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Title:

The role of ADHD symptoms in the relationship between academic achievement and psychopathological symptoms

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Abstract

Background: Previous research results suggest that ADHD symptoms explain the relationship between specific learning disability and externalising psychopathology and between math disability and anxiety, but not between reading disability and anxiety. For depression, previous results are mixed.

Aims: The current study aims to clarify this role of ADHD symptoms in the relationship between various areas of academic achievement (reading, writing, and math skills) and psychopathological symptoms (anxiety, depression, and conduct disorder).

Methods and Procedures: We used linear regressions based on data from a general population sample (N= 3,014) collected using online assessment of 3rd and 4th grade students in Germany, which included measures of academic achievement and parent-reported psychopathological symptoms.

Outcomes and Results: ADHD symptoms completely account for the relationship between reading/writing achievement and anxiety and between writing/math achievement and conduct problems. The negative relationship between academic achievement and depression was strongest for children with average or high ADHD symptom scores.

Conclusions and Implications: ADHD symptoms play an important role in explaining the relationship between academic achievement and psychopathological symptoms in elementary school children. The nature and size of this role depend on the exact constructs under study. We discuss implications for the support of children with learning problems, ADHD, and/or psychopathological problems.

Keywords: academic achievement; ADHD; depression; anxiety; conduct problems

What this paper adds?

Children with specific learning disability (SLD) often have comorbid psychopathological problems. In the literature, attention deficit hyperactivity disorder (ADHD) is regularly proposed to underlie this relationship between SLD and psychopathological problems. More specifically, ADHD symptoms seem to explain the relationship between SLD and externalising psychopathology and between math disability and anxiety, but not between reading disability and anxiety. For depression, results are mixed. Previous results do not give a clear picture about specifically what kind of influence ADHD has (e.g., moderating or confounding). Also, it is unclear if ADHD, or rather attention problems, form the underlying variable.

We studied to what extent ADHD symptoms have a confounding and/or moderating influence on the relationship between academic achievement (reading; writing; math) and psychopathological problems (conduct disorder; depression; anxiety). The results show that ADHD symptoms play both a confounding and moderating role in the relationship between academic achievement and depression. ADHD symptoms confound the relationship between academic achievement and symptoms of both anxiety and conduct disorder. For the relationships between writing or reading and anxiety, and between writing or math and conduct disorder, this confounding effect is so strong that no direct relationship remains when ADHD symptoms are taken into account. It depends on the specific area of achievement or psychopathology under study if only inattention symptoms, or also hyperactivity and impulsivity, account for this full confounding effect. Future, longitudinal, research is needed to investigate causal effects and possible mediating influences and thereby develop a deeper understanding of the role of ADHD symptoms.

1. Introduction

Specific learning disability (SLD) refers to below average scholastic/academic achievement in one or more domains that cannot be explained by factors like intelligence or environmental disadvantage, e.g., insufficient schooling (Individuals with Disabilities Education Act Amendments of 2004; in: Alfonso & Flanagan, 2018). SLD is associated not only with achievement problems in school, but also with both internalising and externalising psychopathological problems (e.g., Carroll, Maughan, Goodman, & Meltzer, 2005; Maughan & Carroll, 2006; Visser, Büttner, & Hasselhorn, 2018; Willcutt et al., 2013).

The comorbidity between distinct forms of psychopathological problems is high as well (Danforth, Connor, & Doerfler, 2016; Hankin et al., 2016). Hence, the question arises of whether the relationship between SLD and psychopathological problems is a result of a direct causal effect, or, alternatively, is a side effect of the presence of psychopathological problems in a different area. Theoretically, attention deficit hyperactivity disorder (ADHD) could underlie this relationship. ADHD is defined in the DSM-V (Diagnostic and Statistical Manual of Mental Disorders, fifth edition; American Psychiatric Association, 2013) on the basis of 9 symptoms of inattention and 9 symptoms of hyperactivity/impulsivity. Vast empirical evidence exists for the distinction made in the DSM-V between a 'predominantly inattentive' and a 'predominantly hyperactive/impulsive' type (Willcutt et al., 2012). A 'combined' type exists as well. Although the DSM-V symptoms do not clearly capture executive function deficits, these are a key feature of persons with ADHD, especially in adulthood and in the case of the inattentive subtype (Adler et al., 2017; Silverstein et al., 2018). In children with ADHD, executive function deficits are also often found and predictive of learning ability (Colomer, Berenguer, Roselló, Baixauli, & Miranda, 2017). This evidence suggests that ADHD symptoms might underlie the relationship between SLD and other psychopathological problems.

Indeed, on the basis of a large community sample of twins, Willcutt and Pennington (2000) found that ADHD accounted for the relationship between reading disorder and oppositional deviant disorder (ODD), conduct disorder (CD), and overanxious disorder (OAD). For males only, ADHD also accounted for the relationship between reading disorder and depression. In a study using a large representative national sample, Carroll et al. (2005) found comparable results for the relationship between literacy difficulties and both CD and depressed mood, which was accounted for by inattentiveness. The relationship between reading difficulties and anxiety, however, appeared to be a direct one, not accounted for by inattentiveness. Goldston et al. (2007) used a sample of children with and without poor reading skills and also found a direct relationship between reading status and anxiety, whereas the relationship between reading status and affective disorders was accounted for by ADHD. Disruptive behavior was not related to reading status at all. In a study using a community sample of boys, Maughan, Rowe, Loeber, and Stouthamer-Loeber (2003) found that inattentiveness accounted for the relationship between reading status and delinquency status.

