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Reciprocal relations between dimensions of attention-deficit/hyperactivity and anxiety disorders from preschool age to adolescence: sex differences in a birth cohort sample

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Background: Symptoms of anxiety and attention-deficit/hyperactivity disorder (ADHD) are prospectively related from childhood to adolescence. However, whether the two dimensions of ADHD—inattention and hyperactivity-impulsivity—are differentially related to anxiety and whether there are developmental and sex/gender differences in these relations are unknown. **Methods:** Two birth cohorts of Norwegian children were assessed biennially from ages 4 to 16 (N = 1,077; 49% girls) with diagnostic parent interviews used to assess symptoms of anxiety and ADHD. Data were analyzed using a random intercept cross-lagged panel model, adjusting for all unobserved time-invariant confounding effects. **Results:** In girls, increased inattention, but not hyperactivity-impulsivity, predicted increased anxiety 2 years later across all time-points and increased anxiety at ages 12 and 14 predicted increased inattention but not hyperactivity-impulsivity. In boys, increased hyperactivity-impulsivity at ages 6 and 8, but not increased inattention, predicted increased anxiety 2 years later, whereas increased anxiety did not predict increased inattention or hyperactivity-impulsivity. **Conclusions:** The two ADHD dimensions were differentially related to anxiety, and the relations were sex-specific. In girls, inattention may be involved in the development of anxiety throughout childhood and adolescence and anxiety may contribute to girls developing more inattention beginning in early adolescence. In boys, hyperactivity-impulsivity may be involved in the development of anxiety during the early school years. Effective treatment of inattention symptoms in girls may reduce anxiety risk at all time-points, while addressing anxiety may decrease inattention during adolescence. Similarly, treating hyperactivity-impulsivity may reduce anxiety risk in boys during late childhood (at ages 8–10). **Keywords:** Anxiety; attention deficit/hyperactivity disorder; inattention; hyperactivity-impulsivity; longitudinal; prospective; random intercept cross-lagged panel model; within-person.

Introduction

Anxiety disorders (Merikangas et al., 2010: with a prevalence rate of 32%) and attention-deficit-hyperactivity disorder (ADHD; Danielson et al., 2018: by a 9.4% rate) are prevalent among children and adolescents worldwide. ADHD and anxiety can lead to a range of negative long-term outcomes, including academic underachievement, and social difficulties (Erskine et al., 2016; Habibi Asgarabad, Steinsbekk, & Wichstrøm, 2023; Hua et al., 2021). The comorbidity of ADHD and anxiety is indeed significant—ranging from 25% (D'Agati, Curatolo, & Mazzone, 2019) to 35% (Gnanavel, Sharma, Kaushal, & Hussain, 2019). Previous studies have shown that ADHD and anxiety disorders predict one another over time (Speyer et al., 2021; Tai, Gau, Gau, & Chiu, 2013). Thus, understanding the nature of the relation between these disorders might inform effective prevention and treatment approaches. Yet the existing provides limited information in this regard.

ADHD is a complex and heterogeneous disorder encompassing two primary dimensions—inattention and hyperactivity-impulsivity—as defined by the *Diagnostic and Statistical Manual of Mental Disorders-Fifth Edition* (American Psychiatric Association, 2013). These dimensions often exhibit distinct associations with various psychopathologies (Gnanavel et al., 2019; Hinshaw, Nguyen, O'Grady, & Rosenthal, 2022). One questionnaire-based study found a cross-sectional association between anxiety and inattention—but not hyperactivity-impulsivity (Baldwin & Dadds, 2008). However, research on the relation between anxiety and the two ADHD dimensions remains limited. While one prospective study indicated that the hyperactivity-impulsivity dimension displayed the strongest links to later anxiety (Speyer et al., 2021), others have suggested that the cross-sectional relation between ADHD symptoms and anxiety may primarily stem from inattention (Michelini et al., 2015). Despite these findings, none of the studies (Baldwin & Dadds, 2008; Gair, Brown, Kang, Grabell, & Harvey, 2021) have explored whether inattention and hyperactivity-impulsivity

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are differentially related to anxiety at the within-person level—a critical inquiry for understanding the etiology of the association between ADHD and anxiety disorders. Given the scarcity of research in this area, our aim is to examine whether the two ADHD dimensions differentially predict symptoms of anxiety disorders and vice versa.

Anxiety disorders have been found to be more prevalent in girls than boys during early adolescence (Steinsbekk et al., 2022), whereas ADHD is more commonly diagnosed in boys in childhood (Mohammadi et al., 2021). Among girls with ADHD, the inattentive presentation is the most common, and girls frequently experience coexisting internalizing issues. On the contrary, boys are more prone to exhibit symptoms of hyperactivity-impulsivity and related externalizing issues (Hinshaw et al., 2022). Such findings indicate that sex/gender[1] differences are not only limited to prevalence rates, but also apply to the association between ADHD and anxiety. Indeed, previous studies conducted in Norway, using registry data among adults, have demonstrated a stronger association between ADHD and anxiety in women compared to men (Solberg et al., 2018). Critically, whether the association between ADHD dimensions and anxiety is sex/gender-specific in children and adolescents has implications for tailoring prevention and treatment approaches for both girls and boys—but it remains an unanswered question. Moreover, prior to adolescence, there is no sex/gender difference in anxiety (Steinsbekk et al., 2022), and the male preponderance in ADHD decreases with age (Lubke, Hudziak, Derks, van Bijsterveldt, & Boomsma, 2009). It is, therefore, possible that the heterotypic continuity between ADHD dimensions and anxiety, also depends on age. However, this possibility has not been addressed in the literature.

Comorbidity and heterotypic continuity between ADHD subtypes and anxiety may result from a variety of factors, including overlapping symptoms, shared etiology, and the influence of one disorder on the other over time (Jarrett & Ollendick, 2008). All of these explanations have some support: symptoms such as restlessness and concentration problems are present in both generalized anxiety disorder and ADHD (American Psychiatric Association, 2013), and there are shared genetic factors contributing to anxiety and ADHD (Gustavson et al., 2021). Furthermore, observational (Perou et al., 2013) and longitudinal (Karalunas, Antovich, Miller, & Nigg, 2023) results suggest that ADHD predicts later anxiety and vice versa. Regarding the latter, it is challenging to interpret the findings from these longitudinal studies because they often fail to distinguish between-person differences and within-person changes, leading to potential confounding effects from stable factors (Hamaker, Kuiper, & Grasman, 2015) such as the time-invariant effects of genetics.

