Differences in cognitive control in children and adolescents with combined and inattentive subtypes of ADHD

Merete Øie\textsuperscript{ab}, Erik Winther Skogli\textsuperscript{a}, Per Normann Andersen\textsuperscript{a}, Kjell Tore Hovik\textsuperscript{a} & Kenneth Hugdahl\textsuperscript{c}

\textsuperscript{a}Innlandet Hospital Trust Lillehammer, Division Mental Health Care, Lillehammer, Norway
\textsuperscript{b}Department of Psychology, University of Oslo, Oslo, Norway
\textsuperscript{c}Department of Biological and Medical Psychology, University of Bergen, and Division of Psychiatry, Haukeland University Hospital, and KG Jebsen Center for Neuropsychiatric Disorders, Bergen, Norway

Published online: 09 Nov 2012.

To cite this article: Merete Øie, Erik Winther Skogli, Per Normann Andersen, Kjell Tore Hovik & Kenneth Hugdahl (2014) Differences in cognitive control in children and adolescents with combined and inattentive subtypes of ADHD, Child Neuropsychology: A Journal on Normal and Abnormal Development in Childhood and Adolescence, 20:1, 38-48, DOI: 10.1080/09297049.2012.741224

To link to this article: http://dx.doi.org/10.1080/09297049.2012.741224

PLEASE SCROLL DOWN FOR ARTICLE

Taylor & Francis makes every effort to ensure the accuracy of all the information (the “Content”) contained in the publications on our platform. However, Taylor & Francis, our agents, and our licensors make no representations or warranties whatsoever as to the accuracy, completeness, or suitability for any purpose of the Content. Any opinions and views expressed in this publication are the opinions and views of the authors, and are not the views of or endorsed by Taylor & Francis. The accuracy of the Content should not be relied upon and should be independently verified with primary sources of information. Taylor and Francis shall not be liable for any losses, actions, claims, proceedings, demands, costs, expenses, damages, and other liabilities whatsoever or
Differences in cognitive control in children and adolescents with combined and inattentive subtypes of ADHD

Merete Øie\textsuperscript{1,2}, Erik Winther Skogli\textsuperscript{1}, Per Normann Andersen\textsuperscript{1}, Kjell Tore Hovik\textsuperscript{1}, and Kenneth Hugdahl\textsuperscript{3}

\textsuperscript{1}Innlandet Hospital Trust Lillehammer, Division Mental Health Care, Lillehammer, Norway
\textsuperscript{2}Department of Psychology, University of Oslo, Oslo, Norway
\textsuperscript{3}Department of Biological and Medical Psychology, University of Bergen, and Division of Psychiatry, Haukeland University Hospital, and KG Jebsen Center for Neuropsychiatric Disorders, Bergen, Norway

The aim of the present study was to investigate the ability of children with attention deficit/hyperactivity disorder-combined subtype (ADHD-C) and predominantly inattentive subtype (ADHD-PI) to direct their attention and to exert cognitive control in a forced attention dichotic listening (DL) task. Twenty-nine, medication-naive participants with ADHD-C, 42 with ADHD-PI, and 40 matched healthy controls (HC) between 9 and 16 years were assessed. In the DL task, two different auditory stimuli (syllables) are presented simultaneously, one in each ear. The participants are asked to report the syllable they hear on each trial with no instruction on focus of attention or to explicitly focus attention and to report either the right- or left-ear syllable. The DL procedure is presumed to reflect different cognitive processes: perception (nonforced condition/NF), attention (forced-right condition/FR), and cognitive control (forced-left condition/FL). As expected, all three groups had normal perception and attention. The children and adolescents with ADHD-PI showed a significant right-ear advantage also during the FL condition, while the children and adolescents in the ADHD-C group showed a no-ear advantage and the HC showed a significant left-ear advantage in the FL condition. This suggests that the ADHD subtypes differ in degree of cognitive control impairment. Our results may have implications for further conceptualization, diagnostics, and treatment of ADHD subtypes.

Keywords: Dichotic listening; Executive functioning; Attention deficit/hyperactivity disorder; ADHD subtypes.