Willcutt et al. (2013) looked at children with reading disability, math disability, a combination of both disabilities, and without any SLD. In all three SLD-groups, they found higher rates of ODD and CD only in children who also had ADHD. Depression, however, appeared to be directly related to reading and/or math disability, although the presence of ADHD had some influence on this relationship. Children with math disability appeared to have elevated rates of generalized anxiety disorder only in cases of comorbid ADHD. In children with reading disability or comorbid reading and math disabilities, however, the rate of generalized anxiety disorder did not differ between children with and without ADHD.

To summarise these findings, the relationship between SLD and externalising psychopathology seems to be explained by the presence of ADHD. The relationship between reading disorder and anxiety seems to be a direct one, not influenced by the presence of ADHD. In contrast, the relationship between math disorder and anxiety seems to be

influenced by the presence of ADHD. For depression, the results are mixed. Most studies find that ADHD influences the relationship between SLD and depression. In many studies, this influence is so strong that ADHD fully explains the relationship. One study found this result only for boys.

The above studies describe the influence of ADHD or inattention on the relationship between SLD and psychopathological problems as a mediating one. However, none of the studies explicitly tested mediation models in a strict statistical sense, but instead examined whether the relationship between SLD and psychopathological problems remained significant after introducing ADHD as an additional predictor into the regression model. This means that the influence of ADHD reported in the literature so far can be described as a confounding one. A confounder is a variable that is related to two other variables and spuriously increases the correlation between these two. By taking into account the confounding variable, a more accurate picture can be obtained about the relationship between the other two variables (MacKinnon, Krull, & Lockwood, 2000). Thus, by taking into account ADHD symptoms, a more accurate picture can be obtained about the relationship between academic achievement and psychopathological symptoms.

In addition to the misclassification of the influence of ADHD symptoms on the relationship between SLD and psychopathological symptoms, it is unclear if all symptoms related to ADHD, or only symptoms of inattention, account for this effect.

In this paper, we will study what kind of influence ADHD symptoms exert on the relationship between academic achievement and psychopathological symptoms. We will extend previous studies by using a large general population sample and taking into account all domains of academic achievement (reading, writing, and math). By looking at academic achievement and psychopathological symptoms in a continuous manner instead of categorizing children as having or not having a disorder, we can study if the relationships are

present on the whole spectrum instead of only in children with a disorder. However, we will not test mediation models in the strict statistical sense, because this requires an explicit assumption about the causal direction of effect. There is not sufficient evidence to support this kind of assumptions and we cannot study causality directly, because our study is not based on longitudinal data. In addition, a mediating role of ADHD, as assumed in the literature described above, is not per definition plausible, as it is likely that ADHD symptoms have an earlier onset than learning disabilities.

More specifically, we will explore to what extent ADHD symptoms have an influence on the relationship between academic achievement and psychopathological problems and whether this potential influence is a confounding and/or moderating one. We will study the influence of ADHD symptoms separately for reading, writing, and math achievement and separately for symptom scores of conduct disorder, depression, and anxiety. For cases in which we find a full confounding effect, meaning that ADHD completely accounts for the relationship between academic achievement and psychopathological problems and no direct correlation remains when ADHD is taken into account, we will study which of the three components of ADHD (inattention, hyperactivity, and/or impulsivity) is responsible. We hypothesize that ADHD symptoms influence the relationship between academic achievement and both conduct disorder and depression. Also, we hypothesize that ADHD symptoms influence the relationship between math achievement and symptoms of anxiety, but not between reading or writing achievement and anxiety. The questions of whether the influence of the ADHD symptoms can be described as a confounding or moderating one, or a combination of both, and which subcomponent of ADHD accounts for confounding effects, are explorative.

2. Method

2.1 Procedure and participants

The data used for the current paper stem from an online study addressing the comorbidity between SLD and psychopathology in a large general population sample that was funded by the German Federal Ministry of Education and Research (BMBF). The study received ethical approval from both the ethics committees of the [blinded for review purposes].

Participants from the German states Hesse and Bavaria were recruited via the Hessian Ministry of Culture and local registration offices in Bavaria. A total of 52.734 families with children in 3rd and 4th grade in Germany received an invitation that included a code to login to an application which could be installed on a smartphone or tablet. After login, parents were asked to give informed consent for participation in the study. Subsequently, on four separate days, the children completed an intelligence test, four academic achievement tests assessing reading, writing, and arithmetic abilities, and answered four questionnaires assessing psychopathological symptoms. The whole procedure was embedded into a cover story involving a magician. Each session took approximately 30 to 45 minutes. The parents answered a questionnaire about family and child background characteristics, four questionnaires about the child's psychopathological symptoms, and a screening instrument assessing the child's motor coordination. In the current study, we used the results of the academic achievement tests and of the parental assessment of psychopathological symptoms.

