Confirmatory Factor Analysis and Exploratory Structural Equation Modeling of the Structure of Attention-Deficit/Hyperactivity Disorder Symptoms in Adults

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Abstract
This study examined the structure of attention-deficit/hyperactivity disorder (ADHD) symptoms in an adult community sample using first-order confirmatory factor analysis, exploratory structural equation modeling (ESEM), and bifactor confirmatory factor analysis and ESEM models, with two group factors (inattention [IA] and hyperactivity/impulsivity [HY/IM]) and two different three group factors (IA, hyperactivity [HY], and impulsivity [IM]; and IA, motoric HY/IM, and verbal HY/IM). A total of 738 adults (males = 374 and females = 364) between 17 and 72 years of age completed the Adult ADHD Self-Report Scale. The results provided most support for the ESEM model with group factors for IA, motoric HY/IM, and verbal HY/IM. The factors in this model were reasonably well defined, had good internal consistency omega reliabilities, and had support for their external validities, thereby making it a suitable model for ratings of the ADHD symptoms presented in the Adult ADHD Self-Report Scale. The theoretical and clinical implications of the findings are discussed.

Keywords
ADHD symptoms, adults, Adult ADHD Self-Report Scale, ASRS, CFA, ESEM, BCFA, and BESEM models

Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder. Starting from the fourth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV; American Psychiatric Association [APA], 1994), ADHD has been accepted as a legitimate disorder in adults. For its diagnosis, DSM-5 (APA, 2013), like DSM-IV (APA, 1994) and DSM-IV-TR (APA, 2000), has 18 symptoms, comprising nine inattention (IA), six hyperactivity (HY), and three impulsivity (IM) symptoms. As the HY and IM symptoms (HI) in these diagnostic systems are viewed together for diagnosis, the DSM-IV and DSM-5 ADHD models can be viewed in terms of a first-order two-factor model (with factors for IA and hyperactivity/impulsivity [HY/IM] symptom groups). Confirmatory factor analysis (CFA) studies have generally supported this model in both children and adults. For both these groups, many recent CFA studies have supported bifactor ADHD models, with one general ADHD factor and either two (IA and HY/IM) or three (usually IA, HY, and IM) specific factors. However, concerns have been raised over the first-order and bifactor CFA approaches for studying the factor structure of the ADHD symptoms. Such concerns can be circumvented using the recently developed exploratory structural equation modeling (ESEM) and bifactor ESEM (BESEM) techniques. To date, these techniques have not been used to study the factor structure of the ADHD symptoms in adults. The major aim of the current study is to use the traditional first-order and bifactor CFA approaches as well as the newly developed ESEM and BESEM approaches to study the ADHD factor structure in adults from the general community.

Factor Analyses of ADHD Symptoms
Exploratory factor analysis (EFA) and CFA have traditionally been standard approaches for testing the factor structure of a measure. In the EFA approach, there is no restriction.

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on cross-loadings of items, and thus items are allowed to freely load on different factors concurrently. In contrast, the traditional CFA approach for first-order factor models (usually referred to as the independent cluster model of CFA) is a model-based approach in which items load only on their target factors, and all the loadings on nontarget factors (cross-loadings) are constrained to zero (Morin et al., 2013). Thus, this approach allows the researcher to test for an a priori defined structure. A bifactor model is also an a priori CFA model. In such a model, there is one general factor and two or more specific factors. Typically, all the items in the measure load on the general latent, and also items belonging to each group load on its own specific latent factors. Also, all the latent factors are not correlated with each other (orthogonal model). Thus, the general factor represents what is common (shared variances) among all the items in the measure, and the specific factors represent variances in them that are not accounted for by the general factor.

Since the publication of DSM-IV, numerous studies have used CFA to test the DSM-IV theorized two-factor ADHD model (factors for IA and HY/IM), as well as three-factor model (factors for IA, HY, and IM; e.g., Gomez et al., 1999; Gomez et al., 2003; Willcutt et al., 2012). The path diagrams for the two- and three-factor ADHD models are shown in the Supplemental Figure S1 available online. As shown, for the two-factor model, all the nine IA symptoms load on only the IA latent factor, and all the nine HY/IM symptoms load only on the HY/IM latent factor. For the three-factor model, all the nine IA symptoms load on only the IA latent factor, the six HY symptoms load only on the HY latent factor, and the three IM symptoms load on only the IM factors. For both models, the latent factors are correlated with each other, and there are no cross-loadings, and all error variances are freely estimated, and all covariances between error variances are set to zero. More recently, many studies have examined the structure of ADHD in terms of a bifactor CFA model (BCFA) with two specific factors (IA and HY/IM) and three specific factors (usually IA, HY, and IM; Gibbins et al., 2012; Martel et al., 2010; Toplak et al., 2009). An alternate BCFA model with specific factors for IA (comprising all the IA symptoms), motoric HY/IM (comprising the five HY/IM symptoms for fidget, seat, run, quiet, and motor), and verbal HY/IM (comprising the remaining four HY/IM symptoms of talk, blurt, wait, and interrupt) has also been proposed (Gibbins et al., 2012; see also, DuPaul, Power, et al., 1998). Supplemental Figure S1 also includes the path diagram for the ADHD bifactor model with the two and three specific factors. Briefly, all the bifactor models have one general ADHD latent factor on which all 18 ADHD symptoms load. In the two-factor version, there is a specific factor for IA on which only the IA symptoms load and a specific factor for HY/IM on which only the HY/IM symptoms load. In the three-factor version with specific factors for IA, HY, and IM, there is a specific factor for IA on which only the IA symptoms load, a specific factor for HY on which only the HY symptoms load, and a specific factor for IM on which only the IM symptoms load. In the three-factor version with specific factors for IA, motoric HY/IM, and verbal HY/IM, there is a specific factor for IA on which only the IA symptoms load, a specific factor for motoric HY/IM on which only the motoric HY/IM symptoms load, and a specific factor for verbal HY/IM on which only the verbal HY/IM symptoms load. In all these models, all the latent factors are not correlated (orthogonal model). Accordingly, in all the bifactor models, the ADHD general factor represents the shared variances among all the 18 ADHD symptoms. The specific factors represent variances in them that are not accounted for by the general factor.

