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Abstract

The aim of the study was to use exploratory structural equation modelling (ESEM) to investigate support for an ADHD factor model with group factors for inattention (IA), hyperactivity (HY), and impulsivity (IM), as proposed in in ICD-10. A total of 202 adults (121 females and 81 males), aged between 18 and 35 years, from the general community, completed the Current Symptoms Scale (CSS). The results for the model showed good global fit, good convergent and divergent validities. However, the IA and IM factors, but not the HY factor, were clearly defined and demonstrated acceptable reliabilities. Taken together, these finding indicate that a revised ESEM model without the HY factor (i.e. with only the IA and IM symptoms) is an appropriate structure for modeling adult ratings of the ADHD behaviors described in the CSS. The taxonomic, theoretical and clinical implications of the findings for ADHD in general are discussed.

Keywords: ADHD symptoms; adults; Current Symptoms Scale; CSS; exploratory structural equation modelling; ESEM.

Introduction

According to the latest edition (fifth edition) of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5; American Psychiatric Association [APA], 2013), Attention-Deficit/Hyperactivity Disorder (ADHD) is a neuro-developmental disorder that is applicable to both children and adults. The ADHD symptoms and their groupings in DSM-5 (APA, 2013) are commensurable to those in DSM-IV (APS, 1994) and DSM-IV-TR (2000). The core symptom groups are inattention (IA; nine symptoms), hyperactivity (HY; six symptoms) and impulsivity (IM; three symptoms). However, for diagnosis, the HY and IM symptoms are considered as a single group (hyperactivity/impulsivity; HY/IM). In contrast to the DSM-5, in the tenth revision of the International Classification of Diseases (ICD-10, World Health Organization [WHO], 1992), ADHD is called Hyperkinetic Disorder (HKD). Although HKD and ADHD share the same set of symptoms, the symptoms are grouped differently. In ICD-10, the HY and IM symptoms are separated into distinct HY and IM groups, and considered separately for diagnosis. Moreover, the 'talkative' symptom (which is considered a HY symptom in DSM-5) is considered an IM symptom in ICD-10. Therefore, there are five HY symptoms and four IM symptoms in the ICD-10. The ICD-10-based HY and IM symptom groups have at time been referred to as motoric HY/IM and verbal HY/IM, respectively (Stanton et al., 2018). For brevity and clarity, the present paper herewith refers to the ICD-10 grouping of the HY and IM symptom as 'motoric HY/IM' and 'verbal HY/IM', respectively.

Related to ADHD symptoms and their groupings, the recently proposed Hierarchical Taxonomy of Psychopathology (HiTOP) posits that ADHD should be subsumed under an 'Antisocial Behavior' sub-factor, related to 'Disinhibited Externalising' spectrum traits, that includes 'problematic impulsivity' and 'distractibility' as traits, but not hyperactivity (Kotov et al, 2017). In HiTOP, hyperactivity is viewed as a peripheral expression rather than a core driver of psychopathology (DeYoung et al., 2020). So, the separation of the HY (or motoric HY/IM) and IM (or verbal HY/IM) symptoms into separate groups have clear theoretical and clinical support. As will be noted later, it also has empirical support.

Although many studies have examined the factor structure of the ADHD symptoms, there is still no complete agreement in this area. A recent study showed that an exploratory structural equation model (with three group factors) aligned to ICD-10 symptom configuration (IA, verbal HY/IM, and motoric HY/IM) represented the most appropriate model for ADHD symptom ratings (Gomez & Stavropoulos, 2020). The present study examined the replicability of this factor structure, and the clarity, reliabilities, and convergent and divergent validities of the factors in this model.

ADHD factor structure

Traditionally, the independent cluster confirmatory factor analysis (ICM-CFA) approach has been used extensively to evaluate two-factor and three-factor models of ADHD symptoms among different types of adult samples (community, student, clinical, and mixed) using different types of ADHD rating scales. An ICM-CFA model is a priori model in which items load only onto the designated factors. Generally, no support has been found for the one-factor model. At least adequate fit has been found for the two- and three-factor models (e.g., Davis et al., 2011; Gibbins et al., 2012; Gomez, 2016; Gomez, 2014; Gomez et al., 2018; Park et al., 2018; Martel et al., 2012; Morin et al., 2016; Proctor & Prevatt, 2009; Span et al., 2002; Stanton et al., 2018), with the three-factor models showing better fit than the two-factor model (Gomez, 2014, 2016; Proctor & Prevatt, 2009; Span et al., 2002). Also for three-factor models, the model based on

ICD-10 symptom configuration has shown better fit than the model based on DSM-5 configuration (Gomez & Stavropoulos, 2020; Gomez, 2016; Stanton et al., 2018).

In addition to these first-order factor models, bi-factor models consisting of one overarching dimension and two (IA and HY/IM) or three specific dimension models (specific dimensions for IA, HY and IM; and specific factors for IA, motoric HY/IM and verbal HY/IM) have also been examined using bi-factor CFA models (Gibbins et al., 2012; Martel et al., 2010; Toplak et al., 2009; Gomez & Stavropoulos, 2020; Stanton et al., 2018). In general, a bi-factor model encompasses orthogonal factor correlations where all items load on one general dimension, and also on their own specific or distinct factors. Error variances were unconstrained and error co-variances constrained to zero. Arias et al. (2016) reviewed 18 studies, of which six papers (Gibbins et al., 2012; Gomez, 2014; Gomez et al., 2018; Martel et al., 2012; Morin et al., 2016; Park et al., 2018) utilized adult community samples, with data collected using a range of psychometric scales, including the ADHD Rating Scale–Fourth Edition (DuPaul et al., 1998), Adult ADHD Self-Report Scale Symptom Checklist (Kessler et al., 2005), and Current Symptom Scale (Barkley & Murphy, 1998). Their review concluded that bi-factor models demonstrate better fit when contrasted with first-order CFA models. They also concluded that bi-factor models incorporating three specific factors generally showed better fit when compared to bi-factor models incorporating two distinct factors (Gibbins et al., 2012; Morin et al., 2016; Park et al., 2018). There are also data showing that for bi-factor models with three specific factors, the model based on ICD-10 symptom configuration fit better than the model based on DSM-5 symptom configuration (Gomez & Stavropoulos, 2020; Gibbins et al., 2012; Stanton et al., 2018). These findings suggest that data for ADHD symptoms among adults can be best explained by a bi-factor model with a general factor and specific factors for IA, verbal HY/IM, and motoric HY/IM. However, considering strong criticism of CFA and bi-factor model application for the validation of factorial structures (Marsh et al., 2009), it can be argued that there are good reasons to view this conclusion cautiously, as discussed next.

