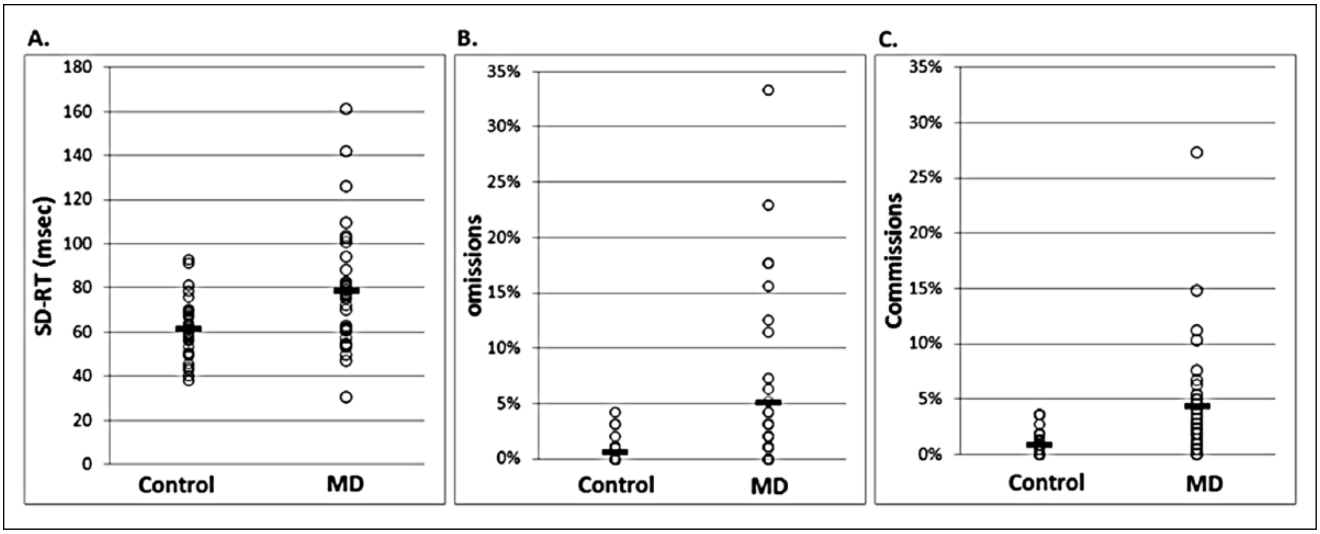

Figure 1. Performance distributions of sustained attention measures from the Conjunctive Continuous Performance Task.
Note. The thickened horizontal line crossing each group's distribution denotes the mean.
(A) Standard deviation of reaction time (SD-RT). (B) Percentage of omission errors. (C) Percentage of commission errors.

(see Methods section; see Figure 2B for descriptive statistics of the accuracy data).

Following the interaction of group and set size in the RT data, we created measures of the RT difference between pairs of set sizes: RT_{32}–RT_{16}, RT_{16}–RT_{8}, and RT_{8}–RT_{4}. These difference measures reflect the effect of attentional load on performance and hence are good estimators of selective attention abilities in individuals. Distributions of the difference measures in each of the groups are displayed in Figure 3.

Subjecting the data of RT_{16}–RT_{8} to cluster analysis using K-means with a two-cluster solution predefined revealed that 17 of the 32 MD participants and 8 of the 37 control participants fell into the low-functioning cluster. The rest of the participants (i.e., 15 and 29 participants from the MD and the control groups, respectively) fell into the high-functioning cluster. The same cluster analysis of RT_{8}–RT_{4} yielded a low-functioning cluster containing 12 of the 32 MD participants and 5 of the 37 control participants. These results indicate a significant relationship between the groups and the level of selective attention functioning, $\chi^2(1) = 7.37$, $p < .01$ and $\chi^2(1) = 5.31$, $p < .05$, respectively. A similar cluster analysis using RT_{32}–RT_{16} yielded a similar, though weaker and insignificant, trend (12 of 32 MD participants and 8 of 37 control participants were classified to the low-functioning cluster; $\chi^2(1) = 2.10$, n.s.