The total number of families that gave informed consent was 4542. For the current study, we excluded children with an intelligence quotient (CFT-20R; Weiß, 2006) below 70, with hearing, visual, or neurological problems, with a genetic disorder, and with incomplete data on one of the tests or questionnaires. Furthermore, we randomly excluded one child per sibling pair. The resulting final sample consisted of 3014 children, of which 1570 (52.1%) were boys and 1444 (47.9%) were girls, 1404 (46.6%) 3rd graders and 1610 (53.4%) 4th graders, and 636 (21.1%) from Hesse and 2378 (78.9%) from Bavaria. The mean age of the participants was 9;9 years (SD = 7 months; range 8;1 to 11;8). Children with mothers from

high educational background, with German nationality, and with German mother-tongue were slightly overrepresented in comparison to statistics of the general population. For a more elaborate description of the sample and details about drop-out, exclusion, and representativeness, we refer to [blinded for review purposes].

2.2 Instruments

Reading ability was assessed using the Würzburger silent reading test – revised (WLLP-R; Schneider, Blanke, Faust, & Küspert), a 180-item-test for grades 1 to 4 assessing reading speed. Children are asked to indicate which of four pictures displays a given word for as many words as possible within 5 minutes. Both parallel test and retest reliability coefficients reported are .80 or higher.

Writing ability was assessed using the Weingartener spelling test for basic vocabulary for third (WRT 3+; Birkel, 2007a; 55 items) and fourth (WRT 4+; Birkel, 2007b; 60 items) grade, in which a text is being read and the child has to fill empty spaces by writing the missing word. The manual reports different forms of reliability, which are all above .80.

Math ability was assessed using the CODY test (Kuhn, Schwenk, Raddatz, Dobel, & Holling, 2017), an online test including nine subtests assessing basic number processing, complex number processing, counting skills, and visuo-spatial working memory. For the current study, we used the total score, for which a test-retest-reliability of .88 is reported.

For measures of psychopathological symptoms, we used the parent-report questionnaires of the Diagnostic System of Mental Disorders for Children and Adolescents – II (DISYPS-II; Döpfner, Görtz-Dorten, & Lehmkuhl, 2008) for depression, conduct disorder, and ADHD. The depression-questionnaire is unidimensional and contains 42 items. The questionnaire for assessing conduct disorder consists of 9 questions about oppositional-aggressive behaviour and 16 about antisocial-aggressive behaviour. The ADHD-questionnaire contains questions for assessing symptoms of inattention (n=9), hyperactivity (n=7), and

impulsivity (n=4), derived from ICD-10 (World Health Organization, 1993) and DSM-IV (American Psychiatric Association, 2000) criteria. The newer version of the instrument based on DSM-V criteria was not yet available at the moment of data collection (May and June 2017), but the DSM-V criteria are also covered, as the underlying dimensions of inattention and hyperactivity/impulsivity do not differ between the DSM-versions. The DISYPS-II is widely used in Germany and has a good internal consistency for the total scales (Cronbach's α = .89 - .94). Anxiety symptoms were assessed using the German parent-report version of the Screen for Child Anxiety Related Emotional Disorders (SCARED; Birmaher et al., 1997; Essau, Muris, & Ederer, 2002), which contains 41 items and has good internal consistency and construct validity (Weitkamp, Romer, Rosenthal, Wiegand-Grefe, & Daniels, 2010). We used the total z-scores of all questionnaires and the z-scores of the ADHD-subscales (inattention, hyperactivity, and impulsivity).

All instruments except the CODY test are typically conducted in paper-pencil form, but were adapted to an online version for the online study.

2.3 Analyses

We used REDCap (Harris et al., 2009) for data management and R (R Core Team, 2017; version 3.4.1) for data analysis. Data and analysis code are available on the Open Science Framework (Database: https://osf.io/rtby3/).

Data preparation consisted of excluding implausible data (e.g., cases in which there was a high likelihood that a child did not seriously work on a test) and standardization. For all instruments, we developed norms based on the sample of the online study. For the intelligence and learning tests, we developed separate norms for 3rd and 4th graders. For the questionnaires assessing psychopathological symptoms, we developed gender-specific norms. For more information on both the plausibility checks and the standardization, we refer to [blinded for review purposes].

We performed linear regression analyses with psychopathological symptom scores (for depression, anxiety, and conduct disorder; in separate analyses) as the dependent variable and standardized school achievement scores (reading, writing, math; again as separate analyses) as the predictor variable, yielding 12 base regression models. In a second step, we added the symptom score for ADHD as an additional predictor variable to each of the models to study if ADHD symptoms had a confounding influence on the respective relationship between a school achievement score and psychopathological symptoms. We operationalized confounding as a change of the regression estimate for the concerning achievement score by more than 10% (Goldstein, 2017) and full confounding if the significance test for the respective regression estimate additionally changed to non-significance. In the case of full confounding, ADHD completely accounts for the relationship between school achievement and psychopathological symptoms and hence, no direct relationship exists between the two variables. In a third step, we added the interaction term between the school achievement score and ADHD symptoms into the analysis to evaluate if ADHD symptoms had a moderating influence. In other words, we studied if the strength of the relationship between the performance in the different school achievement tests and psychopathological symptoms depended on the ADHD symptoms-score.

For the relationships on which ADHD appeared to exert a full confounding effect, as reflected by a non-significant significance test of the regression estimate for the concerning achievement score when ADHD was taken into account, we reran the analyses replacing the ADHD symptom score with standardized measures of symptoms of the three subcomponents of ADHD: inattention, hyperactivity, and impulsivity. We corrected for multiple testing by setting the false discovery rate (FDR) to .05 using the modified FDR procedure by Benjamini and Yekutieli (2001).

