



THE UNIVERSITY *of* EDINBURGH

Edinburgh Research Explorer

Reciprocal developmental relations between ADHD and anxiety in adolescence

Citation for published version:

Murray, AL, Caye, A, McKenzie, K, Auyeung, B, Murray, G, Ribeaud, D, Freeston, M & Eisner, M 2020, 'Reciprocal developmental relations between ADHD and anxiety in adolescence: A within-person longitudinal analysis of commonly co-occurring symptoms', *Journal of Attention Disorders*.
<https://doi.org/10.1177/1087054720908333>

Digital Object Identifier (DOI):

[10.1177/1087054720908333](https://doi.org/10.1177/1087054720908333)

Link:

[Link to publication record in Edinburgh Research Explorer](#)

Document Version:

Peer reviewed version

Published In:

Journal of Attention Disorders

Publisher Rights Statement:

The final version of this paper has been published in Journal of Attention Disorders, March 2020 by SAGE Publications Ltd, All rights reserved. © Murray et al, 2020. It is available at:
<https://doi.org/10.1177%2F1087054720908333>

General rights

Copyright for the publications made accessible via the Edinburgh Research Explorer is retained by the author(s) and / or other copyright owners and it is a condition of accessing these publications that users recognise and abide by the legal requirements associated with these rights.

Take down policy

The University of Edinburgh has made every reasonable effort to ensure that Edinburgh Research Explorer content complies with UK legislation. If you believe that the public display of this file breaches copyright please contact openaccess@ed.ac.uk providing details, and we will remove access to the work immediately and investigate your claim.



Reciprocal developmental relations between ADHD and anxiety in adolescence: A within-person longitudinal analysis of commonly co-occurring symptoms in a normative sample

Aja Louise Murray^{1,2*}, Arthur Caye³, Karen McKenzie⁴, Bonnie Auyeung², George Murray⁴, Denis Ribeaud⁵, Mark Freeston⁶, Manuel Eisner^{1,5}

¹Institute of Criminology, University of Cambridge

²Department of Psychology, University of Edinburgh

³Psychiatry Department, Universidade Federal do Rio Grande do Sul

⁴Department of Psychology, Northumbria University

⁵Jacobs Center for Productive Youth Development, University of Zurich

⁶School of Psychology, Newcastle University

Corresponding author at: Institute of Criminology, University of Cambridge, CB3 9DA;

email: am2367@cam.ac.uk

Funding from the Jacobs Foundation (Grant 2010-888) and the Swiss National Science Foundation (Grants 100013_116829 & 100014_132124) is gratefully acknowledged.

Abstract

Significant anxiety often occurs in the presence of ADHD symptoms; however, the reasons are not well-understood. We examined the developmental relations between ADHD and anxiety symptoms across adolescence (ages 13, 15 and 17) in a community-ascertained, normative longitudinal sample of 1483 youth (52% male). We used an autoregressive latent trajectory model with structured residuals (ALT-SR) to examine within-person developmental relations between ADHD and anxiety symptoms and determine whether it is ADHD symptoms that lead to anxiety symptoms and/or the reverse. Results suggested that there are reciprocal within-person developmental relations between ADHD and anxiety symptoms. These findings support the recommendation that targeting ADHD symptoms can be fruitful for addressing anxiety symptoms; however, they suggest that targeting anxiety symptoms may also benefit ADHD symptoms. Results also underline the importance of careful assessment for underlying ADHD symptoms among adolescents presenting with anxiety.

Attention-deficit/hyperactivity disorder (ADHD) is characterised by impairing levels of inattention and/or hyperactivity/impulsivity (American Psychiatric Association, 2013). Globally, clinically diagnosable levels of ADHD symptoms are thought to affect around 6.5% of children and 2.7% of adolescents (Polanczyk et al., 2015). Significant anxiety is a frequent occurrence in the presence of elevated ADHD symptoms. Approximately 25% of young people and 50% of adults with ADHD meet diagnostic criteria for an anxiety disorder, with the prevalence of anxiety disorders in ADHD exceeding those in the general population and showing a steeper increase over the course of development (Biederman, 2005; Kessler et al., 2006, 2006; Krone & Newcorn, 2015). Anxiety also appears to be a particularly common comorbidity in females with ADHD (Levy et al., 2005; Williamson & Johnston, 2015). When evaluated in terms of symptom levels rather than diagnoses, ADHD-anxiety associations have been reported in the range of $r=.12$ to $.54$ depending on the combination of informants and measures, again with stronger associations for females than for males (Baldwin & Dadds, 2008; Becker et al., 2012; Jarrett, 2016).

Despite widespread recognition that anxiety is a common issue associated with ADHD symptoms, empirical studies of symptoms co-occurring with ADHD symptoms have tended to focus primarily on disruptive behaviour disorders and substance use, with considerably less research focussed on explaining its links with anxiety (Jarrett & Ollendick, 2008). In particular, owing to a paucity of longitudinal evidence on anxiety-ADHD interplay, there is little knowledge of the developmental links between anxiety and ADHD symptoms. It is not known with any certainty, for example, whether anxiety develops secondary to ADHD symptoms, and/or whether anxiety has a role to play in the development or exacerbation of ADHD symptoms. Summing up the situation in a review of the literature in 2008, Jarrett and Ollendick, (2008; p.1275) noted that ‘research on longitudinal relationships has not progressed to the point where the relationship between ADHD and anxiety over time is clearly understood.’ This statement applies equally today.

An improved understanding of the developmental relations between anxiety and ADHD would have potentially significant clinical benefits. For example, when an individual presents with co-occurring anxiety and ADHD, knowledge of which symptoms are most likely to be causally

antecedent helps inform which interventions are likely to have the best and most sustained effects. Indeed, a major question in clinical practice is whether patients with both ADHD and anxiety should initially be treated for ADHD, for anxiety or for both simultaneously. At present, it is generally recommended that pharmacological treatments for anxiety should be introduced after ADHD pharmacological treatments and only if the ADHD treatment fails to adequately resolve anxiety symptoms (Posner et al., 2014). However, high quality evidence on the directionality of influence between ADHD and anxiety symptoms would provide valuable information that can be used to further support or revise such recommendations. Similarly, knowledge of developmental progressions from ADHD symptoms to anxiety symptoms or vice versa can assist with care planning, including potentially implementing preventive interventions for potential secondary symptoms. Finally, characterising the developmental relations between anxiety and ADHD symptoms can indicate the optimal points to intervene, as ADHD and anxiety symptom relations may vary at different stages of development. Some authors have noted that adolescence may be a particularly critical period with respect to ADHD-anxiety relations as during this period, life demands can increase and concerns about peer relations, academic failures and other outcomes that may be associated with ADHD and which may in turn cause anxiety to become more intense (Baldwin & Dadds, 2008; Krone & Newcorn, 2015). Unfortunately, adolescent samples are under-represented in studies of ADHD-anxiety relations.