There is low to moderate correspondence between findings from rating scales and diagnostic interviews where the interviewer decides whether a symptom is present (Achenbach, McConaughy, & Howell, 1987; De Los Reyes et al., 2015; Sveen, Berg-Nielsen, Lydersen, & Wichstrøm, 2016). This inconsistency might stem from a variety of discrepancies between the two methods, including that interviews tapping into the full range of diagnostic criteria typically include onset, duration, frequency, intensity, impairment, and distress criteria, whereas rating scales often are limited to assessing the frequency and intensity of symptoms (Dirks & Boyle, 2010).

Additionally, many parents and youth may lack sufficient knowledge of age-appropriate behavior (Becker-Haimes, Jensen-Doss, Birmaher, Kendall, & Ginsburg, 2018; Carlton, Larkin, Sloss, & Ollendick, 2023). For example, when parents are asked whether their 4-year-old is frequently restlessness or "driven by a motor," they may not have sufficient breadth of experience to tell what atypical behavior for preschoolers is, thus limiting the validity of rating scales (Dirks & Boyle, 2010), an issue which is of lesser concern when expert interviewers are used (Chien & Mou, 2023).

Moreover, the correspondence between informants (e.g. parents and children) on psychopathology is only modest to moderate (De Los Reyes, 2011; De Los Reyes et al., 2015; De Los Reyes & Kazdin, 2005), and this correspondence varies according to the type of psychopathology. Parents typically underestimate internal states in children, such as worry and anxiety (Lagattuta, Sayfan, & Bamford, 2012), whereas children and adolescents with ADHD often underestimate their ADHD symptoms as compared to parent ratings (Hartung, McCarthy, Milich, & Martin, 2005; Hoza, Pelham, Dobbs, Owens, & Pillow, 2002). We therefore used both parents and children (starting at age 8) as informants on anxiety but only relied on parent reports for ADHD.

Finally, the prospective relation between the two ADHD dimensions and anxiety may differ between girls and boys, especially in adolescence, given that adolescent girls more often experience anxiety than boys (Steinsbekk et al., 2022), and the sex/gender disparity in inattention is less pronounced than for hyperactivity-impulsivity (Biederman et al., 2002; Biederman & Faraone, 2004; Hinshaw, Owens, Sami, & Fargeon, 2006; Slobodin & Davidovitch, 2019). However, this possibility has not been thoroughly investigated. Two meta-analyses (Gaub & Carlson, 1997; Gershon & Gershon, 2002) highlight the higher occurrence of internalizing problems (e.g. depression and anxiety disorders) among girls with ADHD and the higher occurrence of externalizing problems among boys with ADHD. Furthermore, the distinct sex/gender patterns observed in ADHD presentations (Levy, Hay, Bennett, & McStephen, 2005)—specifically, a higher prevalence of ADHD inattentive presentation in females and ADHD

combined presentation in males—as well as the well-established comorbidity between ADHD and anxiety disorders (Jarrett & Ollendick, 2008), provides a robust empirical foundation for investigating inattention, hyperactivity-impulsivity, and anxiety as dimensional constructs (Lahey et al., 1988). Hence, girls with ADHD may exhibit a higher prevalence of anxiety compared to boys with ADHD, potentially because females generally face a higher risk of developing anxiety disorders (March, Parker, Sullivan, Stallings, & Conners, 1997; Spence, 1998). Such an approach holds the potential to offer valuable insights into the etiology and manifestation of these sex/gender-based disparities.

In summary, the association between ADHD and anxiety appears to be potentially stronger in girls (Baldwin & Dadds, 2008). However, whether the two subdimensions are differentially related to prospective anxiety (and vice versa), and whether these relations vary by sex/gender and developmental stages, remains largely unexplored. To address these knowledge gaps, we formulate and test hypotheses examining whether increased levels of inattention and/or hyperactivity-impulsivity predict heightened anxiety symptoms (i.e. separation, generalized, and social anxiety disorders and specific phobias). We conducted this analysis at the within-person level. We investigate: (a) whether anxiety is differentially predicted by the inattention and hyperactivity-impulsivity dimensions; (b) whether inattention and hyperactivity-impulsivity are differentially predicted by anxiety; and (c) whether these predictions differ by sex and age. To test these propositions, we use data from a birth cohort sample assessed biennially with clinical diagnostic interviews from ages 4 to 16.

Method

Procedure and participants

Accompanying the invitation to the routine community health screening for 4-year-old children, an invitation was included for the 2003–2004 birth cohorts and their parents in Norway (N = 3,456) to take part in the Trondheim Early Secure Study (TESS; Steinsbekk & Wichstrøm, 2018). Alongside the invitation, parents received the Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997), a tool used to screen children's emotional and behavioral problems. A majority of 2,477 (82.1%) of the 3,358 parents attending the well-child clinic, provided consent to participate. After excluding 176 parents due to language proficiency issues and inadvertently missing 166 by the health nurse, children exhibiting emotional and behavioral problems were intentionally oversampled to increase variability and statistical power. This oversampling was achieved by categorizing children into four strata in terms of their SDQ scores, with cutoff points of 0–4, 5–8, 9–11, and 12–40. The likelihood of being selected for the study was augmented with higher SDQ scores, with probabilities of .37, .48, .70, and .89, respectively, within each stratum. To ensure accurate population estimates, adjustments for oversampling were made in the analyses. Initially, 1,250 families were selected to participate, yielding data from 1,007 families at the first wave (T1; Mean age = 4.7, SD = 0.3; 50.9% girls). Subsequent assessments were conducted at ages 6 (T2; n = 795; Mean age = 6.72, SD = 0.17; 49.8% girls), 8 (T3; n = 699; Mean age = 8.8, SD = 0.24; 51.1% girls), 10 (T4; n = 702; Mean age = 10.51, SD = 0.17; 52.3% girls), 12 (T5; n = 668; Mean age = 12.49, SD = 0.15; 51.9% girls), 14 (T6; n = 628; Mean age = 14.33, SD = 0.59; 53.0% girls), and 16 (T7; n = 666; Mean age = 16.98, SD = 0.31; 55.0% girls). The analytic sample for the current study comprised participants for whom valid data was available from at least one subsequent measurement wave (N = 1,077). Most children (91.0%) were Norwegian, while 5.8% hailed from Europe, Canada, the USA, New Zealand, or Australia, and 3.2% were from Latin America, Africa, or Asia. For detailed sample characteristics at baseline (age 4), refer to Steinsbekk and Wichstrøm (2018). Approval for the study was obtained from the Regional Committee for Medical and Health Research Ethics of Mid-Norway. Health nurses informed parents of the TESS study and obtained written consent from parents, while adolescents provided their own consent at age 16.