3. Results

Tables 1, 2, and 3 show the results of the linear regression models with depression, anxiety, and conduct disorder symptoms, respectively, as the outcome variable. Each table contains the results of three different regression models, namely with the three school achievement test scores (writing, reading, math) as predictor variables.

In all models, scholastic achievement significantly predicts depression, anxiety, and conduct disorder scores, respectively, when ADHD symptoms are not taken into account. Furthermore, in all models, ADHD symptoms significantly predict depression, anxiety, and conduct disorder and show a stronger relationship with the psychopathology symptom scores than the scholastic achievement test scores do. Based on the value of the estimates, the influence of ADHD is larger for symptoms of depression or conduct disorder (range .55 –.58) than for symptoms of anxiety (range .33 –.36).

The type of influence that the ADHD symptoms exert on the negative relationship between scholastic achievement and psychopathological symptoms depends on the specific combination of predictor and outcome variables. Depression symptoms are predicted by the performance in all three school achievement tests (writing, reading, and math), ADHD symptoms, as well as the interaction between these two predictor variables. The predictor estimate for the different domains of scholastic achievement changes by 69 to 78% when adding ADHD to the model, suggesting a confounding effect of ADHD symptoms. The significant interaction term suggests a moderating effect of ADHD symptoms. As is visualized in Figure 1, children with higher symptom scores for ADHD have higher symptom scores for depression. Symptoms of depression decrease with increasing school achievement level. This decrease is most pronounced in children with average or high ADHD symptom scores. In children with low ADHD symptom scores, writing achievement scores seem to be unrelated to depression symptoms.

In the model with anxiety symptoms as the outcome variable, reading or writing achievement are not significant predictors when ADHD symptoms are added to the model,

suggesting a full confounding effect of ADHD symptoms. In contrast, math achievement still predicts anxiety when ADHD symptoms are taken into account, although its regression estimate decreases by 58%. The interaction between academic achievement and ADHD symptoms is not significant, irrespective of the domain of academic achievement.

Regarding symptoms of conduct disorder, writing or math achievement are not significant predictors when ADHD symptoms are taken into account, again suggesting a full confounding effect. Interestingly, when ADHD symptoms are taken into account, the effect of reading as a predictor reverses, meaning that conduct problems increase when reading achievement increases. However, the effect is small: when the z-score for reading achievement increases with 1 point, the z-score for symptoms of conduct disorder increases with .04 points, which is equivalent to an increase in t-score of .4. The interaction between academic achievement and ADHD symptoms is not significant, irrespective of the learning domain.

ADHD symptoms thus completely account for the negative relationship between reading/writing achievement and anxiety, and for the negative relationship between writing/math achievement and symptoms of conduct disorder. We subsequently replaced the score for ADHD symptoms by those for its subcomponents: inattention, hyperactivity, and impulsivity. The statistical results can be found in Tables 4 and 5.

For the relationship between reading achievement and anxiety, the results stayed the same for inattention and hyperactivity. The reading score does not significantly predict anxiety when inattention or hyperactivity is taken into account. However, reading remained a significant predictor when only impulsivity was added to the model. For the relationship between writing and anxiety, the results stayed the same (e.g., full confounding) for all three subcomponents.

For the relationship between both writing and math on the one side and conduct disorder on the other, the results stayed the same for inattention symptoms, which fully accounted for the relationship. However, in case of both hyperactivity and impulsivity, the writing or math score remained a significant predictor. In addition, we found an interaction between writing achievement and hyperactivity in that symptoms of conduct disorder decrease with increasing writing achievement only in children with low hyperactivity scores.

4. Discussion

The aim of the current study was to investigate to what extent ADHD symptoms confound and/or moderate the relationship between scholastic or academic achievement and psychopathological problems. In general, ADHD symptoms appeared to be more strongly related to psychopathological problems than scholastic achievement is. ADHD symptoms are more strongly related to symptoms of depression or conduct disorder than to symptoms of anxiety.

Our results largely support our hypothesis that ADHD symptoms influence the negative relationship between academic achievement and both conduct disorder and depression. ADHD symptoms confound, but do not completely account for the relationship between academic achievement and depression symptoms. The finding that children with low academic achievement more often show symptoms of depression can thus partly be explained by co-occurring ADHD symptoms. ADHD symptoms also have a moderating influence—the negative relationship between academic achievement and depression symptoms is strongest when children have average or high levels of ADHD symptoms.

Regarding conduct problems, in disagreement with the results by Goldston et al. (2007), we found a negative relationship with reading achievement, which can partly be explained by ADHD symptoms. The finding that children with low writing or math achievement more often have conduct problems can be fully explained by co-occurring

ADHD symptoms. This is in line with previous studies (e.g., Willcutt et al., 2013) and with the fact that conduct problems are the most common comorbidity in children with ADHD (Harvey, Breaux, & Lugo-Candelas, 2016; Jensen, Martin, & Cantwell, 1997; Thapar & van Goozen, 2018). Unexpectedly, conduct problems increase with increasing reading achievement when ADHD symptoms are taken into account. This relationship is, however, weak and, given the large sample, possibly not practically relevant.

