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ADHD symptoms among adolescents: Measurement invariance across mother and adolescent self-ratings

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ABSTRACT

This study employed confirmatory factor analysis (CFA) to examine measurement invariance (configural, metric, and scalar) across mother and adolescent self-ratings of ADHD symptoms [inattention (IA), hyperactivity (HY), and impulsivity (IM)] as presented in the Disruptive Behavior Rating Scale (DBRS; Barkley & Murphy, 1998). The ADHD model used for this analysis was the ICD-10 3-factor model, with factors for IA, HY and IM. Findings supported configural invariance. Of the 18 ADHD symptoms, 4 symptoms (three of which were IA symptoms) lacked metric invariance. Nine thresholds (1 IA symptom, 6 HY symptoms, and 2 IM symptoms) lacked scalar invariance, with six being for the first thresholds. The psychometric and practical implications of the findings are discussed.

1. Introduction

Attention-Deficit/Hyperactivity Disorder (ADHD) is a highly prevalent disorder in children, adolescents, and adults (American Psychiatric Association, APA, 2013). The current edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5; American Psychiatric Association, APA, 2013) and the earlier editions (e.g., DSM-IV, APA, 1994) have inattention (IA), hyperactivity (HY) and impulsivity (IM) as core symptoms for ADHD. However, in DSM-IV/DSM-5 the HY and IM symptoms are combined as a single group (HY/IM) for diagnostic purposes. In the International Classification of Diseases-10 (ICD-10, World Health Organization, 1999), ADHD is referred to as Hyperkinetic Disorder (HD), and has the same 18 symptoms as in DSM-IV/DSM-5. However, in contrast to DSM-IV/DSM-5, the HY and IM symptom groups in ICD-10 are considered separately for diagnosis. Furthermore, the 'talkative' symptom is designated as an IM symptom, instead of a HY symptom, as in the DSM-IV/DSM-5. Thus, the structure of ADHD in the DSM-IV/DSM-5 is seen as a two-factor model, with factors for IA (9 symptoms) and HY/IM (9 symptoms), whereas in ICD-10, ADHD or more specifically HD, is viewed as a three-factor model, with factors for IA (9 symptoms), HY (5 symptoms), and IM (4 symptoms).

Major practice guidelines for the diagnosis of ADHD have proposed that when adolescents are being diagnosed, their self-reports of ADHD behaviors should be obtained and integrated with information from others, in particular mothers and teachers (American Academy of Child and Adolescent Psychiatry, 2007). For credible integration of self-reports of ADHD symptoms by adolescents with reports of the their ADHD symptoms provided by others it is necessary to have a sound understanding of the equivalency or measurement invariance of the ADHD information provided by the respondents in question. In the context of measurement invariance across adolescent self-reports and mother reports, measurement invariance means that for reporting the same latent score in the adolescent, the adolescent and the mother will both endorse the same observed score (Brown, 2006). With weak or no support for invariance, the groups cannot be justifiably compared since the scores can be assumed to be confounded by different measurement and scaling properties. Thus, for creditable integration of information of ADHD reports (provided by adolescents and their mothers) corresponding empirical information on measurement invariance of the ADHD symptoms is required.

There are reasons to suspect that adolescents' self-reports of ADHD symptoms and those provided by their mothers may lack invariance.

Abbreviations: DSM, Diagnostic and Statistical Manual of Mental Disorders; CFA, confirmatory factor analysis; DBRS, Disruptive Behavior Rating Scale; DBRS-P, Disruptive Behavior Rating Scale-Parent; DBRS-A, Disruptive Behavior Rating Scale-Adolescent; ADHD, Attention-Deficit/Hyperactivity Disorder; IA, inattention; HY, hyperactivity; IM, impulsivity; HY/IM, hyperactivity/impulsivity; APA, American Psychiatric Association; ICD, International Classification of Diseases; WLMSV, mean and variance-adjusted weighted least squares; RMSEA, root mean squared error of approximation; CFI, comparative fit index; TLI, Tucker-Lewis Index.

