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Heterogeneity in Clinical Symptoms and Cognitive Functioning of Children with Hyperactivity-Impulsivity and Inattention: Dimensional and Person-Centered Perspectives

Abstract*: The goal of this study was to investigate heterogeneity in clinical symptoms and cognitive functioning among children with hyperactivity-impulsivity and inattention using a novel approach that combined dimensional and person-centered perspectives. Executive, verbal and visuo-spatial functioning, hyperactivity-impulsivity, inattention, externalizing and internalizing symptoms were examined in 102 children (37 girls and 65 boys) at risk for ADHD and 62 children (31 girls and 31 boys) not at risk for ADHD in the age range of 8–10 years. We extracted seven groups with various profiles of psychopathological symptoms and cognitive functioning. We propose that symptoms of inattention and hyperactivity-impulsivity in these groups are related to different cognitive and affective-motivational problems.*

Key words*: ADHD, hyperactivity, impulsivity, inattention, executive functions, person-centered approach*

Our population of interest is children with parent- and teacher-rated ADHD symptoms. For a diagnosis of ADHD, the child must display symptoms in at least two different settings, such as at home and at school and information needs to be gathered from two or more informants (APA, 2000). However, a lot of children with subclinical ADHD symptoms suffer from self-regulation difficulties, experience problems in day-to-day life (especially in social and school functioning) and are often referred to psychologists and other specialists as they need therapeutic help (Kóbor, Takács, Urbán & Csépe, 2002; Rielly, Craig & Parker, 2006). Children with subclinical and clinical ADHD are characterized by high heterogeneity in terms of, among others: cognitive functioning, clinical symptoms, comorbid symptoms, and presentation of symptoms in different settings. Thus, it is important to differentiate groups of children with elevated ADHD symptoms characterized by various profiles of self-regulation difficulties in order to enable the development of more effective therapeutic and educational methods adjusted to the areas of problems in functioning.

Several studies revealed heterogeneity in cognitive functioning, especially in efficiency of executive functions, of children with ADHD symptoms (Chhabildas, Pennington & Willcutt, 2001; Nigg,Willcutt, Doyle & Sonuga-Barke, 2005). In many theoretical models (e.g., Barkley, 1997; Nigg, 2001; Schachar, Tannock, & Logan, 1993), executive function deficits are central to the explanation of the underlying mechanisms that lead to the manifestation of symptoms of inattention, hyperactivity and impulsivity. Studies have consistently shown that the average performance in executive function tests of children with ADHD (especially those diagnosed with either the combined or predominantly inattentive subtypes) is significantly lower than the performance of children in a control group (Chhabildas et al., 2001; Nigg et al., 2005). However, the meta-analysis conducted by Nigg and colleagues (2005) revealed that there is a much greater variance in the scores of children with ADHD in comparison to children without ADHD on executive function tests. The distributions of these test scores for children in the control group and in the clinical group do overlap with some children with ADHD performing within the normal range on these tasks.

Moreover, deficits in other various spheres of cognitive functioning were observed in children with ADHD symptoms: they achieve lower results on

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standardized tests of general intelligence (lower by 9 points, equivalent to 0.6 standard deviations) and reading and math tasks (Biederman et al., 2009; Ek et al., 2007; Frazier, Demaree & Youngstrom, 2004) and these abilities vary depending on ADHD subtype (Marshal, Hynd, Handwerk, & Hall, 1997). Therefore, executive function weakness is not a single, core dysfunction that leads to ADHD symptoms. Researchers have sought other deficits that underlie symptoms of hyperactivity, impulsivity and inattention including, among others: difficulties in affective-motivational self-regulation; the presence of a specific motivational style, in particular one associated with an excessive tendency to seek pleasure and rewards; difficulty in coping with delay aversion; and low sensitivity to punishment and pain (Derryberry & Tucker, 2006; Quay, 1997, Sjöwall, Roth, Lindqvist & Thorell, 2013; Sonuga-Barke, 2005; Sonuga-Barke, Sergeant, Nigg & Willcutt, 2008; Sonuga-Barke & Halperin, 2010).

Nigg and colleagues (2005) have pointed out that greater emphasis in research should be given to the identification of psychological subtypes of children with hyperactivity-impulsivity and inattention symptoms by relying on neuropsychological measures and not only on symptom measures. However, we did not find studies with this kind of analysis in children with ADHD. Cluster analysis concerning hyperactivity-impulsivity and inattention was performed in previous studies, however most of them included only psychopathological symptoms (Hudziak et al., 1998; Neuman et al., 2001). We found one study (Frazier, Youngstrom & Naugle, 2007) in which clustering based on both clinical symptoms and neuropsychological variables was performed, however the aim of the study was to explore if ADHD may be best represented by a dimensional, or categorical latent structure. Authors of this research did not presented characteristics of the obtained clusters. The aim of our study is to fill this gap by looking for subtypes of children with hyperactivity-impulsivity and inattention symptoms relying on both neuropsychological measures (executive function, verbal and visuo-spatial abilities tests) and symptom measures.

The second issue undertaken in our study concerns heterogeneity in psychopathological symptoms that are comorbid with ADHD. The co-occurrence of comorbid disorders – both internalizing (e.g., anxiety and depression) and externalizing (e.g., aggressive and delinquent behaviors) – with ADHD is a consistently replicated finding (Baeyens, Roeyers & Walle, 2006; Milich, Balentine & Lynam, 2001). Previous studies shown that it is important to look for higher-order patterns among symptoms of different disorders (Hudziak, Althoff, Derks, Faraone, & Boomsma, 2005; Hudziak, Achenbach, Althoff & Spine, 2007; Stevenson et al., 2005). Mechanisms underlying various constellations of psychopathological symptoms may differ (Hudziak et al., 2005, 2007; Stevenson et al., 2005). For example, a study performed by Hudziak and colleges (2005) shows that children with comorbid ADHD, ODD and MDD are characterized by distinct genetic factors compared to children with different configurations of these psychopathological symptoms. Thus, we found it important to include in the clustering performed in the current study not only hyperactivity-impulsivity and inattention but also comorbid psychopathological symptoms – both internalizing and externalizing.