Our results do not support our hypothesis regarding anxiety. In contrast to most of the earlier studies (Carroll et al., 2005; Goldston et al., 2007; Willcutt et al., 2013), we found that the existence of ADHD symptoms completely explains the finding that children with low reading or writing achievement have more anxiety symptoms. Regarding math achievement, the existence of ADHD symptoms explains the relationship with anxiety symptoms only partially. This contradicts the conclusions by Willcutt et al. (2013), who report that children with math disability had anxiety symptoms only in cases of co-occurring ADHD. This inconsistency could be due to the fact that our results are based on data from a general population sample, i.e., that we considered the full spectrum of scholastic achievement and psychopathological symptoms. ADHD symptoms might exert a different influence when looking specifically at a sample of children with SLD, as in the study by Willcutt et al. (2013).

Based on earlier studies, it was unclear which exact construct, ADHD or inattentiveness, influences the relationship between academic achievement and psychopathological symptoms (e.g., Carroll et al., 2005; Maughan et al., 2003). To clarify which aspect of ADHD plays the key role, we took into account both ADHD in general and the separate symptoms. In the recent literature addressing the conceptualisation of ADHD, most support is found for a bifactor model that is based on orthogonal factors—a general factor for ADHD and two specific factors for symptoms of inattention and hyperactivity/impulsivity. However, due to the poor reliability of the two specific factors, this

model cannot be considered the final conceptualization (Arias, Ponce, & Núñez, 2018; Willoughby, Fabiano, Schatz, Vujnovic, & Morris, 2019). We assessed symptom scores for inattention, hyperactivity, and impulsivity using a questionnaire that is used in daily practice. In interpreting these observed symptom scores, it needs to be taken into account that they include not only symptom-specific, but also ADHD-general variation (Willoughby et al., 2019).

Our results show that inattention symptoms explain the full confounding effect on the relationships between writing or math achievement and symptoms of conduct disorder. Symptoms of both inattention and hyperactivity account for the confounding effect of ADHD on the relationship between reading and anxiety symptoms. All three subcomponents (including impulsivity) explain the confounding effect of ADHD on the relationship between writing and anxiety symptoms. This could explain why Carroll et al. (2005) found a direct relationship between reading/writing achievement and anxiety when focussing on the inattentiveness-component only, as inattentiveness alone might not have explained a sufficient amount of variance to find an effect. Inattention symptoms thus play an important, but not a deciding role. The finding that executive functions form a key aspect in inattention symptoms (Adler et al., 2016; Silverstein et al., 2018) could explain this important role of the inattention-component of ADHD. Similarly, Pham (2016) found that the relationship between ADHD and reading achievement is mainly explained by the inattention-component.

The operationalisation of ADHD symptoms in terms of continuous variables instead of categorical diagnoses is in line with the empirical support for viewing ADHD symptoms in a dimensional way instead of based on subtypes (Willcutt et al., 2012). In general, the advantage of our dimensional approach (as opposed to a categorical, diagnosis-based approach), is that one does not have to choose a cut-off to define SLD or psychopathology, which can greatly influence the results.

It was known that many children with SLD also suffer from psychopathological symptoms and that ADHD is one of the highest comorbidities [blinded for review purposes]. The results of our study show that the existence of ADHD symptoms influences the relationship between academic achievement and the prevalence of psychopathological symptoms for all domains we studied. This means that ADHD symptoms might play a key role in explaining the prevalence and aetiology of these comorbidities. Given the important role of executive functions in both ADHD (Ahmadi, Mohammadi, Araghi, & Zarafshan, 2014; Colomer et al., 2017) and SLD (Brandenburg et al., 2015), they might form an important part of the explanation. Possibly, ADHD symptoms do not only play a role in the emergence of SLD, but also make it more difficult for children to deal with their SLD and thereby cause internalising and/or externalising behaviour problems.

4.1 Limitations and Directions for Future Research

It must be taken into account that children with mothers from high educational background, with German nationality, and with German mother-tongue were overrepresented in our study. Although this will have influenced the average scores regarding both academic achievement and psychopathological symptoms, we do not expect it has influenced the results regarding the relationship between these variables.

A further limitation of the current study is that it is based on tests and questionnaires administered in an online format. Except for the Cody test measuring arithmetic achievement, the validity of these online versions is still focus of ongoing research. In addition, the families used the application in their own homes and we did not interact with them directly. To account for possible data quality issues associated with this research design, we executed extensive plausibility analyses on the data. In addition, the current study is based on a non-clinical sample of children in 3rd and 4th grade in Germany, hence an age range of 8 to 11

years. The conclusions made are thus only valid regarding this target group. Possibly, the role of ADHD symptoms is different for younger or older children.

As illustrated by the contradictory results described above, more research is needed to answer the question of which role the different components of ADHD (inattention, hyperactivity, and impulsivity) play in influencing the relationship between academic achievement and psychopathological symptoms. Different conceptualisations of ADHD and its subcomponents could be used to see if the conceptualisation influences the conclusions in any way. Also, longitudinal research is needed to investigate causal effects and possible mediating influences and thereby develop a deeper understanding of the role of ADHD symptoms.

We considered the full range of academic achievement and studied reading, writing, and math, separately. Given the finding that children with SLD in multiple domains are particularly vulnerable for having ADHD and other psychopathological problems [blinded for review purposes], it could be that the role of academic achievement in one domain (e.g., reading) not only depends on the level of ADHD symptoms, but also on the level of academic achievement in a different domain (e.g., math). This could be another direction for future research.