Limitations of the CFA and bi-factor CFA approach

CFA is a type of structural equation modelling in which items load only on their designated factors, and have zero loadings on all other factor (Jöreskog, 1969; Morin et al., 2013). Imposing this restriction on cross-loadings is considered too restrictive as observed items tend to load on several factors. Therefore, this approach has an embedded degree of error attributed to association of conceptually-related construct-relevant factors (Morin et al., 2016). In this sense, CFA can be considered to express an imprecise representation of observed dataset resulting in poor fit to data even when this is not the case. Marsh et al. (2009) highlighted the high difficulty of obtaining good fit to data for multidimensional models when examined only with CFA. This remark is especially valid for ADHD symptoms considering that cross-loadings of ADHD symptoms have being found in previous studies using exploratory factor analyses (e.g., Döpfner et al., 2006; DuPauI et al., 1998; Rohde et al., 2001). As past studies of bi-factor models of ADHD have generally used the CFA framework, the limitations of the aforementioned CFA approach are also applicable to studies involving bi-factor CFA models of ADHD symptoms. Bonifay and Reise (2017) highlighted further concerns in relation to the bi-factor model approach. One such concern is how intricate bi-factor model interpretation is, given that specific factors perceived as statistical inconveniencies are in fact meaningful variances that otherwise would not be explained by the model. Park et al. (2018) suggest that a satisfactory explanation depends upon the validity, stability, and reliability of factors that address unique variances included in the model. Similarly, Arias et al. (2016) observed that while the general factor in a bi-factor ADHD model is highly reliably and clearly defined, the specific factors (HY/IM in particular) have demonstrated poor reliability, with many non-significant loadings and even negative loadings. A second concern rests upon the inherent ability of the bi-factor model to improve goodness of fit to observed data. Consequently, this makes potential nonsensical patterns of response in the dataset appear justifiable. A third concern arises out of the lack of parsimony this model represents given the added (and potentially redundant) parameters compared with an equivalent first-order CFA model.

Exploratory structural equation modelling (ESEM) and ADHD factor structure

An alternative analysis utilizing exploratory structural equation modelling (ESEM) has been implemented to circumvent CFA shortcomings (Asparouhov & Muthén, 2009; Marsh et al., 2009). ESEM can be understood as a combination of CFA and EFA extracting advantages of these two methods. That is, ESEM allows items to cross-load (from EFA) while testing the validity of a previously defined factorial structure (from CFA). The bi-factor notion can be applied to ESEM creating a model that includes cross-loading items (EFA), tests *a priori* defined structures (CFA), and uses uncorrelated general and specific factors to increase explained variance (bi-factor; Marsh et al.2014; Morin et al, 2016). Therefore, the bi-factor ESEM method offers several advantages of construct-relevant multidimensionality when compared to EFA, CFA, or basic ESEM (Morin et al., 2016).

To the best of the present authors’ knowledge, ESEM methodology has previously been used in three studies involving DSM IV/DSM IV-TR/DSM-5 ADHD symptoms (Arias et al., 2016; Gomez & Stavropoulos, 2020; Rodenacker ey al., 2017). Of relevance to the present study is the study by Gomez and Stavropoulos (2020) because it involved (like the present study) an adult community sample. ADHD ratings were collected using the Adult ADHD Self-Report

Scale Symptom Checklist (ASRS: Kessler et al., 2005). That study compared the fit of 12 different ADHD models (differing in terms of 1 to 3 group symptom factors; DSM-5 and ICD-10 symptom configurations; and modeling procedures [CFA, BCFA and ESEM]), The findings showed that the ESEM with three group factors aligned to ICD-10 symptom configuration (IA, verbal HY/IM, and motoric HY/IM) represented the most appropriate model. In had good fit, well-defined IA factor and reasonably well-defined verbal HY/IM and motoric HY/IM factors, with all three factors showing acceptable model-based reliabilities (omega), and external validities.

Limitations of existing data

Although there are now data showing that the ESEM model with three group factors aligned to ICD-10 symptom configuration (IA, verbal HY/IM, and motoric HY/IM) represents the optimal structural modelling for ADHD among adults, it is argued that more studies of this model are needed. First, as there has been only one study that has examined and supported this model (Gomez & Stavropoulos, 2020), there is need for replication. Second, although that study supported the external validity of the factors in the model, it did not provide data related to the convergent and divergent validity of the factors as the ADHD factors showed the same pattern of correlations with depression, anxiety, and stress. In this respect, for clear interpretation, it is useful for studies testing this to focus on external constructs that are known to have robust and clinically meaningful relationships with ADHD, such as internalizing behaviors, externalizing behaviors, interpersonal behavior problems, and Oppositional Defiant Disorder [ODD]).

Relationships of ADHD with internalizing, externalizing and interpersonal behavior problems, and ODD

In relation to internalizing behaviors, previous studies have shown that ADHD, IA, and HI symptoms are related to anxiety (Jacob et al., 2007; Jarrett & Ollendick, 2008) and depression (Semeijn et al., 2015), with the relationships being stronger for IA. Related to this, scores on the Depression, Anxiety and Stress Scale (DASS; Lovibond & Lovibond, 1995) for depression, anxiety, and stress have shown significant and positive associations with ADHD, IA, HY, and IM scale scores (Alexander, & Harrison, 2013; Harrison et al., 2013). In relation to externalizing behavior, there is strong evidence of the associations between aggression-related behaviors with ADHD, with the associations being stronger for the HY/IM symptom group (e.g., Babinski et al., 1999; Barkley et al., 2004; Kuja-Halkola et al., 2015; Mannuzza et al., 2004; Pardini & Fite, 2010; Satterfield et al., 2007; Tseng et al., 2012). Existing data also indicate that ADHD, especially the HY symptoms, is positively associated with interpersonal behavior problems (Brod et al., 2005; Prada et al., 2014; Schütte & Petermann, 2006). Positive associations for ODD and its dimensions with ADHD have also been previously demonstrated (e.g., Angold et al., 1999; Biederman et al., 1991; Gomez et al., 2018; Krieger et al., 2013; Stringaris & Goodman, 2009).