The project has received financial support from Innlandet Hospital Trust (Grant Number 150170) and the Regional Resource Center for Autism, ADHD, Tourette syndrome and Narcolepsy, Oslo University Hospital (Grant Number 150182). The authors declare no conflict of interest with respect to authorship or publication of this article.

Address correspondence to Merete Øie, PhD, Innlandet Hospital Trust Lillehammer, Division Mental Health Care, Anders Sandvigsgate 17, 2609 Lillehammer, Norway. E-mail: mail@mereteoie.no

© 2012 Taylor & Francis
Following the *Diagnostic and Statistical Manual of Mental Disorders*, text revision (*DSM-IV-TR*; American Psychiatric Association, 2000), attention deficit/hyperactivity disorder (ADHD) is categorized into three subtypes, including the predominantly inattentive subtype (ADHD-PI), the predominantly hyperactive/impulsive subtype (ADHD-H), and the combined subtype (ADHD-C). The ADHD-PI subtype shares the inattentiveness of the ADHD-C subtype but lacks the accompanying hyperactivity-impulsivity. The validity of *DSM-IV-TR* ADHD-H, ADHD-PI, and ADHD-C has been debated for decades (Milich, Balentine, & Lynam, 2001). Children with the ADHD-PI subtype often have later age of referral, are less likely to respond to methylphenidate treatment and are often more easily bored, hypoactive, self-conscious, unmotivated, and shy in contrast to children with ADHD-C (see Adams, Derefinko, Milich, & Fillmore, 2008). Reading and language deficits are more commonly comorbid with ADHD-PI than with ADHD-C (Weiss, Worling, & Wasdell, 2003). Children with ADHD-PI are significantly less likely to display disruptive behavior compared to children with ADHD-C (Willcutt, Pennington, Chhabildas, Friedman, & Alexander, 1999). They are also more likely than children with ADHD-C to be drowsy, sluggish, and daydreamy; characteristics termed “sluggish cognitive tempo” (Hartman, Willcutt, Rhee, & Pennington, 2004). ADHD-PI is more prevalent than ADHD-C in community-based studies but constitutes only 30% of clinic-referred children with ADHD-C, suggesting it may be underrecognized and undertreated (Solanto et al., 2007). It has been proposed that the subtypes are best differentiated by ratings, observations, and tests of cognitive tempo and behavioral impulsivity because traditional neuropsychological methods have not identified critical differences (Solanto et al., 2007).

Executive functions (EF) refer to higher order cognitive functions relating to control of thought, action, and emotion (Zelazo & Cunningham, 2007) and are considered key impairments in ADHD (Doyle, 2006). EF encompasses specific neuropsychological functions such as inhibition (cognitive control), working memory, cognitive flexibility, planning, and verbal fluency (Pennington & Ozonoff, 1996). Despite the centrality of EF in ADHD, distinct EF profiles for the two main ADHD subtypes have not been established. In a meta-analytic review of 83 studies with sufficient group sizes and numerous EF tasks, Willcutt, Doyle, Nigg, Faraone, and Pennington (2005) did not find support for reliable EF differences between ADHD-C and ADHD-PI subtypes.

The lack of reliable EF differences between ADHD-C and the ADHD-PI subtypes across studies could be due to psychometric methodological aspects, such as a low test specificity characteristic of the typical neuropsychological test and test battery. Further, the traditional neuropsychological test approach typically applies tests that differ in difficulty and require a general understanding of the test situation; two factors that may differentially affect test scores in clinical groups (Westerhausen & Hugdahl, 2010). Another possible factor is that many prevalent EF tests are highly complex and implicate many different subprocesses (both EF and non-EF), the so called “task impurity problem” (Miyake, Emerson, & Friedman, 2000). Due to the fact that reading problems, language deficits, and reduced cognitive tempo are more common in ADHD-PI than in ADHD-C, it is important not to use tests or methods that involve multiple executive processes when examining possible EF differences between clinical subtypes. The Dichotic Listening (DL) forced-attention paradigm may reflect different cognitive processes: perception (nonforced condition), attention (forced-right condition), and cognitive (executive) control (forced-left condition) (Gadea et al., 2002; Gootjes et al., 2006; Hugdahl et al., 2009; Jäncke & Shah, 2002; Milovanov, Tervaniemi, Takio, & Hämäläinen, 2007). The term attention as used here refers to the natural tendency to focus attention on the right-ear stimulus in the
absence of a competing attention stimulus; since the bottom-up perceptual process also favors the selection of the right-ear stimulus. Thus, the forced-right condition can be seen as a measure of the ability to facilitate reports from the attended ear or a kind of attention shift. The term cognitive control refers to the ability to direct attention to the left-ear stimulus in the presence of a strong competing right-ear stimulus, since the bottom-up percept is in conflict with the attention instruction demand. DL is a classic example of an experimental approach that is simple to understand and solve and not dependent on rapid cognitive tempo. The forced-attention DL task would not differentially affect different clinical groups or subgroups from the perspective of a general understanding of and coping with the test situation. The differences in instructions between conditions are minimalistic with all aspects of the situation, except one, being identical across experimental conditions.