A third research topic raised in our study concerns heterogeneity in the presentation of ADHD symptoms observed by various informants: teachers and parents. For a diagnosis of ADHD, the child mus display symptoms in at least two different settings, such as at home and at school (APA, 2000). Therefore, information needs to be gathered from two informants. The important problem is low agreement between different informants (various teachers and parents) in the assessment of the intensity of hyperactivity-impulsivity and inattention symptoms (Amador-Campos, Forns-Santacana, Guardia-Olmos, & Pero-Cebollero, 2006; Stevenson et al., 2005; Schultz & Evans, 2012; Thapar, Langley, O'Donovan, & Owen, 2006). Although guidelines how to integrate parent and teacher DSM symptom ratings of ADHD (i.e., And/Or Rule) exist (Evans, Owens & Bunford, 2014), a dimensional approach makes it easier to use data from multiple sources of information, such as parents, teachers, and the children themselves and assess their intensity on the rating scales (Hudziak et al., 2007). Based on this approach, we can perceive symptoms observed by parents and teachers as related, but distinct dimensions. Little research has been conducted examining profiles of neuropsychological functioning and risk factors associated with ADHD symptoms observed by different informants. Preliminary studies on this topic found that there are differences in genetic factors related to ADHD symptoms observed by parents and teachers (Stevenson et al., 2005; Thapar et al., 2006). Thus, we have decided to explore profiles of cognitive functioning associated with ADHD symptoms observed by one or both informants (parents and teachers).

To capture heterogeneity in cognitive functioning, clinical symptoms, comorbid disorders, and presentation of symptoms in different settings in children at risk for ADHD, we joined dimensional (Principal Components Analysis (PCA)) and person-centered (cluster analysis) approaches. Previous studies show that ADHD is likely to represent the extreme of a continuously distributed trait found in the general population which is concordant with dimensional approaches to psychopathology (Chen et al., 2008; Hudziak et al., 2007; Stevenson et al., 2005). However, recognising that psychopathology is generally best classified along continuous distributions does not imply that instances of qualitatively distinct conditions would not exist or could not be recognised (Beauchaine, 2003; Gambin, Gambin & Sharp, 2015; Hudziak et al., 2007; Pickles & Angold, 2003; Widiger & Samuel, 2005). A categorical, person-centered approach – such as cluster analysis, latent class analysis and mixture modeling – complements a variable-centered approach and allows researchers to distinguish groups of children characterized by similar genetic, neuropsychological and behavioural features (Bergman & Magnusson, 2003; Gambin, Gambin et al., 2015).

Because we examine psychopathological symptoms as dimensions, a group of children at risk for ADHD from Polish schools (defined as children with higher than one standard deviation from the mean for the population intensity of symptoms of hyperactivity-impulsivity and inattention), observed by parents and/or teachers, took part in our study. First we conducted dimensional and variable-based analysis – principal component analysis – to explore covariance among measured variables and to reduce number of dimensions on which clustering will be performed. These principal components were then used to perform person-centered analysis (clustering), which allowed us to capture heterogeneity within our group of children and look for the common types of individuals who share similar profiles of symptoms observed by teachers and/or parents, as well as broadly comparable levels of executive and intellectual functioning.

In our study, we have chosen to use clustering variables that give a more complete picture of ADHD than solely clinical symptoms. We have included symptoms that most often co-occur with ADHD, including both internalizing (anxiety and depression) and externalizing (aggressive and rule-breaking behaviours) symptoms (Baeyens et al., 2006; Milich et al., 2001), as well as symptoms observed by different informants: parents and teachers. We took into account executive functions that were found to be the most impaired in children with ADHD symptoms: response inhibition, planning and working memory (Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005) and we have chosen commonly used executive function tests: Stop Signal Task, Tower of Hanoi, and Digit Span (Klinberg et al., 2005; Nigg, Blaskey, Huang-Pollock, & Rappley, 2002). Furthermore, relying on the postulates posed by Dennis and colleagues (2009), as well as by Frazier and colleagues (2004), we decided to include IQ scores in our analysis. These researchers emphasized the importance of including IQ scores in models explaining the emergence of symptoms in neurodevelopment disorders. This postulate seems particularly important in children with inattention and hyperactivity-impulsivity symptoms as cognitive deficits are part of the clinical picture of ADHD (Biederman et al., 2009; Ek et al., 2007; Frazier et al., 2004). As indicators of IQ we chosen two subtests from the Wechsler Intelligence Scale for Children: Block Design that measures visuo-spatial functioning and Vocabulary test that measures verbal functioning. These subtests have been shown to correlate highly with the full-scale IQ score.

Method

Participants

The study included children, aged 8–10 years, drawn from 12 schools in Warsaw and 4 schools in the suburban areas surrounding Warsaw. In the first stage of the study, 450 parents completed rating scales concerning hyperactivity-impulsivity and inattention symptoms. From this group, 164 children (68 females and 98 males) in the age range of 8–10 years old (mean age: 9 years) at risk for ADHD and not at risk for ADHD were chosen (basing on the criteria described in the next paragraph) and participated in further sections of the study. Participants were sorted into two groups: 1) 102 children with a high severity of hyperactivity-impulsivity and inattention observed by their parents; and 2) 62 children with a low severity of hyperactivity-impulsivity and inattention observed by their parents.