Aims and predictions of the present study

Given the limitations noted for the ESEM model with three group factors aligned to ICD-10 symptom configuration (IA, verbal HY/IM, and motoric HY/IM), there were two major aims in the present study. The first major aim was to replicate support for the ESEM model with group factors for IA, verbal HY/IM, and motoric HY/IM. The second major aim was to examine the convergent and divergent validities of the factors in this model. To place the study in context, the study compared this model and two other modes: a three-factor CFA model (factors for IA, verbal HY/IM, and motoric HY/IM) model, and a bi-factor ESEM model (a general factor, and distinct specific factors for IA, verbal HY/IM and motoric HY/IM). In relation to convergent and divergent validities of the factors in the ESEM model, the study tested the unique associations of the three factors (factors for IA, verbal HY/IM, and motoric HY/IM) in the ESEM model with constructs measuring internalizing behaviors (assessed using the Depression, Anxiety and Stress Scales [DASS-21; Lovibond & Lovibond, 1995], which has subscales for depression, anxiety, and stress); externalizing behaviors (assessed using the Aggression Inventory [Gladue, 1991], with subscales for physical aggression, impulsivity, verbal aggression, impatience, and avoidance); interpersonal behavior problems (assessed using the Inventory of Interpersonal Problems-32 [IIP-32; Barkham et al., 1996], with subscales for hard to be social, hard to be assertive, being too aggressive, being too caring, hard to be involved, being too dependent, being too open, and hard to be supportive); and ODD dimensions (assessed using DSM-5 ODD symptoms with facets for angry/irritable mood, argumentative/defiant, and vindictiveness). Based on existing data it was predicted that, structurally, there would be reasonably good support for the ESEM model in terms of global fit, with well-defined factors that have acceptable reliabilities, and convergent and divergent validities. For the latter, it was expected that IA would be associated more with internalizing behaviors, and that HY and IM factors (in particular veral HY/IM) would be associated more with externalizing behavior, ODD, and poor interpersonal behavior.

Method

Participants

The sample comprised 202 adults (121 females and 81 males) with ages ranging from 18 to 35 years. They were recruited in Australia through several sources from the State of Victoria, Australia. The mean ages for females and males were 21.01 years (SD=3.23) and 21.92 years

(SD=3.69), respectively. The mean age for females and males did not differ significantly (t[200]=0.22; p=.07). Table 1 includes the mean and SD scores for the individual ADHD symptom ratings (see ‘Measures’ section below). The scores for all symptoms ranged from 0 to 4. The mean scores ranged from 0.42 to 1.25, and the standard deviation scores ranged from 0.70 to 0.99. These figures can be interpreted as meaning that there was little evidence of range restriction for the ADHD symptom ratings. Generally, when there are four interval points for ratings of the symptoms, ranging from 0 to 3 (as is the case in the present study), scores of 2 (“often”) and 3 (“very often”) are considered indicative of the symptoms present (Barkley & Murphy, 1998). Therefore, the mean scores for all ADHD symptom ratings for the sample in the present study can be interpreted as not being at clinical levels. The mean scores for the IA, motoric HY/IM and verbal HY/IM total scores were 7.69 (SD=4.79), 6.25 (SD=4.53), and 8.62 (SD=5.69), respectively.

Measures

Current Symptom Scale (CSS; Barkley & Murphy, 1998)

As in previous studies (Gomez et al., 2018; Martel et al., 2012; Park et al., 2018), ADHD symptom ratings were obtained using the CSS. The CSS include the 18 ADHD symptoms and the eight ODD DSM-IV/DSM-IV-TR symptoms. ODD symptom ratings were also collected using the CCS. The ADHD and ODD symptoms in DSM-IV/DSM-IV-TR are similar to those in DSM-5. Participants indicate the frequency of experiencing the symptoms over the past six months on a four-point Likert scale (0=“never or rarely”, 1=“sometimes”, 2=“often”, and 3= “very often”). Higher scores indicate higher presence of symptoms. In the present study, the Cronbach’s alpha values for the total ADHD, IA, motoric HY/IM, and verbal HY/IM were .89, .85, .74 and.80, respectively. Internal consistency (Cronbach’s α) values for total ODD and for the ODD dimensions of angry/irritable mood, and being argumentative/defiant were .87, .86, and .80, respectively. With one item for vindictiveness, the Cronbach's alpha value for this factor is meaningless.

Depression Anxiety Stress Scales (DASS; Lovibond & Lovibond, 1995)

The DASS is a 42-item self-report scale designed to assess depression (14 items), anxiety (14 items), and stress (14 items). Examples of an item in each subscale are "I found it difficult to work up the initiative to do things" (depression); "I found it difficult to relax" (anxiety); and "I found it hard to wind down" (stress). Participants were required to rate the frequency of having experienced the behavior described in the items during the past week utilizing a four point Likert scale ranging from 0 ("did not apply to me at all") to 3 ("applied to me very much or most of the time"). DASS subscales have shown high internal consistency (Cronbach's α), and good convergent and discriminant validity (Lovibond & Lovibond, 1995). Internal consistency (Cronbach's α) for depression, anxiety, and stress subscales in the present study were .85, .73 and .85, respectively.

Aggression Inventory (AI; Gladue, 1991)

The 20-item AI has five subscales related to aggression. They are physical aggression (four items), verbal aggression (seven items), impulsivity (seven items), and avoidance (two items). Examples of an item in each subscale are "Get into fights with other people" (physical aggression); "When a person is unfair to me, I get angry and protest" (verbal aggression); "I often act before I think" (impulsivity); "Others say that I lose patience easily" (impatience); and "Whenever someone is being unpleasant, I think it is better to be quiet than to make a fuss" (avoidance; reverse coded). Each item is rated on a five-point scale from 1 ("the statement does not apply to me at all") to 5 ("the statement applies exactly to me"). Higher scores indicate higher levels of aggression. Cronbach's α values for the subscales in the present study were .84, .75, .67, .69 and 63 for the physical aggression, verbal aggression, impulsivity, impatience, and avoidance subscales, respectively.