However, recent research has highlighted that even longitudinal data cannot necessarily adequately inform on the causes of symptom relations when analysed with conventional statistical methods such as the commonly used cross-lagged panel model (CLPM). In particular, several authors have highlighted the importance of ensuring that the longitudinal models used to evaluate hypotheses regarding variable inter-relations over time successfully disaggregate within- and between-person effects (Berry & Willoughby, 2017; Curran et al., 2014). In the context of ADHD-anxiety relations, within-person effects refer to how individual deviations from their own baseline in one symptom domain (e.g., ADHD) affect deviations from their own baseline in the other (e.g. anxiety). In contrast, between-person effects refer to the fact that person A may have higher levels of both anxiety and

ADHD symptoms than person B due, for example, to factors such as gender or genetic risk that vary between individuals but remain largely constant within individuals over time. Arguably, it is the within-person relations that are most of interest in relation to illuminating the relations between ADHD and anxiety because they suggest how individual-level interventions on ADHD versus anxiety symptoms would be expected to affect symptoms in the other domain. It is thus important to isolate these effects from potential between-person confounds. Recent discussions surrounding this issue have highlighted that traditionally-utilised statistical techniques for examining the developmental relations between variables – in particular, CLPMs yield results that provide an amalgam of between- and within-person effects that are difficult to interpret and can be relatively uninformative about developmental relations between phenotypes (Berry & Willoughby, 2017).

As a solution, (Curran et al., 2014) presented the autoregressive latent trajectory model with structured residuals (ALT-SR). ALT-SR models are an extension of cross-lagged panel and latent growth curve models that can disaggregate within- and between-person developmental processes. Its specification allows between-person time-stable confounds (i.e., factors such as genetic effects common to ADHD and anxiety, gender, or socioeconomic status, that vary between individuals but are likely to be relatively stable within individuals over time) to be partialled out, permitting the isolation of within-individual developmental relations. ALT-SRs are thus a potentially powerful tool for illuminating developmental processes (such as how anxiety and ADHD symptoms influence one another) within individuals.

The issue of conflating within- and between-person effects has been demonstrated in several analyses comparing ALT-SR and CLPM results. For example, using simulated data, (Berry & Willoughby, 2017) illustrated that it was possible to find a significant cross-lagged effect in the presence of between-person confounds but no true within-person effect. Using a real data example from the *Family Life Project*, they similarly found no within-person effect of corporal punishment on aggression an ALT-SR, despite a significant cross-lagged effect in a CLPM, suggesting again that the CLPM results were affected by between-person confounding. In a previous study in the current sample, ALT-SR analyses revealed within-person effects that appeared to have been masked in the

corresponding CLPM (Murray et al., 2019). Specifically, a negative cross-lagged effect of externalising problems on internalising problems in adolescence was found only when between- and within-person effects were disaggregated in an ALT-SR.

A further methodological issue that must be considered in estimating the magnitude of developmental relations between ADHD and anxiety symptoms is the type of sample. While many previous studies have used clinical samples to evaluate ADHD-anxiety relations, it is important that these studies be complemented with studies in community-ascertained samples. Comorbid cases are over-represented in clinical samples because young people with more than one issue are considerably more likely to present for treatment than those with only one issue (Costello et al., 1996). This can lead to an overestimate of the extent of ADHD-anxiety symptom co-occurrence in clinical samples, a situation known as ‘Berkson’s bias’. More generally, evidence suggests that both ADHD and anxiety symptoms are on continua, both phenotypically and etiologically (Groen-Blokhuis et al., 2014; Lebeau et al., 2012; Lubke et al., 2009; Shaw et al., 2011), implying that community-ascertained samples which capture the full variation in symptom levels using continuous symptom measures rather than dichotomous diagnostic status may provide a more accurate picture of ADHD-anxiety covariation as it occurs in the population.

Given the clinical relevance of understanding ADHD-anxiety developmental relations and the paucity of evidence on the issue, we here evaluate the developmental relations between ADHD and anxiety in a normative, community-ascertained sample of $n=1483$ adolescents measured at ages 13, 15 and 17. Using an autoregressive latent trajectory model with structured residuals (ALT-SR), we evaluate whether within individuals ADHD symptoms lead to anxiety and vice versa.

Method

Participants

Participants were from the Zurich Study on Social Development from Childhood to Adulthood (z-proso). Z-proso is a normative, community-ascertained longitudinal study based in Zurich, Switzerland with a substantive focus on the development of core dimensions of psychosocial

functioning, including ADHD symptoms (Murray, Eisner, Obsuth, et al., 2017b, 2017a; Murray, Booth, Auyeung, et al., 2018; Murray, Booth, Eisner, et al., 2018; Murray, Booth, Ribeaud, et al., 2018; Murray, Ribeaud, et al., 2018). It has collected, among other data, information on child mental health and behaviour problems, substance use, socioemotional skills, peer problems, school issues, parenting, media use, leisure time activities, and life events. The study began in 2004 when participants were beginning school at age 7, will follow-up waves at ages 8,9,10,11,12,13,15, 17 and 20 and is ongoing to this date.

The sample was selected based on a stratified random sampling procedure with schools as the sampling unit. Fifty-six state schools in Zurich were selected to participate. Stratification was based on study size and location, with the latter variable used to help ensure adequate representation of different socioeconomic strata in the sample. In each of the 56 schools, all children entering first grade were invited to participate via their parents, giving a target sample of 1675 children. At first, informed consent was obtained from the parents of participating children; however, from age 13, the participants were able to provide direct informed consent, though parents retained the right to opt their child out of the study.