Executive Attention Task (LDST)

Analysis of RTs in the LDST revealed a significant main effect of group, $F(1, 64) = 7.85$, $p < .01$, $\eta^2 = 0.11$, with MD participants being slower than controls. There was also a significant main effect for subtask, $F(1, 64) = 101.36$, $p < .001$, $\eta^2 = 0.61$, in which responses for direction judgments were slower than responses for location judgments. There was also a large and significant main effect for congruency, $F(1, 64) = 130.79$, $p < .001$, $\eta^2 = 0.67$, revealing slower responses for incongruent trials, as expected in this paradigm (congruent trials: 502 msec; incongruent trials: 536 msec). A significant interaction was obtained for subtask and congruency, reflecting a larger effect of congruency in direction judgments than in location judgments, $F(1, 64) = 35.53$, $p < .001$, $\eta^2 = 0.36$. Crucially, congruency and group interacted significantly, $F(1, 64) = 6.60$, $p < .05$, $\eta^2 = 0.09$, indicating a larger effect of congruency for the MD participants than for controls (see Figure 4A). Post hoc tests revealed that the congruency interference (i.e., the decrease in performance as a result of conflicting information) in the MD group was significantly larger than in the control group: MD: $M = 42$ msec, $SD = 29$; Control: $M = 27$ msec, $SD = 19$; $t(50.20) = 2.51$, $p < .05$, suggesting a specific executive attention dysfunction in MD participants on the group level. An analogous analysis of the accuracy data in the executive attention task revealed similar though smaller main effects: group: $F(1, 64) = 12.65$, $p < .001$, $\eta^2 = 0.17$; subtask: $F(1, 64) = 4.31$, $p < .05$, $\eta^2 = 0.06$; congruency: $F(1, 64) = 29.16$, $p < .001$, $\eta^2 = 0.31$, and an interaction of subtask and congruency effects $F(1, 64) = 12.01$, $p < .001$, $\eta^2 = 0.16$, but no interaction of group and congruency (see Figure 4B.)

Following the interaction of group and congruency in the RT data, we created measures of the RT difference between congruent and incongruent trials (pooled across location