Inventory of Interpersonal Problems-32 (IIP-32, Barkham et al., 1996)

The 32-item IIP-32 comprises eight subscales that assess different forms of interpersonal problems. They are: hard to be social (e.g., "Hard to socialize with other people"; Cronbach's α=.85), hard to be assertive (e.g., "Hard to be firm when I need to be"; Cronbach's α=.83), being too aggressive (e.g., "I lose my temper too easily"; Cronbach's α=.70), being too caring (e.g., "I am overly generous to other people"; Cronbach's α=.72), hard to be involved (e.g., "Hard to show affection to people"; Cronbach's α=.72), being too dependent (e.g., "I am too dependent on other people"; Cronbach's α=.69), being too open (e.g., "I open up to people too much"; Cronbach's α=.77), and hard to be supportive (e.g., "Hard to really care about other people's problems"; Cronbach's α=.75). Each item is rated on a five-point scale, from 0 ("not at all") to 4 ("extremely"), in response to the stem statement: "How much have you been distressed by this problem?" Higher scores indicate higher scores for the specific facet.

Procedure

Following ethics approval from the University of Ballarat Human Ethics Committee, participants were recruited from various work and social settings in the general community. These included individuals recruited at workplace and shopping centers, and sporting, recreational, hobby, and social cubs and associations. The procedure was explained to potential participants, and a plain language statement about the study was given to them. If individuals showed interest in participating, the survey was given to them along with a prepaid reply envelope. The survey included the CSS, DASS, AI, and IIP-32. Completed surveys were either returned via mail or in person to researchers. A debriefing statement was distributed at the end of the study. Over 300 questionnaires were handed out to potential participants with a return rate of 67%. Participants received no compensation for their involvement in the study.

Statistical analysis

The CFA and ESEM models were tested using the weighted least squares mean and variance adjusted (WLSMV), fitted to polychoric correlation matrices. This estimation method has demonstrated robustness and does not require the assumption of normality. WLSMV has been prescribed for CFA models that include ordered-categorical scores and outlined as the best method for models involving categorical data, and can produce accurate parameter estimates for variables with floor or ceiling effects (as can be expected when participants from a community sample complete questionnaires measuring clinical symptoms) (Brown, 2006). All statistical analysis involving CFA modelling employed Mplus software (version 7) (Muthen & Muthen, 2012).

Considering that χ^2 has been considered a stringent measure for comparison given its tendency to increase as sample size increases, the study used three additional indexes to determine goodness of fit to data. Indices employed were the root mean squared error of approximation (RMSEA), the comparative fit index (CFI), the Tucker Lewis Index (TLI), and the Weighted Root Mean Square Residual (WRMR). Guidelines suggest that RMSEA values<0.06 represent a good fit, between 0.07 and 0.08 a moderate fit, 0.08 to .10 marginal fit, and >.10 poor fit (Hu & Bentler, 1998). CFI and TLI values >.95 represent good fit, values between .90 and .95 represent acceptable fit, and poor fit for values<.90. For the WRMR, values ≥ 1.0 are considered to be good fit (DiStefano, Liu, Jiang & Shi, 2018). The difference in the fit of nested models was examined using differences in chi-square, and differences in RMSEA (≥ 0.015) and CFI (≥ 0.010) values (Chen, 2007; Cheung & Rensvold, 2002).

For the model, the level to which the factors were clearly defined was examined in terms of the pattern of factor loadings and cross-loadings for the factors. A factor was considered to be well-defined if most of the targeted symptoms for that factor loaded significantly and saliently on it, and there was no or minimal non-target symptom loading saliently on it. To establish this empirically, the proportion of common variance explained in each symptom by the target loading versus cross-loadings (iECV), is indicative of the discriminant validity of that symptom on its primary factor. Generally, values of .70 or above are preferred. Additionally, the model-based reliabilities (omega; Zinbarg et al., 2005) of the factors in the model were examined. Omega values range from 0 to 1, with higher values reflecting better reliabilities (Brunner et al., 2012). According to Reise et al. (2013), and ω values need to be at least .50 with values of at least .75 preferred for meaningful interpretation of a scale.

Following suggestions by Park et al. (2018), to examine the external and differential validities of ADHD factors, the DASS, AI, IIP-32, and ODD scale scores were regressed (using an Structural Equation Modeling [SEM] approach) on all the factors in the three-factor ESEM ADHD model. The analyses were conducted separately for the scores in each scale. For comparison, SEM was also used to separately compute the path coefficients of the factors in three-factor CFA model with the scores in each scale. Age and gender were incorporated as covariates to control for potential confounding effects.

Results

Missing values

In all, there were 33 missing values in the dataset, out of a possible 3636 (18 symptoms x 202 (number of study participants). Consequently, the number of missing values equates to around 0.91% of possible scores in the dataset. No imputation of missing values was necessary because the response rates on all items exceeded 85%.

Model fit for the three-factor ESEM model

The fit value of the bi-factor ESEM model with a general factor, and specific factors for IA, motoric HY/IM, and verbal HY/IM were WLSMVχ^2 (df = 87) = 104.78, $p < .001$; RMSEA = .032 (90% CI = .000 - .052); CFI = .992; TLI = 0.986; and WRMR = .478. The fit values for the three-factor ESEM model with group factors for IA, motoric HY/IM, and verbal HY/IM were WLSMVχ^2 (df = 102) = 125.73, $p < .001$; RMSEA = .034 (90% CI = .000 - .052); CFI = .990; TLI = 0.985; and WRMR = .546. All values indicated good fit. The three-factor ESEM model and the bi-factor ESEM model with a general factor, and specific factors for IA, motoric HY/IM, and verbal HY/IM did not differ significantly from each other, ΔWLSMVχ^2 (Δdf = 15) = 22.52, p = .094; ΔRMSEA = .002; ΔCFA = .000). As the three-factor ESEM model is a more parsimonious model, it can be considered a better model than the bi-factor ESEM model with a general factor, and specific factors for IA, motoric HY/IM, and verbal HY/IM

The fit value of the CFA model with group factors for IA, motoric HY/IM, and verbal HY/IM were WLSMVχ^2 (df = 132) = 216.72, p<.001; RMSEA = .056 (90% CI = .043 - .070); CFI = .963; TLI = 0.958; and WRMR = .882. Although all fit values indicated good fit, this model was less well fitting than the three-factor ESEM model, ΔWLSMVχ2 (Δdf = 30) = 80.06, p < .001,thereby providing more support for the three-factor ESEM model.