In relation to children and adolescents, the findings in many past studies have supported the first-order two- and three-factor (group factors for IA, HY, and IM) models, with the latter model showing a slightly better fit (e.g., Gomez et al., 1999; Gomez et al., 2003; Willcutt et al., 2012). Despite the difference in fit, in view of the difference being small, and because the two-factor model is more parsimonious and theoretically relevant, most researchers have argued in favor of the two-factor model over the three-factor model.

To date, many studies have examined the factor structure of the ADHD symptoms in the adult community (Gomez, 2016; Gomez et al., 2014; Gomez et al., 2018; Morin et al., 2016), university students (Davis et al., 2011; Span et al., 2002), clinical (Gibbins et al., 2012; Proctor & Prevatt, 2009; Stanton et al., 2018) and mixed samples, including parents of ADHD children, and some with ADHD samples (Martel et al., 2012; Park et al., 2018). Across these studies, several different ADHD rating scales measures have been used, including Barkley and Murphy’s (1998) Clinical Symptom Scale (Gomez, 2016; Gomez et al., 2014; Gomez et al., 2018; Martel et al., 2012; Park et al., 2018; Proctor & Prevatt, 2009), Kessler et al.’s (2005) Adult ADHD Self-Report Scale Symptom Checklist (ASRS; Morin et al., 2016; Stanton et al., 2018), the ADHD Rating Scale–IV (DuPaul, Power, et al., 1998), the Conners’s Adult ADHD Rating Scales (Conners et al., 1999), the Brown Attention-Deficit Disorder Scale for Adults (Brown, 1996), the Wender Utah Rating Scale (Ward et al., 1993), and unnamed questionnaires comprising the 18 ADHD symptoms (Davis et al., 2011; Span et al., 2002). In general, independent of the type of samples examined and the ADHD measures used, for first-order models, these studies found adequate fit for the two-factor model. When examined, the findings showed better fit for three-factor models with group factors for IA, HY, and IM, and IA, motoric HY/IM, and verbal HY/IM over the two-factor model (Gomez, 2014, 2016; Proctor & Prevatt, 2009; Span et al., 2002). Although Davis et al. (2011) reported adequate fit and no difference in fit
between these three- and two-factor models, they argued in favor of the two-factor model as it is more parsimonious. It is worthy of note that there is also evidence of little or no support for both these first-order two- and three-factor models (Stanton et al., 2018).

A recent review by Arias et al. (2016) that involved 18 studies, including five studies on adults (Gibbins et al., 2012; Gomez et al., 2014; Gomez et al., 2018; Martel et al., 2012; Morin et al., 2016; Park et al., 2018), concluded that bifactor models showed good and better fit than the corresponding first-order CFA models. In this respect, independent of the type of samples examined or the ADHD rating scales used, when reported, bifactor models with three specific factors have generally demonstrated better fit than bifactor models with two specific factors (Gibbins et al., 2012; Morin et al., 2016; Park et al., 2018). For bifactor model with three specific factors, the model with specific factors for IA, motoric HY/IM, and verbal HY/IM fitted better than the model with specific factors for IA, HY, and IM (Gibbins et al., 2012; Stanton et al., 2018). Of extra relevance here are the findings for the ASRS as the current study also used the ASRS. To date, at least two studies have used the ASRS to examine the structure of the ADHD symptoms. For a community sample, Morin et al. (2016) reported support for a bifactor model with specific factors for IA, HY, and IM. They did not test the bifactor model with specific factors for IA, motoric HY/IM, and verbal HY/IM. For a general outpatient sample with some individuals having ADHD, Stanton et al. (2018) reported most support for a bifactor model with specific factors for IA, motoric HY/IM, and verbal HY/IM. Indeed, this model showed better fit than the bifactor model with specific factors for IA, HY, and IM. In all the bifactor models, the general factor in the bifactor models explained most of the variance in the ADHD symptoms. When reported, the general factor had high reliability and acceptable validity, whereas one or more of the specific factors had low reliabilities and poor (incremental) validities. For example, although Morin et al. (2016) showed good fit for the bifactor model with three specific factors, they also reported that the IM specific factor was weakly defined.

Overall, in summary, studies based on first-order CFA and BCFA models have demonstrated that the ADHD symptoms are multidimensional, with two (IA and HY/IM) or three group/specific factors (either IA, HY, and IM; or IA, motoric HY/IM, and verbal HY/IM). Additionally, there is so much shared variances in these symptoms that bifactor models rather than first-order factor models are likely to better represent how the variances in these symptoms are distributed. In this respect, there appears to be most support for the BCFA model with specific factors for IA, motoric HY/IM, and verbal HY/IM. Although BCFA models have shown better fit than first-order CFA models, it is uncertain what underlines this finding. Park et al. (2018) have argued that the superior statistical fit for the bifactor model is related to the increased complexity of this model and that the importance of the bifactor ADHD model may have been overstated. Related to this, recently, there have been criticisms leveled at the application of CFA approaches for studying the factor structure of measures and at the application of the BCFA approach for studying the factor structure of the ADHD symptoms, as explained below.