In this task, two different auditory stimuli (syllables) are presented simultaneously, one in each ear, without the subject being aware of the dichotic nature of the stimulus presentation. The participants are asked to report the syllable they hear on each trial with no instruction of focus of attention (nonforced [NF] condition) or to explicitly focus attention and report either the right- or left-ear syllable (forced-right [FR] and forced-left [FL] condition, respectively). The single experimental manipulation that differentiates the forced-right and forced-left conditions is a single word in the instruction (“right” versus “left”), whereas all other parameters are kept identical. Second, the overall structure of the DL paradigm is the same across instruction conditions, with the sole exception of the direction of the instruction.

The typical finding in healthy participants in the nonforced condition is a stimulus-driven, bottom-up right-ear advantage (REA), which means more correct reports for the right-ear stimulus (Hugdahl, 1995). The REA is inferred to reflect a speech-processing specialization of the left hemisphere and the wiring of the auditory neural pathways (Kimura, 1967). Most individuals can, however, increase or decrease the ear advantage through controlled (forced) shifting of attention to either the left or right ear (Bryden, Munhall, & Allard, 1983; Hiscock, Inch, & Kinsbourne, 1999; Hugdahl, 2003; Hugdahl & Andersson, 1986). While the REA in the FR condition reflects the combined synergistic effects of the bottom-up perceptual and top-down attentional effects, the left-ear advantage (LEA) in the FL condition is the result of executive control to report the left-ear stimulus and to inhibit and suppress the bottom-up NF tendency to report the right-ear stimulus (Westerhausen & Hugdahl, 2010). Thus, the DL procedure makes it easier to target a unique cognitive domain and is not confounded by differences in an overall understanding of the situation.

Davidson and Prior (1978), Hiscock, Kinsbourne, Caplan, and Swanson (1979) and Prior, Sanson, Freethy, and Geffen (1985) investigated hyperactive children and matched controls using a similar dichotic listening task. None of the studies found significant differences between the hyperactive and healthy children. The results were replicated in a study by Øie, Rund, Sundet, and Bryhn (1998) that found no differences in any of the forced-attention conditions in the DL task between participants with ADHD and healthy controls when they were adolescents. However, the results from a 13-year follow-up study of the same participants showed significant impairment in cognitive control (reduced LEA in the FL condition) in the ADHD group (Øie & Hugdahl, 2008). Thus, the data indicated cognitive decline as the ADHD patients became older, indicating a possible increase in cognitive control problems. These results were supported by Dramsdahl, Westerhausen, Haavik, Hugdahl, and Plessen (2011), who found cognitive control deficits in adults with ADHD using the same DL procedure as Øie and Hugdahl.
None of the ADHD studies using the DL task investigated possible subtype differences that could have confounded previous failures to find significant differences between the clinical and healthy control groups. Since the FL condition primarily measures the ability to inhibit an in-built, bottom-up tendency to report the right-ear stimulus and to shift focus to the perceptually less salient left-ear stimulus, it could be hypothesized individuals with ADHD-PI would be impaired in this condition. These individuals may struggle with inhibiting irrelevant stimulus cues in the environment and to refocus on relevant, less salient cues. Interestingly, Diamond (2005) suggested that laboratory measures, such as dichotic listening tasks, are better than traditional neuropsychological measures in detecting deficits in cognitive control in participants with ADHD-PI subtype, because of less sensitivity to other cognitive manifestations (sluggish cognitive tempo, reading/language disorder, impulsivity etc.). Further, tasks in the auditory domain, such as the DL task, are predicted to be particularly sensitive to the problems of children with ADHD-PI (Diamond, 2005). The present study is thus an attempt to empirically test the suggestion put forward by Diamond (2005), with specific directed hypotheses regarding performance in an ADHD-PI versus an ADHD-C subgroup.