4.2 Practical implications

Although a lot is known about psychopathological comorbidities in SLD as well as ADHD, less is known about how these comorbidities relate. The results of our study show that symptoms of anxiety, depression, and conduct disorder are strongly related to ADHD symptoms, and also, but less strongly, to academic achievement. This means that teachers and people working in clinical practice need to be aware of the risks for developing other psychopathological problems, in- or outside of the clinical range, when a child has ADHD. This speaks for a screening of ADHD symptoms in schools as well as an additional screening

for SLD and internalising and externalising behaviour problems in children who are identified as having ADHD symptoms.

If a child has both ADHD and low academic achievement, the risk for depression is particularly high. If teachers and other people working in daily practice with these children are aware of this risk, this would help in recognising depression symptoms. This would enable intervening in an early stage, so that more profound psychopathological problems can be prevented and learning interventions can be adjusted to the specific needs of the child.

The incidence of ADHD symptoms appears to play a key role in the relationship between academic achievement and psychopathological symptoms. This means that interventions aimed at remediating ADHD symptoms have the potential to lead to improvements not only with regard to these symptoms, but also in relation to both learning achievement and internalising and externalising behaviour problems. Given the fact that ADHD has an onset before age 7 in approximately half of the cases (Kieling et al., 2010), early ADHD-interventions could be especially beneficial for these children in the long run, as secondary learning and psychopathological problems could be prevented or minimised.

5. Conclusions

The results of the current study showed that ADHD symptoms confound and thereby completely account for the negative relationship between reading or writing achievement and anxiety symptoms (explained by inattention and hyperactivity, respectively inattention, hyperactivity, and impulsivity) and between writing or math achievement and conduct problems (explained by inattention symptoms). ADHD symptoms confound, but do not completely account for the negative relationships between academic achievement and depression symptoms, between math achievement and anxiety symptoms, and between reading achievement and conduct problems. Furthermore, ADHD symptoms moderate the negative relationship between scholastic achievement and depression symptoms, which is

strongest for children with average or high ADHD symptom scores. Awareness of the risks for other psychopathological problems when a child has ADHD is the first step in optimizing the support for these children.

Competing Interests Statement

The authors declare that there are no competing or potential conflicts of interest.

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Table 1

Results of the Regression Analyses for Predicting Symptoms of Depression

model		**model parameters**					**model comparisons**			
	predictor	***p***	***est.***	***est. change***	***95% CI (low)***	***95% CI (high)***	***AIC***	***deviance***	***deviance diff.***	***p***
predictor only	writing	<.001*	-0.1908		-0.2240	-0.1575	7,978.422	2,485.618	104.4866	<.001
predictor + confounder	writing	<.01*	-0.0416	78%	-0.0701	-0.0132	6,816.212	1,689.198	796.4198	<.001
	ADHD	<.001*	0.5532		0.5244	0.5820	6,816.212	1,689.198	796.4198	<.001
predictor + confounder + interaction	writing	<.01*	-0.0395		-0.0679	-0.0111	6,803.842	1,681.163	8.0347	<.01
	ADHD	<.001*	0.5518		0.5231	0.5805	6,803.842	1,681.163	8.0347	<.01
	interaction	<.001*	-0.0550		-0.0834	-0.0266	6,803.842	1,681.163	8.0347	<.01
predictor only	reading	<.001*	-0.1582		-0.1915	-0.1249	8,017.062	2,517.689	72.4152	<.001
predictor + confounder	reading	<.01*	-0.0433	73%	-0.0712	-0.0154	6,815.196	1,688.628	829.0607	<.001
	ADHD	<.001*	0.5554		0.5271	0.5838	6,815.196	1,688.628	829.0607	<.001
predictor + confounder + interaction	reading	<.01*	-0.0428		-0.0707	-0.0149	6,810.150	1,684.685	3.9430	<.05
	ADHD	<.001*	0.5565		0.5282	0.5848	6,810.150	1,684.685	3.9430	<.05
	interaction	<.01*	-0.0371		-0.0645	-0.0097	6,810.150	1,684.685	3.9430	<.05
predictor only	math	<.001*	-0.2183		-0.2513	-0.1853	7,930.975	2,450.772	136.9882	<.001
predictor + confounder	math	<.001*	-0.0668	69%	-0.0953	-0.0384	6,798.557	1,681.431	769.3411	<.001
	ADHD	<.001*	0.5456		0.5168	0.5745	6,798.557	1,681.431	769.3411	<.001
predictor + confounder + interaction	math	<.001*	-0.0665		-0.0949	-0.0381	6,788.532	1,674.729	6.7018	<.01
	ADHD	<.001*	0.5458		0.5170	0.5746	6,788.532	1,674.729	6.7018	<.01
	interaction	<.001*	-0.0495		-0.0775	-0.0215	6,788.532	1,674.729	6.7018	<.01

Notes. * estimate is significant after FDR correction; est. = estimate; AIC = Akaike information criterion; diff. = difference.