### Limitations of CFA and Bifactor Approaches for Studying the Factor Structure of ADHD Symptoms

As noted earlier, the traditional independent cluster model of CFA approach is a model-based approach in which items load only on their target factors, and all the loadings on non-target factors (cross-loadings) are constrained to zero (Morin et al., 2013). The restriction on cross-loadings in the CFA approach is considered highly restrictive as items are rarely pure indicators of their latent factors, and therefore, some degree of construct-relevant association with nontarget but conceptually related factors is to be expected (Morin et al., 2016). Indeed, cross-loadings for ADHD symptoms have been often observed in EFA studies of ADHD symptoms (e.g., Döpfner et al., 2006; DuPaul, Anastopoulos, et al., 1998; Rohde et al., 2001). Thus, the CFA approach does not generally express the reality of the data set and could consequently show poor fit even when this is not the case. Indeed, Marsh et al. (2009) has argued that it is almost impossible to get acceptable fitting models for good multi-dimensional rating scales when examined only with CFA. In relation to studying the structure of the ADHD symptoms using BCFA, Park et al. (2018) have summarized three major concerns (see also Bonifay et al., 2017, for a more general discussion of the problems of the bifactor approach). First is the difficulty in the interpretation of the meaning of specific factors in an ADHD bifactor model. This is because, statistically, the specific factors are seen as nuisance variables, whereas from a theoretical viewpoint, the specific factors for ADHD are considered to constitute substantially meaning specific variances not accounted for by the general ADHD factor. According to Park et al. (2018), the appropriate explanation will depend on the reliability, stability, and incremental validities of the specific factors. In this respect, the review by Arias et al. (2016) concluded that while the general ADHD factor was reliable in explaining most of the variances in the ADHD symptoms, the specific factors (especially HY/IM) were not reliable, poorly defined, and meaningless, with some negative loadings and nonsignificant loadings. Although the IA specific factor demonstrated incremental validity, this was limited to clinical samples. In their own study, Park et al. (2018) found that the specific factors had poor reliabilities and construct replicability. A second concern relates to the fact that the bifactor model
will always fit better than the corresponding first-order factor model as they can better accommodate nonsense response patterns in the data set, thereby making it appear better even if this is not the case. A third concern is that as more parameters are estimated in a bifactor model, this is more complex and less parsimonious and potentially an unnecessary model compared with the corresponding first-order factor model.

Alternate New Approaches for Studying the Factor Structure of the ADHD Symptoms

To overcome the limitation of the CFA approach (i.e., all cross-loadings constrained to zero), the ESEM approach has been developed (Asparouhov & Muthén, 2009; Marsh et al., 2009). ESEM is a synergy of the EFA and CFA approaches, incorporating the advantages of the EFA approach (allowing cross-loadings) and CFA approach (model-based, and testing an a priori defined structure). Supplemental Figure S1 shows the ESEM models as applied to the ADHD symptoms. As shown in the figure, the targeted symptoms load on their own factors as well as nontargeted factors (at values close to zero). Existing findings have demonstrated the superiority of the ESEM approach over the EFA and CFA approaches (Marsh et al., 2009; Marsh et al., 2014). The basic ESEM model can be expanded to a bifactor ESEM (BESEM) model, thereby combining concurrently the advantage of the CFA approach (a priori model specifications), the EFA approach (fullility of the items and allowing cross-loadings), and the bifactor approach (allowing a general factor and specific factors that are not correlated; Marsh et al., 2014; Morin et al., 2016). Thus, compared with the EFA, CFA, and ESEM approaches, the BESEM approach offers the most advanced method to explore different sources of construct-relevant multidimensionality (Morin et al., 2016). This is especially relevant to the ADHD symptoms as they have demonstrated multidimensional cross-loadings and the presence of general and specific factors. For a bifactor model, it is also important to evaluate if the factors in a bifactor model are substantially meaningful. Morin et al. (2016) have proposed the integrated test of multidimensionality procedure for this purpose. Additionally, Park et al. (2018) have suggested evaluation of the reliabilities and validities of the factors in this model, especially the incremental validities of the specific factors.

As far as it can be ascertained, the ESEM approach has been applied in at least two studies involving DSM-IV ADHD symptoms (Arias et al., 2016; Rodenacker et al., 2017). The study by Arias et al. (2016), involving teacher ratings of preschool children, examined the fit of several CFA and ESEM first-order and bifactor models. The findings showed better support for ESEM models. In contrast, the study by Rodenacker et al. (2017), involving parent and teacher ratings of clinically referred children (60.4% with primary or secondary ADHD diagnosis) between 6 and 18 years, found no difference between CFA and ESEM models, including BESEM models. Thus, the existing studies in this area involving children and adolescents have shown inconsistent findings. More important, existing data are limited as there has been no test of the structure of the ADHD symptoms in adults using ESEM and BESEM approaches.

Aims of Current Study

Given existing limitations, the major aim of the current study was to examine the structure of the ADHD symptoms in adults from the general community, using CFA, bifactor CFA, ESEM, and BESEM approaches. In all, we tested 12 models: CFA two-factor model, with IA and HY/IM group factors; CFA three-factor model, with IA, HY, and IM as group factors; CFA three-factor model, with IA, motoric HY/IM, and verbal HY/IM as group factors; ESEM two-factor model, with IA and HY/IM group factors; ESEM three-factor model, with IA, HY, and IM as group factors; ESEM three-factor model, with IA, motoric HY/IM, and verbal HY/IM as group factors; BCFA model, with specific factors for IA and HY/IM; BCFA model, with specific factors for IN, HY, and IM; BCFA model, with specific factors for IA, motoric HY/IM, and verbal HY/IM; BESEM model, with specific factors for IA and HY/IM; BESEM model, with specific factors for IA, HY, and IM; and BESEM model, with specific factors for IA, motoric HY/IM, and verbal HY/IM. These models were described earlier (see also Supplemental Figure S1). To establish the optimum ADHD model, we followed closely the integrated test of multidimensionality procedure proposed by Morin et al. (2016). For the optimum structural model, we also computed model-based reliabilities for the different factors. More specifically, the omega (ω) values were computed (Zinbarg et al., 2005). For the same model, we also examined the external/incremental validity of the group/specific factors by regressing measures of depression, anxiety, and stress on ADHD factors in the optimum model. In relation to predications, based on existing data, we expected more support for the ESEM model or BESEM model with group/specific factors for IA, motoric HY/IM, and verbal HY/IM.