Thus, possible differences in perception, attention and cognitive control between ADHD-PI and ADHD-C subtypes were investigated using the DL procedure. A matched, healthy comparison (HC) group was included, but the primary comparison of interest was between the two ADHD subtypes. The prediction was that none of the groups would show deficits in perception (NF) or attention (FR), but that the participants with ADHD-PI would show impaired performance compared to the ADHD-C group in the FL condition, because of the cognitive conflict between bottom-up and top-down processing demands in this condition.

METHOD

Participants and Procedure

Data for the present study were derived from a larger study examining cognitive functions in children with ADHD, Asperger syndrome, or Tourette’s syndrome (see Andersen, Egeland, & Øie, 2012 for detailed recruitment strategy and diagnostic measures). The ADHD subgroups in the present study consisted of 29 children (ages 9–15) with DSM-IV-TR 314.01 ADHD-C (17 males; age: \(M = 12.0, SD = 1.9\)), 42 children (ages 9–16) with DSM-IV-TR 314.00 ADHD-PI (20 males; age: \(M = 11.6, SD = 1.9\)), and 40 healthy controls (HC; ages 9–15) (19 males; age: \(M = 12.0, SD = 2.0\)). There were no significant differences in age between the three groups. The Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999) was administered to estimate IQ in the ADHD participants. The ADHD subgroups did not differ significantly with regard to IQ. The ADHD participants were recruited as consecutive referrals from seven outpatient Child and Adolescent Mental Health Centres in Innlandet Hospital Trust (IHT) for assessment of ADHD. All participants underwent a comprehensive assessment according to common clinical practice. DSM-IV-TR (American Psychiatric Association, 2000) diagnoses for ADHD were based on separate semi-structured clinical interviews for children/adolescents and parents (Kiddie-Schedule for Affective Disorders and Schizophrenia [K-SADS]; Kaufman et al., 1997). The interviewers were experienced clinicians and were trained to high levels of interrater reliability for diagnostic assessment. In addition, the diagnostic evaluation was supplemented with information from the ADHD Rating Scale IV.
(DuPaul, Power, Anastoupoulos, & Reid, 1998), and the Child Behavior Checklist/6–18 (CBCL/6–18; Achenbach & Rescorla, 2001), both filled out by the parents. Information from teachers about the child’s school functioning was mandatory on referral and was taken into consideration when deciding diagnosis. Diagnoses of ADHD and an ADHD subtype were considered positive if, based on a comprehensive evaluation of K-SADS, teacher information, and rating scales, the *DSM-IV-TR* (American Psychiatric Association, 2000) criteria were met.

Exclusion criteria for the ADHD participants included prematurity (< 36 weeks), IQ below 70, and a history of stimulant medication. Two ADHD individuals originally recruited for the project were not eligible for the present study. The HC participants were selected from the Bergen DL database that consists of 1800 healthy individuals between 5 and 89 years of age. The 40 HC participants were randomly drawn from the relevant age (between 9–16 years), sex, and handedness sections of the database to match the ADHD participants (see Table 1).

The study was approved by the Regional Committee for Medical Research Ethics in Eastern Norway (REK-Øst) and by the privacy protection ombudsman for research at Innlandet Hospital Trust. It was conducted in accordance with the Helsinki Declaration of the World Medical Association Assembly.