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This is because existing data indicate only moderate to low agreement between adolescent and mother reports for the IA symptoms, and low agreement for the HY/IM symptoms (Hartung et al., 2005; Kaner, 2011; Wan Ismail et al., 2013). In general, these differences have been explained in terms of either situational specificity (i.e., different ADHD symptoms being present in different settings), or bias (i.e., different respondents perceiving and interpreting the same ADHD symptoms differently; see Gomez, 2007). Such findings and explanations imply that mother reports of their adolescents' ADHD symptoms may not be equivalent to adolescent self-reports of their ADHD symptoms, particularly for HY/IM. Expressed differently, their reports of the ADHD symptoms will lack invariance. To date, no empirical study has examined the measurement invariance of ADHD symptoms across adolescent self-reports and those of their mothers.

1.1. Aim of the study

The current study sought to examine measurement invariance across mother reports of ADHD symptoms and self-reports of ADHD symptoms provided by their adolescents. Mother reports and adolescent self-reports were obtained using ratings of ADHD symptoms, as measured by the Disruptive Behavior Rating Scale (DBRS; Barkley & Murphy, 1998). The DBRS includes the 18 IA, HY and IM DSM-5/ICD-10 ADHD/HD symptoms. In this respect, ADHD rating scales such as the DBRS are seen as proxies for clinical assessment (Power et al., 1998; Wolraich et al., 2004), and are used extensively in ADHD research. For the DBRS, a recent study (citation withheld for blind review) involving the same group of adolescents as in this present study found greater support for the ICD-10 3-factor model than the DSM-IV/DSM-5 2-factor model, for both mother and adolescent self-ratings. Taking this into consideration, we examined measurement invariance for the ICD-10 3-factor model.

2. Method

2.1. Participants

The sample comprised 300 adolescents (females = 170; males = 130) ranging in age from 12 to 17 years (Mean age = 13.88 years, *SD* = 1.29 years), from the general community. Approximately 45 %, 20 % and 35 % of adolescents were from metropolitan, regional, and rural regions in Australia, respectively. Overall, these adolescents were of middle social class status, with the majority (>95 %) having a European background. Soper (2022)'s software for computing sample size requirements for CFA models was used to evaluate the sample size requirement for the present study. For this, the anticipated effect size was set at 0.3, power at 0.8, the number of latent variables at 6, the number of observed variables at 36, and probability at 0.05. The analysis recommended a minimum sample size of 200. Our sample size ($N = 300$) exceeds this recommendation.

It should be noted that the adolescents in this current study were involved in one or more of our previous studies and therefore brief information pertaining to these studies and their aims appear in Supplementary Table S1. (For meeting the requirements for blind review the names of the authors and references have presently been withheld). As can be seen in the table, the objectives in these previous studies were completely different from that of the current study.

2.2. Measures

All of the mothers who participated provided demographic information (via questionnaire), including their adolescent's age, gender, ethnicity, country of birth, and their (or their partner's, if they wished) education level, and employment status. Mothers also rated their adolescent's ADHD symptoms using the DBRS-Parent (DBRS-P; Barkley & Murphy, 1998). Adolescents self-rated their own ADHD symptoms using a scale that was adapted from the DBRS-P, which we named DBRS-Adolescent (DBRS-A; Gomez & Gomez, 2015).

2.3. Disruptive Behavior Rating Scale

The DBRS-P and the DBRS-A include the nine DSM-IV/DSM-5/ICQ-10 ADHD/HD IA symptoms and the nine DSM-IV/DSM-5/ICD-10 ADHD/HD HY/IM symptoms, with the word 'often' omitted from the list of symptoms. Of the nine HY/IM symptoms in DSM IV/DSM-5 there were 6 and 3 IA and HY symptoms respectively. For ICD-10, there were 5 and 4 symptoms respectively. For both respondent versions, individual are requested to circle the number that best describes the child's behavior in the previous 6 months. For both versions, respondents rate the presence of each symptom on a 4-point scale (0 = never or rarely, 1 = sometimes, 2 = often, and 3 = very often). In the adolescent version, the wordings of the original items were modified to make them amenable to self-report. For example, the first IA symptom "fails to give close attention to detail or makes careless mistakes in schoolwork" in the parent version was modified to "fails to give close attention to detail or makes careless mistakes in my schoolwork" in the adolescent self-rating version. For this study, the Cronbach's alphas for the IA, HY and IM scales for mother ratings were 0.92, 0.83 and 0.86, respectively. For adolescent self-ratings they were 0.89, 0.72 and 0.75, respectively.