Method

Participants

The sample comprised a total of 738 individuals, with ages ranging from 17 to 72 years (M = 25.22 years; SD = 7.67 years). The sample included 374 (50.7%) males (mean age = 25.24 years, SD = 7.76 years) and 364 (49.3%) females (mean age = 25.21 years, SD = 7.60 years). Our sample
size is well above the generally recommended sample size for the type of study we have conducted (see Myers et al., 2011). The gender groups did not differ by age, t(736) = 0.05, ns. Supplemental Table S1 available online shows additional background information. As shown in the table, more than half the participants were employed and had completed technical or university education. Also, on average, participants had completed at least 12 years of education. Based on the normative scores for the Depression Anxiety Stress Scales–21 (DASS–21; Lovibond & Lovibond, 1995), published by Henry and Crawford (2005), the mean scores for the participants in the current study for depression (7.41), anxiety (5.37), and stress (6.86) were less than 1 SD from the mean, around 1.5 SD from the mean, and just above 1 SD from the mean, respectively. According to Kessler et al. (2005), a total score of 24 or more for IA or HI symptom groups on the ASRS Symptom Checklist () is indicative of a high likelihood of an ADHD diagnosis. In the current study, the total mean scores for IA and HI were 14.43 and 14.28, respectively. Thus, on the whole, the participants in the current study can be seen as reasonably well-adjusted with no problematic levels of depression, anxiety, stress, and/or ADHD symptoms.

Supplemental Table S2 shows the descriptive statistics of the ADHD symptoms for all participants together. As shown for all 18 symptoms, the scores ranged from 0 to 4. The mean scores ranged from 0.64 to 3.37, and the SD scores ranged from 0.89 to 1.30. Although details are not shown, all five response categories were scored for all 18 symptoms. These figures can be interpreted to mean that there is little evidence of range restriction for the ADHD symptom ratings. Participants were not compensated in any way for their participation. Below, we report all measures in the study. We have not reported on data exclusions and manipulations as these are not relevant to the study.

Measures

Adult ADHD Self-Report Scale Symptom Checklist. The ASRS was developed by the World Health Organization to screen for ADHD among adults (Kessler et al., 2005). This measure was used in this study for obtaining ratings for the ADHD symptoms that were subjected to the various factor analyses. The ASRS contains the DSM-IV symptoms of ADHD (nine IA symptoms and nine HY/IM symptoms). For all symptoms, participants indicated how often they have experienced those symptoms over the past 6 months on a scale with options of 0 (never), 1 (rarely), 2 (sometimes), 3 (often), and 4 (very often). The ASRS has high concurrent validity with clinically administered adult ADHD interview measures (Kessler et al., 2005). In the current study, the Cronbach’s alpha values for the IA, HY/IM, and total (both IA and HY/IM symptoms together) scales were .85, .77, and .89, respectively. The Cronbach’s alpha values for motoric HY/IM and verbal HY/IM were .72 and .74, respectively.

Depression Anxiety Stress Scales–21. The DASS–21 is a self-report measure that has 21 items, grouped into seven-item scales for depression, anxiety, and stress (Lovibond & Lovibond, 1995). Respondents rate all items in terms of how often they experienced them in the past week, using a 4-point scale, ranging from 0 (did not apply to me at all) to 3 (applied to me very much or most of the time). Previous studies have demonstrated good convergent and discriminant validities and also high internal consistencies for all three scales of the DASS–21 (Lovibond & Lovibond, 1995). The internal coefficient (Cronbach’s alphas) for the depression, anxiety, and stress scales in the current study are .84, .71, and .83, respectively. The DASS–21 scale scores were used to test the incremental validity of the ADHD factors in the optimum model. This is appropriate, as studies have shown that ADHD symptoms are related to depression (Semeijn et al., 2015) and anxiety (Jacob et al., 2007; Jarrett & Ollendick, 2008). More specific to the current study, for the longer version of the DASS (Lovibond & Lovibond, 1995), previous studies have shown that its total score and the scores for depression, anxiety, and stress were associated significantly and positively with ADHD total score and IA, HY, and IM scale scores, respectively (Alexander & Harrison, 2013; Harrison et al., 2013).

Procedure

The study was approved by the research team’s institutional Human Research Ethics Committee. Participants were recruited online via advertisements on various platforms, including social media (e.g., Facebook) and internet chat-rooms (e.g., Discord). Individuals who clicked the survey link were debriefed on the first page with a description of the study and its aims via the plain language information statement. Verification that participants’ data would be recorded anonymously was provided, and a statement ensuring that they had the choice to stop participating in the survey at any point in time was also included. Participants digitally provided their informed consent by clicking to proceed to take part in the survey.