The majority of participants were born between May 1997 and April 1997. Most (90%) were born in Switzerland; however, only 42.6% of the mothers of participating children were born in Switzerland. Previous analyses have suggested a small degree of non-random participation and drop-out, particularly related to being of immigrant status but have concluded that the study can otherwise generally be considered representative of the underlying same-aged population (N. L. Eisner et al., 2018). The effect of immigrant status on participation also lessened when consent procedures switched from being based on parental consent to being based on child consent at age 13.

The current study focusses on the waves of z-proso when participants were aged 13,15, and 17, where both self-reported ADHD and anxiety data were available (computer assisted interviews collected self-reported ADHD and anxiety data at earlier ages but it is not clear that this data is comparable to the data collected in adolescence). Across these three waves, 1483 youth (52% male) contributed data to the current study (n=1363 at age 13, n=1446 at age 15, and n=1305 at age 17). In

terms of socioeconomic status, the mean International Socioeconomic Index Score (ISEI Ganzeboom et al., 1992) for the sample was 49.27 (SD= 18.84), approximately corresponding to the occupational prestige level of a clerical worker. The sample was diverse in terms of cultural/ethnic background. For example, among the primary caregivers of the children, although the biggest group was those who were born in Switzerland, this accounted for less than half the sample (43%). Other common caregiver birthplaces included former Serbia-Montenegro (9.2%), Portugal (4.9%), Sri Lanka (4.1%), Germany (5.6%), and Turkey (3.8%). Further details of the z-proso study, including information on recruitment, retention, and assessment procedures, and attrition can be found in previous publications (M. Eisner & Ribeaud, 2007; N. L. Eisner et al., 2018) and via the z-proso website (<https://www.jacobscenter.uzh.ch/en/research/zproso/aboutus.html>).

Measures

ADHD and anxiety were measured using an adapted self-report version of the *Social Behavior Questionnaire* Anxiety and ADHD scales (Tremblay et al., 1991). All were administered in German, the official language of the study location in the context of questionnaires that also measured a range of other constructs relating to youth psychosocial functioning. Four items measured ADHD and were part of section labelled 'Things that you do', which also included questions on prosociality, conduct problems, oppositionality, and aggression, all of which were also derived from the SBQ. The ADHD questions were distributed throughout this section. Respondents were to rate on a 5-point Likert scale from *never* to *very often* the extent to which they experienced the following symptoms (as translated into English): '*you were restless, and struggled to sit still*'; '*you struggled to concentrate on a task*', '*you were inattentive*', and '*you fidgeted*'. The omega (total) reliability values (McDonald, 1999) for the ADHD items at age 13, 15 and 17 were .78, .80, and .74 respectively.

Four items measured anxiety and were distributed across a section labelled 'How you feel'. The 'How you feel' section also included items on self-harm, depression (also from the SBQ) and in later waves, suicidal ideation. These items asked respondents to rate on a 5-point Likert-type scale from *never* to *very often*, the extent to which they experienced the following symptoms: '*I cried*', '*I*

was scared, fearful, or anxious, *I couldn't fall asleep*, and *I was worried*'. The omega (total) reliability values for the Anxiety items at age 13,15 and 17 were .63, .70, and .71 respectively.

Previous studies have supported the reliability and validity of these items for measuring ADHD and anxiety (Murray, Eisner, Obsuth, et al., 2017c; Murray, Eisner, & Ribeaud, 2017; Murray, Obsuth, et al., 2017). For example, Murray, Obsuth, et al., (2017) found developmental invariance at the metric level for the self-reported anxiety items and scalar level for the ADHD items across adolescence (age 11, 13, 15 and 17 for anxiety and age 13, 15 and 17 for ADHD). Murray, Eisner, & Ribeaud, (2017) examined the reliability of the teacher-reported SBQ items (which are parallel to the self-reported items) and found them suitably reliable for measuring a wide of symptom levels; not just those in the more 'severe' or 'clinical' end. Importantly, given concerns about inflated comorbidity estimates due to measures of ADHD and anxiety having symptom indicators in common (e.g., see Baldwin & Dadds, 2008), previous exploratory factor analyses have supported the distinctness of the SBQ ADHD and anxiety subscales in the current sample, suggesting that the anxiety and ADHD items consistently load on different group factors (Murray, Eisner, et al., 2016; Murray, Eisner, Obsuth, et al., 2017c). Finally, the criterion validity of the items has been supported in previous studies confirming their correlations with other variables in the expected directions, e.g., ADHD with sensation-seeking, substance use, delinquency, and aggression (Murray, Booth, Auyeung, et al., 2018; Murray, Eisner, Obsuth, et al., 2017b, 2017a; Murray, Obsuth, et al., 2016) and anxiety with depression and bullying victimisation (Averdijk et al., 2011; Murray, Eisner, Obsuth, et al., 2017c). These studies add to the evidence for the reliability and validity of the SBQ items accumulated in other international studies over the past three decades (Lösel et al., 2013; Rouquette et al., 2012; Tremblay et al., 1991)

ADHD and anxiety factor scores were computed from the above-described items. In a joint longitudinal measurement model, ADHD and anxiety at age 13,15 and 17 were specified as latent factors. For both constructs, scaling and identification were achieved by fixing the loading and intercept of one item equal across time and fixing the mean and variance at baseline to 0 and 1 respectively. Previous analyses indicated that ADHD shows scalar invariance over ages 13 to 15 in

the current sample, therefore, the choice of reference indicator was arbitrary and the first item was used (Murray, Obsuth, et al., 2017). However, the same study showed that the first item of the anxiety subscale did not show scalar invariance over time. The second item was, therefore, used as the reference indicator. Residual covariances between the same indicators at different time points were included in the model. All latent factors were also allowed to covary. Model fit, parameters and other information pertaining to the suitability of this model for generating ADHD and anxiety factor scores are provided in the Results section.

Statistical procedure

ALT-SR

We examined the developmental relations between ADHD and anxiety using an ALT-SR (Curran et al., 2014) model fit to the ADHD and anxiety latent factor scores, computed as described in the measures section. The specification of our ALT-SR can be divided into two parts. First, a parallel process model (i.e., a two-phenotype growth curve model) was fit to the ADHD and anxiety factor scores. The intercept factor loadings were all fixed to one and the slope factor loadings were fixed proportional to the distance between waves based on the median age of participants at each measurement wave. The intercept factor variances for both ADHD and anxiety were freely estimated but the slope factor variances were fixed to zero. Intercept and slope factor means were freely estimate. The intercept factors for ADHD and anxiety were also allowed to covary. This latter aspect of the model is important for accounting for between-person confounds.