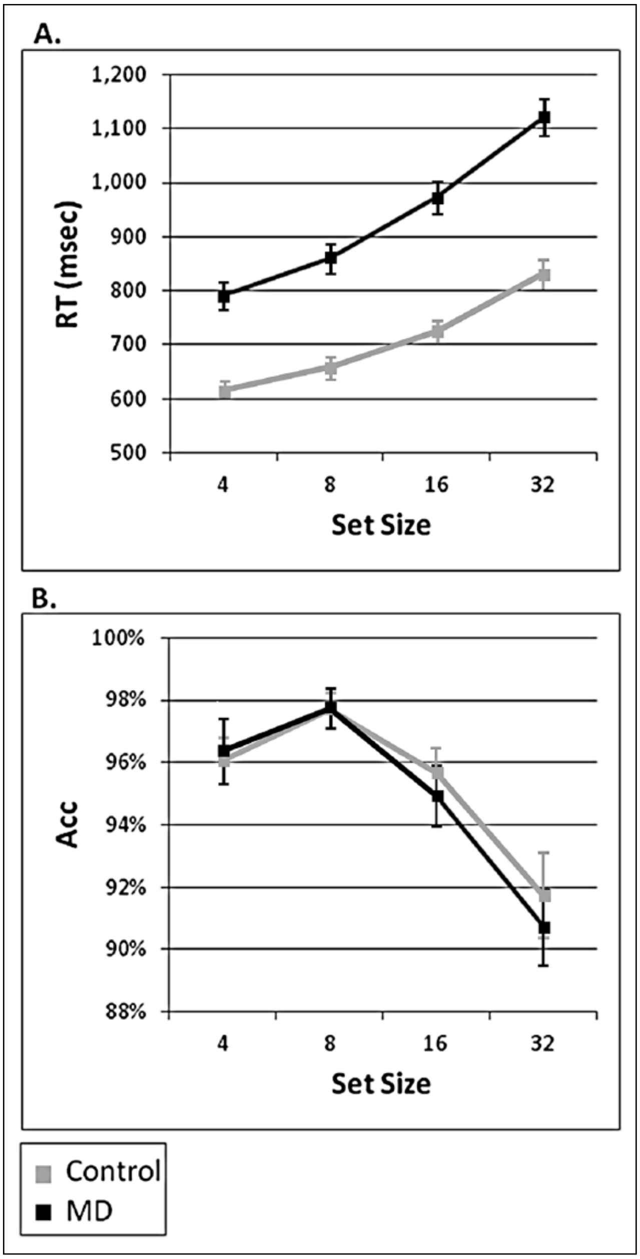

Figure 2. Mean performance of the control and multiple deficits groups in the conjunctive visual search test.
Note. Error bars denote the standard error.
(A) Reaction time data. (B) Accuracy data.

and direction subtasks): $RT_{Incongruent}$–$RT_{Congruent}$. This difference indicates the effect of congruency on performance; hence, it can serve as an index of conflict resolution ability and executive attention functioning. The distribution of the difference measure in each group is presented in Figure 5.

Subjecting the data of $RT_{Incongruent}$–$RT_{Congruent}$ to cluster analysis using K-means with a two-cluster solution predefined revealed that 17 of the 31 MD participants and 9 of the 35 control participants fell into the low-functioning cluster. The rest of the participants (14 and 26 from the MD and control groups, respectively) fell into the high-functioning cluster. These results show a significant relationship between the groups and the level of executive attention functioning (i.e., the magnitude of the interference from conflicting information; $\chi^2(1) = 5.84$, $p < .05$).

Teachers Subjective Evaluations of Behavioral Symptoms (CTRS-R)

At the group level, the MD group scored well above the norm on all subscales of the CTRS-R examined (see Table 2). At the individual level, 35 participants (approximately 92%) deviated more than 2 standard deviations from the norm in at least one of the five factors. Of the participants in the MD group, 74% (28 of 38) were rated as deviating more than 2 standard deviations in at least one of the two ADHD factors (inattention and hyperactivity-impulsivity).

Correlations of the CTRS-R scores of MD participants and attention measures were calculated. The attention measures used were SD-RT, omissions and commissions in CCPT as measures of sustained attention, RT differences between display sizes in CVST as measures of selective attention, and the RT difference between congruent and incongruent trials in the executive attention as a measure of executive attention. The correlations were low to moderate ($-.44 < r < .31$). The *DSM* Inattention factor, the impulsivity factor, and the cognitive problems factor were negatively correlated with RT difference between displays containing 32 items and displays containing 16 items in the CVST ($r = -.44$, $r = -.37$, and $r = -.38$, respectively). However, none of the above correlations reached significance when applying the Benjamini-Hochberg false discovery rate correction (Benjamini & Hochberg, 1995).

Discussion

The present study examined the attention characteristics of a unique sample of adolescents who suffer from a multitude of intense difficulties in attention and behavioral, academic, and emotional aspects of everyday functioning. To give an idea regarding the complexity and intensity of the various problems with which these adolescents are coping, approximately 60% of the participants in the study MD group were rated by their teachers as having severe symptoms in at least four out of the five subscales of CTRS-R that were evaluated (inattention, hyperactivity-impulsivity, oppositional behavior, social problems, and emotional lability). Data from three neuropsychological tests of attention for participants from both groups were collected in the field rather than in lab settings, which meant noisy settings and problematic circumstances. Nevertheless, the expected patterns of results were obtained in both groups (main effects of set