Measures

Anxiety disorder symptoms. At ages 4 and 6, symptoms of anxiety disorders were evaluated employing the semi-structured parent interview of Preschool Age Psychiatric Assessment (PAPA; Egger et al., 2006), where symptoms are coded as 0 (*not present*) or 1 (*present*). Subsequently, at ages 8, 10, 12, and 14, both children and parents underwent separate interviews, and the age-appropriate Child and Adolescent Psychiatric Assessment (CAPA; Angold & Costello, 2000) was administered. In the CAPA, if either the child or the parent endorsed a symptom, it was considered present. Finally, at age 16, children and parents underwent separate interviews employing the Schedule for Affective Disorders and Schizophrenia for School-Age Children Present and Lifetime version (K-SADS-PL; Kaufman et al., 1997). Both the CAPA and the K-SADS encompass symptoms of anxiety and ADHD as defined by DSM-5, while the PAPA utilizes the DSM-IV definition. Trained interviewers, possessing a minimum of a bachelor's degree in pertinent fields along with having considerable experience with children and families, conducted the assessments. The instruments consist of mandatory questions alongside optional follow-ups, with interviewers persisting until a determination was reached regarding the presence of a symptom. The onset, duration, and intensity of symptoms occurring at any time during the last 3 months were recorded. Symptom counts of the number of social anxiety (range = 0–2), separation anxiety (range = 0–8), generalized anxiety (range = 0–6), and specific phobias (range = 0–7) were created. The observed mean, standard deviation, minimum, and maximum number of anxiety symptoms across ages 4–16 are reported in the supplementary online information (Table S1). Blinded coders reevaluated recordings of 88 PAPA (T1), 187 CAPA (T3 and T4), and 114K-SADS (T7) interviews, yielding *good to excellent reliability* with intraclass correlation coefficients (ICC; Koo & Li, 2016) for the number of anxiety symptoms at .83, .88, and .94, respectively.

Attention-deficit hyperactivity disorder symptoms. Symptoms of ADHD were measured using the above diagnostic instruments. Due to the unreliability of self-reports of ADHD among youth (Angold & Costello, 2000); only parents were interviewed. The inattention and hyperactivity-impulsivity symptoms exhibited *excellent reliability*, with ICC values of .91 and .93, respectively (further details: Table 1).

Sex. In accordance with the terminology presented by Hartung and Lefler (2019), sex is defined as biological sex and assessed as sex assigned at birth, which is coded based on

Table 1 Descriptive statistics and bivariate correlation coefficients among inattention, hyperactivity-impulsivity, and symptoms of anxiety for youths aged 4–16 (N = 1,077)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	*M*	*SD*	ICC
1. ANX_4 (n = 1,021)	1																				0.61	1.13	
2. ANX_6 (n = 793)	.12**	1																			0.87	1.51	
3. ANX_8 (n = 699)	.25***	.35***	1																		0.88	1.24	
4. ANX_{10} (n = 702)	.20***	.24***	.39***	1																	1.10	1.47	
5. ANX_{12} (n = 663)	.26***	.17***	.36***	.40***	1																2.23	1.68	
6. ANX_{14} (n = 688)	.16***	.15***	.25***	.32***	.49***	1															1.30	1.76	
7. ANX_{16} (n = 661)	.06	.13*	.19***	.23***	.30***	.35***	1														1.58	2.72	
8. IA_4 (n = 895)	.24***	.21***	.23***	.18***	.11**	.07	.01	1													0.39	0.92	T1 = .89 (n = 88)
9. IA_6 (n = 995)	.13**	.29***	.32***	.25***	.23***	.12**	.05	.37***	1												0.61	1.25	–
10. IA_8 (n = 973)	.11*	.26***	.44***	.34***	.32***	.23***	.07	.32***	.50***	1											0.83	1.58	T3 = .88 (n = 187)
11. IA_{10} (n = 689)	.13***	.21***	.31***	.38***	.32***	.20***	.06	.29***	.50***	.60***	1										0.87	1.64	T4 = .88 (n = 187)
12. IA_{12} (n = 700)	.12**	.16***	.33***	.27***	.40***	.22***	.10	.25***	.41***	.57***	.65***	1									0.68	1.54	–
13. IA_{14} (n = 656)	.11**	.17***	.27***	.27***	.42***	.29***	.08	.23***	.36***	.53***	.62***	.75***	1								0.70	1.62	–
14. IA_{16} (n = 618)	.02	.08	.17**	.26***	.26***	.26***	.23***	.10*	.32***	.33***	.37***	.41***	.48***	1							0.56	1.46	T7 = .95 (n = 114)
15. HI_4 (n = 995)	.22***	.18**	.31***	.16***	.12**	.06***	.02	.48***	.25***	.26***	.22***	.18***	.15**	.07	1						0.66	1.22	T1 = .95 (n = 88)
16. HI_6 (n = 793)	.06	.27**	.32***	.25***	.18***	.12**	.02	.32***	.54***	.45***	.37***	.27***	.30***	.21**	.36***	1					0.69	1.32	–
17. HI_8 (n = 689)	.11**	.22**	.43***	.32***	.23***	.13*	−.01	.30***	.42***	.62***	.39***	.30***	.33***	.17**	.34***	.49***	1				0.55	1.35	T3 = .91 (n = 187)
18. HI_{10} (n = 700)	.11*	.11**	.27***	.30***	.20***	.05***	−.03	.27***	.40***	.41***	.55***	.37***	.32***	.23**	.20***	.47***	.51***	1			0.41	1.18	T4 = .91 (n = 187)
19. HI_{12} (n = 656)	.17**	.17**	.35***	.34***	.33***	.15***	.06	.24***	.45***	.44***	.46***	.47***	.43***	.31***	.25***	.40***	.52***	.65***	1		0.26	0.89	–
20. HI_{14} (n = 618)	.15***	.13*	.28***	.32***	.25***	.20**	.07	.30***	.37***	.41***	.39***	.35***	.52***	.37***	.28***	.37***	.47***	.41***	.62***	1	0.22	0.78	–
21. HI_{16} (n = 660)	.01	.04	.15**	.17**	.24***	.15***	.08	.10	.27**	.26***	.19***	.23***	.26***	.56***	.10*	.30**	.24**	.22**	.33***	.32**	0.17	0.71	T7 = .92 (n = 114)

Note: The subscript numbers indicate the age at 7 waves. n = sample size in each wave. ANX, symptoms of anxiety; HI, hyperactivity-impulsivity; IA, inattention; ICC, intraclass correlation; M, mean; *SD*, standard deviation.
*p < .05, **p < .01, ***p < .001.

participant's Norwegian identification numbers. These contain a specific digit that directly corresponds to an individual's biological sex (even numbers = females; odd numbers = males).