**Measures**

The dichotic stimulus materials consisted of six stop-consonants (b, d, g, p, t, and k) that were paired with the vowel “a” to form six basic consonant-vowel (CV) syllables: ba, da, ga, pa, ta, ka (Hugdahl & Andersson, 1986). The subject is presented through head-phones with pairs of consonant-vowel syllables, based on the six stop-consonants /b/, /d/, /g/, /p/, /t/, /k/, all paired with the vowel /a/, to form syllables of the type /ba/, /da/, /ga/ etc. The syllables were paired with each other for all possible combinations, yielding 36 dichotic pairs including the six homonymic pairs such as /ba/-/ba/. The homonymic pairs were included as a control to ensure that the participants perceived the syllables, and they were not included in the statistical analysis. Each pair was randomly recorded three times, digitally, on a compact disc (CD), yielding a total of 108 trials. The DL task was administered under three conditions (see Hugdahl & Andersson, 1986): nonforced (NF) condition, forced-right (FR) condition, and the forced-left (FL) condition. The NF condition was given first, followed by the FR and FL conditions in a counterbalanced order. During the NF condition, the participants were informed that they would hear a series of syllables and that their task was to report the syllable sound they perceived on each trial,

<table>
<thead>
<tr>
<th>Variable</th>
<th>ADHD-C (<em>n</em> = 29)</th>
<th>ADHD-PI (<em>n</em> = 42)</th>
<th>Healthy Controls (<em>n</em> = 40)</th>
<th>Group Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (male/female)</td>
<td>17/12</td>
<td>20/22</td>
<td>19/21</td>
<td>ns</td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>11.96 (1.9)</td>
<td>11.59 (1.9)</td>
<td>12.02 (2.0)</td>
<td>0.57 ns</td>
</tr>
<tr>
<td>Left handers</td>
<td>7</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>FSIQ (WASI)*</td>
<td>98.0 (13.9)</td>
<td>93.6 (14.7)</td>
<td>1.52 ns</td>
<td></td>
</tr>
</tbody>
</table>

*FSIQ = Full-Scale IQ; WASI = The Wechsler Abbreviated Scale of Intelligence (Wechsler, 1999).*
with the instruction to a single response after each presentation, either by saying the sound aloud or by pointing to a sheet in front of them that listed all six possible responses vertically. They were told that if they thought they heard more than one syllable on a trial, they were to select the one they heard most clearly. This was done in order to avoid invoking working memory, which would automatically be a component of the processing if two responses were allowed. The second stimulus would have to “wait” in the working memory buffer until the first response is given. During the FR condition, the participants were explicitly told to focus attention on the right-ear syllable and to report only what they heard in the right ear. During the FL condition, the participants were explicitly told to focus attention on the left-ear syllables and to report only what they heard in the left ear. Responses were scored as number of correctly reported syllables separate for the left- and right-ear stimulus, during each of the three attentional instruction conditions.

The intertrial interval between stimulus presentations was about 4 seconds. Each CV syllable had a duration of about 320–350 ms. The syllables were played to the subject from a portable CD player and headphones at a sound intensity level indicated by the subject to be a comfortable listening level. The syllables were read by a male voice with intonation and intensity held constant. The DL test with CV stimuli has yielded test-retest reliabilities between 0.70 (Bakker, Van der Vlugt, & Claushuis, 1978) and 0.90 (Harper & Kraft, 1986).

**Data Analysis**

Data analyses were conducted using the Statistica v. 10 analysis software package (StatSoft Inc, http://www.statsoft.com/#). The dichotic listening data were subjected to a factorial analysis of variance (ANOVA) based on the design 3 Groups (ADHD-C, ADHD-PI, HC) × 2 Ear (right, left) × 3 Attention instruction (NF, FR, FL). Significant main and interaction effects were followed-up with Fisher’s Least Significant Difference (LSD) post hoc test.

**RESULTS**

The ANOVA showed significant main effects of Ear, F(1, 104) = 47.77, p < .001, \( \eta^2 = .315 \), with better performance for the right-ear stimulus, and of Group, F(2, 104) = 6.33, p = .003, \( \eta^2 = .109 \). Follow-up tests showed that the main effect of Group was due to significantly better performance for the ADHD-C group compared to the ADHD-PI group (p = .027), and for the HC group compared to the ADHD-PI group (p < .001).