2.4. Procedure

Permission to conduct the research was obtained from the Human Ethics Research Committee of the (University of "withheld for blind review", Australia) and the directors of education and school principals of 14 randomly selected schools.

Participants were recruited from 14 randomly selected schools. The teachers from these schools received sealed envelopes from the researchers containing the relevant study questionnaires (i.e., the DBRS-P for mothers and the DBRS-A for adolescents, and a number of other questionnaires). These envelopes were forwarded to parents via the students. In addition to the questionnaires, a consent form and a letter describing the study and highlighting the importance of completing questionnaires independently, was also included. To reduce bias in ratings, the letter explained that the study was focused on adolescent's behaviors, and that no one would be identified. Only the DBRS-P and DBRS-A ratings are reported in this study.

Of the questionnaires distributed through adolescents, 320 were completed by parents. Of these, 315 (98.4 %) were completed by adolescents. Participants were selected for inclusion in the study where all items on the DBRS-P and DBRS-A had been completed. The final sample which was 300 had no missing values in the data set for both parents and adolescents. Given the negligible number of non-completers (1.6 %) and missing values, these were not considered problematic. Additionally, there was no differences across parent ratings for overall ADHD for adolescent who completed and who did not complete the DBRS-A, t ($df = 306$) = 1.586, $p = .114$. None of the participants were compensated for their participation.

2.5. Statistical procedures

All CFA models were conducted using M*plus* (Version 7) software (Muthén & Muthén, 2012). The mean and variance-adjusted weighted least squares or WLSMV were adopted for analyses. The highly robust WLSMV was considered suitable for the present study because it is strongly recommended for CFAs with ordered-categorical scores (see Brown, 2006). The WLSMVχ^2 was utilized to examine goodness-of-fit of the CFA models. Similar to other χ^2 values, large sample sizes lead to WLSMVχ^2 values being exaggerated. As well as providing the WLSMVχ^2, M*plus* also makes available estimated (or practical) fit indices. These include the root mean squared error of approximation (RMSEA), the comparative fit index (CFI), and the Tucker-Lewis Index (TLI). The current study employed these to assess the goodness-of-fit of models. For these fit indices, Hu and Bentler (1999)'s recommendations were adopted: RMSEA values of 0.06 or below indicate good fit, 0.07–<0.08

moderate fit, 0.08 to 0.10 marginal fit, and >0.10 poor fit. Values of 0.95 > signified good model-data fit, and values of 0.90 and <0.95 was taken as acceptable fit for the CFI and TLI. With reference to order-categorical data, these fit values have also been found to be suitable (Muthén & Muthén, 2012).

With reference to measurement invariance, the study examined configural (equality in form), metric (equality in factor loadings), and scalar invariance (equality in thresholds). Since most methodologists consider error (uniqueness) variances invariance as excessively rigorous and unnecessary (Brown, 2006) this was not carried out. In addition to the ratings supplied by mothers, adolescents also provided self-ratings. Therefore mother and adolescent ratings lacked independence. Given this, multiple group CFA (usually applied for testing measurement invariance) could not be used. Rather, an extended single group CFA model that included the ratings of both mothers and adolescents - comparable to models applied for examining test-retest measurement invariance was used.

Although the various nested CFA models can be compared using the WLSMVχ^2 difference test, this was not employed in the current study because the ΔWLSMVχ^2 values are also inflated by large sample sizes (Chen, 2007). Instead, the differences in the approximate fit indices (CFI and RMSEA) were used, with differences to reject invariance for both factor loadings and thresholds set at ΔCFI > 0.01, and ΔRMSEA > −0.015, respectively (Chen, 2007).