Table 2

Results of the Regression Analyses for Predicting Symptoms of Anxiety

model		**model parameters**					**model comparisons**			
	predictor	***p***	***est.***	***est. change***	***95% CI (low)***	***95% CI (high)***	***AIC***	***deviance***	***deviance diff.***	***p***
predictor only	writing	<.001*	-0.0639		-0.0995	-0.0282	8,408.423	2,866.778	11.711	<.001
predictor + confounder	writing	.057	0.0338	153%	-0.0011	0.0686	8,028.353	2,525.462	341.317	<.001
	ADHD	<.001*	0.3622		0.3270	0.3973	8,028.353	2,525.462	341.317	<.001
predictor + confounder + interaction	writing	.053	0.0345		-0.0004	0.0693	8,029.316	2,524.593	0.869	.351
	ADHD	<.001*	0.3617		0.3265	0.3969	8,029.316	2,524.593	0.869	.351
	interaction	.309	-0.0181		-0.0529	0.0167	8,029.316	2,524.593	0.869	.351
predictor only	reading	<.001*	-0.0653		-0.1009	-0.0298	8,407.761	2,866.149	12.341	<.001
predictor + confounder	reading	.644	0.0081	112%	-0.0261	0.0422	8,031.753	2,528.312	337.837	<.001
	ADHD	<.001*	0.3546		0.3199	0.3892	8,031.753	2,528.312	337.837	<.001
predictor + confounder + interaction	reading	.639	0.0082		-0.0260	0.0423	8,033.534	2,528.128	0.184	.668
	ADHD	<.001*	0.3548		0.3201	0.3895	8,033.534	2,528.128	0.184	.668
	interaction	.640	-0.0080		-0.0415	0.0255	8,033.534	2,528.128	0.184	.668
predictor only	math	<.001*	-0.1587		-0.1939	-0.1234	8,334.479	2,802.222	72.358	<.001
predictor + confounder	math	<.001*	-0.0660	58%	-0.1008	-0.0311	8,009.642	2,513.975	288.247	<.001
	ADHD	<.001*	0.3340		0.2987	0.3692	8,009.642	2,513.975	288.247	<.001
predictor + confounder + interaction	math	<.001*	-0.0659		-0.1007	-0.0310	8,010.985	2,513.427	0.548	.459
	ADHD	<.001*	0.3340		0.2988	0.3693	8,010.985	2,513.427	0.548	.459
	interaction	.418	-0.0142		-0.0485	0.0201	8,010.985	2,513.427	0.548	.459

Notes. * estimate is significant after FDR correction; est. = estimate; AIC = Akaike information criterion; diff. = difference.

Table 3

Results of the Regression Analyses for Predicting Symptoms of Conduct Disorder

model	**model parameters**						**model comparisons**			
	predictor	***p***	***est.***	***est. change***	***95% CI (low)***	***95% CI (high)***	***AIC***	***deviance***	***deviance diff.***	***p***
predictor only	writing	<.001*	-0.1415		-0.1760	-0.1071	8,199.505	2,674.796	57.533	<.001
predictor + confounder	writing	.380	0.0132	109%	-0.0163	0.0428	7,035.679	1,816.787	858.009	<.001
	ADHD	<.001*	0.5742		0.5443	0.6040	7,035.679	1,816.787	858.009	<.001
predictor + confounder + interaction	writing	.364	0.0137		-0.0159	0.0432	7,037.065	1,816.417	0.370	.543
	ADHD	<.001*	0.5739		0.5440	0.6037	7,037.065	1,816.417	0.370	.543
	interaction	.434	-0.0118		-0.0413	0.0177	7,037.065	1,816.417	0.370	.543
predictor only	reading	<.001*	-0.0783		-0.1129	-0.0437	8,244.039	2,714.611	17.718	<.001
predictor + confounder	reading	<.01*	0.0417	153%	0.0127	0.0706	7,028.484	1,812.455	902.156	<.001
	ADHD	<.001*	0.5794		0.5501	0.6088	7,028.484	1,812.455	902.156	<.001
predictor + confounder + interaction	reading	<.01*	0.0420		0.0131	0.0709	7,027.497	1,810.660	1.795	.180
	ADHD	<.001*	0.5801		0.5508	0.6094	7,027.497	1,810.660	1.795	.180
	interaction	.084	-0.0250		-0.0534	0.0034	7,027.497	1,810.660	1.795	.180
predictor only	math	<.001*	-0.1409		-0.1753	-0.1065	8,189.119	2,670.154	57.055	<.001
predictor + confounder	math	.208	0.0190	113%	-0.0106	0.0486	7,024.964	1,812.738	857.417	<.001
	ADHD	<.001*	0.5760		0.5461	0.6060	7,024.964	1,812.738	857.417	<.001
predictor + confounder + interaction	math	.204	0.0192		-0.0104	0.0487	7,024.972	1,811.539	1.199	.274
	ADHD	<.001*	0.5761		0.5462	0.6060	7,024.972	1,811.539	1.199	.274
	interaction	.158	-0.0210		-0.0501	0.0082	7,024.972	1,811.539	1.199	.274

Notes. * estimate is significant after FDR correction; AIC = Akaike information criterion; diff. = difference.