Table 1 shows the standardized factor loadings for CFA and ESEM models, and the inter-correlations of the latent factors. As can be seen, there were notable differences for item loadings on designated factors, especially for the motoric HY/IM item loading, with virtually all loadings being higher in the CFA model than the ESEM model. It can also be seen that the inter-correlations between like factors were higher in the CFA model than the ESEM model. These findings suggest that the better fitting ESEM model would be more preferable than the CFA model.

Table 1 also includes the proportion of common variance explained in each symptom by the target loading versus cross-loadings (iECV). As shown in Table 1, the iECV values ranged from .28 (quiet) to .99 (forgetful), with a total of four symptoms (quiet, seat, inattention, and talk) having problems discriminating properly on their factors (iECV < .70). Additionally, as shown in Table 1, the motoric HY/IM factor had a very low omega (which is a measure of model-based reliability), whereas the IA and verbal HY/IM factors had reasonably high omega values. These findings were evident whether cross-loadings were included or not in the analyses.

Convergent and divergent validities of the factors in the ESEM model

Table 2 shows the standardized path coefficients for predictions of depression, anxiety, and stress (DASS) in the three-factor ESEM and CFA models including two covariates (age and gender). IA and motoric HY/IM showed a positive and significant predictive ability for all three DASS symptoms in the ESEM model. None of the DASS scale scores were predicted by verbal HY/IM. These findings indicate support for the convergent and divergent validities for the IA, motoric HY/IM, and verbal HY/IM factors. For the CFA model, IA and motoric HY/IM were positively associated with both anxiety and stress. All other associations involving the ADHD factors were non-significant.

Table 3 shows the standardized path coefficients for factor predictive ability of symptom scores within the AI scale (physical aggression, impulsivity, verbal aggression, impatience, and avoidance) in ESEM and CFA models. As shown, motoric HY/IM positively predicted all the AI scale scores, and verbal HY/IM positively predicted all AI scale scores, except physical aggression. IA did not predict any of the AI scale scores. These findings indicate support for the convergent and divergent validities for the IA, motoric HY/IM, and verbal HY/IM factors. For the CFA model, (i) motoric HY/IM was positively associated with verbal aggression, and (ii) verbal HY/IM was positively associated with verbal aggression, impatience, and avoidance. All other associations involving the ADHD factors were non-significant.

Table 4 shows the standardized path coefficients for factor predictive ability of all IIP-32 scale scores in the IIP-32 in ESEM and CFA models. As shown, motoric HY/IM positively predicted all the IIP-32 scale scores, except being too dependent. Being too dependent was not predicted by motoric HY/IM. Verbal HY/IM negatively predicted the scale scores for hard to be social, hard to be assertive, and being too open. None of the IIP-32 scale scores were predicted by IA. These findings indicate support for the convergent and divergent validities for the IA, motoric HY/IM, and verbal HY/IM factors. For the CFA model, (i) motoric HY/IM was positively associated with being too involved and hard to be supportive, and (ii) verbal HY/IM was positively associated with being too involved. All other associations involving the ADHD factors were non-significant.

Table 5 shows the standardized path coefficients for the predictions of the ODD dimensions of angry/irritable, argumentative/defiant, and vindictiveness, and overall ODD by the factors in the ESEM models. As shown, IA and motoric HY/IM positively predicted all the ODD dimensions, and overall ODD. Verbal HY/IM did not predict any ODD dimension, or overall ODD. These findings indicate support for the convergent and divergent validities for the IA, motoric HY/IM, and verbal HY/IM factors. For the CFA model, motoric HY/IM was positively associated with being defiant, vindictiveness, and overall ODD. All other associations involving the ADHD factors were non-significant.

When the findings are considered together, support for the convergent and divergent validities for the IA, motoric HY/IM, and verbal HY/IM factors in the three-factor ESEM model can be inferred. This can also be inferred, albeit to a lesser degree, for the three-factor CFA model. However, the associations were not the same across the two models. From a theoretical viewpoint, the associations with the external criterion variables were wider and more clinically meaningful for the factors in the ESEM model than the CFA model.

Discussion

Summary of aims and study findings

The main objective of the present study was to evaluate the statistical validity of the three-factor ESEM model, with group factors for IA, motoric HY/IM, and verbal HY/IM. This involved evaluating the model's global fit, pattern of factor loadings and cross-loadings, and reliabilities and convergent and divergent validities of the factors in the model. For comparison, the study also tested the global fit of a first-order CFA three-factor, with IA, motoric HY/IM and, verbal HY/IM as group factors; and a bi-factor ESEM model with a general factor, and specific factors for IA, motoric HY/IM, and verbal HY/IM. All three models demonstrated good fit. The ESEM and bi-factor ESEM models showed better fit than the CFA model. The magnitude of item loadings, especially for the motoric HY/IM symptoms, differed across the CFA and ESEM models, with virtually all loadings being higher in the CFA model than the ESEM model. The inter-correlations between like factors were higher in the CFA model than the ESEM model. These findings suggest that the ESEM model would be more preferable than the CFA model for modeling the ratings of the ADHD symptoms. The ESEM and bi-factor ESEM showed no differences in fit. However, as the ESEM model is more parsimonious than the bi-factor ESEM model, the ESEM model can be considered more preferable. Four symptoms (quiet, seat, inattention, and talk) in the ESEM model showed were poorly defined as they lacked discrimination (iECV < .70) on their factors. Of these, two symptoms belonged to the motoric HY/IM symptom group. Also, while the IA and verbal HY/IM factors showed acceptable model based (omega) reliabilities, the motoric HY/IM did not.