The group of children at risk for ADHD was characterized by children whose scores in the hyperactivity-impulsivity and/or inattention subscales of the Rating Scale for Parents were more than one standard deviation higher than the mean for the population. This meant the selection of about 15% of children from among the population with the highest intensity of hyperactivity-impulsivity and/or inattention symptoms. Cutoff of one standard deviation above the mean for results of other rating scales of ADHD symptoms was shown to have good predictive value of diagnosis of ADHD (Biederman et al., 1993; Geller et al., 2004). Thus, we assumed that using this cutoff we would identify children with both clinical and subclinical ADHD.

The second group of children was composed of those whose scores on the hyperactivity-impulsivity and/or inattention subscales of the Rating Scales for Parents were more than one standard deviation below the average for the population. This was equivalent to the selection of about 25% of children with the lowest intensity of these symptoms. There were proportionately a greater number of girls with a low intensity of hyperactivity-impulsivity and inattention symptoms than there were boys in the sample population. Thus, equal proportions of girls and boys were randomly assigned to the second group out of 25% children with the lowest intensity of symptoms in order to minimize any distorting effects of the variable gender.

Children who took part in the study were not taking medications to reduce the severity of symptoms of hyperactivity-impulsivity and inattention. Two of the children from the first group had psychiatric diagnoses of hyperkinetic disorder (according to the ICD-10). It is worth noting that results of previous studies (Gambin & Święcicka, 2009) and clinical observations made by the authors of this paper have shown that a number of children exhibiting a high intensity of inattention and/or hyperactivity-impulsivity symptoms in Poland do not use psychological and/or psychiatric services.

Descriptive statistics (age and gender, parent's education level) for whole sample and groups extracted in the cluster analysis are presented in the Table 1.

Permission to conduct this investigation was provided by the respective school principals, the individual classroom teachers and the University of Warsaw Institutional Review Board. All parents gave their written, informed consent prior to their child's participation in the study.

Measures

The Rating Scales for Teachers and Parents

The Rating Scales for Teachers and Parents (Gambin & Swiecicka, 2009, 2012; Święcicka, Matuszewski & Woźniak, 2008) were constructed at the University of Warsaw. We applied an empirically-based, bottom-up

Table 1. Descriptive Statisitics

	C	IA	HI	C1-P	C2-P	WD	C-T	Whole sample
Females (n)	1	14	5	15	2	26	5	68
Males (n)	16	16	14	9	10	26	5	96
Age (in months)	108	108	110	108	104	108	108	108
Mother's education (1–4*)	2.94	3.19	3.22	3.35	3.50	3.18	3.20	3.22
Father's education (1–4*)	3.06	3.41	3.17	3.78	3.58	3.42	3.33	3.39

Note. * 4 – higher education, 3 – secondary education, 2 – vocational education, 1 – primary education

approach (Achenbach, Dumenci & Rescorla, 2003) to the construction of these scales, in which the researcher does not make any initial assumptions concerning the existence of certain diagnostic categories. Therefore, the initial set of items included in the scales came not from the diagnostic manual but from the actual comments of teachers and parents who were describing the behavior of their children as they displayed hyperactivity-impulsivity and inattention symptoms.

The Rating Scale for Teachers includes 22 items and consists of four subscales that were extracted through factor analysis. The hyperactivity-impulsivity subscale (8 items, Cronbach's alpha = .94) measures the intensity of impulsive and hyperactive behaviors (e.g. *Acts very quickly, often without thinking*). Two more subscales measure the intensity of two dimensions of inattention. The withdrawal of attention subscale (seven items, $\alpha = 0.94$) assesses the tendency to withdraw attention and carelessness (e.g. *Often seems to be absent-minded*). The distractibility-fatigability subscale (ten items, $\alpha = 0.90$) concerns the tendency to be easily distracted and tire quickly of mental activities (e.g. *Ideally needs silence to pay attention to schoolwork*). The low emotional control subscale (4 items, $\alpha = 0.91$) assesses the tendency toward uncontrolled emotional outbursts (e.g. *It is easy to provoke her/ him to outbursts of emotion*). The teacher's task is to rate on a four-degree scale (1 – not true; 2 – somewhat true; 3 – rather true; 4 – definitely true) the extent to which the behavior described in the item matches the child's behavior.

The intensity of symptoms of hyperactivity-impulsivity and inattention in children as displayed at home was measured with the *Rating Scale for Parents*. The scale includes 22 items and consists of two subscales extracted through factor analysis. The hyperactivity-impulsivity subscale (11 items, $\alpha = .90$) measures the intensity of impulsive and hyperactive behaviors (e.g. *It is difficult for him/her to sit in one place*). It also includes items concerning low emotional control, which were joined into one component in this scale (unlike in the scale for teachers) basing on the exploratory factor analysis. The inattention subscale (11 items, $\alpha = .92$) assesses the child's tendency to become easily distracted, to tire quickly of mental activities, to withdraw attention and to be careless (e.g. *He/she forgets his/her homework or what the teacher asked*). The parent is asked to rate on a four-degree scale (1 – not true; 2 – somewhat true; 3 – rather true; 4 – definitely true) the extent to which the behavior described in the item matches the child's behavior.

Previous studies conducted in Poland (Gambin & Swiecicka, 2009, 2012, 2015) show that the scales are characterized by good convergent and discriminant validity. The Rating Scale for Parents was completed either by mother (for 89% of participants) or by father (for 11% of participants).