In addition the three-way interaction of Group × Ear × Attention instruction was significant, F(4, 208) = 3.11, p = .016, \( \eta^2 = .056 \). The interaction was followed up with Fisher’s LSD test for pair-wise comparisons between all means. This revealed that all three groups had an REA during the NF and FR conditions with no significant difference between the groups. Follow-up testing also showed a significant right-ear advantage for the ADHD-PI group during the FL condition (p = .002), with the HC group showing a significant left-ear advantage (p = .016), and the ADHD-C group showing a no-ear advantage (see Figure 1 for means and standard errors).

Moreover, a follow-up analysis with Fishers’ LSD test for the ADHD groups showed that there was a “shift facilitation” effect for both ADHD groups for the right-ear reports in the FR condition. There was an “inhibition suppression” effect for the left-ear reports in the FL condition, which was shown by comparing the increase in the right-ear reports in the FR condition, and the increase in the left-ear reports in the FL condition. Fisher’s LSD
Figure 1 Mean percentage correct reports on the dichotic listening test for the left- (LE) and right- (RE) ear scores for the three attention conditions (nonforced, NF, forced-right, FR, and forced-left, FL) and diagnostic groups (HC, ADHD-C, ADHD-PI). Vertical bars denote standard errors. See text for further explanations.

test showed that both ADHD subgroups reported significantly more correct items from the right-ear in the FR condition ($p < .001$ and $p < .001$, for the ADHD-PI and ADHD-C groups, respectively), thus, revealing intact shift facilitation function. However, while the ADHD-PI group still showed significantly more right-ear reports for the right-ear stimulus in the FL condition ($p = .002$), this was no longer the case for the ADHD-C subtype ($p = .405$, ns), revealing failure by the ADHD-PI group to suppress the right-ear stimulus during the FL instruction condition.

Moreover, a separate one-way ANOVA based on the left-ear score during the FL condition showed that the ADHD-PI group had significantly ($p < .001$, $\eta^2 = .137$) fewer correct reports compared to the ADHD-C and the HC groups, with no significant difference between the two latter groups. A separate analysis comparing right- and left-handers did not change any of the results. Further, there were no significant differences between males and females in five out of six conditions using independent group $t$-tests (NF right ear and NF left ear, FR left ear, FL right ear, and FL left ear). In only one condition (FR right ear), females’ performance was somewhat better than the males’ performance ($p = .023$).

Finally, magnitude of laterality effects and intrusions were scored and analyzed. Magnitude of laterality effects were analyzed as laterality index scores from the formula:

$$\left[\frac{(\text{REcorrect} - \text{LEcorrect})}{(\text{REcorrect} + \text{LEcorrect})}\right] \times 100.$$

Intrusions were scored as reports of errors, that is, a report of one of the syllables not presented on any given trial. The analysis of the laterality index scores showed a significant main effect of attention instruction, $F(2, 208) = 31.73$, $p < .001$, $\eta^2 = .234$. Follow-up tests with Fisher’s LSD test showed that the main effect was due to a larger laterality index in the FR condition ($M = 27.40$) compared to the two other conditions.
COGNITIVE CONTROL IN ADHD SUBTYPES

(M = 2.74, p < .001 and M = 12.55, p < .001 for the FL and NF conditions, respectively). The laterality index for the FL also was significantly smaller than the laterality index during the NF condition (p < .001). The means show that the HC group differed in magnitude of laterality from the other two groups during the FL condition with a negative laterality index (M = −7.383). Analysis of intrusions was done in a factorial ANOVA with Groups and Attention Instruction as factors. This showed significant main effects of Groups, F(2, 104) = 6.339, p = .003, η² = .109, and Attention Instruction, F(2, 208) = 12.668, p < .001, η² = .108. Follow-up tests with Fisher’s LSD test showed that the Group effect was due to more intrusions in the ADHD-PI group (M = 22.75) compared to the ADHD-C (M = 16.94) and the HC (M = 14.97) groups. The differences were significant (p = .022 and p < .001 for the comparisons with the ADHD-C and HC groups, respectively).