In the second part of the ALT-SR, a cross-lagged structure was fit to the residuals of the parallel process model. These residuals represent time-specific deviations from an average trajectory. Anxiety and ADHD residuals at each wave were regressed on both anxiety and ADHD residuals at the previous wave. (Residual) covariances between ADHD and anxiety residuals were also included at each wave. Gender differences were evaluated and controlled for by regressing both the anxiety and ADHD intercepts on gender. Full analysis code can be found at: <https://osf.io/dyz5p/>

Power analysis

A Monte Carlo power analysis with 1000 replications was used to determine the power for $\alpha=0.05$ and our sample size of $n=1483$. Results suggested that the minimum within-person cross-lagged effect size detectable with $\beta=.80$ was approximately equivalent to $r=.15$. The study can, therefore, be considered powered to detect reasonably small effect sizes. The relevant analysis can be found at: <https://osf.io/w7gry/>.

Results

Measurement model

The measurement model used to generate the factor scores for anxiety and ADHD fit well (RMSEA=.037, 95%CI = .034 to .041; CFI=.95; TLI=0.93; SRMR=.045). Standardised model results are provided in Figure 1. Only factor correlations across concurrent and adjacent time points are shown and residual variances are omitted for visual clarity. All loadings were statistically significant. Factor score determinacies ranged from .87 to .90. Full model results are available at: <https://osf.io/dyz5p/>.

ALT-SR

Full ALT-SR model results can be found at: <https://osf.io/hzvqb/>. The model fit well according to TLI (0.98), CFI (.93) and SRMR (.04) but less well according to RMSEA (.11, 95%CI =.09 to .12).

Standardised autoregressive and cross-lagged parameters from the ALT-SR model are provided in Table 1 and presented in Figure 2. The autoregressive parameters capture the within-person stability of ADHD and anxiety i.e., the extent to which individuals' deviations in symptoms from their base level of symptoms are stable over successive measurement waves. The cross-lagged parameters capture the within-person relations between ADHD and anxiety over time, i.e., the extent to which within-person deviations from base symptom levels in one domain predict within-person deviations in the other.

These autoregressive parameters suggested that anxiety and ADHD symptoms were only partially stable at the within-person level across adolescence. Specifically, the autoregressive effect for anxiety symptoms between ages 13 and 15 and the autoregressive effect for ADHD between ages 15 and 17 were non-significant.

The cross-lagged parameters suggested that at the within-person level, higher levels of ADHD symptoms at age 13 and 15 predicted relatively higher levels of anxiety symptoms at ages 15 and 17 respectively. In addition, higher levels of anxiety symptoms at age 15 predicted relatively higher levels of ADHD symptoms at age 17.

Within-person ADHD and anxiety symptom levels were also significantly correlated within time-points, with correlations with $r = .37$ ($p < .001$) at age 13, $r = .61$ ($p < .001$) at age 15, and $r = .66$ at age 17 ($p < .001$).

There was also a significant effect of gender on both ADHD and anxiety symptom intercepts, with females showing higher levels of anxiety ($\beta = .50$, $p < .001$) and very slightly higher levels of ADHD symptoms ($\beta = .07$, $p = .02$).

Discussion

Despite it being well-established that ADHD and anxiety commonly co-occur, there is a lack of evidence that can speak to the nature of their developmental relations. In this study, we thus evaluated whether there was any evidence for directional or reciprocal developmental effects; that is, whether ADHD symptoms influence anxiety symptoms and/or the reverse over the course of adolescence. We used longitudinal data from a sample of $n = 1483$ community-ascertained youth to examine the developmental relations between ADHD and anxiety over ages 13, 15 and 17. In order to examine developmental processes occurring within individuals, we used an autoregressive latent trajectory model with structured residuals (ALT-SR; Curran et al., 2014) to disaggregate between- and within-person effects. Using this approach, we found that there were within-person reciprocal relations between ADHD and anxiety. Higher ADHD symptoms at ages 13 and 15 predicted higher

anxiety symptoms at ages 15 and 17 respectively, and higher anxiety symptoms at age 15 predicted higher ADHD symptoms at age 17.

The pathways we identified from ADHD to anxiety are consistent with previous discussions that have pointed to the many psychosocial difficulties associated with ADHD symptoms that could put an individual at increased risk of anxiety symptoms. These include problems in the peer and broader social domains, academic and occupational domains, and in risky behaviours with consequences such as injury and criminal convictions (Arnold et al., 2014; Hurtig et al., 2016; Lewis et al., 2015; Lundström et al., 2014; Stenseng et al., 2016). It has been proposed that repeatedly facing such negative circumstances can erode self-esteem and create stress, in turn increasing the risk for anxiety (Schatz & Rostain, 2006).

A causal link between ADHD symptoms and anxiety is further supported by some preliminary evidence that ADHD treatment results in improvements in anxiety symptoms (Biederman et al., 2009; Jensen et al., 2016). It is not clear whether this is due to an amelioration of the consequent life events associated with ADHD; though evidence supports the idea that pharmacological and psychosocial interventions for ADHD have a positive impact on some of the proposed mediators, including academic outcomes and conduct problems (Biederman et al., 2009; Coates et al., 2015). However, in addition to the above-discussed psychosocial difficulties, there may be a range of alternative or additional mediators that could link ADHD symptoms with anxiety, such as a subjective feeling of cognitive disorganisation or emotion regulation difficulties associated with ADHD (Schatz & Rostain, 2006; Seymour et al., 2012).

However, results also suggest that the developmental relations between ADHD and anxiety are not uni-directional over adolescence. In particular, while our results suggest homotypic continuity in ADHD between ages 13 and 15, this switches to heterotypic continuity between ages 15 and 17. That is, while ADHD appears to be perpetuated across early stages of adolescence, it continues through expression as anxiety symptoms in later adolescence. This is consistent with the idea that the manifestation of ADHD symptoms evolves over development (Kessler et al., 2010). For example, while overt hyperactivity may be an important manifestation of ADHD symptoms in childhood,

internal feelings of restlessness may become a more important manifestation in adulthood (Kessler et al., 2010). Our hint at the possibility that over the course of adolescence, ADHD symptoms may come to increasingly resemble or be labelled as anxiety.