Child Behavior Checklist (CBCL) and Teacher's Report Form (TRF)

The CBCL (for 4- to 18-year-olds; Achenbach & Rescorla, 2001) and the TRF (for 5- to 18-year-olds; Achenbach & Rescorla, 2001) consist of 118 and 113 problem-specific items, respectively. Items are rated on the following scale: 0 – not true, 1 – somewhat or sometimes true and 2 – very true or often true. The CBCL and TRF generate Internalizing, Externalizing, and Total Problem scales, in addition to eight syndrome scales: Withdrawn, Somatic Complaints, Anxious/Depressed, Social Problems, Thought Problems, Attention Problems, Delinquent Behavior and Aggressive Behavior. As we were interested in attention problems and externalizing and internalizing symptoms in the current study, the following scales were used: Delinquent Behavior, Aggressive Behavior, Anxious/Depressed, Withdrawn and Attention Problems scales. For both measures, the raw scores were used as recommended for research purposes by Achenbach & Rescorla (2001). The Polish adaptations of these scales was prepared by Tomasz Wolanczyk (2002).

Stop signal task

The stop signal task (Logan, 1994; Logan & Cowan, 1984) is a computerized measure of executive inhibitory control that was developed based on Logan's 'race model' of inhibition (1994). On primary task trials, the letters X or O are presented with the instruction to press a corresponding key as quickly as possible, creating a pre-potent tendency to respond in most trials. In a randomly selected 25% of the trials, a tone is presented that indicates

that the participant should stop the response. The version of the stop signal task applied in the current study utilizes a tracking procedure in which the delay between the presentation of the visual stimulus and the onset of the stop signal changes after every trial with a stop signal. It allows participants to successfully inhibit their responses to the signal in roughly 50% of the stop signal trials over the course of the experiment. This was necessary in order to estimate the stop signal reaction time (SSRT) by subtracting stop-signal delay from mean go-signal reaction time. Longer SSRT scores were indicative of deficits in inhibition. All participants in our study were asked to individually complete the stop signal task.

Tower of Hanoi

The Tower of Hanoi was used to measure planning. The procedure used in this study was based on that developed by Borys, Spitz and Dorans (1982) and described by Bishop, Aamodt-Lepper, Creswell, McGurk and Skus (2001). The apparatus consisted of a board containing 3 upright rods and 4 discs of varying sizes. One apparatus was designed for the participant of the study. On the second apparatus is presented a model arrangement of the discs, which the participant must duplicate in the minimum number of moves while obeying the following rules: (1) only one disc may be moved at a time; (2) a larger disc must not be placed on top of a smaller one; (3) discs may not be placed on the table. The participant was given problems of increasing complexity, starting with 3-move problems and increasing up to 9-move problems, until two consecutive problems were failed. There were two problems for each number of moves. To be credited as having passed a given problem, the child had to solve it once in the minimum number of moves. The child's final score was the highest level of task they successfully completed in terms of number of moves, with an additional half point added if both tasks at this level of moves were completed.

The Digit Span (Digits backward and forward) subtest from the Wechsler Intelligence Scale for Children (Matczak et al., 1991; Wechsler, 1974) was used to measure working memory abilities.

The Vocabulary and Block Design subtests from the Wechsler Intelligence Scale for Children (Wechsler, 1974) were used to estimate intellectual functioning: verbal and visuo-spatial skills. These subtests have been shown to correlate highly with the full-scale IQ test.

Results

To extract subtypes of children that differ in severity of hyperactivity/impulsivity, inattention, and comorbid symptoms as well as in executive functioning and verbal and visuospatial skills, the following steps were applied: 1) Principal component analysis (PCA) to reduce the number of dimensions on which clustering would be carried out. 2) Hierarchical clustering to divide children into groups 3) Silhouette width to determine the number of groups.

Rationale for the choice of methods of analysis

Principal component analysis (PCA) was performed in order to reduce the number of dimensions on which clustering would be carried out. Previous studies (e.g., Ben-Hur & Guyon, 2003; Gambin et al., 2015; Jackson, 1991; Jolliffe, 2002) had indicated that the clustering could benefit from a preprocessing step of feature/variable selection by using PCA to construct a set of uncorrelated directions that are ordered by their variance. In many cases, directions with the most variance are the most relevant to the clustering. Ben-Hur and Guyon (2003) showed that removing features with low variance acted as a filter that resulted in a distance metric that was able to provide a more robust clustering; PCA is also useful as a visualization tool, in that it can provide a low dimensional summary of the data (Ben-Hur & Guyon, 2003; Joliffee, 2002).

It is not clear what number of principal components we ought to have chosen to clustering. Some researchers (e.g., Jackson, 1991), as a criterion for selecting the number of components, consider the percentage of the total variance in the first component. However, Ben-Hur and Guyon (2003) have shown that, even in the case that the first principal components include a small percentage of the total variance—in this study, the three first components contained only 31% of the variance—the use of 3 to 5 first components provided the most stable results of the clustering. This was due to the fact that the aim of performing PCA before clustering is not the reconstruction of the original data matrix but the extraction of those features that are the most important for the clustering.

To divide children into groups, a hierarchical clustering method was applied. To calculate the distance between objects, the authors used squared Euclidean distance, whereas to calculate the distance between groups, the authors used Ward's method (1963), which was designed to generate clusters in such a way that the variance within the clusters is minimal. Clusters extracted by this method are characterized by a small variance obtained by minimizing the error sum of squares among the members of each cluster. Ward's method strives to create groups that contain equal numbers of observations.

To determine the number of groups, the authors used silhouette width (Rousseeuw, 1987), which provides an evaluation of cluster validity. Silhouette width is a composite index that reveals the compactness and separation of clusters. A larger average silhouette width indicates a better overall quality of the clustering result. Silhouette values of zero indicate that the observed data point lies between two clusters, while negative silhouette values indicate that the observation is poorly or incorrectly classified. Silhouette width can be calculated for individual objects, groups and for a complete dataset.