3. Results

Prior to evaluation of measurement invariance, the mean, standard deviation, and dispersion statistics of the DBRS symptoms for mother ratings and adolescent self-ratings were computed. These are displayed in Supplementary Table S3. Supplementary Table S4 displays the results of the test for measurement invariance for the ICD 3-factor model across mother ratings and adolescent self-ratings. Table 1 presents an overall summary of these results. As can be seen, the fit values (RMSEA, CFI and TLI) indicated good fit and therefore provide support for the configural invariance model (Model 1). The tables also show there were differences in both the CFI (−0.032) and RMSEA (0.017) values between the configural invariance model (Model 1) and the full metric invariance model (Model 2), thereby demonstrating lack of invariance for one or more factor loadings. Further analyses specified lack of metric invariance for four factor loadings, namely loadings for IA symptoms 5 (disorganized), 7 (loses things) and 9 (forgetful), and IM symptom 16 (talks a lot). There was also a difference in the CFI (−0.023) values between this partial metric invariance model and the full scalar invariance model (Model 3), in so doing signifying lack of invariance for one or more thresholds. Additional analyses indicated lack of scalar invariance for nine thresholds. These were the first thresholds for symptoms 3 (Listen), 10 (Fidget), 11 (Seat), 12 (Run), 13 (Quiet), 14 (Motor), and 15 (Talk); and the second thresholds for symptoms 14 (Motor) and 16 (Blurt). Thus, the threshold for only one IA symptom lacked invariance, and there were six HY thresholds that lacked invariance. Table 1 shows there was no difference in the CFI (0.000) and RMSEA (0.000) values between this partial scalar invariance model and the full latent mean equivalency model, thereby demonstrating equivalency of all the latent factors in this model. For this model, the correlations between the same factors in DBRS-A and DBRS-P were fixed to 1. This is feasible, since the error correlations between the same items in DBRS-A and -P were estimated in the model.

Supplementary Tables S5 shows the factor loadings and correlations of latent factors, and Supplementary Tables S6 shows the thresholds for the symptoms for the ICD 3-factor CFA configural model for mother ratings and adolescent self-ratings. Table 2 shows the differences between mother ratings and adolescent self-ratings for all of the parameters that lacked invariance. As can be observed, for all four non-invariant factor loadings, mothers had higher scores. For all thresholds but one, mothers also had higher scores, the exception being IA symptom 3 where adolescents had higher scores.

Table 2
Comparison of adolescent self-ratings and mother ratings for the parameters that were not invariant.

	Adolescent self-ratings	Mother self-ratings	Groups compared
Loadings			
IA by S5	0.549	0.823	M > S
IA by S7	0.578	0.794	M > S
IA by S9	0.579	0.796	M > S
IM by S16	0.545	0.827	M > S
Thresholds			
S3$1	0.376	−0.185	S > M
S10$1	0.025	0.440	M > S
S11$1	0.341	0.772	M > S
S12$1	−0.271	0.305	M > S
S13$1	0.305	0.717	M > S
S14$1	−0.505	0.151	M > S
S14$2	0.583	1.080	M > S
S15$1	−0.806	−0.193	M > S
S16$2	1.080	1.192	M > S

Note. IA = inattention; IM = impulsivity; S = symptom.
As an example, the thresholds are to be interpreted as follows: For S3$1, S3 is the Symptom number and $1 is the threshold number- in this instance the first threshold.

Table 1
Results of the test for measurement invariance for the ICD 3-factor CFA model across mother ratings and adolescent self-ratings.

#	Model (M)	χ^2 (*df*)	CFI	TLI	RMSEA (90 % CI)	M compared	ΔCFI	ΔRMSEA
1	Configural	845.893 (561)	0.968	0.964	0.041 (0.035–0.047)			
2	Metric - M1 with all loadings free	1157.696 (579)	0.936	0.930	0.058 (0.053–0.063)	M2 - M1	−0.032	0.017
2a	M2.1 with loading for items 5, 16, 9, 7 free	920.414 (575)	0.962	0.958	0.045 (0.039–0.050)	M2.1 - M1	−0.006	0.004
3	Scalar – M3 with all thresholds free	1179.754 (631)	0.939	0.939	0.054 (0.049–0.059)	M3 – M2.1	−0.023	0.009
3a	M3.1 with threshold S14$1, S15$1, S12$1, S3$1, S14$2, S10$1, S16$2, S11$1, S13$1 free	1042.350 (622)	0.953	0.953	0.047 (0.042–0.052)	M3.1 – M2.1	−0.009	0.002
4	Mean equal	1034.195 (619)	0.954	0.953	0.047 (0.042–0.052)	M4 - M3.1	0.000	0.000