Statistical analysis

To examine whether changes in inattention and/or hyperactivity-impulsivity symptoms predicted changes in anxiety and vice versa, a random intercept cross-lagged panel model (RI-CLPM; Hamaker et al., 2015) was fitted employing Mplus Version 8.8 (Muthén & Muthén, 1998–2020). In our analysis, three latent random intercepts were incorporated, loading on the number of inattentions, hyperactivity-impulsivity, and anxiety disorder symptoms across all time-points. These intercepts aimed to capture time-invariant between-person variations, with factor loadings fixed to 1 and permitted correlations among them. Additionally, for every observed variable, a corresponding latent variable was established with a factor loading of 1, while variance in the observed variable was constrained to 0, to transfer variance from the observed variable to its latent counterpart. Consequently, the latent variables delineate the deviation of each youth from their own average level of the respective variable. Except for the initial time-point (T1), all these latent variables predicted latent variables at the subsequent time-point, while allowing concurrent residuals of the latent variables to correlate. Figure 1 represents the conceptual model.

Following a Little's MCAR analysis, the data exhibited missingness completely at random (χ^2 = 1454.626, df = 2,161, p = 1.00). A robust maximum likelihood estimator with robust standard errors (MLR) was conducted, and missing data were managed according to a full information maximum likelihood method (FIML) procedure. To address the oversampling of participants with emotional and behavioral problems, we applied a population weight. This weight was computed as the ratio of children within each stratum to the total participants in that stratum. These weights were utilized to obtain accurate population estimates, employing a sandwich estimator.

For the selection of the most efficient parsimonious model, where the degrees of freedom are identical between two models, we have implemented a nesting and equivalence testing (NET) methodology (Asparouhov & Muthén, 2019). We assessed potential developmental and sex differences in the cross-lagged paths among inattention, hyperactivity-impulsivity, and anxiety symptoms, including an examination of sex-specific paths (Byrne Barbara, 1998; pp: 259–286). This evaluation involved employing the "MODEL CONSTRAINT" and the Wald test to scrutinize parameter disparities, comparing models in which these paths were freely estimated with models in which they were constrained to be equal. Standardized RI-CLPM benchmark values were interpreted as small (.03), medium (.07), and large (.12) effect sizes (Orth et al., 2022).

Results

Descriptive statistics and bivariate correlations are presented in Table 1. As can be seen, hyperactivity-impulsivity levels remained relatively stable throughout development, whereas the number of inattention and anxiety symptoms increased. The contribution of the various anxiety disorders to the overall anxiety disorder symptom count varied across disorders and age. Specific and social phobia contributed the least, but with increasing contribution

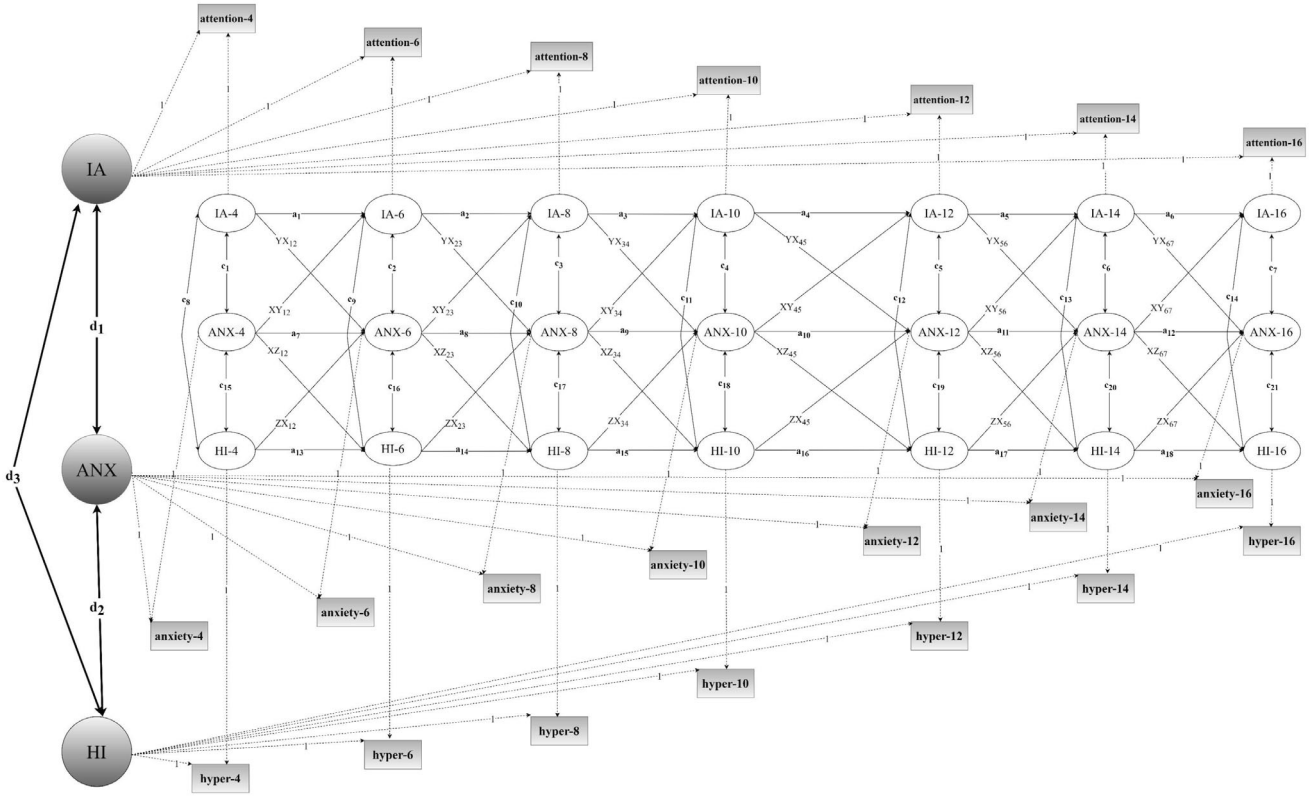

Figure 1 Conceptual model: random intercept cross-lagged panel model from symptoms of anxiety to inattention and hyperactivity-impulsivity and vice versa over ages 4–16 (seven waves). *Note*: All paths were evaluated across sex for the moderator role. To minimize complexity, the paths from hyperactivity-impulsivity to inattention and vice versa included in our conceptual model are not shown. HI, ANX, and IA = Abbreviations to represent latent variables for hyperactivity-impulsivity, anxiety, and inattention, respectively

from social anxiety disorder in adolescence, whereas the contribution from separation anxiety disorder decreased and generalized anxiety increased with age (Table 1 and Table S1), mirroring changes in prevalence of the respective disorders in the population (Steinsbekk et al., 2022). Supplementary online information (Table S2) displays the cross-sectional covariance estimates from anxiety symptoms to inattention and hyperactivity-impulsivity latent factors over ages 4–16, as derived from the RI-CLPM. Overall, higher rates of inattention and hyperactivity-impulsivity symptoms of ADHD were cross-sectionally associated with higher levels of anxiety symptoms across all time-points ($p < .05$).