In relation to convergent and divergent validities of the factors in the ESEM model, the findings showed that internalizing problems of depression, anxiety, and stress were predicted significantly and positively by IA, and motoric HY/IM, but were not predicted by verbal HY/IM. For problems related to aggression, motoric HY/IM positively predicted physical aggression, impulsivity, verbal aggression, impatience, and avoidance. Verbal HY/IM positively predicted all these variables, except physical aggression. For problems related to interpersonal problems, motoric HY/IM positively predicted hard to be social, hard to be assertive, being too aggressive, being too caring, hard to be involved, being too open, and hard to be supportive. Verbal HY/IM negatively predicted hard to be social, hard to be assertive, and being too open, For ODD, IA and motoric HY/IM positively predicted all ODD dimensions, and overall ODD. Taken together, although the reliability findings called into question the viability of the motoric HY/IM factor in three-factor ESEM model proposed in this study (and therefore the associations involving this factor), the validity findings do indeed provide support for the convergent and divergent validities of the factors in this model.

For comparison, the study also examined how the IA, motoric HY/IM and verbal HY/IM factors in a CFA model were associated with the external criterion variables. Compared to the ESEM model, for the CFA model, IA and motoric HY/IM were associated with both anxiety and stress. For the aggression external criterion variables, motoric HY/IM was positively associated with verbal, and verbal HY/IM was positively associated with verbal, impatience, and avoidance.

For interpersonal problems, motoric HY/IM was positively associated with too involved and hard to be supportive, and verbal HY/IM was positively associated with too involved. For ODD, motoric HY/IM was positively associated with being defiant, vindictiveness, and overall ODD. Therefore, the associations with the external criterion variables were fewer and less clinically meaningful in the CFA model than the ESEM model. Given these findings, as well as model fit and the pattern of loadings and cross-loading for the three-factor ESEM model, it can be argued that the ESEM model, without the motoric HY/IM factor, can be considered a good and clinically relevant and meaningful model for representing the variances for the DSM IV/DSM IV-TR/DSM-5 ADHD symptoms rated in the CSS.

Comparisons with previous findings

The fit findings in the present study are in line with the results reported by Gomez and Stavropoulos (2020) who showed that the ESEM model with group factors for IA, motoric HY/IM, and verbal HY/IM fitted the ADHD symptom ratings better than other models, including the first-order CFA three-factor, with IA, motoric HY/IM and, verbal HY/IM as group factors; and a bi-factor ESEM model with a general factor, and specific factors for IA, motoric HY/IM, and verbal HY/IM (also tested in the present study). However, unlike the present study, Gomez and Stavropoulos interpreted their findings in terms of the IA factor being well-defined, and the motoric HY/IM and verbal HY/IM factors being reasonably well-defined. It can therefore be argued that the factors, especially the motoric HY/IM factor, in the three-factor ESEM model lack consistency. Although such a possibility reduces the support for this proposed ESEM model, they do not however challenge an ESEM models with factors for IA and IM symptoms.

In general, the findings involving the relationships of the ADHD factors with the external criterion variables are consistent with existing data. In relation to internalizing behaviors, previous studies have shown that IA and HI are related to depression, anxiety, and stress, with the relationships being stronger for IA (Alexander, & Harrison, 2013; Gomez & Stavropoulos, 2020; Harrison et al., 2013; Jacob et al., 2007; Jarrett & Ollendick, 2008; Semeijn et al., 2015). There is evidence of the associations of aggression-related behaviors with ADHD, with the associations being especially strong among the HY/IM symptom group (e.g., Babinski et al., 1999; Barkley et al., 2004; Kuja-Halkola et al., 2015; Mannuzza et al., 2004; Pardini & Fite, 2010; Satterfield et al., 2007; Tseng et al., 2012). Existing data also indicate that ADHD, especially HY, is positively associated with interpersonal behavior problems (Biederman et al., 1992; Brod et al., 2005; Prada et al., 2014; Schütte & Petermann, 2006). Positive associations for ODD and its dimensions (especially being head-strong) with ADHD have also been demonstrated in past studies (Angold et al., 1999; Biederman et al., 1991; Gomez et al., 2018; Krieger et al., 2013; Stringaris & Goodman, 2009). Although the findings here are generally consistent with existing finding, they also extend existing findings because the findings here are for ICD-10 based symptom groupings of IA, motoric HY/IM, and verbal HY/IM and not DSM-based groupings of these symptoms, as is the case with the previous studies cited in the paragraph.

Implications for taxonomy

Overall, while the findings suggested that the ESEM model was a preferable and clinically meaningful model (with the IA factor and verbal HY/IM factors being well defined and having acceptable reliabilities, and convergent and divergent validities), the motoric HY/IM factor was not well defined, and lacked sufficient reliability for it to be useful as a measure of motor impulsivity or as a predictor of other variables. This is indicative of only partial support for the three-factor ESEM ADHD model proposed in the study. Also, limiting the ADHD symptoms to only inattention and impulsivity symptoms is congruent with the HiTOP proposal where ADHD is considered without reference to hyperactivity or motor overactivity traits (Kotov et al, 2017). In HiTOP, ADHD is conceptualized within the disinhibited externalizing spectrum, characterized by impulsivity (i.e., acting spontaneously on the spur of the moment without consideration for consequences), irresponsibility (i.e., failing to fulfil obligations or act in a dependable manner), distractibility (i.e., inattentive and not completing tasks), risk taking (i.e., sensation-seeking, engaging in potentially dangerous activities in a reckless manner), and (low) perfectionism (i.e., not completing work to acceptable standards). In it, hyperactivity is viewed as a peripheral expression rather than a core driver of psychopathology (DeYoung et al., 2020).

Theoretical, diagnostic, and clinical implications

The findings of the present study have theoretical, diagnostic, and clinical implications for ADHD in general. First, the findings suggest that a review of the current ADHD symptom groups (IA and HY/IM) for adults. as outlined in DSM-5 is warranted. These findings suggest the HY symptoms are not useful. That is, adults showing ADHD symptoms could present mainly symptoms of inattentiveness and impulsivity. These could mean that adult ADHD types could be inattentive, impulsive, and a combined type of inattentive/impulsive symptoms. However, it should be mentioned that both these considerations are directly related to the effectiveness of the CSS in providing an accurate measurement of ADHD clinical symptoms. Moreover, the present authors also acknowledge at this point the proposed subtypes are purely speculative, needing empirical validation.