DISCUSSION

As expected, all three groups had normal lateralized perception (nonforced condition/NF) and attention (forced-right condition/FR). The FL condition additionally requires the ability to resolve a cognitive conflict resulting from the requirement to select a weaker over a stronger source of information. Thus, this condition of the test is suggested to involve elements of cognitive control to a larger degree than the FR condition. As predicted, we found that children and adolescents with ADHD-PI showed a right-ear advantage also during the FL condition indicating a deficit in cognitive control compared to participants with ADHD-C and HC. The ADHD-C group showed a no-ear advantage and the HC showed a significant left-ear advantage in the FL condition. This suggests that the DL task does not truly separate out a cognitive difference between ADHD subtypes but indicates that the ADHD subtypes differ in degree of cognitive control impairment due to that only the HC group demonstrated ability to resolve the cognitive processing conflict. As such, the present results are novel also in the sense that they demonstrate a dimensionality perspective on cognitive deficits in ADHD with subgroups differing in the amount of deficit or impairment observed. Further research, however, is needed to clarify whether the observed FL effect is a “cognitive conflict effect,” or if directing one’s attention to the stimulus presented to the left ear during the FL instruction means that this stimulus takes on new saliency thereby becoming the stronger stimulus compared to the right-ear stimulus. This could then be viewed as a deficit of orienting rather than cognitive conflict, following Posner’s theory of attentional networks (Fan, McCandliss, Sommer, Raz, & Posner, 2002).

The present study revealed ADHD subtype differences of early developing cognitive control skills when assessed with a DL task as proposed by Diamond (2005). The results are moreover in accordance with the results of Davidson and Prior (1978), Hiscock and colleagues (1979), Prior and colleagues (1985) and Øie and colleagues (1998) who all found no impairment in perception and attention in children and adolescents with ADHD. The adolescents with ADHD in the Øie and colleagues study were however diagnosed with both ADHD-C and ADHD-PI, and differences between subtypes were not examined. Thus, it is possible that the ADHD-PI participants in the study of Øie and colleagues had impairment in cognitive control, but when the results were collapsed with the results of the ADHD-C group, the impairment was not detectable. Because EFs are not fully developed until early adulthood, it is possible that the deficit in cognitive control is simply more difficult to detect in young ADHD patients, especially when subtypes are not examined.
Research using the DL procedure has repeatedly shown significant impairments in cognitive control, in the FL condition, and in various clinical groups such as adults with schizophrenia, depression, or ADHD compared to healthy controls (see Westerhausen & Hugdahl, 2010). As far as we know, the present study is the first to demonstrate significant differences in degree of cognitive control ability between subtypes within the same diagnostic category, which could have important consequences for an understanding of cognitive impairments in diagnostic groups like ADHD. In this respect, the present paradigm has the power to detect subtle differences in cognitive control and executive functioning not seen in other test procedures. The paradigm could be used in further explorations of, for example, subcomponents of executive functions (cf. Miyake et al., 2000) and how inhibition relates to shifting of focus and information updating. The separate follow-up analyses of the interaction effect showed, for example, that while both ADHD subgroups managed to facilitate scores for the right ear during the FR instruction condition, interpreted as the ability to facilitate attentional shifts, only the ADHD-C subgroup managed to suppress the right ear during the FL instruction condition, interpreted as suppression inhibition. There is also the possibility that the failure to report the left-ear stimulus in the FL condition by the ADHD-PI group may be a problem with orienting. Previous research has documented that many individuals with ADHD get lower grades in school (Faraone, Biederman, Monuteaux, & Seidman, 2001). The verbal component for school functioning is tremendously important. The clinical implication of difficulties in inhibiting irrelevant auditory syllables in the FL condition in the DL task in the ADHD-PI group may be associated with difficulties in ignoring irrelevant and interfering “noise” in the classroom or in social settings. An experimentally based study like the present one, showing impairments in cognitive control in a highly structured environment, testifies to the importance of addressing the issue of techniques to improve cognitive control for this group of young students.

Original manuscript received April 1, 2012
Revised manuscript accepted October 13, 2012
First published online November 8, 2012

REFERENCES