Our results also suggest that monitoring anxiety levels in individuals with ADHD and facilitating access to preventive interventions could be beneficial for reducing the overall burden of ADHD symptoms. Further, when adolescents present with anxiety, care should be taken to establish whether there are underlying ADHD symptoms that can wholly or partially account for these symptoms. This may be especially important in females whose ADHD symptoms, it has been argued, are particularly liable to be missed or mistaken for an internalising disorder and for whom ADHD-anxiety comorbidity appears to be particularly common (Williamson & Johnston, 2015).

In addition to confirming the previously hypothesised effect of ADHD symptoms on anxiety symptoms, our results suggest that anxiety-ADHD relations are reciprocal. Though the empirical evidence base on causes of the links between ADHD symptoms and anxiety is thin, the idea is consistent with previous proposals regarding the relations between attention and anxiety. It is, for example, consistent with the basic tenets of attentional control theory which proposes that anxiety interferes with the central executive role of working memory (Eysenck et al., 2007) and with preliminary imaging evidence that suggests that those high in trait anxiety show abnormalities in the allocation of attentional resources (Bishop, 2009). The link with the hyperactivity dimension of ADHD is less clear. While there is face validity to the suggestion that nervousness and overarousal associated with anxiety could manifest in hyperactive and impulsive behaviours (Jarrett & Ollendick, 2008) one previous study found no association between hyperactivity and anxiety (Michellini et al., 2015).

The effects of anxiety on ADHD identified in the current study may help address some outstanding questions regarding variations in ADHD symptom levels over the course of development. Current evidence suggests that the levels of ADHD symptoms can vary considerably across the life-course and across individuals (Caye et al., 2016). For example, growth mixture analyses suggest that while some individuals show an early onset of symptoms in childhood which remain fairly stable

across childhood and adolescence, others show declines or increases in symptom levels from childhood and/or a peak in symptoms at a particular point in development (Malone et al., 2010; Robbers et al., 2011). Our results suggest that anxiety could be one factor that influences the severity (or onset) of ADHD symptoms at a given time-point. For example, it has been proposed that those with late onset ADHD have the same underlying propensity for ADHD as those with early onset ADHD but have a delayed onset due to a lower environmental risk factor load (or higher load of protective factors). If this is correct, the onset of anxiety could be one factor that triggers the behavioural manifestation of the underlying liability of ADHD. Future work will be required to test this hypothesis.

Limitations and Future Directions

It is important to highlight the limitations of the current study. First, although adolescence is an important period of development with respect to both ADHD and anxiety, both can have onsets considerably earlier and an association between anxiety and ADHD can already be observed in preschool children (Overgaard et al., 2016). Thus, future studies tracing the developmental relations between the two symptom domains from an earlier stage of development and into adulthood would be valuable for providing a fuller lifespan picture of their relations. Second, due to the fact that they were administered as part of a broadband longitudinal cohort study, our ADHD and anxiety measures were both brief and relatively general. Replication in cohorts with more comprehensive measures of ADHD and anxiety symptoms would be informative in order to illuminate relations between subdimensions of ADHD and anxiety and better separate the latter from other forms of internalising problems, especially depression. Finally, while our modelling strategy of using ALT-SRs can be effective in controlling for between-person, time-stable confounds, they can be vulnerable to the effects of confounds that covary (within individuals) across time with the focal phenotypes.

In terms of other future directions, as discussed above further illumination of the mechanisms that link ADHD and anxiety symptoms would be valuable for informing interventions. A small number of cross-sectional studies have provided evidence that features and sequelae of ADHD such as emotion dysregulation and peer problems may mediate the path from ADHD to anxiety (Rosen &

Factor, 2015; Yip et al., 2013). However, there are likely to be a number of mediators, such as behavioural problems and associated issues such as contact with the criminal justice system and school exclusion; parent, peer, and intimate partner relationship issues; academic issues; substance use; that could also contribute to this relation (e.g., Arnold et al., 2015; Lewis et al., 2015; Murray, Eisner, Obsuth, et al., 2017b; Stenseng et al., 2016; Wymbs et al., 2017). In terms of the path from anxiety to ADHD, it is possible that this reflects a more direct effect of worry, excessive arousal, intrusive thoughts, and attentional biases towards negative stimuli and other features of anxiety on an individual's ability to concentrate (Jarrett & Ollendick, 2008; Michelini et al., 2015), which would also be valuable to explore in future studies. Finally, it would be valuable to explore whether the relations between ADHD and anxiety are moderated by any leverage-able factors that could also be targeted by interventions, such as the presence of supportive relationships, psychological resilience, or coping styles (e.g., Oddo et al., 2018).

Conclusions

There are reciprocal developmental relations between ADHD and anxiety in adolescence. This suggests that individuals presenting with anxiety in adolescence should be carefully assessed for underlying ADHD symptoms and sequelae. In addition, individuals presenting with ADHD symptoms in adolescence could benefit from continual monitoring of anxiety symptoms as well as access to preventive interventions. Future studies will be required to better understand the mechanisms by which ADHD symptoms increase anxiety symptoms, and vice versa. Such investigations can lead to improved prevention of co-occurring anxiety symptoms associated with ADHD symptoms and vice versa.

References

- Arnold, L. E., Ganocy, S. J., Mount, K., Youngstrom, E. A., Frazier, T., Fristad, M., Horwitz, S. M., Birmaher, B., Findling, R., & Kowatch, R. A. (2014). Three-year latent class trajectories of attention-deficit/hyperactivity disorder (ADHD) symptoms in a clinical sample not selected for ADHD. *Journal of the American Academy of Child & Adolescent Psychiatry*, *53*(7), 745–760.
- Arnold, L. E., Hodgkins, P., Kahle, J., Madhoo, M., & Kewley, G. (2015). Long-term outcomes of ADHD: Academic achievement and performance. *Journal of Attention Disorders*, 1087054714566076.
- Association, A. P. (2013). *Diagnostic and statistical manual of mental disorders (DSM-5®)*. American Psychiatric Pub.
- Averdijk, M., Müller, B., Eisner, M., & Ribeaud, D. (2011). Bullying victimization and later anxiety and depression among pre-adolescents in Switzerland. *Journal of Aggression, Conflict and Peace Research*, *3*(2), 103–109.
- Baldwin, J. S., & Dadds, M. R. (2008). Examining alternative explanations of the covariation of ADHD and anxiety symptoms in children: A community study. *Journal of Abnormal Child Psychology*, *36*(1), 67–79.
- Becker, S. P., Luebke, A. M., Stoppelbein, L., Greening, L., & Fite, P. J. (2012). Aggression among children with ADHD, anxiety, or co-occurring symptoms: Competing exacerbation and attenuation hypotheses. *Journal of Abnormal Child Psychology*, *40*(4), 527–542.
- Berry, D., & Willoughby, M. T. (2017). On the practical interpretability of cross-lagged panel models: Rethinking a developmental workhorse. *Child Development*, *88*(4), 1186–1206.
- Biederman, J. (2005). Attention-deficit/hyperactivity disorder: A selective overview. *Biological Psychiatry*, *57*(11), 1215–1220.