Second, the findings here indicated that IA was associated with anxiety, stress, and ODD and its dimensions. Motoric HY/IM was associated with anxiety, stress, a wide range of aggressive and interpersonal relationship problems, and ODD and its dimensions. Verbal HY/IM was associated with impulsively driven verbally aggressive responses, and with poor assertive and social behaviors. Therefore, when examining the profiles of the ADHD symptoms using the three-factor ESEM model as a framework, clinicians would be able to ascertain the major problems that are being experiencing by an individual diagnosed with ADHD, and therefore be more focused in treatment and intervention. For example, an individual with mostly verbal HY/IM symptoms is likely to be experiencing impulsively driven verbally aggressive responses, and to have poor assertive and social behaviors, and therefore would require treatment focusing on these areas.

Third, some of the symptoms may not be good indicators for their targeted factors. In this respect, symptoms that do not load on their targeted factors or cross-load saliently on non-targeted factors could be seen as problematic. Based on these criteria, the findings in the present study indicated that the problematic symptoms were IA symptom 2 (inattention), motoric HY/IM symptom 4 (quiet), motoric HY/IM symptom 2 (seat) and verbal HY/IM 1 (talk). Therefore, it is suggested that during clinical interviews, the presence or otherwise of these symptoms should be evaluated with extra care, and/or if these symptoms are endorsed, clinicians should carefully consider if these symptoms are indeed assessing the relevant targeted factors.

Fourth, contrary to the findings reported by Gomez and Stavropoulos (2020), verbal HY/IM was not associated with depression, anxiety, and stress. For the bifactor ESEM model with specific factors for IA, motor HY/IM, and verbal HY/IM, Stanton et al. (2018) reported that for an adult outpatient sample, the verbal HY/IM specific factor was negatively associated with major depressive disorder. Therefore, it is possible that high levels of verbal HY/IM symptoms could be unrelated or even act in reducing internalizing behavior problems. Clinicians should be mindful of this when assessing ADHD among adults.

Summary and limitations

In summary, the findings provided support for the ESEM model with group factors for IA, and verbal HY/IM. In general, in this model, internalizing problems could be associated positively with IA; and aggression and interpersonal problems would be associated positively with verbal HY/IM. Additionally, the proposed ADHD model limiting the ADHD symptoms to only inattention and impulsivity symptoms is congruent with the HiTOP proposal where ADHD is considered without reference to hyperactivity or motor overactivity traits (Kotov et al, 2017). It may be worth noting that all response categories of all ADHD symptoms were endorsed, the findings were not confounded by range restriction for these symptom ratings.

Despite the positive features and novel findings in the present study, some limitations should be considered. First, the study employed a community sample. A major disadvantage of using non-clinical samples to validate a clinical measure developed for a clinical sample is that the information provided by clinical and non-clinical samples may lack measurement invariance or equivalency, and therefore cannot be compared, This is particularly relevant for ADHD symptom rating because such ratings are prone to the 'halo' effect (e.g., DeVries, Hartung, & Golden, 2007). The halo effect occurs when an individual who is displaying one discrete behavior, falsely endorses the presence of other related behaviors. This could lead to overestimation of the presence of ADHD symptoms, and the potential for cross-loadings of symptoms across different factors. Therefore, caution should be exercised when translating these findings to ADHD adults with clinical diagnosis. Considering that the CSS has been devised to assist ADHD diagnosis, replicating the present study with a sample of diagnosed ADHD adults (or individuals presenting high levels of symptoms associated with ADHD) would be useful. Second, self-reports for assessing adult ADHD symptoms can be perceived as problematic given the tendency of false-positive responses that ADHD individuals exhibit (Sibley et al., 2018). Scores utilized in the present study were obtained from a self-reported measure, therefore caution of interpretation should be exercised. Third, the CSS requires participants to rate symptoms on a four-point Likert scale whereas ADHD symptoms in clinical practice represent a binary variable (either present or absent). Fourth, given the present study used the CSS, it is not possible to assess the relevance of these findings for scores arising out of a clinical interview context. Therefore, research using clinical interviews assessing symptoms of ADHD among adults in binary form (either present or absent) is much needed for an enhanced understanding of ADHD symptoms structure. Despite the aforementioned limitations of generalizability of findings in the present study, positive features of these results provide a good incentive for further research in the area.

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Table 1

Descriptive results and factor loadings of the three-factor ESEM model

			CFA			ESEM			
Symptom #	Brief description	Mean (*SD*)	IA	Motoric HY/IM	Verbal HY/IM	IA	Motoric HY/IM	Verbal HY/IM	iECV
IA 1	Careless	0.86 (0.70)	**.70**			**.55**	.26	-.10	.80
IA 2	Inattention	0.86 (0.77)	**.63**			**.64**	.34	-.45	.56
IA 3	Listen	0.66 (0.82)	**.70**			**.44**	.25	.11	.72
IA 4	Instruction	0.57 (0.70)	**.73**			**.76**	-.06	.05	.99
IA 5	Disorganized	0.78 (0.72)	**.67**			**.77**	-.18	.10	.93
IA 6	Unmotivated	1.08 (0.83)	**.62**			**.78**	-.21	.04	.93
IA 7	Lose	0.73 (0.84)	**.68**			**.57**	-.05	.28	.80
IA 8	Distracted	1.25 (0.90)	**.81**			**.65**	.22	-.02	.90
IA 9	Forgetful	0.91 (0.79)	**.61**			**.68**	-.04	-.03	.99
MHY/IM 1	Fidget	1.21 (0.99)		**.62**		.26	**.50**	-.05	.78
MHY/IM 2	Seat	0.42 (0.80)		**.65**		.28	**.30**	.18	.45
MHY/IM 3	Run	0.60 (0.84)		**.81**		.19	**.56**	.23	.78
MHY/IM 4	Quiet	0.59 (0.75)		**.70**		.30	**.26**	.29	.28
MHY/IM 5	Motor	0.93 (0.85)		**.52**		-.08	**.49**	.29	.73
VHY/IM 1	Talk	1.18 (0.92)			**.65**	-.10	.36	**.49**	.63
VHY/IM 2	Blurt	1.00 (0.91)			**.87**	.01	.14	**.82**	.97
VHY/IM 3	Wait	0.79 (0.89)			**.81**	.02	.06	**.80**	.99
VHY/IM 4	Interrupt	0.72 (0.78)			**.76**	.14	.07	**.63**	.94

Factor Correlation					
Motoric HY/IM	.82		.62		
Verbal HY/IM	.51	.71	.40	.33	
Reliability					
Omega (not including cross-loadings)			.745	.559	.801
Omega (including cross-loadings)			.737	.396	.786

Note. ESEM=exploratory structural equation model; IA=inattention; HY/IM=hyperactivity/impulsivity. IECV = item explained common variance.