Note. CI = confidence interval; RMSEA = root mean square error of approximation; CFI = comparative fit index; TLI = Tucker-Lewis Index. All WLSMVχ^2 values were significant ($p < .001$).
For M2.1, items 5, 7 and 9 are thresholds IA symptoms. For M3.1, S3$1 is a threshold for an IA factor symptom; S10$1, S11$1, S12$1, S13$; S14$2 and S15$1 are thresholds for HY symptoms, and S16$2 is a threshold for ab IM symptoms.

4. Discussion

The present study findings provide new data on measurement invariance across mother and adolescents self-ratings of the ADHD symptoms in the DBRS. The findings showed no support for full measurement invariance for the ADHD symptoms in the DBRS across mother ratings and adolescent self-ratings. Of the nine IA ICD-10 symptoms, only five symptoms exhibited both metric and scalar invariance. These were careless (IA1), inattention (IA2), instruction (IA4), unmotivated (IA6), and distracted (IA8). Three IA symptoms, [namely disorganize (IA5), lose (IA7), and forgetful (IA9)] also lacked metric invariance. None of the five HY ICD-10 symptoms showed full invariance. Although they all showed metric invariance, they all lacked scalar invariance. Two of the four IM symptoms [wait (IM17) and interrupt (IM18)] showed both metric and scalar invariance, and the other two IM symptoms [talk (HY/IM15) and blurt (HY/IM16)] lacked scalar invariance. Blurt (HY/IM16) also lacked metric invariance.

Overall, therefore only seven (IA symptoms for careless inattention, instruction, unmotivated, and distracted; and IM symptoms for wait and interrupt) ADHD symptoms demonstrated measurement equivalency in terms of both metric and scalar invariance across adolescent self-ratings and mother ratings, whereas the remaining 11 symptoms lacked either metric and/or scalar invariance. Although these findings might suggest that only the observed scores for these 7 invariant symptoms (but not the remaining 11 non-invariant symptoms) can justifiably be compared across adolescent and mother ratings, our interpretation is more complex, as presented next.

Our metric invariance findings indicated there were four symptoms that lacked metric invariance. They were symptoms 5 (disorganized), 7 (loses things) and 9 (forgetful), and IM symptom 16 (talks a lot). As metric invariance indicates that the relationship between the common factor and the item is the same across the groups being compared, the higher loadings would suggest that relative to adolescents, parents provide more accurate ratings for these symptoms. This highlights the greater value in using the DBRS-P than the DBRS-SR in diagnosis. For the other 14 symptoms, nine symptoms lacked scalar invariance. Lack of scalar invariance indicates that even with the same scaling measure, the groups in question are endorsing different levels of observed scores for the same level of latent trait score. Given that six of the nine symptoms that lacked scalar invariance involved their first thresholds, and the other three involved the second threshold, it can be speculated that while invariance will not hold for these symptoms at low levels of ADHD (most likely ratings of 0 and 1), it is likely to hold at high levels of ADHD (most likely 2 and 3). Thus, our findings raise the possibility that the DBRS has potential for scalar invariance for these six symptoms when adolescents have high levels of ADHD. As this is generally the case for children referred for ADHD, it means that when the goal is to diagnose ADHD, mother ratings *and* adolescent self-ratings can be justifiably and directly integrated for adolescents with high levels of most of the ADHD symptoms in the DBRS. The exceptions to this being symptoms 5 (disorganized), 7 (loses things) and 9 (forgetful), and IM symptom 16 (talks a lot) as these symptoms lack metric invariance and disqualifies them from being directly compared. Related to the invariance finding in the study, as the invariance violations of the first threshold (generally higher thresholds for parents) indicate that, for the same trait levels, adolescents are less prone to respond “never” than parents, it could be speculated, that removing the first category response from the DBRS could improve the invariance across mother and adolescent self-ratings.