By means of RI-CLPM, we examined the prospective relations between changes in anxiety, inattention, and hyperactivity-impulsivity. The initial RI-CLPM with freely estimated cross-lagged paths fitted the data well (see Figure 2 and Table S3) [M_1]: χ^2 (129) = 280.17, $p = .001$, RMSEA = 0.033, SRMR = 0.066, CFI = 0.95, TLI = 0.92). In Figures 2 and 3, freely estimated cross-lagged models for the total sample, along with sex-specific constrained best-fitting models are shown. The coefficients in Figures 2 and 3 are presented in unstandardized form in the figures but are reported in standardized form here.

At the between-person level, the random intercepts were positively correlated (see Figure 2), meaning that youth who exhibited higher levels of inattention and hyperactivity-impulsivity tended to experience more symptoms of anxiety across ages 4–16 years. At the within-person level, increased inattention at ages 4–6 ($\beta = .13$, $p = .046$), 6–8 ($\beta = .16$, $p = .016$), 8–10 ($\beta = .17$, $p = .002$), and 10–12 ($\beta = .23$, $p = .001$) predicted increased anxiety symptoms 2 years later, whereas at ages 12–14 ($\beta = .15$, $p = .009$) and 14–16 ($\beta = .14$, $p = .011$) the reverse association was observed—increased anxiety predicted increased inattention 2 years later, all with large effects (Orth et al., 2022). These results were not found for hyperactivity-impulsivity, except that increased levels of hyperactivity-impulsivity at ages 6–8 ($\beta = .16$, $p = .017$) and 8–10 ($\beta = .13$, $p = .042$) years predicted increased anxiety 2 years later, with large effects, but not at other measurement waves and the reverse order of effect was not evident.

Age differences across sexes

These results indicate that cross-lagged effects emerged at some ages but not at others. To test whether these effects differed across ages we examined whether: (a) increased levels of anxiety at ages 12 and 14 were predictive of increased levels of inattention at ages 14 and 16 to an identical extent and that earlier effects were of identical (nonsignificant) magnitude but differed from the ages 12 and 14 effects; (b) the effect of increased levels of inattention at ages 4, 6, 8, and 10 on increased levels of anxiety at ages 6, 8, 10, and 12, respectively, were identical and differed from the effect from ages 14–16; (c) increased levels of hyperactivity-impulsivity at ages 6 and 8 on anxiety at ages 8 and 10, respectively, were identical

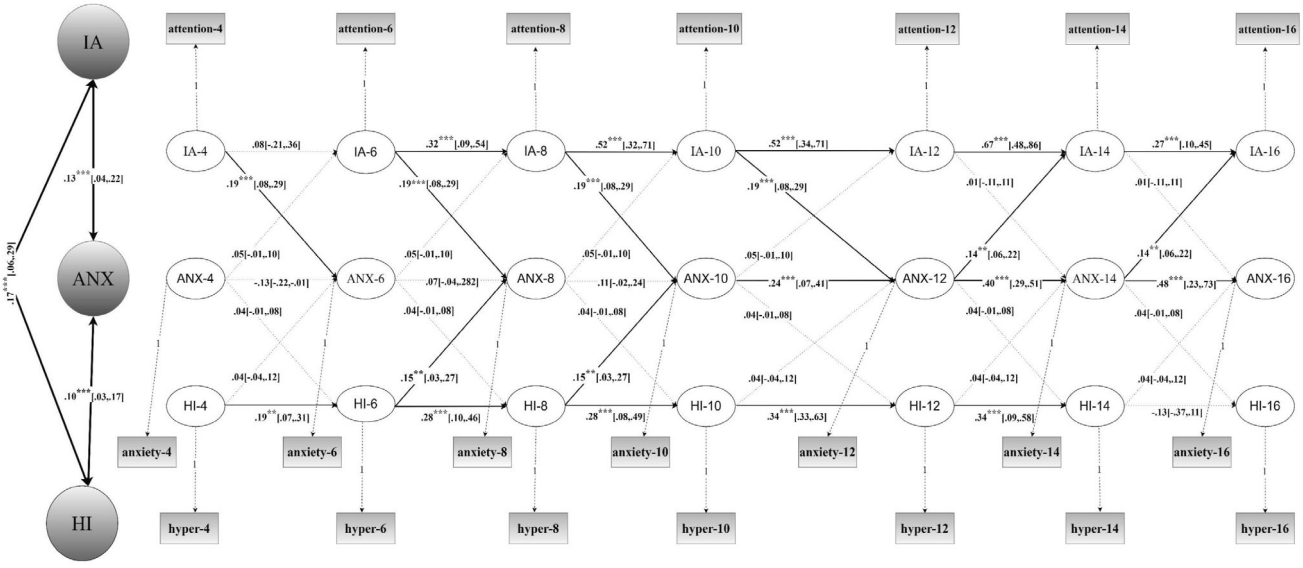

Figure 2 Results for the random intercept cross-lagged panel model (RI-CLPM) for the symptoms of anxiety, inattention, and hyperactivity-impulsivity at ages 4–16 (seven waves): represents the best-fitting constrained model for the total sample. *Note*: To minimize complexity, covariances among of symptoms of anxiety, inattention, and hyperactivity-impulsivity, and the paths from hyperactivity-impulsivity to inattention and vice versa included in our conceptual model are not presented here. HI, ANX, and IA = abbreviations to represent latent variables for hyperactivity-impulsivity, anxiety, and inattention, respectively. All autoregressive and cross-lagged path coefficients are unstandardized for the best-fitting constrained model; significant paths are shown in bold, but nonsignificant paths are depicted as dashed lines. Measurement errors are depicted as dashed lines and fixed at 1.00 in the model across waves. Dotted lines are all fixed at value 1.00. Confidence intervals from an unstandardized model are shown in square brackets. *$p < .05$, **$p < .01$, ***$p < .001$