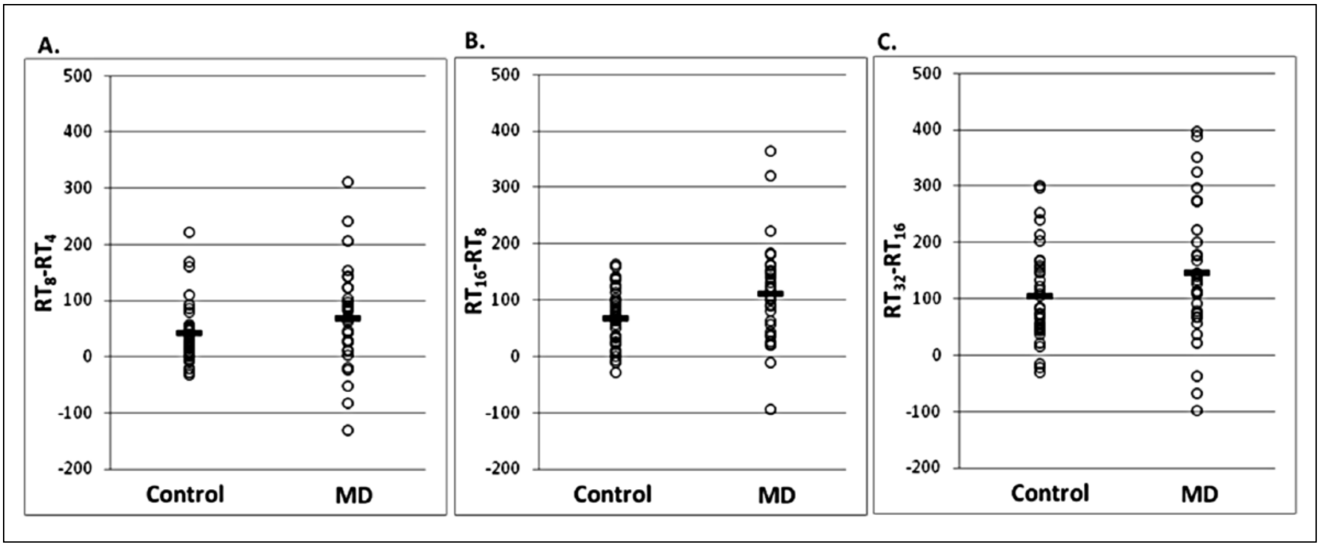

Figure 3. Performance distributions of selective (spatial) attention measures from the conjunctive visual search test.
Note. The thickened horizontal line crossing each group's distribution denotes the mean.
(A) Reaction time differences between displays containing 8 items and displays containing 4 items. (B) Reaction time differences between displays containing 16 items and displays containing 8 items. (C) Reaction time differences between displays containing 32 items and displays containing 16 items.

size in the selective [spatial] attention task and main effects of subtask and congruency in the executive attention task), which confirm the experimental manipulations in the selective (spatial) attention and the executive attention tasks.

One prominent finding in the present study was slower RTs in the MD group, evident in all three attention tasks. However, slow RT, interpreted sometimes as evidence of slow speed of processing, is widely found in clinical and subclinical samples and is specifically known to characterize individuals with LDs and individuals with attention problems. Thus, slowness of RT in itself does not contribute to the attempt to disentangle specific difficulties within the MD group, and we sought to account for it by using more specific measures of attention. Indeed, when examining the performance of the MD participants and comparing it to that of the controls in such specific measures, more subtle but substantial differences were revealed.

The most pronounced group differences were found in the CCPT (which measures sustained attention), both in terms of variability of RTs and of misses of target stimuli altogether (i.e., significantly higher rate of omission errors). This indicates that the adolescents with broad learning and attention deficits were less capable than their age- and gender-matched control participants in maintaining attention on a monotonic task across a long period of time. In general, these findings are in agreement with the extremely high levels of inattention reported for the MD adolescents by their teachers and in line with previous suggestions of RT variability as a useful marker of a phenotype of attention difficulties (Hervey, Epstein, & Curry, 2004; Kolodny, Seidel, Azulay, & Shalev, 2012; Leth-Steensen, King Elbaz, & Douglas, 2000). Yet it is important to note that no significant correlations were obtained between the teachers' subjective evaluations of inattention symptoms and the neuropsychological measures of sustained attention. In addition, participants in the MD group made substantially more false alarms (i.e., responded to distractors as if they were targets—commission errors) than participants in the control group. These types of errors are considered by many researchers and clinicians to reflect impulsivity that is the result of failure to inhibit a response (Riccio, Reynolds, Lowe, & Moore, 2002; Wang et al., 2011; Wang et al., 2013). Note, however, that in the cluster analysis only 25% of participants in the MD group (compared with 6% of participants in the control group) were classified in the low sustained attention group. Thus, although a large effect size was obtained in sustained attention at the group level, when analyzing the individual data, we found that many of the MD participants performed reasonably well in the sustained attention task.