- Biederman, J., Monuteaux, M. C., Spencer, T., Wilens, T. E., & Faraone, S. V. (2009). Do stimulants protect against psychiatric disorders in youth with ADHD? A 10-year follow-up study. *Pediatrics, 124*(1), 71–78.
- Bishop, S. J. (2009). Trait anxiety and impoverished prefrontal control of attention. *Nature Neuroscience, 12*(1), 92.
- Caye, A., Swanson, J., Thapar, A., Sibley, M., Arseneault, L., Hechtman, L., Arnold, L. E., Niclasen, J., Moffitt, T., & Rohde, L. A. (2016). Life span studies of ADHD—conceptual challenges and predictors of persistence and outcome. *Current Psychiatry Reports, 18*(12), 111.
- Coates, J., Taylor, J. A., & Sayal, K. (2015). Parenting interventions for ADHD: A systematic literature review and meta-analysis. *Journal of Attention Disorders, 19*(10), 831–843.
- Costello, E. J., Angold, A., Burns, B. J., Stangl, D. K., Tweed, D. L., Erkanli, A., & Worthman, C. M. (1996). The Great Smoky Mountains Study of Youth: Goals, design, methods, and the prevalence of DSM-III-R disorders. *Archives of General Psychiatry, 53*(12), 1129–1136.
- Curran, P. J., Howard, A. L., Bainter, S. A., Lane, S. T., & McGinley, J. S. (2014). The separation of between-person and within-person components of individual change over time: A latent curve model with structured residuals. *Journal of Consulting and Clinical Psychology, 82*(5), 879.
- Eisner, M., & Ribeaud, D. (2007). Conducting a criminological survey in a culturally diverse context: Lessons from the Zurich Project on the Social Development of Children. *European Journal of Criminology, 4*(3), 271–298.
- Eisner, N. L., Murray, A. L., Eisner, M., & Ribeaud, D. (2018). A practical guide to the analysis of non-response and attrition in longitudinal research using a real data example. *International Journal of Behavioral Development, 0165025418797004*.
- Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion, 7*(2), 336.
- Ganzeboom, H. B., De Graaf, P. M., & Treiman, D. J. (1992). A standard international socio-economic index of occupational status. *Social Science Research, 21*(1), 1–56.
- Groen-Blokhuis, M. M., Middeldorp, C. M., Kan, K.-J., Abdellaoui, A., Van Beijsterveldt, C. E., Ehli, E. A., Davies, G. E., Scheet, P. A., Xiao, X., & Hudziak, J. J. (2014). Attention-

- deficit/hyperactivity disorder polygenic risk scores predict attention problems in a population-based sample of children. *Journal of the American Academy of Child & Adolescent Psychiatry*, 53(10), 1123–1129.
- Hurtig, T., Ebeling, H., Jokelainen, J., Koivumaa-Honkanen, H., & Taanila, A. (2016). The association between hospital-treated injuries and ADHD symptoms in childhood and adolescence: A follow-up study in the northern Finland birth cohort 1986. *Journal of Attention Disorders*, 20(1), 3–10.
- Jarrett, M. A. (2016). Attention-deficit/hyperactivity disorder (ADHD) symptoms, anxiety symptoms, and executive functioning in emerging adults. *Psychological Assessment*, 28(2), 245.
- Jarrett, M. A., & Ollendick, T. H. (2008). A conceptual review of the comorbidity of attention-deficit/hyperactivity disorder and anxiety: Implications for future research and practice. *Clinical Psychology Review*, 28(7), 1266–1280.
- Jensen, C. M., Amdisen, B. L., Jørgensen, K. J., & Arnfred, S. M. (2016). Cognitive behavioural therapy for ADHD in adults: Systematic review and meta-analyses. *ADHD Attention Deficit and Hyperactivity Disorders*, 8(1), 3–11.
- Kessler, R. C., Adler, L., Barkley, R., Biederman, J., Conners, C. K., Demler, O., Faraone, S. V., Greenhill, L. L., Howes, M. J., & Secnik, K. (2006). The prevalence and correlates of adult ADHD in the United States: Results from the National Comorbidity Survey Replication. *American Journal of Psychiatry*, 163(4), 716–723.
- Kessler, R. C., Green, J. G., Adler, L. A., Barkley, R. A., Chatterji, S., Faraone, S. V., Finkelman, M., Greenhill, L. L., Gruber, M. J., & Jewell, M. (2010). Structure and diagnosis of adult attention-deficit/hyperactivity disorder: Analysis of expanded symptom criteria from the Adult ADHD Clinical Diagnostic Scale. *Archives of General Psychiatry*, 67(11), 1168–1178.
- Krone, B., & Newcorn, J. H. (2015). Comorbidity of ADHD and anxiety disorders. *Attention-Deficit Hyperactivity Disorder in Adults and Children*, 98.
- Lebeau, R. T., Glenn, D. E., Hanover, L. N., Beesdo-Baum, K., Wittchen, H.-U., & Craske, M. G. (2012). A dimensional approach to measuring anxiety for DSM-5. *International Journal of Methods in Psychiatric Research*, 21(4), 258–272.