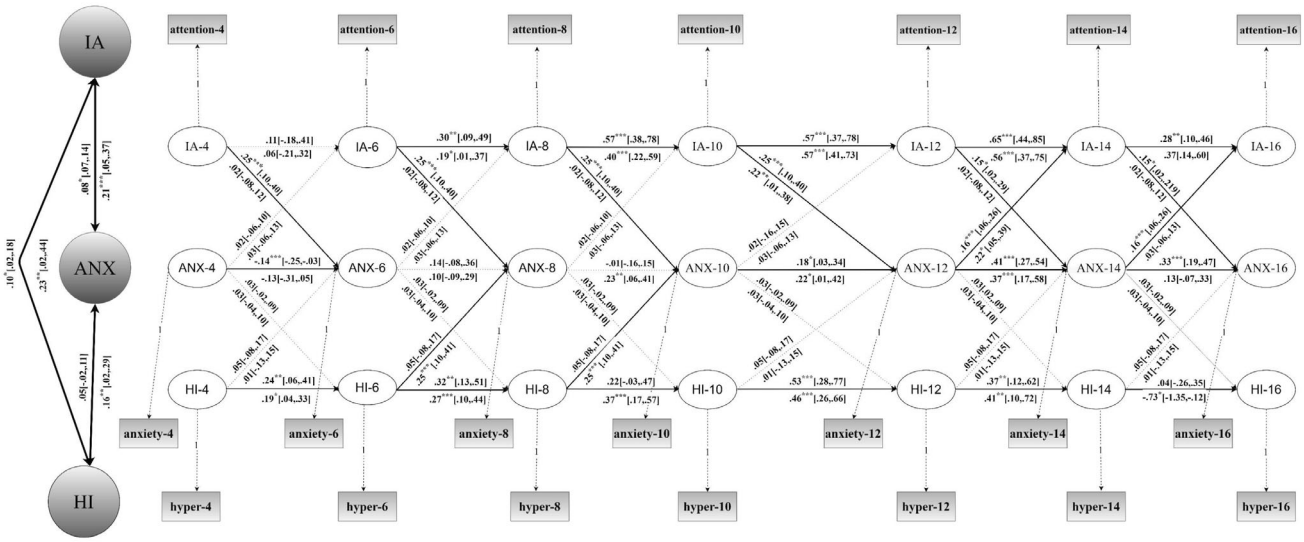

Figure 3 Results for the random intercept cross-lagged panel model (RI-CLPM) of symptoms of anxiety, inattention, and hyperactivity-impulsivity at ages 4–16 (seven waves): represents the best-fitting constrained model for the boys and girls with a multigroup analysis approach. *Note*: To minimize complexity, covariances among the anxiety, inattention, and hyperactivity-impulsivity, and the paths from hyperactivity-impulsivity to inattention and vice versa included in our conceptual model are not presented here. HI, ANX, and IA = abbreviations to represent latent variables for hyperactivity-impulsivity, anxiety, and inattention, respectively. All autoregressive and cross-lagged path coefficients are unstandardized; significant paths are shown in bold, but nonsignificant paths are depicted as dashed lines. Values above all the lines are for girls and below for boys. Measurement errors are depicted as dotted lines and fixed at 1.00 in the model across waves. Results from an unstandardized model are shown in square brackets with confidence intervals of 95%. *p < .05, **p < .01, ***p < .001

and differed from identical (but nonsignificant) effect from ages 4, 10, 12, and 14. We did so by comparing the fit of these models to the fit of the freely estimated model (above). As shown in Table S3, a model with the above constraints did not have a worse goodness-of-fit than the freely estimated model. This indicates that a model incorporating the mentioned constraints fit equally well as a freely estimated model (further details: Figure 2 and Table S3: $M_{1.1}$ [$\Delta\chi^2 = 20.43$, $df = 18$, $p = .309$] and $M_{1.2}$ [$\Delta\chi^2 = 16.84$, $df = 17$, $p = .464$]), suggests that these relations do not differ across age groups, specifically for ages 4–12 and 12–16.

Sex differences across ages

To test equality assumptions of cross-lagged coefficients across sex and assessment waves, a freely estimated model was compared to: (a) a model with cross-lagged constraints to be the same over measurement waves, but not across sexes and (b) a model with cross-lagged constraints set to be identical across measurement waves and sexes. Both models fit the data worse than the freely estimated model (Figure 3 and Table S3 for M_2 and M_3: $\Delta\chi^2 = 263.73$, $df = 169$, $p < .001$ and $\Delta\chi^2 = 271.32$, $df = 173$, $p < .001$, respectively), suggesting significant developmental and sex differences across ages 4–16.

To establish baseline models for each sex, a freely estimated model (Table S3: M_1) was run separately for boys (M_4) and girls (M_5; see Table S3). This served as an initial step in evaluating multigroup models across sexes and measurement points and was then fitted individually for boys and girls (Table S3 for the best-fitting constrained models for boys: $M_{4.1}$ and girls: $M_{5.1}$). To examine whether the findings from the total sample were equally applicable to both boys and girls over time, a multigroup model combining the models $M_{4.1}$ and $M_{5.1}$ was conducted to test for sex differences (see Table S3 for detailed information on the model specifications for the best-fitting constrained models for boys and girls). Finally, the best-fitting model for boys and girls was determined (Table S3: $M_{6.1}$). The multigroup analysis of RI-CLPM revealed (Table S3 for $M_{6.1}$ and Figure 3): (a) among girls, increased inattention at all ages was predictive of increased number of anxiety disorder symptoms 2 years later at ages 6 ($\beta = .15$, $p < .001$), 8 ($\beta = .26$, $p < .001$), 10 ($\beta = .25$, $p < .001$), 12 ($\beta = .22$, $p < .001$), 14 ($\beta = .11$, $p = .040$), and 16 ($\beta = .07$, $p = .041$). However, this was only true for boys at ages 10–12 ($\beta = .24$, $p = .015$); (b) the effect of change in anxiety on change in inattention was stronger among girls (at age 12: $\beta = .17$, $p < .001$, and age 14: $\beta = .19$, $p < .001$, [Wald = .54, $df = 1$, $p = .462$]) than for boys (at age 12: $\beta = .20$, $p = .022$, and age 14: $\beta = .04$, $p = .352$, [Wald = 5.62, $df = 1$, $p = .017$]); (c) As depicted in Figure 3 and Table S3, change in anxiety at ages 4–14 did not forecast hyperactivity-impulsivity at ages 6–16, for neither boys nor girls—hence, all paths across sexes and waves were set to be identical; (d) in boys, increased anxiety at ages 6 and 8 was predictive of hyperactivity-impulsivity at ages 8 ($\beta = .29$, $p < .001$) and 10 ($\beta = .27$, $p < .001$), but not prior to or later than these ages, and not for girls at any ages (see Figure 3).

Discussion

A few former studies have investigated the prospective association between ADHD and anxiety during childhood and adolescence, albeit within a constrained age range and without separating between- from within-person effects. We extend current knowledge by testing whether increased inattention and/or hyperactivity-impulsivity predict increased symptoms of anxiety, and vice-versa—at the within-person level. Furthermore, we also examined whether: (a) inattention and/or hyperactivity-impulsivity had distinct associations with anxiety, (b) anxiety had varying effects on predicting ADHD dimensions, and (c) any predictions from inattention and/or hyperactivity-impulsivity to anxiety and vice-versa differed across time-points and sexes. Our findings revealed that increased inattention predicted increased anxiety across all ages, but only consistently so in girls. For boys, the prediction was significant at ages 10–12 only. Moreover, increased anxiety consistently predicted increased inattention in girls during adolescence and only at ages 12–14 in boys. Furthermore, increased hyperactivity-impulsivity during two childhood time-points was associated with increased anxiety 2 years later in boys, but not girls. Notably, anxiety did not predict hyperactivity-impulsivity in either girls or boys at any age.