To compare groups Kruskal-Wallis and U-Mann Whitney post hoc tests were performed for all the variables included in the PCA. We used non-parametric tests as variables included in our study were not normally distributed.

Results of analysis

Variable-based analysis

Variables designated to clustering varied in their scope. Therefore, scaling and centering of data was performed prior to PCA.

PCA was performed on the selected for the clustering 22 variables. Varimax rotation was used and three factors were extracted, capable of explaining 51% of the variance (Table 2). These were:

C1: Hyperactivity-impulsivity, low emotional control, aggressive behaviors observed by parents and teachers; delinquent behaviors, attention problems and anxiety-depression reported by teachers;[1]

C2: Inattention, cognitive and executive difficulties in planning, inhibition, working memory, verbal and visuo-spatial abilities; and,

C3: Problem behaviors (attention problems, anxiety, depression and withdrawal symptoms, aggressive and delinquent behaviors) observed by a parent.

Loadings for the listed above variables were higher than 0.4 for the corresponding component. The information contained within the original variables was then projected onto three principal components.

Person-centered analysis

Next, hierarchical clustering was performed. The first part of our analysis was conducted on the group of 102 children with high intensity of hyperactivity-impulsivity and inattention in the Rating Scale for Parents. Indicators of cluster validity were compared for a number of groups, from 2 to 8. Silhouette width reached its highest values when the data were clustered into 5 groups.

The five groups have the following characteristics:

1. C: combined symptoms of hyperactivity-impulsivity and inattention, severe cognitive difficulties (in executive functioning, verbal and visuo-spatial abilities) and high intensity of problem behaviors (aggressive, delinquent, depression, anxiety and withdrawal symptoms) (n = 17);
2. IN: high intensity of inattention, middle intensity of hyperactivity-impulsivity symptoms and severe cognitive difficulties (in executive functioning, verbal and visuo-spatial abilities) (n = 30);
3. HI: high intensity of hyperactivity-impulsivity, middle intensity of inattention symptoms, low emotional control and high intensity of aggressive, delinquent behaviors, anxiety-depression and withdrawal observed by teachers and aggressive behaviors observed by parents (n = 19);
4. C1-P: combined symptoms of hyperactivity-impulsivity and inattention observed only by parents, high efficiency of executive functioning, high verbal and visuo-spatial abilities (n = 24); and,
5. C2-P: combined symptoms of hyperactivity-impulsivity and inattention observed only by parents and high intensity of problem behaviors (aggressive, delinquent depression, anxiety and withdrawal symptoms) observed only by parents; low efficiency of executive functioning and low verbal abilities (n = 12).

Table 2. Results of Principal Component Analysis

	C1	C2	C3
Aggressive Behaviours (T)	**.89**	.02	.19
Hyperacivity-Impulsivity (T)	**.82**	.11	.08
Low Emotional Control (T)	**.82**	-.06	.07
Delinquent Behaviours (T)	**.81**	.21	.14
Attention Problems (T)	**.64**	**.57**	-.03
Anxiety-Depression (T)	**.59**	.13	-.10
Hypearcivity-Impulsivity (P)	**.43**	-.23	.29
Anxiety-Withdrawal (T)	.29	.29	-.02
Tower of Hanoi	-.18	-.15	.07
Distractibility-Fatigability (T)	**.44**	**.72**	-.11
Digits Forward	-.05	**-.67**	-.01
Inattention (P)	.07	**.65**	.10
Vocabulary	-.01	**-.63**	-.22
Digits Backward	.01	**-.61**	-.09
Withdrawal of Attention (T)	**.36**	**.54**	-.21
Block Design	.12	**-.52**	.08
Stop Signal Reaction Time	.24	**.41**	-.05
Anxiety-depression (P)	-.07	-.02	**.79**
Delinquent Behaviours (P)	.14	.03	**.78**
Attention Problems (P)	.14	.31	**.76**
Depression-Withdrawal (P)	-.24	-.03	**.75**
Aggressive Behaviours (P)	**.37**	-.10	**.72**

Note. Values greater than .35 are highlighted (bold). T – teacher, P – parent

The same procedure was applied to the group of 62 children with low intensity of hyperactivity-impulsivity and inattention symptoms observed in the Rating Scale for Parents. Silhouette width reached its highest value when the dataset was divided into two groups. Children from these two groups were characterized by:

1. WD: those without difficulties in functioning, with low intensity of symptoms and problem behaviors observed by parents and teachers (n = 52);

[1] We use wording Hyperactivity-impulsivity (HI) and inattention (IA) when we refer to data obtained from the Rating Scales for Teachers and Parents. We use wording ,'attention problems'' when we refer to data obtained from the Child Behaviour Checklist and the Teacher Report Form.

2. C-T: those with combined symptoms of hyperactivity-impulsivity and inattention observed only by teachers and high intensity of problem behaviors (aggressive, delinquent, depression, anxiety and withdrawal symptoms) observed only by teachers; cognitive difficulties (in executive functioning, verbal and visuo-spatial abilities) (n = 10).

Profiles (average values for each variable) for all seven groups—the five groups with high severity of hyperactivity-impulsivity and inattention in the Rating Scale for Parents and the two groups of children with low intensity of symptoms in the Rating Scale for Parents—are presented in Figure 1. Descriptive statistics were calculated for each of the selected groups (Table 1). The groups did not differ significantly in terms of mean age of participants and parents' education level. Comparison of groups using Kruskal-Wallis and U-Mann Whitney post hoc tests were performed for all the variables included in the PCA. We checked to see to which groups' participants with clinical diagnoses had been assigned. Participants with psychiatric diagnoses of hyperkinetic disorder according to ICD-10 were assigned to Group C.