In the selective (spatial) attention and the executive attention tasks, significant interactions were found between the manipulated factor and group, indicating specific attentional weakness in the MD group. In the selective attention task, greater decrease in performance as a function of higher demand of selective-spatial attention (as expressed in a larger number of items in a search display) was observed in the MD group compared to the control group. This indicates a specific difficulty in focusing attention in a restricted area of the visual field while ignoring adjacent irrelevant information. Such difficulty in effectively inhibiting irrelevant adjacent distracting information when performing a search for relevant information

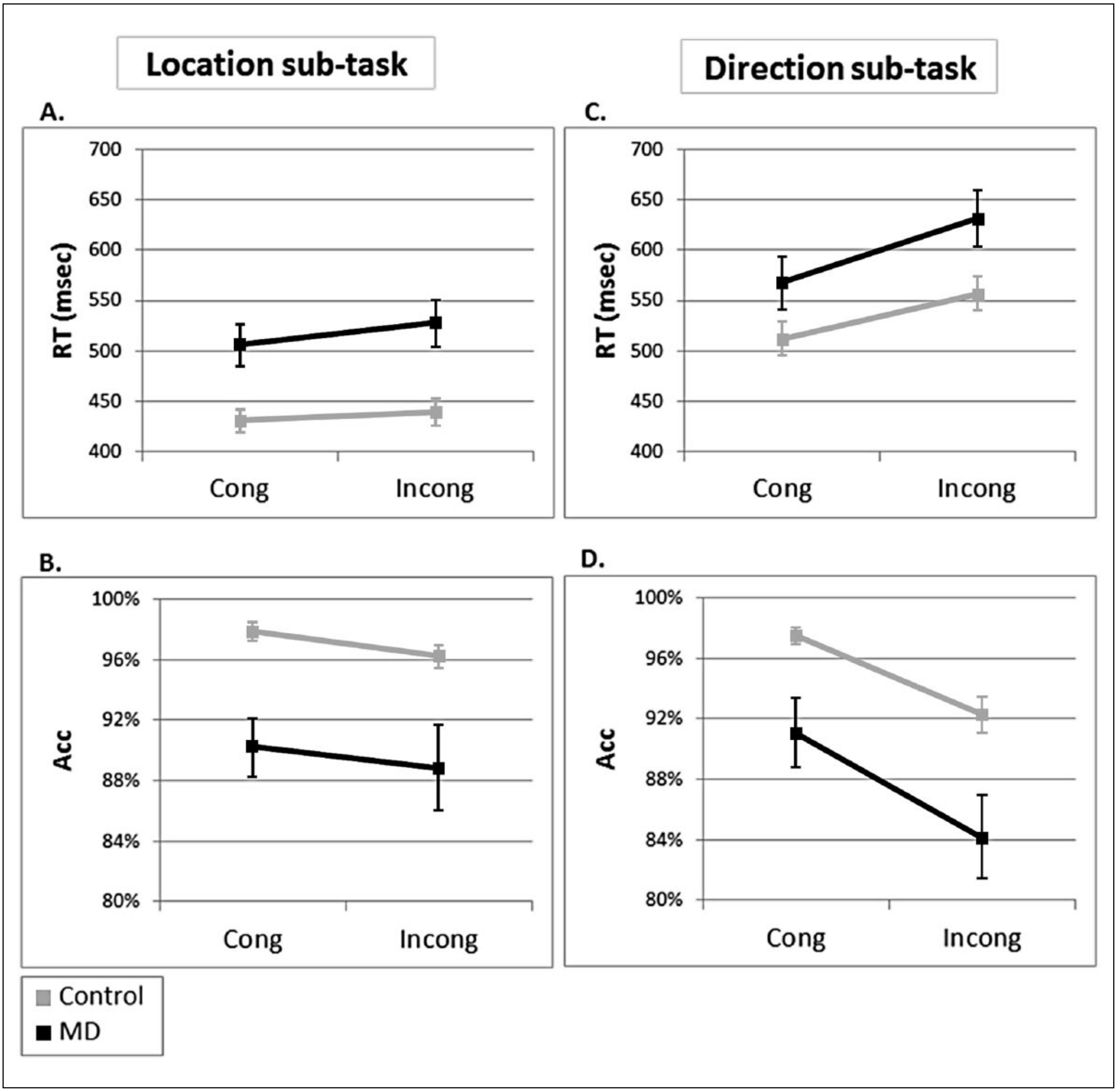

Figure 4. Mean performance of the control and multiple deficits groups in the executive attention task.
Note. Error bars denote the standard error.
(A) Reaction time data. (B) Accuracy data.