Inattention predicting increased anxiety in girls

Our findings indicate that heightened inattention predicted increased anxiety in girls across all time-points, while in boys, this effect was observed at only one time-point. These results bear resemblance to the findings of Baldwin and Dadds (2008), who, through questionnaires administered to children, parents, and teachers, observed a stronger cross-sectional (but not prospective) association between ADHD and inattention in girls. However, our study extends these findings by demonstrating a prospective link at the within-person level when parent and child interviews were employed.

To shed light on this finding, we turn to Barkley's executive inhibition model (1997) which states that cognitive deficits associated with inattention, such as poor cognitive inhibition and executive functioning, are primarily linked to emotion dysregulation and effortful control (Gray, 1991; Steinberg & Drabick, 2015). Additionally, impaired executive functioning, including difficulty disengaging from persistent rumination and worry, can heighten anxiety levels. Such difficulties in regulating cognitive processes may intensify anxiety experiences (Shaw, Stringaris, Nigg, & Leibenluft, 2014). Notably, these regulatory impairments are specific to inattention rather than hyperactivity-impulsivity, as highlighted by Willcutt (2015).

With this theoretical foundation in mind, we now explore why the implications of Barkley's executive inhibition model might be more pronounced in girls. Societal pressures and expectations may contribute to this phenomenon, as they can lead to increased cognitive demands on girls (Hwang, Hong, Cheng, Peng, & Wu, 2013). Such pressures could heighten vulnerability to feelings of concern, stress, competition anxiety, and academic pressure in girls, particularly when they grapple with inattention and its associated executive dysfunction (Campbell, Bann, & Patalay, 2021; Lai, Lin, & Ameis, 2022). These additional cognitive stressors may result in heightened inattention symptoms among girls (Huang, Cheng, Cheng, & Chen, 2020), subsequently triggering worry, rumination about academic performance—all of which might intensify anxiety symptoms (Spira & Fischel, 2005; Vytal, Cornwell, Arkin, & Grillon, 2012). Accordingly, Barkley's executive inhibition model offers valuable insights into the link between inattention and anxiety symptoms, while societal pressures and cognitive demands provide context for why this link may be more prominent in girls.

Anxiety predicting increased inattention in adolescence

Increased anxiety at two adolescent time-points in girls predicted increased levels of inattention. Importantly, this predictive relation only occurred in adolescence (not childhood) and in girls (not boys). To understand these findings, we need to explore the complex interplay of developmental and sex-specific factors that may underpin this phenomenon. Adolescence is characterized by profound hormonal shifts that can influence emotional regulation and arousal levels (Deckert, Schmoeger, Auff, & Willinger, 2020), thereby affecting adolescents' capacity to maintain sustained attention (Beck, Emery, & Greenberg, 2005). Furthermore, adolescents face a myriad of challenges, encompassing self-identity formation, peer relationships, and academic demands. These developments require greater cognitive and emotional demands (Young et al., 2020), making adolescents more susceptible to anxiety interfering with attentional processes, particularly during this pivotal phase.

Our study also uncovered a sex-specific dimension: the pronounced association between anxiety and inattention in girls during adolescence. Girls in early adolescence frequently contend with an elevated risk of experiencing low self-esteem, anxiety, rumination, and worry (Solberg et al., 2018). This vulnerability can be attributed to societal expectations and internal pressures to excel academically and socially, which are often influenced by sex/gender norms (Bölte et al., 2023). Additionally, a higher level of need for validation and positive feedback in adolescent girls (Coulthard & Ogden, 2018), along with occasionally lower self-esteem (Casale, 2020), might magnify their

concerns, potentially disrupting their ability to maintain focus, pay attention to details, and sustain their attention.

The age-related pattern observed in our study aligns with prior research indicating that anxiety has a more pronounced impact on inattention during adolescence than childhood (Jarrett, 2016). Possibly, the increased autonomic arousal and the worry seen in many anxieties exacerbate the working memory deficits associated with ADHD. Additionally, our findings regarding the stronger association from inattention to anxiety symptoms, compared to the limited prediction from anxiety to later inattention, corroborate existing research (Gair et al., 2021). Previous studies have demonstrated that an initial diagnosis of ADHD often precedes the development of anxiety symptoms (Bussing, Mason, Bell, Porter, & Garvan, 2010; Taurines et al., 2010). Individuals with an initial diagnosis of ADHD are more likely to experience subsequent anxiety symptoms, whereas, individuals with primary anxiety tend to exhibit fewer ADHD symptoms compared to those with primary ADHD symptoms (Avni, Ben-Itzchak, & Zachor, 2018), suggesting that anxiety may not substantially contribute to the development of ADHD symptoms. We extend these findings by showing that the association between ADHD and later anxiety may primarily be linked to inattention. Overall, our findings highlight the importance of early intervention strategies for individuals with ADHD to mitigate the risk of later anxiety symptoms.

Hyperactivity-impulsivity not predicting anxiety

While hyperactivity-impulsivity generally did not predict anxiety in our study, there were exceptions. Increased hyperactivity-impulsivity at one time-point in childhood in boys, but not girls, predicted anxiety 2 years later, which may be attributed to the transition from daycare to elementary school, introducing escalating social and academic expectations. For children with elevated hyperactivity-impulsivity these demands can lead to heightened stress and anxiety symptoms (Cueli, Rodríguez, Cañamero, Núñez, & González-Castro, 2020; Tan et al., 2022; Tannoia & Lease, 2021). Additionally, (Barkley, 1997, 2015) posited that hyperactivity-impulsivity in elementary school may cause emotional impulsivity (particularly concerning anger, frustration, and impatience), that challenges children's ability to meet academic standards, adhere to social norms, and cope with environmental demands, potentially culminating in increased anxiety symptoms (Gardner & Gerdes, 2015; Walerius, Reyes, Rosen, & Factor, 2018).

It is widely accepted that hyperactivity-impulsivity is more strongly associated with externalizing behaviors in boys than in girls (Bölte et al., 2023; Hinshaw et al., 2022). This trend may be attributed to girls exhibiting fewer overt ADHD symptom (Hinshaw et al., 2022; Young et al., 2020) and displaying superior emotional regulation abilities (Sanchis-Sanchis, Grau, Moliner, & Morales-Murillo, 2020), which collectively decrease the likelihood of anxiety disorders emerging in girls when ADHD is present.