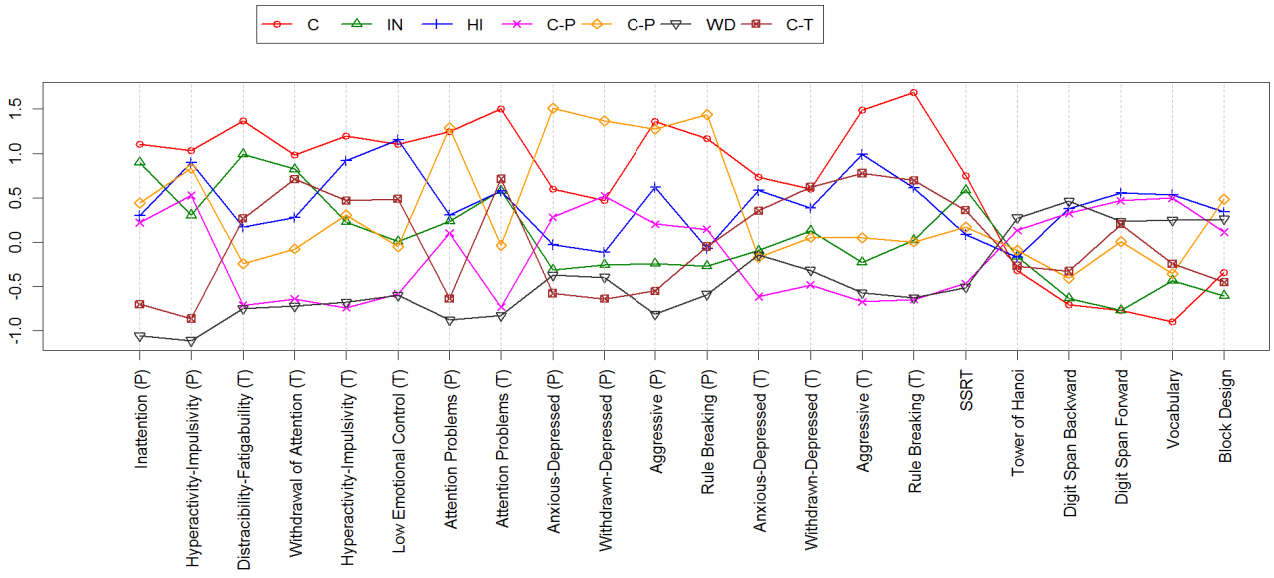
Discussion

The aim of this study was to explore heterogeneity in cognitive functioning, clinical symptoms in children at risk for ADHD and to identify groups of children with various profiles of functioning in these spheres. Seven groups of children with different profiles of self-regulation difficulties were extracted: three groups with high-intensity ADHD symptoms as observed by teachers and parents, three groups in which only one informant perceived a high intensity of symptoms and one group without self-regulation difficulties. The configuration of symptoms in the three groups with high intensity of ADHD symptoms observed by both parents and teachers is similar to the ADHD subtypes distinguished in the DSM-V: predominantly inattentive, predominantly hyperactive-impulsive and combined.

The first research topic raised in our study concerns heterogeneity in cognitive functioning of children with ADHD. In the PCA, which was conducted to reduce the number of dimensions on which clustering was performed, three components were extracted. One of them joined all cognitive abilities, such as working memory, response inhibition, verbal and visuo-spatial abilities, and symptoms of inattention observed by parents and teachers (e.g., distractibility-fatigability and withdrawal of attention). The presence of inattention symptoms and executive abilities in one component was consistent with the previous studies that have shown that these variables are associated with one another (Chhabildas et al., 2001; Gambin & Święcicka, 2009; Geurts et al., 2004). Moreover, our results show that symptoms of inattention and executive functioning are also related to low verbal and visuo-spatial abilities. Previous studies indicate that executive functions, verbal and visuo-spatial abilities are linked to each other (Blair & Razza, 2007; Espy et al., 2004; Luciano et al., 2001; Miyake, Friedman, Shak, Rettinger, & Hegarty, 2001). It may be that children characterized by poor executive functioning gain fewer experiences crucial for the development of other cognitive abilities. On the other hand, low verbal and visuo-spatial abilities make it more difficult to control their own behaviour and regulate attention. These hypotheses should be tested in longitudinal studies in future research. Cognitive abilities were not included in the two other components (C1 and C3) that will be described in further part of the discussion.

Seven groups extracted in our study differ in their cognitive functioning. The IA group with predominant inattentive symptoms observed by parents and teachers is characterized by low efficiency of executive functions (e.g., response inhibition, working memory and planning)

Figure 1. Group Profiles



and low visuo-spatial and verbal abilities. These results are consistent with findings that show inattention to be related to executive function weakness (Chhabildas et al., 2001; Gambin & Święcicka, 2009). Children from HI group, characterized by low emotional control, high intensity of rule-breaking and anxious-depressive problems observed by teachers, as well as a high severity of aggression observed by teachers and parents, do not display difficulties in cognitive functioning. Similarly, previous studies have shown that children with a predominantly hyperactive-impulsive subtype of ADHD do not exhibit deficits in executive functioning (Baeyens et al., 2006; Milich et al., 2001). The C group manifests the highest severity of psychopathological symptoms and difficulties in cognitive functioning. These results are consistent with the findings of studies concerning the combined subtype of ADHD, which is characterized by severe difficulties in functioning across domains and poor executive functioning (Baeyens et al., 2006; Chhabildas et al., 2001; Gambin & Święcicka, 2009; Geurts et al., 2004; Milich et al., 2001).