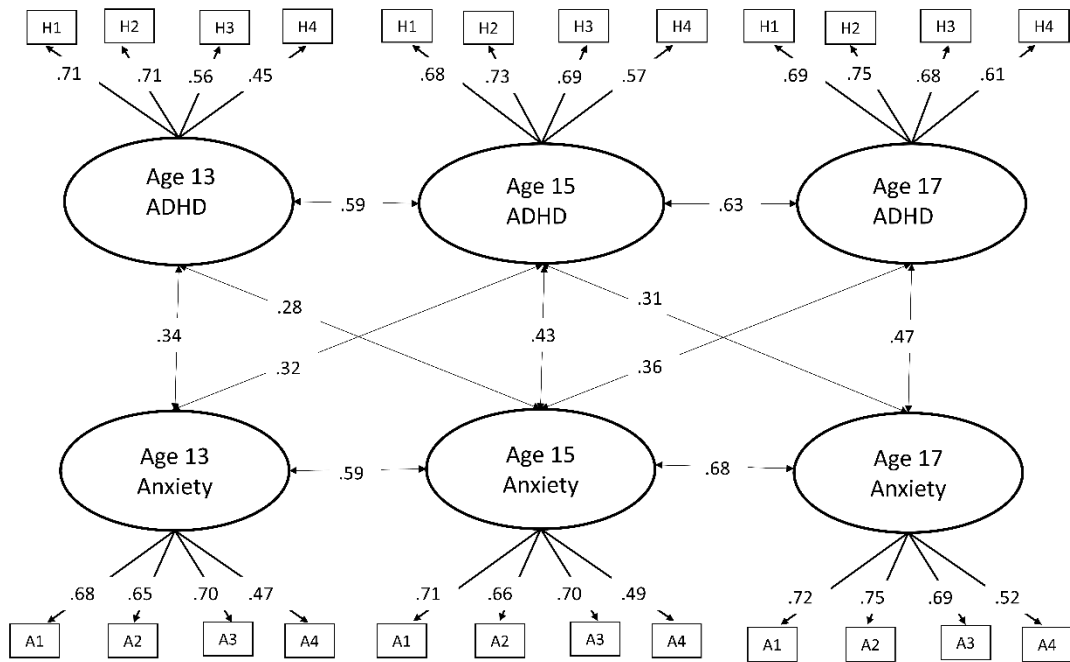
- Levy, F., Hay, D. A., Bennett, K. S., & McStephen, M. (2005). Gender differences in ADHD subtype comorbidity. *Journal of the American Academy of Child & Adolescent Psychiatry, 44*(4), 368–376.
- Lewis, T., Schwebel, D. C., Elliott, M. N., Visser, S. N., Toomey, S. L., McLaughlin, K. A., Cuccaro, P., Tortolero Emery, S., Banspach, S. W., & Schuster, M. A. (2015). The association between youth violence exposure and attention-deficit/hyperactivity disorder (ADHD) symptoms in a sample of fifth-graders. *American Journal of Orthopsychiatry, 85*(5), 504.
- Lösel, F., Stemmler, M., & Bender, D. (2013). Long-term evaluation of a bimodal universal prevention program: Effects on antisocial development from kindergarten to adolescence. *Journal of Experimental Criminology, 9*(4), 429–449.
- Lubke, G. H., Hudziak, J. J., Derks, E. M., van Bijsterveldt, T. C., & Boomsma, D. I. (2009). Maternal ratings of attention problems in ADHD: Evidence for the existence of a continuum. *Journal of the American Academy of Child & Adolescent Psychiatry, 48*(11), 1085–1093.
- Lundström, S., Forsman, M., Larsson, H., Kerekes, N., Serlachius, E., Långström, N., & Lichtenstein, P. (2014). Childhood neurodevelopmental disorders and violent criminality: A sibling control study. *Journal of Autism and Developmental Disorders, 44*(11), 2707–2716.
- Malone, P. S., Van Eck, K., Flory, K., & Lamis, D. A. (2010). A mixture-model approach to linking ADHD to adolescent onset of illicit drug use. *Developmental Psychology, 46*(6), 1543.
- McDonald, R. P. (1999). *Test theory: A unified treatment*.
- Micheline, G., Eley, T. C., Gregory, A. M., & McAdams, T. A. (2015). Aetiological overlap between anxiety and attention deficit hyperactivity symptom dimensions in adolescence. *Journal of Child Psychology and Psychiatry, 56*(4), 423–431.
- Murray, A. L., Booth, T., Auyeung, B., Eisner, M., Ribeaud, D., & Obsuth, I. (2018). Outcomes of ADHD Symptoms in Late Adolescence: Are Developmental Subtypes Important? *Journal of Attention Disorders, 1087054718790588*.
- Murray, A. L., Booth, T., Eisner, M., Auyeung, B., Murray, G., & Ribeaud, D. (2018). Sex differences in ADHD trajectories across childhood and adolescence. *Developmental Science, e12721*.

- Murray, A. L., Booth, T., Ribeaud, D., & Eisner, M. (2018). Disagreeing about development: An analysis of parent-teacher agreement in ADHD symptom trajectories across the elementary school years. *International Journal of Methods in Psychiatric Research*, e1723.
- Murray, A. L., Eisner, M., Obsuth, I., & Ribeaud, D. (2017a). Identifying early markers of “Late Onset” attention deficit and hyperactivity/impulsivity symptoms. *Journal of Attention Disorders*, 1087054717705202.
- Murray, A. L., Eisner, M., Obsuth, I., & Ribeaud, D. (2017b). No evidence that substance use causes ADHD symptoms in adolescence. *Journal of Drug Issues*, 47(3), 405–410.
- Murray, A. L., Eisner, M., Obsuth, I., & Ribeaud, D. (2017c). Situating violent ideations within the landscape of mental health: Associations between violent ideations and dimensions of mental health. *Psychiatry Research*, 249, 70–77.
- Murray, A. L., Eisner, M., & Ribeaud, D. (2016). The development of the general factor of psychopathology ‘p factor’ through childhood and adolescence. *Journal of Abnormal Child Psychology*, 44(8), 1573–1586.
- Murray, A. L., Eisner, M., & Ribeaud, D. (2017). Can the Social Behavior Questionnaire help meet the need for dimensional, transdiagnostic measures of childhood and adolescent psychopathology? *European Journal of Psychological Assessment*.
- Murray, A. L., Eisner, M., & Ribeaud, D. (2019). Within-person analysis of developmental cascades between externalising and internalising problems. *Journal of Child Psychology and Psychiatry*.
- Murray, A. L., Obsuth, I., Eisner, M., & Ribeaud, D. (2017). Evaluating longitudinal invariance in dimensions of mental health across adolescence: An analysis of the Social Behavior Questionnaire. *Assessment*, 1073191117721741.
- Murray, A. L., Obsuth, I., Zirk-Sadowski, J., Ribeaud, D., & Eisner, M. (2016). Developmental relations between ADHD symptoms and reactive versus proactive aggression across childhood and adolescence. *Journal of Attention Disorders*, 1087054716666323.
- Murray, A. L., Ribeaud, D., Eisner, M., Murray, G., & McKenzie, K. (2018). Should We Subtype ADHD According to the Context in Which Symptoms Occur? Criterion Validity of