Statistical Analysis

All statistical analyses were conducted using Mplus Version 7.3 (Muthén & Muthén, 2012). Robust maximum likelihood (MLR) estimator was used for all CFA and ESEM models. MLR can correct for nonnormality in the data set and is suited for responses with five or more response categories (Lubke & Muthén, 2004; Muthén & Muthén, 2012), as is the case with the symptoms listed in the ASRS.
To establish the best ADHD model, we followed closely the integrated test of multidimensionality procedure proposed by Morin et al. (2016). This was done in several phases. In the initial phase, we examined and compared the global fit of the first-order CFA and ESEM models. As $\chi^2$ values, including the MLR$\chi^2$, are inflated by large sample sizes; the fit for these models and all other models in the study was also evaluated by three approximate or practical fit indexes. The indexes used were the root mean squared error of approximation (RMSEA), the comparative fit index (CFI), and the Tucker–Lewis index (TLI). The guidelines suggested by Hu and Bentler (1999) are that RMSEA values close to 0.06 or below, be taken as good fit, 0.07 to 0.08 as moderate fit, 0.08 to 0.10 as marginal fit, and $>$0.10 as poor fit. Where necessary, the difference in the fit of nested models was examined using values less than 0.90 be taken as poor fit. Where necessary, values close to 0.90 and 0.95 be taken as acceptable fit, and values close to 0.95 or above are to be taken as good fit, values less than 0.90 be taken as poor fit. Where necessary, the difference in the fit of nested models was examined using differences in the RMSEA and CFI values. Generally, differences in CFI values of 0.010 and RMSEA of 0.015 or more are interpreted as difference for the models being compared (Chen, 2007; Cheung & Rensvold, 2002).

In a subsequent phase, we compared the correlations between the factors in the CFA and ESEM first-order factor models. In general, when the correlations for the factors are lower in the ESEM model than in the CFA model, it means that the ESEM model captures better the distribution of the variances in the ADHD symptoms than the CFA model (Marsh et al., 2009; Morin et al., 2013). When several ESEM models are under investigation, the next phase focuses on establishing the preferred ESEM model. The preferred ESEM model is established in terms of which ESEM model shows better global fit. The next phase involved evaluating for the preferred ESEM model, the presence of construct-relevant psychometric multidimensionality due to the fallible nature of the indicators. This involves comparing the patterns of item–factor mapping and item factor loadings in the preferred ESEM model. Significant cross-loadings in the ESEM model for many nontarget symptoms (e.g., an IA symptom loading on the HI factor) in the ESEM model can be interpreted as supportive of construct-relevant psychometric multidimensionality and, therefore, more support for the application of ESEM model than CFA model. In the next phase, we evaluated the need to model a hierarchically superior general factor by comparing the global fit of ESEM and the BESEM models. If the preferred model is a BESEM model, then the patterns of loadings and cross-loadings in this model is examined. Even when there is support for a strong general factor, significant cross-loadings for many nontarget symptoms for the specific factors and nonsignificant loadings for targeted items on their own factors can be interpreted as weakening the support of the bifactor model.

For the best model, model-based reliabilities for the different factors were computed. More specifically, the $\omega$ values for the factors were computed (Arias et al., 2018; Zinbarg et al., 2005). The $\omega$ can be interpreted as an estimator of how much variance in summed (standardized) scores can be attributed to that factor (McDonald, 1999). For a bifactor model, the $\omega$ values for the general and specific factors are referred to as omega hierarchical ($\omega_h$) and omega-subscale ($\omega_s$), respectively (McDonald, 1999; Zinbarg et al., 2005). The values for all types of $\omega$ values range from 0 to 1, with 0 indicating no reliability and 1 reflecting perfect reliability (Brunner et al., 2012). According to Reise et al. (2013), $\omega_s$ values need to be at least .50 with values of at least .75 preferred for meaningful interpretation of a scale.

Corresponding to the approach used by Park et al. (2018), to test for the external/incremental validity of the ADHD specific or group factors in our best model, the DASS-21 scale scores for depression, anxiety, and stress were regressed on all the factors in the ADHD model. To control for possible confounding effects of age and gender, both these variables were entered as covariates in the analyses. Significant positive predictions of any one of the DASS-21 scale scores by any of the factors in the model can be taken as support for the external validity of the relevant factors.

### Results

#### Missing Values

There were no missing values in the data set.

#### CFA Versus ESEM Models

**Model Fit and the Correlations Between Latent Factors.** Table 1 shows the fit values and information criteria for all the ADHD models tested in the study. Although the CFA two-factor and both the three-factor models showed good fit in terms of their RMSEA values, their CFI and TLI values indicated poor fit. The ESEM two-factor model showed acceptable fit in terms of its CFI and TLI values and good fit in terms of its RMSEA value. Both the ESEM three-factor models showed good fit in terms of its CFI and RMSEA values and adequate fit in terms of its TLI value. Across all these models, both the ESEM three-factor models had the lowest information criteria (Akaike information criterion [AIC] and Bayesian information criterion [BIC]) values. Taken together, these findings can be interpreted as showing relatively more support for the ESEM three-factor models than the CFA two-factor and three-factor models, and the ESEM two-factor models.

**Correlations Between the Factors in the CFA and ESEM Models**

Supplemental Table S2 also shows the correlations of the latent factors in the CFA and ESEM two- and three-factor models. As shown, the correlations of the latent factors in
the CFA two- and three-factor models were much higher than the corresponding correlations in the ESEM two- and three-factor models, respectively. Generally, when this is the case, the ESEM model is considered a better model than the CFA model to reflect the variances in the items (Marsh et al., 2009; Morin et al., 2013).

Establishing the Preferred ESEM Model(s)

Given that both the ESEM three-factor models showed better global fit than the ESEM two-factor model, it follows that these three-factor ESEM models are better models than the ESEM two-factor model for representing the variances for the ratings of the ADHD symptoms in the ASRS.

Item Factor Loadings in the Three-Factor ESEM Models

Table 2 shows the factor loadings for the ESEM three-factor models, with group factors for IA, HY, and IM, and with group factors for IA, motoric HY/IM, and verbal HY/IM. As shown, for the model with group factors for IA, HY, and IM, for the IA factor, all nine targeted symptoms loaded significantly and saliently on the IA factor; and four nontargeted symptoms cross-loaded significantly on the IA factor, with one of them being salient. For the HY factor, three (out of six) targeted symptoms loaded significantly and saliently on the HY factor; and six nontargeted symptoms cross-loaded significantly on the HY factor, with three of them being salient. For the IM factor, only one of the three targeted symptoms loaded significantly and saliently on the IM factor; and nine nontargeted symptoms cross-loaded saliently on the IM factor, with two being salient.