Boldface values indicate factor loadings in the primary dimension; underlined values indicate significant loading and cross-loadings ($p<.05$).

For all symptoms, the ratings ranged from 0 to 4.

Table 2

Standardized beta coefficients for the predictions of the DASS Scale (depression, anxiety, and stress) scores by the factors in the ESEM and CFA models with group factors for IA, motoric HY/IM and verbal HY/IM (with gender and age as covariates)

	Depression	Anxiety	Stress
Gender	-0.13 (0.13)	0.09 (0.09)	-0.00 (-0.00)
Age	-0.11 (-0.12)	-0.10 (0.10)	-0.06 (-0.06)
Inattention	0.25** (.14)	0.21* (0.04)	0.21* (0.05)
Motoric hyperactivity/impulsivity	0.27* (0.40)	0.31** (0.56**)	0.41*** (0.67**)
Verbal hyperactivity/impulsivity	-0.05 (-0.13)	0.12 (-0.07)	0.06 (-0.15)

Note. ESEM=Exploratory structural equation model. Values in parenthesis are the path coefficients for the predictions involving the three-factor CFA model.

****p*<.001; ***p*<.01; **p*<.05.

Table 3

Standardized beta coefficients for the predictions of the AI Scale (physical aggression, impulsivity, verbal aggression, impatience, and avoidance) scores by the factors in the ESEM and CFA models with group factors for IA, motoric HY/IM and verbal HY/IM (with gender and age as covariates)

	Physical aggression	Impulsivity	Verbal aggression	Impatience	Avoidance
Gender	0.33***	0.23***	0.37***	0.21**	0.28***
	(0.33***)	(0.23***)	(0.37***)	(0.21**)	(0.28***)
Age	-0.15*	-0.07	-0.21***	-0.10	-0.08
	(-0.15*)	(-0.07)	(-0.21***)	(-0.10)	(-0.08)
Inattention	0.00	-0.12	-0.03	0.03	0.16
	(0.22)	(-0.04)	(-0.13)	-0.00)	(0.25)
Motoric	0.38***	0.44**	0.44***	0.24*	0.26**
hyperactivity/impulsivity	(0.00)	(0.23)	(0.51**)	(0.20)	(0.08)
Verbal hyperactivity/impulsivity	0.24	0.23*	0.39***	0.44***	0.34***
	(0.28*)	(0.20)	(0.21*)	(0.39***)	(0.33**)

Note. ESEM=Exploratory structural equation model. Values in parenthesis are the path coefficients for the predictions involving the three-factor CFA model.

***p<.001; **p<.01; *p<.05.

Table 4

Standardized beta coefficients for the predictions of the IIP-32 Scale (Social, Assertive, Aggression, Care, Involvement, Dependent, Open, and Supportive) scores by the factors in the ESEM and CFA models with group factors for IA, motoric HY/IM and verbal HY/IM (with gender and age as covariates)

	Social	Assert	Aggress	Care	Involve	Dependent	Open	Supportive
Gender	0.02	0.07	0.12	0.05	0.17*	0.14*	0.06	0.26***
	(0.02)	(0.07)	(0.12)	(0.05)	(0.17*)	(0.14*)	(0.06)	(0.26***)
Age	-0.17*	-0.21**	-0.11	0.02	-0.20**	-0.13*	0.13*	-0.08
	(-0.17*)	(-0.21**)	(-0.11)	(0.02)	(-0.20**)	(-0.13*)	(0.13*)	(-0.08)
Inattention	-0.04	0.08	0.03	0.22*	0.13	0.17	0.08	0.08
	(0.15)	(0.15)	(0.15)	(0.12)	(-0.12)	(0.29)	(-0.18)	(-0.05)
Motoric HY/IM	0.80***	0.46**	0.45**	0.34**	0.48**	0.27	-0.53**	0.62***
	(0.13)	(0.20)	(0.20)	(0.37)	(0.69*)	(-0.01)	(0.09)	(0.53*)
Verbal HY/IM	-0.39*	-0.25*	0.15	0.07	-0.21	-0.03	0.42**	-0.06
	(-0.11)	(-0.22)	(-0.22)	(0.01)	(-0.38*)	(0.11)	(0.21)	(-0.04)

Note. Motoric HY/IM=motoric hyperactivity/impulsivity; Verbal HY/IM=verbal hyperactivity/impulsivity; Social=hard to be social; Assert=hard to be assertive; Aggressive=being too aggressive; Care=being too caring; Involve=hard to be involved; Open=being too open; Supportive=hard to be supportive. ESEM=Exploratory structural equation model.

Values in parenthesis are the path coefficients for the predictions involving the three-factor CFA model.

****p*<.001; ***p*<.01; **p*<.05.

Table 5

Standardized beta coefficients for the predictions of the ODD dimension (angry/irritable mood, argumentative/defiant, and vindictiveness) scores by the factors in the ESEM models with group factors for IA, motoric HY/IM and verbal HY/IM (with gender and age as covariates)

	Angry/Irritable	Defiant	Vindictiveness	Overall ODD
Gender	0.13 (0.03)	0.09 (0.09)	-0.00 (-0.00)	0.07
Age	-0.12 (-0.12)	-0.10 (-0.10)	-0.06 (-0.06)	-0.09
Inattention	0.21** (0.14)	0.21* (0.04)	0.21* (0.05)	.0.27** (0.07)
Motoric HY/IM	0.27* (0.40)	0.31** (0.67**)	0.41*** (0.67**)	0.32**(0.60**)
Verbal HY/IM	-0.05 (-0.13)	0.12 (-0.15)	0.06 (-0.15)	0.06 (-0.12)

Note. ESEM=Exploratory structural equation model. Values in parenthesis are the path coefficients for the predictions involving the three-factor CFA model.

***p<.001; **p<.01; *p<.05.