In the current study, two groups in which only parents observed a high intensity of combined symptoms of hyperactivity-impulsivity and inattention and one group in which only teachers assessed severe symptoms were distinguished. Two groups – C2-P and C-T – obtained poorer results in executive function tests and in verbal functioning. Furthermore, the C-T group displayed difficulties in its visuo-spatial functioning, whereas the C2-P group did not have problems in this domain. To the contrary, the C1-P group was characterized by the high efficiency of its cognitive functioning. These results show that some of the children with ADHD symptoms observed by only one informant, which are usually not included in studies concerning ADHD symptoms, exhibit difficulties in cognitive functioning.

The second area of interest was heterogeneity in comorbid symptoms in children with hyperactivity-impulsivity and inattention. In the PCA, two components joining various psychopathological symptoms were extracted. The first one merged symptoms of hyperactivity-impulsivity and aggressive behaviours observed by parents and teachers, low emotional control, distractibility-fatigability, rule-breaking behaviours and anxious-depressed and attention problems observed by teachers. It was noteworthy that most of the psychopathological symptoms observed by teachers, except anxiety-withdrawal, were joined in the first component. The highest factor loadings in this component were achieved by aggressive behaviours, hyperactivity-impulsivity, rule-breaking behaviours and low emotional control observed by teachers. It may be that these psychopathological symptoms and difficulties in functioning can be related to the low efficiency of affective-motivational self-regulation – that is, the presence of a specific motivational style associated with the excessive tendency to seek pleasure and rewards, difficulty in coping with delay aversion and a low sensitivity to punishment and pain (Derryberry & Tucker, 2006; Quay, 1997; Sonuga-Barke, 2005). It is surprising that symptoms of anxiety-depression were joined in a single component with externalizing symptoms and were not joined with anxiety-withdrawal. Anxiety-depression, as measured by TRF, seems to relate to mood liability, which was found to be associated with hyperactivity-impulsivity (Sobanski et al., 2010). As PCA was conducted in the group characterized by a higher-than-the-population proportion of children with hyperactivity-impulsivity symptoms, these variables were merged together in one component.

The third component joins various psychopathological symptoms observed by parents in CBCL: anxiety-depression, anxiety-withdrawal, aggressive and rule-breaking behaviours and attention problems. In contrast to the first component, joining most of the problems observed by teachers, in this component all factor loadings have similar values – no group of psychopathological symptoms dominates. These results are consistent with previous findings showing that parent reports produce higher comorbidity estimates than teacher reports (Youngstrom, Findling, & Calabrese, 2003). It may be that parents encounter more difficulties when differentiating between psychopathological symptoms than do teachers. Moreover, the fact that symptoms of externalizing and internalizing disorders were joined together in one component may be a result of having conducted PCA in a specific group that contained a higher-than-average proportion of children with symptoms of hyperactivity-impulsivity and inattention. Previous studies revealed the occurrence of high comorbidity of clinical disorders among children with ADHD (Jensen et al., 2001).

All seven extracted groups differed in the configuration of psychopathological symptoms comorbid with ADHD. In accordance with previous findings on predominant hyperactive-impulsive subtype (Baeyens et al., 2006; Milich et al., 2001), HI group is characterized by a higher intensity of externalizing symptoms and a lower intensity of internalizing symptoms, except of anxiety depression observed by teachers. As was noted earlier, this subscale seems to be related to mood liability, which was found to be associated with hyperactivity-impulsivity (Sobanski et al., 2010). The IA group is characterized by a low intensity of comorbid symptoms. This result is contrary to previous studies concerning ADHD subtypes showing that the predominant inattentive subtype displays a higher intensity of internalizing problems (Baeyens et al., 2006; Milich et al., 2001). Our results show that difficulties in executive functioning and other cognitive abilities are related to symptoms of inattention in the IA group. It could be that the predominant inattentive group, differentiated based only on the presence/absence of the clinical symptoms listed in DSM-V, joins children who display symptoms of inattention related to difficulties in cognitive self-regulation and children for whom inattention symptoms arise from emotional problems (e.g., the presence of depression and anxiety). In our study, we did not find a group of children with predominant inattentive symptoms associated with internalizing problems. However, we can assume that if our study were to include a larger number of participants such a group could have been extracted. The C group displays the highest severity of

all psychopathological symptoms. It may be that difficulties in different domains interact with and intensify one another, which causes serious problems in functioning. Previous studies show that comorbid externalizing and internalizing symptoms are related to a higher severity of clinical presentation in children with ADHD (Connor et al., 2003).

The groups with ADHD symptoms observed by only one informant manifested elevated intensity for all psychopathological symptoms assessed by either parent or teacher: C1-P groups exhibited middle intensity of externalizing and internalizing symptoms observed by a parent, C2-P group displayed severe intensity of comorbid symptoms observed by a parent and C-T group exhibited high intensity of comorbid symptoms observed by a teacher. Thus, a high disproportion is observed between parent's and teacher's assessments – one of the informants observes problems in multiple spheres of functioning, whereas the other perceives much lower or no severity of these problems.

The third topic explored in the current study concerned heterogeneity in ADHD symptoms observed by different informants. Two groups in which only parents observed a high intensity of hyperactivity-impulsivity and inattention and one group in which only teachers assessed severe symptoms were distinguished. Children included in the C-T group may display more psychopathological symptoms at school than at home due to their difficulties in verbal and visuo-spatial functioning accompanied by their poor executive functioning. They tend to exhibit more prominent ADHD symptoms at school, where they are faced with tasks that exceed their cognitive abilities. On the contrary, in the C2-P group, teachers may observe fewer ADHD symptoms than parents due to the good executive functioning of these children, and chiefly their high non-verbal abilities. We can assume that the level of a child's cognitive functioning has a greater impact on teachers' assessments of ADHD symptoms than parents' assessments of the same.