For the model with group factors for IA, motoric HY/IM, and verbal HY/IM, for the IA factor, all nine targeted IA symptoms loaded significantly and saliently on the IA factor; and four nontargeted symptoms cross-loaded significantly on the IA factor, with one being salient. For the motoric HY/IM factor, four of the five targeted symptoms loaded significantly and saliently on the motoric HY/IM factor; and six nontargeted symptoms cross-loaded significantly on the motoric HY/IM factor, with one being salient. For the verbal HY/IM factor, all four targeted symptoms loaded significantly and saliently on the verbal HY/IM factor; and six nontargeted symptoms cross-loaded significantly on the HY/IM factor, with one being salient.

Overall, therefore, for the ESEM three-factor model with group factors for IA, HY, and IM, the IA factor can be considered to be well-defined, whereas the HY and IM factors can be considered to be poorly defined. For the ESEM three-factor models with group factors for IA, motoric HY/IM, and verbal HY/IM, the IA factor can be considered to be well-defined and the motoric HY/IM and verbal HY/IM factors to be reasonably well-defined. Given this, we deemed the ESEM three-factor models with group factors for IA, motoric HY/IM, and verbal HY/IM as a better model than the ESEM three-factor models with group factors for IA, HY, and IM for representing the variances for the ratings of the ADHD symptoms in the ASRS. Despite this, as there were many significant nontargeted cross-loadings (with some being salient), the findings raise the possibility

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**Table 1. Fit of All the Models Tested in the Study.**

| Models                                           | χ² (df) | CFI  | TLI  | RMSEA [90% CI] | AIC   | BIC   |
|--------------------------------------------------|--------|------|------|----------------|-------|-------|
| CFA 2-F (IA, HY/IM)                              | 529.05 (134) | .891 | .875 | .063 [0.058, 0.069] | 36,812 | 37,066 |
| CFA 3-F (IA, HY, IM)                             | 519.73 (132) | .893 | .876 | .063 [0.057, 0.069] | 36,805 | 37,067 |
| CFA 3-F (IA, MHY/IM, VHY/IM)                     | 500.55 (132) | .898 | .882 | .062 [0.056, 0.067] | 36,781 | 37,043 |
| BCFA 2-s-F (G, IA, HY/IM)                        | 410.46 (117) | .919 | .894 | .058 [0.052, 0.064] | 36,674 | 37,005 |
| BCFA 3-s-F (G, IA, HY, IM)                       | 421.24 (117) | .916 | .890 | .059 [0.053, 0.066] | 36,705 | 37,037 |
| BCFA 3-s-F (G, IA, MHY/IM, VHY/IM)               | 403.63 (117) | .921 | .896 | .058 [0.052, 0.064] | 36,677 | 37,009 |
| ESEM 2-F (IA, HY/IM)                             | 378.57 (118) | .928 | .907 | .055 [0.049, 0.061] | 36,656 | 36,983 |
| ESEM 3-F (IA, HY, IM)                            | 248.96 (102) | .959 | .939 | .044 [0.037, 0.051] | 35,625 | 35,925 |
| ESEM 3-F (IA, MHY/IM, VHY/IM)                    | 248.96 (102) | .959 | .939 | .044 [0.037, 0.051] | 35,625 | 35,925 |
| BESEM 2-s-F (G, IA, HY/IM)                       | 248.96 (102) | .959 | .939 | .044 [0.037, 0.051] | 35,625 | 35,925 |
| BESEM 3-s-F (G, IA, HY, IM)                      | 223.78 (87)  | .962 | .934 | .046 [0.039, 0.054] | 34,495 | 34,964 |
| BESEM 3-s-F (G, IA, MHY/IM, VHY/IM)              | 223.78 (97)  | .962 | .934 | .046 [0.039, 0.054] | 34,495 | 34,964 |

Note. F = factor; s-F = specific factor; IA = inattention; HY/IM = hyperactivity/impulsivity; HY = hyperactivity; IM = impulsivity; MHY/IM = motoric hyperactivity/impulsivity; VHY/IM = verbal hyperactivity/impulsivity; CI = confidence interval; χ² = chi-square; df = degrees of freedom; CFA = confirmatory factor analysis; ESEM = exploratory structural equation modeling; BCFA = bifactor confirmatory factor analysis; BESEM = bifactor exploratory structural equation modeling; RMSEA = root mean square error of approximation; CFI = comparative fit index; TLI = Tucker–Lewis index; AIC = Akaike information criterion; BIC = Bayesian information criterion.
of construct-relevant psychometric multidimensionality for the ADHD symptom ratings and, therefore, the need to include a general factor in the ESEM model, or a BESEM ADHD model.

Comparing the Global Fit of the ESEM and BESEM Models With Group Factors for IA, Motoric HY/IM, and Verbal HY/IM

The CFI, TLI, and RMSEA values of BCFA model with specific factors for IA, motoric HY/IM, and verbal HY/IM were adequate, poor, and good, respectively. Thus, there was inadequate support for this model. Like the ESEM model, the BESEM model with specific factors for IA, motoric HY/IM, and verbal HY/IM showed good fit in terms of the CFI and RMSEA values and adequate fit in terms of the TLI values. While the ACI value was lower for the BESEM model, the BIC value was lower for the ESEM model. When compared using ΔCFI and ΔRMSEA values, these models did not differ from each other (ΔCFI = −0.003; ΔRMSEA = −0.002). Taken together, these findings can be interpreted as indicating comparable support for the ESEM and BESEM models with group factors for IA, motoric HY/IM, and verbal HY/IM. Given this, and as the ESEM model is more parsimonious, we selected this model as the optimum model. This conclusion concurs with our prediction.