In summary, the results of this current study that examined measurement invariance (configural, metric, and scalar) across mothers and adolescent self-ratings for the DBRS ADHD symptoms, supported configural invariance. Of the 18 ADHD symptoms, 4 symptoms (three of which were IA symptoms) lacked metric invariance. Nine thresholds (1 IA symptom, 6 HY symptoms, and 2 IM symptoms) lacked scalar invariance, with six of them being for the first thresholds. Strictly speaking, our findings are applicable to the ADHD symptoms included in in the DBRS, and not to ADHD symptoms in general. However there are reasons to suspect that such a possibility cannot be ruled out. This is because the content and format (including response categories) of the DBRS are highly comparable to most other ADHD rating scales, including for example the ADHD Rating Scale-IV (DuPaul et al., 1998). Also, there is close approximation in the information on the ADHD symptoms provided through ADHD rating scales and clinical interviews (Sprafkin et al., 2001; Wolraich et al., 2004). Taken together, based on such findings, it can be speculated that the findings in this present study may also be applicable to information derived through other ADHD rating scales and clinical interviews, and by extension to ADHD in general (Gomez, 2007).

Although the current study has delivered original and valuable information regarding invariance about psychometric properties of ADHD ratings for mother's ratings of adolescents and adolescent's self-ratings on the DBRS, the findings and interpretations need to be deliberated with several limitations in mind. First, ADHD ratings are influenced by age, gender, ethnicity and cultural differences (DuPaul et al., 1998; Gomez et al., 1999; Reid et al., 1998). Not controlling for these variables in the present study may have confounded findings. Second, all participants in this study were from the general community and not selected randomly, so our findings may be further confounded and limited in terms of generalization, including their application to clinically diagnosed adolescents (although there are data that ADHD ratings are invariant across clinic-referred and normative samples of children and adolescents) (see Dobrean et al., 2021). Third, all data used were collected using a questionnaire (the DBRS). Again, it is possible that the ratings were influenced by this method and as such our results may be subject to confounding by common method variance. Fourth, our findings have been obtained from a single study, and therefore replication is essential. Fifth, in this study the ADHD model applied for testing measurement invariance was the ICD-10 three-factor model that differs slightly from the DSM-IV/DSM-5 ADHD model. Thus, a relevant question is whether the findings are applicable to the DSM-IV/DSM-5 ADHD two-factor model. Sixth, while we establish sufficient power for the study, it may still be possible that the findings would have different if the sample had been larger. Seventh, although our findings showed that while for many symptoms, invariance did not hold for low levels of symptoms, it held for high levels. It is conceivable that this may have arisen due to more observations concerning low levels of ADHD (due to typically-developing children involved in the study) and lack of power for high levels of ADHD? Although we did not report it in this paper (due to word limitation), we did find similar for the DSM-IV/DSM-5 ADHD two-factor model as we have reported here for the ICD-10 three-factor model. Notwithstanding, this remains an empirical question. Given these limitations, future research is crucial.

In concluding, despite the limitations mentioned, the findings in this study are new and novel as this is the first study to examine the measurement invariance across mother ratings and adolescent self-ratings of ADHD symptoms. As such it can be expected to contribute significantly to theory and clinical practice in ADHD. In terms of important clinical and practical implications, the key finding in this present study is that although there is likely to be inadequate measurement invariance across mother's ratings and adolescent's self-ratings at lower levels of ADHD for their scores to be compared directly, the opposite is more likely to be the case at high levels of ADHD. We recommend that clinicians and researchers consider the findings and interpretations from this present study when integrating information on ADHD symptoms provided by mothers and adolescents.

CRediT authorship contribution statement

Rapson Gomez: Conceptualization, Methodology, Data curation, Writing- Original draft preparation, Investigation, Supervision.

Stephen Houghton: Writing, Reviewing and Revising Drafts, and Editing.

Data availability

Data will be made available by RG for reasonable request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.paid.2023.112317.

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