Children from the C1-P and C2-P groups may exhibit more severe psychopathological symptoms at home due to factors identified in previous studies that increase the intensity of ADHD symptoms, such as experiencing serious family conflicts, stress or inconsistent parenting practices (Chronis, Chacko, Fabiano, Wymbs, & Pelham, 2004; Snyder, Cramer, Afrank, & Patterson, 2005). It may also be that parents of children from these groups display high intensity of depression, stress or anxiety – factors that have been pointed out in the literature as being associated with greater numbers of psychopathological symptoms in children as reported by parents (De Los Reyes & Kazdin, 2005).

Our study shows that it is important to pay more attention in future research to children with ADHD symptoms observed by only one informant and to look at symptoms observed by parents and teachers as distinct, but related dimensions. A significant number of children with symptoms observed by only one informant exhibit difficulties in cognitive functioning and they are also in need of professional help or treatment. It is important in future research to explore various mechanisms and risk factors leading to ADHD symptoms observed by different informants.

We can assume that various mechanisms underlie psychopathological symptoms in different groups. Difficulties in cognitive self-regulation may underlie ADHD symptoms in the IA, C-T and C2-P groups, whereas problems in affective-motivational self-regulation may lead to psychopathological symptoms in the HI group. Children from the C group probably exhibit difficulties in both: affective-motivational and cognitive self-regulation. Noteworthy is the fact that, in groups in which there is a predominance of hyperactivity-impulsivity or inattention, the intensity of the other ADHD symptom is also elevated. However, we can assume that the mechanisms that underlie these same symptoms as they occur in different groups are varied. Inattention displayed by children from the HI group can be a result of their emotional problems or can be a result of the hyperactive and impulsive behaviours of these children. Hyperactivity-impulsivity as exhibited by the IA group may have arisen from problems in their cognitive functioning. We can assume that there are separate and shared mechanisms underlying these two groups of behavioural symptoms.

Limitations

This study has some important limitations. Firstly, it has been limited by the small sample size and thus replication of the results using a larger sample is required before any firm conclusions can be drawn. The children included in this study were selected to participate based on the Rating Scale for Parents, not on the basis of any psychiatric diagnosis. This approach, despite bearing many advantages, also has important weaknesses – namely, we do not have information on whether any hyperactivity-impulsivity and inattention symptoms may be the result of other developmental disorders or illnesses. We cannot directly compare our results with the findings from other studies concerning ADHD. As children with low and high intensity of symptoms in the Rating Scale for Parents were selected for the current study, our findings may not generalize to children characterized by average intensity of ADHD symptoms. Moreover, no conclusions on cause-effect relations can be drawn based on our results. For example, we do not know if symptoms of inattention are a result of cognitive deficits or whether both of these problems are caused by another factor. However, we can put forth hypotheses concerning mechanisms underlying symptoms of ADHD (such as cognitive and affective-motivational self-regulation) that can be verified in future research.

Clinical implications

Our results have important clinical and research implications. We propose that different therapeutic approaches should be applied and verified in future research for the subgroups of children with various profiles of self-regulation difficulties. We assume that for children with ADHD symptoms associated predominantly with

cognitive difficulties (groups IA, CP-1, CT), therapeutic approaches focused on strengthening cognitive abilities and supporting children and their parents in dealing with children's cognitive deficits would be the most effective. We can predict that therapy concerning motivational processes (such as ability to delay aversion, maintaining focus on proximal and distant goals) and enhancing emotion regulation skills would be effective for children in the HI group. Moreover, the C group would probably benefit from therapeutic approaches addressing difficulties in both areas: cognitive and affective-motivational. Furthermore, it would be important to include family functioning characteristics in future studies examining profiles of children with different self-regulation difficulties and then consider them in building therapeutic strategies for various subgroups.

Future directions

Our study also has important research implications. It shows that it is valuable to identify subtypes of children with ADHD relying not only on psychopathological symptoms, but also on neuropsychological abilities and perhaps other variables (for example, family functioning characteristics) that can be related or lead to manifestation of hyperactivity-impulsivity and inattention symptoms. Such an approach could allow one to identify neurological and genetic factors underlying various profiles of self-regulation difficulties. It would be also worth to include other indices of functional impairment that are commonly associated with ADHD, in particular academic and social difficulties (Ek et al., 2007; Hoza, 2007) and social cognitive abilities (Gambin et al., 2015; Gambin & Sharp, 2016). It would be valuable to examine our model in individuals from various age groups (adolescent and adult samples) and to include reports from various informants (parents, teachers and self-report). Moreover, this proposed research strategy can be applied to studies with other clinical disorders not only ADHD.

Future research may wish to explore different pathways leading to the manifestation of symptoms of hyperactivity-impulsivity and inattention. It is important to conduct further studies that distinguish between subtypes of children exhibiting these symptoms on the bases of different mechanisms that can lead to hyperactivity-impulsivity and inattention, such as difficulties in cognitive functioning, poor affective-motivational self-regulation, emotional problems or characteristic of family functioning. Furthermore, it is important that future researchers pay more attention to children who display symptoms observed by only one informant.

Summary

In conclusion, our study has shown that joining the dimensional and person-centered perspectives to study heterogeneity in children with symptoms of hyperactivity-impulsivity and inattention is a promising idea. It allows researchers to identify children with varied profiles of neuropsychological functioning associated with certain combinations of psychopathological symptoms and the child's psychosocial functioning. We can assume that such an approach would enable the development of more effective therapy methods for different subgroups of children with ADHD symptoms. Moreover, it could allow researchers to examine the neurological and genetic factors that lead to various profiles of self-regulation difficulties.

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