was obtained in several previous studies of children with ADHD (Richards, Samuels, Turnure, & Ysseldyke, 1990; Shalev & Tsal, 2003; Taranowski, Prinz, & Nay, 1986; Tsal et al., 2005). In the executive attention task, greater decrease of performance as a result of conflict between target dimensions (i.e., an arrow pointing upwards presented below the center of the screen) was revealed in the MD group compared to the control group. This finding indicates a specific difficulty in inhibiting the processing of irrelevant conflicting information in the MD group, and it corroborates the results of various previous studies of children, adolescents, and adults with ADHD (Hervey et al., 2004; Mazor-Karsenty et al., 2015; Mullane & Klein, 2008; Shalev et al., 2008; Tsal et al., 2005).

Taken together, the present findings show that at the group level adolescents with a broad range of learning and

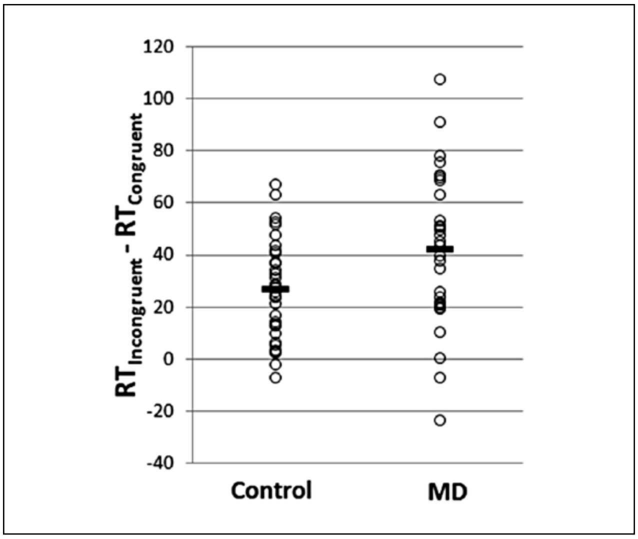

Figure 5. Performance distributions of executive attention measures from the executive attention task: Reaction time differences between incongruent trials and congruent trials.
Note. The thickened horizontal line crossing each group's distribution denotes the mean.

behavioral difficulties experience specific attention deficits in the three neuropsychological tasks that were used to assess sustained, selective, and executive attention. Obviously, these differences are not surprising. Nonetheless, it is important to note that when looking at specific attention measures (i.e., RT differences between display sizes in the selective attention task and RT differences between incongruent and congruent trials in the executive attention task) the performance distributions of the MD group and the control group overlap extensively. This overlap was reflected in the cluster analyses, which showed that 53% and 55% of participants in the MD group were classified as low selective attention and executive attention, respectively, whereas 22% and 26% of the participants in the control group were classified in the same categories. The overlapping distributions suggest that although the unequivocal general lower performance of the MD participants was reflected in slower RTs across all tasks and in lower accuracy, in regard to specific attention indexes, only a subgroup of the MD participants exhibited specific attention difficulties.

Another important finding in this study is that no significant correlations were obtained in the MD group between the neuropsychological measures of attention and the subjective evaluations of symptoms of inattention, hyperactivity, and impulsivity provided by the teachers. Thus, we infer that in our extremely complex comorbid sample the subjective evaluations of symptoms of ADHD did not translate to performance in the neuropsychological measures. Future studies will have to unravel the nature and causes of this discrepancy. A major potential reason for such a divergence is the multiple comorbid difficulties that characterized the participants in the present MD group that may have masked any possible relationships between ADHD symptoms and performance in the neuropsychological tasks. Similar inconsistencies were previously reported in the literature in studies of typical ADHD samples (Jonsdottir, Bouma, Sergeant, & Scherder, 2006; Mahone et al., 2002; Thorell & Wåhlstedt, 2006; Wåhlstedt, Thorell, & Bohlin, 2009). Moreover, on the individual level, the absence of the above correlations emphasizes the importance of using neuropsychological tools in populations who are characterized by multiple difficulties because it can disentangle cases in which basic attention (as well as other cognitive) functions are impaired and hamper the efficiency of learning from cases in which these functions are intact but high levels of symptoms of inattention, hyperactivity, and impulsivity are experienced, probably as a result of other difficulties. Such information can contribute to the formation of personally adjusted interventions that will facilitate learning in different contexts for individuals who suffer from multiple difficulties.