Reliabilities of the Factors in the Optimum Three-Factor ESEM Model

As noted previously, for the optimum model, the Cronbach’s alpha values for the IA, motoric HY/IM, and verbal HY/IM factors were .85, .74, and .87, respectively. Thus, there was good support for the internal consistency reliabilities of the factors in this model.

Validity of the Factors in the BESEM Models

Table 3 shows the standardized path coefficients for the predictions of the DASS-21 scale scores of depression, anxiety, and stress by the factors in the ESEM models with IA, motoric HY/IM, and verbal HY/IM as the group factors. For this analysis, we control for the effects of gender and age. As shown, depression, anxiety, and stress were all predicted significantly and positively by the IA, motoric HY/IM, and verbal HY/IM factors. These findings indicate support for the external validity of the IA, motoric HY/IM, and verbal HY/IM factors.

Discussion

The major aim of the present study was to use ESEM and BESEM procedures to examine the factor structure of DSM-IV/DSM-5 ADHD symptoms (as presented in the

Table 2. Factor Loadings of the First-Order and Bifactor ESEM Models.

| Specific factors | IA | HY | IM | Specific factors | IA | Motoric HY/IM | Verbal HY/IM |
|------------------|----|----|----|------------------|----|--------------|--------------|
| Careless (IA1)   | .52** | -.06 | .12 |                 | .52** | -.09 | .12 |
| Inattention (IA2)| .67** | -.08 | .14 |                 | .67** | -.11 | .13 |
| Listen (IA3)     | .58** | -.01 | .01 |                 | .58** | -.01 | .01 |
| Instruction (IA4)| .72** | -.17** | .03 |                 | .72** | -.17** | -.01 |
| Disorganized (IA5)| .34** | -.57** | -.36* |               | .35** | -.63** | -.27 |
| Unmotivated (IA6)| .99** | -.04 | -.17** |               | .99** | .00 | -.18** |
| Lose (IA7)       | .64** | -.07 | .04 |                 | .64** | -.07 | .03 |
| Distracted (IA8) | .58** | .11 | -.01 |                 | .58** | .11 | .01 |
| Forgetful (IA9)  | .44** | .21** | .11* |                 | .44** | .17* | .15* |
| Fidget (HY1)     | .36* | .16 | .21** |               | .35** | .09 | .25** |
| Seat (HY2)       | .17 | .38** | .20* |                 | .17* | .31** | .27** |
| Run (HY3)        | .11 | .31 | .31** |               | .10 | .21** | .37** |
| Quiet (HY4)      | .21** | .71** | -.13 |               | .22** | .70** | .00 |
| Motor (HY5)      | .05 | .42** | .23* |                 | .05 | .34** | .30** |
| Talk (HY6)       | .07 | .23 | .30* |                 | .06 | .14 | .35** |
| Blurt (IM1)      | .02 | .27** | .24 |                 | .02 | .19** | .31* |
| Wait (IM2)       | .14* | .33* | .38** |               | .14* | .21** | .46** |
| Interrupt (IM3)  | .15* | .31** | .24 |                 | .14 | .23** | .31* |

Note. ESEM = exploratory structural equation model; IA = inattention; HY = hyperactivity; IM = impulsivity; HY/IM = hyperactivity/impulsivity. Boldface values indicate factor loadings in the primary dimension; underlined values indicate significant cross-loadings over .30 in absolute value. *p < .05. **p < .01.
Table 3. Standardized Beta Coefficients for the Predictions of the DASS Scale (Depression, Anxiety, and Stress) 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).

|                         | Depression | Anxiety | Stress |
|-------------------------|------------|---------|--------|
| Gender                  | −0.08      | 0.03    | 0.03   |
| Age                     | −0.02      | −0.12** | −0.05  |
| Inattention             | 0.41***    | 0.40*** | 0.40** |
| Motoric hyperactivity/impulsivity | 0.30*     | 0.41*** | 0.45*** |
| Verbal hyperactivity/impulsivity  | 0.18*     | 0.21**  | 0.25*** |

Note. ESEM = exploratory structural equation model; IA = inattention; HY/IM = hyperactivity/impulsivity.
*p < .05, **p < .01, ***p < .001.

ASRS) in a group of adults from the general community. To achieve our goal, we used the integrated test of multidimensionality procedure proposed by Morin et al. (2016). Consequently, we examined CFA two-factor model, with IA and HY/IM group factors; CFA three-factor model with IA, HY, and IM as group factors; CFA three-factor model with IA, motoric HY/IM, and verbal HY/IM as group factors; ESEM two-factor model with IA and HY/IM group factors, ESEM three-factor model with IA, HY, and IM as group factors; ESEM three-factor model with IA, motoric HY/IM, and verbal HY/IM as group factors; BCFA model with specific factors for IA and HY/IM; BCFA model with specific factors for IN, HY, and IM; BCFA model with specific factors for IA, motoric HY/IM, and verbal HY/IM; BESEM model with specific factors for IA and HY/IM, BESEM model with specific factors for IA, HY, and IM; and BESEM model with specific factors for IA, motoric HY/IM, and verbal HY/IM. For the best of these models, we also computed the reliabilities and external validities of its factors.