- Recognising Context-Based ADHD Presentations. *Child Psychiatry & Human Development*, 1–13.
- Oddo, L. E., Knouse, L. E., Surman, C. B., & Safren, S. A. (2018). Investigating resilience to depression in adults with ADHD. *Journal of Attention Disorders*, 22(5), 497–505.
- Overgaard, K. R., Aase, H., Torgersen, S., & Zeiner, P. al. (2016). Co-occurrence of ADHD and anxiety in preschool children. *Journal of Attention Disorders*, 20(7), 573–580.
- Polanczyk, G. V., Salum, G. A., Sugaya, L. S., Caye, A., & Rohde, L. A. (2015). Annual Research Review: A meta-analysis of the worldwide prevalence of mental disorders in children and adolescents. *Journal of Child Psychology and Psychiatry*, 56(3), 345–365.
- Posner, J., Kass, E., & Hulvershorn, L. (2014). Using stimulants to treat ADHD-related emotional lability. *Current Psychiatry Reports*, 16(10), 478.
- Robbers, S. C., van Oort, F. V., Polderman, T. J., Bartels, M., Boomsma, D. I., Verhulst, F. C., Lubke, G. H., & Huizink, A. C. (2011). Trajectories of CBCL attention problems in childhood. *European Child & Adolescent Psychiatry*, 20(8), 419–427.
- Rosen, P. J., & Factor, P. I. (2015). Emotional impulsivity and emotional and behavioral difficulties among children with ADHD: An ecological momentary assessment study. *Journal of Attention Disorders*, 19(9), 779–793.
- Rouquette, A., Côté, S. M., Pryor, L. E., Carbonneau, R., Vitaro, F., & Tremblay, R. E. (2012). Cohort profile: The Quebec longitudinal study of kindergarten children (QLSKC). *International Journal of Epidemiology*, 43(1), 23–33.
- Schatz, D. B., & Rostain, A. L. (2006). ADHD with comorbid anxiety: A review of the current literature. *Journal of Attention Disorders*, 10(2), 141–149.
- Seymour, K. E., Chronis-Tuscano, A., Halldorsdottir, T., Stupica, B., Owens, K., & Sacks, T. (2012). Emotion regulation mediates the relationship between ADHD and depressive symptoms in youth. *Journal of Abnormal Child Psychology*, 40(4), 595–606.
- Shaw, P., Gilliam, M., Liverpool, M., Weddle, C., Malek, M., Sharp, W., Greenstein, D., Evans, A., Rapoport, J., & Giedd, J. (2011). Cortical development in typically developing children with

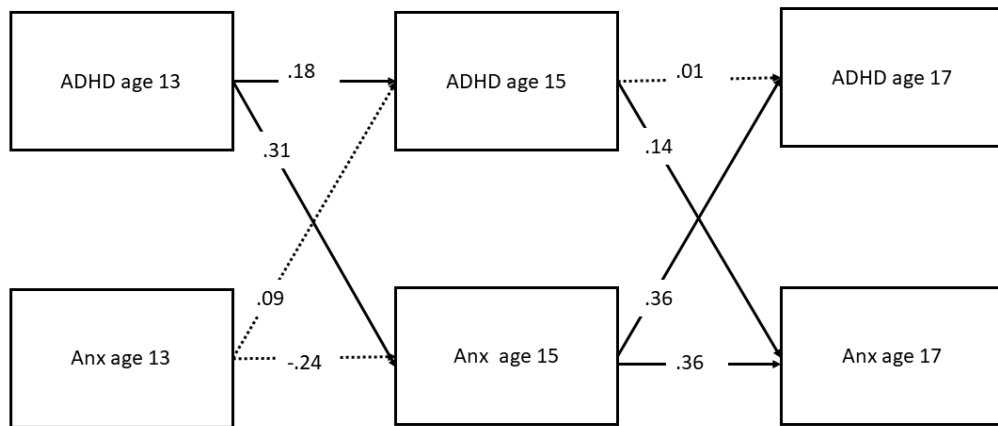
- symptoms of hyperactivity and impulsivity: Support for a dimensional view of attention deficit hyperactivity disorder. *American Journal of Psychiatry*, *168*(2), 143–151.
- Stenseng, F., Belsky, J., Skalicka, V., & Wichstrøm, L. (2016). Peer rejection and attention deficit hyperactivity disorder symptoms: Reciprocal relations through ages 4, 6, and 8. *Child Development*, *87*(2), 365–373.
- Tremblay, R. E., Loeber, R., Gagnon, C., Charlebois, P., Larivee, S., & LeBlanc, M. (1991). Disruptive boys with stable and unstable high fighting behavior patterns during junior elementary school. *Journal of Abnormal Child Psychology*, *19*(3), 285–300.
- Williamson, D., & Johnston, C. (2015). Gender differences in adults with attention-deficit/hyperactivity disorder: A narrative review. *Clinical Psychology Review*, *40*, 15–27.
- Wymbs, B. T., Dawson, A. E., Suhr, J. A., Bunford, N., & Gidycz, C. A. (2017). ADHD symptoms as risk factors for intimate partner violence perpetration and victimization. *Journal of Interpersonal Violence*, *32*(5), 659–681.
- Yip, V. T., Ang, R. P., Ooi, Y. P., Fung, D. S., Mehrotra, K., Sung, M., & Lim, C. G. (2013). The association between attention problems and internalizing and externalizing problems: The mediating role of peer problems. *Child & Youth Care Forum*, *42*, 571–584.

Figure 1: Measurement model used to generate Anxiety and ADHD factor scores



Note A1-A4 = SBQ anxiety items 1-4; H1-4= SBQ ADHD items 1-4.

Figure 2: ALT-SR autoregressive and cross-lagged parameters



Note. For clarity only autoregressive and cross-lagged parameters are shown. Anx= anxiety. Dashed lines represent non-significant paths and solid lines represent significant paths.