Limitations

Since the tasks were administered in the field rather than in the lab, the data were collected in relatively noisy settings, which probably affected the reliability of the measures. Nonetheless, the expected patterns of results were obtained at the intraindividual level: RTs were slower for larger displays in the selective attention task and slower for incongruent trials relative to congruent trials in the executive attention task. This confirms the experimental manipulations and indicates that the neuropsychological tools produced valid measures even though data collection was conducted in a noisy location.

Another constraint is that several students in the MD group performed the tasks under the effect of stimulant medications that they used on a regular basis. Note, however, that exclusion of the data of the 9 participants who were under the effect of medication during testing yielded similar patterns of results with the same significant effects.

Also, in the present study subjective behavioral evaluations of participants in the control and the MD groups were collected using different questionnaires (the Home Version of the *DuPaul ADHD Rating Scale* in the control group [parents] and CTRS-R in the MD group). Collection of both teacher and parent ratings for all of the participants could be beneficial and enable better assessment of correlations between behavioral symptoms and attention measures. Finally, participants in the control group were assessed in their homes and were not matched to participants in the MD group for socioeconomic status.

Another methodological restriction of the present MD group is that it included participants with various difficulties in academic, behavioral, social, and emotional

Table 2. *Conners' Teacher Rating Scale* Results.

Measure	*DSM-IV* inattention	*DSM-IV* hyperactivity-impulsivity	Social problems	Emotional lability	Oppositional behavior
Mean *Z*-score	−2.48	−5.61	−3.24	−3.50	−3.04
Number of participants with scores at least 2 standard deviations above norm (out of 38)	23	27	24	27	26

Note. DSM-IV = Diagnostic and Statistical Manual of Mental Disorders, fourth edition. Results are available for multiple deficits participants only.

functioning. We would like to emphasize that although this is a disadvantage from a methodological point of view, the investigation of such a neglected group that is hardly ever studied is of great educational and social importance. The present study provides important findings that contribute to the understanding of the complex nature of such heterogenic groups. In future studies with larger samples, researchers may be able to subdivide highly heterogeneous groups into subgroups according to the specific combinations of symptoms (e.g., high inattention, hyperactivity-impulsivity and oppositional behavior, high social problems, and emotional lability).

Educational Implications

In cases in which deficient attention functioning is measured, specific recommendations can be provided for school settings as well as for other learning environments. For instance, to cope with deficient sustained attention, we recommend restricting the length of the school day, using relatively short learning units, and introducing brief active breaks between them, which will enable the learners to maintain their alertness and effectively focus on the materials they study. In addition, to minimize lapses of attention, it is advisable to refrain from passive silent reading and instead to encourage learners to semantically process the text during reading (e.g., underline the central characters). In fact, such recommendations were successfully implemented in the school setting for the participants in the MD group on a personal level. Further studies will establish the relationship between the specific attention difficulties of individuals with ADHD and the aiding techniques that can ameliorate these deficiencies and support effective learning.

Conclusion

In this study we examined a highly heterogenic group of adolescents, characterized by complex profiles of difficulties. We demonstrated that such a sample relying solely on behavioral symptoms cannot produce a valid identification of individuals with specific attentional problems. On the other hand, we demonstrated that neuropsychological attention tasks hold the potential to identify core attention deficits and distinguish them from other psychopathologies that may cause symptoms of inattention and/or hyperactivity-impulsivity. In the future such differentiation may be effective in guiding appropriate interventions and in adjusting efficient teaching techniques.

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