The absence of a significant prediction from hyperactivity-impulsivity to anxiety in older age groups might be explained by children developing improved cognitive and social skills as progress into later childhood which may enable better self-control of hyperactivity-impulsivity symptoms (Bloemsma et al., 2013) which might, in turn, decrease the risk for negative outcomes such as anxiety. Furthermore, as children acclimatize to the structured school environment over time, they may develop coping strategies and adaptive behaviors that reduce the likelihood of symptoms related to hyperactivity-impulsivity triggering anxiety. While we understand the importance of elucidating the precise mechanisms through which hyperactivity-impulsivity may lead to anxiety, further research is necessary to provide a comprehensive understanding of these intricate links between sex, hyperactivity-impulsivity, and the manifestation of anxiety symptoms. Investigating the specific mechanisms will be a valuable avenue for future studies in this area.

Anxiety not predicting hyperactivity-impulsivity

Anxiety did not predict hyperactivity-impulsivity at any age in either girls or boys. Notably, our findings align with previous research (Baldwin & Dadds, 2008), indicating an association between anxiety and inattention for adolescent girls and no association between anxiety and hyperactivity-impulsivity for either sex at any age. While past studies have suggested that the inattentive presentation of ADHD is more prone to co-occur with anxiety disorders than other ADHD presentations (e.g. Lahey et al., 1988), we delved into their prospective association in depth in our study. This finding might be seen in light of research indicating that biological factors, such as genetics, contribute more to hyperactivity-impulsivity symptoms (Freitag et al., 2012; Overgaard, Aase, Torgersen, & Zeiner, 2016) than psychosocial factors. The latter have been shown to play a more influential role in the development of inattention, however (Freitag et al., 2012; Ouyang, Fang, Mercy, Perou, & Grosse, 2008), which accords with the present findings showing inattentiveness to predict anxiety.

Strengths and limitations

The study has several strengths, including the use of a birth cohort sample, conducting diagnostic interviews with children and parents, and employing

strong statistical methods allowing for the examination of within-person predictions over time. However, we acknowledge some limitations in our study. First, anxiety assessment at ages 4 and 6 relied on parent reports only, and although we included child reports from age 8 and adjusted for concurrent anxiety, there may still be common rater effects in our prospective findings involving parent-reported ADHD symptoms. However, to the extent that such rater effects are present, we accounted for these effects through the inclusion of time-invariant random intercepts in our analyses. Second, our study conceptualized anxiety as a continuous construct, limiting generalization to specific diagnostically defined anxiety disorders. Therefore, despite the lack of evidence for the idea that anxiety disorders are naturally categorical (Haslam, Holland, & Kuppens, 2012), our results cannot be generalized to diagnostically defined anxiety disorders. Third, the findings from this community sample might not generalize to clinical samples. Fourth, as per DSM-5, the different anxiety disorders are characterized by differing number of symptoms. When adding these symptoms across disorders, one might run the risk of overemphasizing some disorders at the expense of others. For example, social anxiety is represented by only two symptoms, whereas there are six generalized anxiety symptoms. However, the age-specific distribution of symptom counts for individual disorders mirrors to the age-specific prevalence of categorically defined anxiety disorders in the population (Steinsbekk et al., 2022), albeit with a potential underrepresentation of specific phobias in our composite score. Finally, although we adjusted for all time-invariant confounding effects, unmeasured time-varying effects could have influenced our results—including changes in family dynamics, fluctuations in socioeconomic status, or variations in educational experiences over time.

Conclusions

The conclusions drawn from our study underscore the sex-specific nature of the associations between ADHD dimensions and anxiety symptoms throughout childhood and adolescence. Specifically, increased inattention predicts heightened anxiety symptoms, primarily in girls, whereas heightened anxiety predicts increased inattention in adolescent girls. Conversely, heightened hyperactivity-impulsivity forecasts more anxiety, particularly in boys during early school years. These findings suggest that efforts to minimize attention problems may mitigate the risk of anxiety in girls throughout childhood and adolescence, whereas targeting hyperactivity-impulsivity in boys during early school years may reduce their susceptibility to anxiety. However, these assumptions warrant validation through intervention studies.

Supporting information

Additional supporting information may be found online in the Supporting Information section at the end of the article:

Table S1. The observed mean number of anxiety symptoms across ages 4–16 (seven waves).

Table S2. Covariance estimates from anxiety symptoms to inattention and hyperactivity-impulsivity latent factors.

Table S3. Estimates of the random intercept cross-lagged panel model (RI-CLPM) examining the relations between symptoms of anxiety, inattention, and hyperactivity-impulsivity from age 4 to 16.

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Author contributions

Mojtaba Habibi Asgarabad: Conceptualization, methodology, software, investigation, interpreted the data, and drafted the results section, data curation, writing-original draft preparation, review, and editing, visualization, reviewed and approved the final draft. **Silje Steinsbekk:** Conceptualization, investigation, resources, project administration, funding acquisition, review, and editing, reviewed and approved the final draft. **Cynthia M. Hartung:** Conceptualization, interpreting the results, review, and editing, reviewed, and approved the final draft. **Lars Wichstrom:** Conceptualization, methodology, interpreting the results, investigation, resources, data curation, supervision, project administration, funding acquisition, review, and editing, reviewed and approved the final draft.

Ethics approval statement

The study was approved by the Regional Committee for Medical and Health Research Ethics, Mid-Norway (approval number 2009/994).

Participants' consent statement

In accordance with procedures approved by the Regional Committee for Medical and Health Research Ethics, Mid-Norway, the health nurse informed the parents of the TESS study.

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Key points

- Anxiety co-occurs with the two ADHD dimensions—inattention and hyperactivity-impulsivity, but the prospective relations between anxiety and these ADHD-dimensions are unknown, as is whether these prospective relations are different for boys and girls and across different ages.
- Increased inattention predicted heightened anxiety from early childhood to adolescence, especially in girls. Heightened anxiety consistently predicted subsequent increases in inattention among girls across all ages, whereas for boys, this effect was observed only from age 10 to 12.
- Hyperactivity-impulsivity and anxiety were not consistently prospectively related, except that, increased hyperactivity-impulsivity at ages 6 and 8 predicted increased anxiety at ages 8 and 10—only in boys.
- These sex-specific associations highlight the complex interplay between ADHD dimensions and anxiety disorders across development, warranting further investigation into sex/gender differences and developmental trajectories.

Endnote

1. We use the term sex/gender in the background section because sex and gender are often conflated in the literature and it is difficult to determine whether biological sex, sex assigned at birth, or gender identity was measured. In the method, results, and discussion, we use the term "sex" to refer specifically to biological sex since that is what was measured in our study.

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