In all instances, the correlations of the latent factors in the first-order CFA models were much higher than the correlation of the latent factors in the ESEM models. This finding can be explained in terms of the failure of the CFA model to parameterize the shared variances of all the ADHD symptoms as all cross-loadings were fixed to zero. According to experts, when this occurs, the shared variances are reflected in terms of increased correlation between the latent factors in the CFA model (Marsh et al., 2009; Morin et al., 2013). Under such circumstances, the ESEM model is considered a better model than the first-order CFA model to study the structure of a measure (Marsh et al., 2009; Morin et al., 2013). Although, like previous studies (Gibbins et al., 2012; Gomez et al., 2014; Gomez et al., 2018; Martel et al., 2012; Morin et al., 2016; Park et al., 2018; for a review, see, Arias et al., 2016), the BCFA model had better fit than the first-order CFA model, our findings showed that this model had lower fit compared with the ESEM model with three factors, including the one with group factors for IA, motoric HY/IM, and verbal HY/IM. Given this, and as the ESEM model is more parsimonious, we selected this model as the optimum model. Additional analyses showed good support for the internal consistency reliabilities and external validities of the factors in this model. Thus, it can be argued that from among the models examined, the three-factor ESEM model with group factor models IA, motoric HY/IM, and verbal HY/IM emerged as the best model for representing the variances for the ADHD symptoms rated in the ASRS. This was as expected.

At a more general level, as the ASRS is designed to measure ADHD as presented in DSM-IV-TR/DSM-5, the findings here could be extrapolated to theoretical, diagnostic, and clinical issues related to ADHD in general. First, as our findings showed support for the first-order factor for IA, motoric HY/IM, and verbal HY/IM, it follows that for adults, the ADHD symptoms need to be split into separate IA, motoric HY/IM, and verbal HY/IM symptom groups, and not simply IA and HY/IM, as is currently the case in DSM-5. This has implications for diagnosing different types of ADHD in adults. Our findings suggest that the different types of ADHD could be ADHD predominantly inattentive presentation (presence of mostly IA symptoms), ADHD predominantly motoric HY/IM presentation (presence of mostly motoric HY/IM symptoms), ADHD predominantly verbal HY/IM presentation (presence of mostly verbal HY/
IM symptoms), and combinations of these different presentation types, including a ADHD combined presentation type (presence of IA, motoric HY/IM, and verbal HI/IM symptoms). These presentation types differ from that currently proposed in DSM-5. They are ADHD combined type (presence of IA and HY/IM symptoms), ADHD predominantly IA presentation (presence of mostly IA symptoms), and ADHD predominantly hyperactive/impulsive presentation (presence of mostly HY/IM symptoms). Second, the absence of separate IA and HI/IM symptom groups also calls into question multiple-pathway ADHD theories (Nigg et al., 2004; Sonuga-Barke, 2002, 2005) that implicates different ethological processes for the IA and HI/IM groups of symptoms. Consequently, our findings could indicate a need to refine the diagnostic aspects (in particular, indicators and types) for ADHD in adults. One possibility is to include additional symptoms, such as that provided in the Conners’s Adult ADHD Rating Scales (Conners et al., 1999) and the Adult Attention Deficit Disorders Evaluation Scale Self-Report Version (McCarney & Anderson, 1996). Third, as our findings support distinct factors for motoric HI/IM and verbal HI/IM, it raised the possibility that ADHD in adults could be associated with experiencing restlessness without being overtly hyperactive (Barkley & Murphy, 2006; Gibbins et al., 2012). Related to all these implications, it is important to keep in mind that their merits are dependent on the effectiveness of the ASRS to measure accurately the clinical symptoms of ADHD. However, this remains an open empirical question.

In summary, this is the first study to examine the factor structure of the ADHD symptoms in adults using ESEM and BESEM. The findings provided support for the ESEM model with three group factors (IA, motoric HY/IM, and verbal HY/IM). Our findings were not confounded by range restriction for the ADHD symptom ratings. However, the findings in the current study have to be viewed with some limitations in mind. First, the motoric HY/IM factor in the ESEM model was not completely well-defined. Second, the support for their validities was based on a limited number of external variables. Related to this, it would be useful if future studies could include a wider range of relevant variables, such as executive and neurocognitive functioning (Barkley, Murphy & Bush, 2001), and personality constructs (Gomez & Corr, 2014) to study the external validities of the IA, motoric HY/IM, and verbal HY/IM factors. Third, as this study examined a community sample, it is uncertain if the findings are applicable to clinically diagnosed ADHD adults. As the ASRS is a clinical measure to facilitate the diagnosis of ADHD, it would be useful to replicate this study with adults diagnosed or with high levels of the ADHD symptoms. Fourth, as demonstrated by Sibley et al. (2018), self-reports can be seen as problematic for measuring the ADHD symptoms in adults as they are prone to false-positive responses. As we collected our scores for the ADHD symptoms using a self-report measure, our scores may be distorted. Fifth, we used the ASRS (Kessler et al., 2005) to assess ADHD symptoms. For the ASRS, respondents are required to rate the 18 ADHD symptoms on a 5-point scale. This is different from most other adult ADHD rating scales as they use scales with four response options. Also, in clinical practice, ADHD symptoms are scored dichotomously as either present or absent. Thus, the relevance of the findings for the ASRS reported in the current study for most of the other adult ADHD rating scales and for clinical interview-based scores is unknown. Research, involving assessment of ADHD symptoms based on other adult ADHD rating scales, such as the Current Symptoms Scale–Self-Report Form (Barkley & Murphy, 1998), and clinical interviews, is needed for a more comprehensive understanding of the structure of the ADHD symptoms. Notwithstanding these limitations to the generalization of the findings of this study, it could however be argued that the results of the current study do provide impetus for more studies in this area, controlling for the limitations identified here. This study has also shown that the use of ESEM and BESEM procedures can provide valuable additional psychometric information and also inform practical and theoretical issues. It is hoped that this study will encourage other researchers to use these procedures to evaluate the psychometric properties of other commonly used adult ADHD rating scales. Such data will help improve the quality of these clinical tools, which in turn has the potential to improve their clinical use and our understanding of ADHD. Clearly, more studies are needed in this area.

Declaration of Conflicting Interests
The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding
The author(s) received no financial support for the research, authorship, and/or publication of this article.

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Supplemental Material
Supplemental material for this article is available online.

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