Table 4

Results of the Regression Analyses for Predicting Symptoms of Anxiety on the Basis of Reading/Writing Achievement, Attention, Hyperactivity, and Impulsivity Symptoms.

model		**model parameters**					**model comparisons**			
	predictor	***p***	***estimate***	***estimate change***	***95% CI (low)***	***95% CI (high)***	***AIC***	***deviance***	***deviance diff.***	***p***
predictor only	reading	< .001*	-0,0653		-0,1009	-0,0298	8407,761	2866,149	12,341	< .001
predictor + confounder	reading	0.350	0,0167	126%	-0,0183	0,0517	8112,278	2596,772	269,377	< .001
	attention	< .001*	0,3096		0,2753	0,3440	8112,278	2596,772	269,377	< .001
predictor + confounder + interaction	reading	.359	0,0164		-0,0186	0,0515	8112,868	2595,557	1,215	.270
	attention	< .001*	0,3133		0,2784	0,3482	8112,868	2595,557	1,215	.270
	interaction	.235	0,0198		-0,0129	0,0526	8112,868	2595,557	1,215	.270
predictor only	reading	< .001*	-0,0653		-0,1009	-0,0298	8.407,761	2.866,149	12,341	< .001
predictor + confounder	reading	.062	-0,0332	49%	-0,0679	0,0016	8.225,642	2.696,303	169,846	< .001
	hyperact.	< .001*	0,2395		0,2054	0,2736	8.225,642	2.696,303	169,846	< .001
predictor + confounder + interaction	reading	.061	-0,0333		-0,0681	0,0015	8.227,481	2.696,158	0,145	.704
	hyperact.	< .001*	0,2408		0,2061	0,2755	8.227,481	2.696,158	0,145	.704
	interaction	.688	0,0068		-0,0262	0,0397	8.227,481	2.696,158	0,145	.704
predictor only	reading	< .001*	-0,0653		-0,1009	-0,0298	8.407,761	2.866,149	12,341	< .001
predictor + confounder	reading	< .001*	-0,0549	16%	-0,0897	-0,0200	8.283,212	2.748,299	117,850	< .001
	impulsivity	< .001*	0,1980		0,1639	0,2322	8.283,212	2.748,299	117,850	< .001
predictor + confounder + interaction	reading	< .001*	-0,0554		-0,0903	-0,0205	8.284,514	2.747,662	0,637	.425
	impulsivity	< .001*	0,1987		0,1645	0,2329	8.284,514	2.747,662	0,637	.425
	interaction	.404	0,0141		-0,0190	0,0472	8.284,514	2.747,662	0,637	.425

Table 4 (continued)

model			**model parameters**					**model comparisons**		
	predictor	***p***	***estimate***	***estimate change***	***95% CI (low)***	***95% CI (high)***	***AIC***	***deviance***	***deviance diff.***	***p***
predictor only	writing	< .001*	-0,0639		-0,0995	-0,0282	8.408,423	2.866,778	11,711	< .001
predictor + confounder	writing	.037	0,0381	160%	0,0023	0,0738	8.108,797	2.593,774	273,004	< .001
	attention	< .001*	0,3170		0,2821	0,3519	8.108,797	2.593,774	273,004	< .001
predictor + confounder + interaction	writing	.042	0,0372		0,0014	0,0730	8.109,194	2.592,395	1,379	.240
	attention	< .001*	0,3228		0,2868	0,3588	8.109,194	2.592,395	1,379	.240
	interaction	.206	0,0214		-0,0118	0,0546	8.109,194	2.592,395	1,379	.240
predictor only	writing	< .001*	-0,0639		-0,0995	-0,0282	8.408,423	2.866,778	11,711	< .001
predictor + confounder	writing	.428	-0,0143	78%	-0,0496	0,0211	8.228,505	2.698,865	167,913	< .001
	hyperact.	< .001*	0,2410		0,2065	0,2755	8.228,505	2.698,865	167,913	< .001
predictor + confounder + interaction	writing	.433	-0,0142		-0,0495	0,0212	8.229,778	2.698,214	0,651	.420
	hyperact.	< .001*	0,2466		0,2098	0,2835	8.229,778	2.698,214	0,651	.420
	interaction	.394	0,0149		-0,0194	0,0492	8.229,778	2.698,214	0,651	.420
predictor only	writing	< .001*	-0,0639		-0,0995	-0,0282	8.408,423	2.866,778	11,711	< .001
predictor + confounder	writing	.016	-0,0434	32%	-0,0785	-0,0082	8.286,877	2.751,643	115,135	< .001
	impulsivity	< .001*	0,1965		0,1622	0,2308	8.286,877	2.751,643	115,135	< .001
predictor + confounder + interaction	writing	.017	-0,0430		-0,0782	-0,0078	8.288,193	2.751,019	0,624	.430
	impulsivity	< .001*	0,1947		0,1601	0,2293	8.288,193	2.751,019	0,624	.430
	interaction	.409	-0,0145		-0,0489	0,0199	8.288,193	2.751,019	0,624	.430

Notes. * significant after FDR correction; AIC = Akaike information criterion; diff. = difference; ; hyperact. = hyperactivity.

Table 5

Results of the Regression Analyses for Predicting Symptoms of Conduct Disorder on the Basis of Writing/Math Achievement, Attention, Hyperactivity, and Impulsivity Symptoms.

model		**model parameters**					**model comparisons**			
	predictor	***p***	***estimate***	***estimate change***	***95% CI (low)***	***95% CI (high)***	***AIC***	***deviance***	***deviance diff.***	***p***
predictor only	writing	< .001*	-0,1415		-0,1760	-0,1071	8199,505	2674,796	57,533	< .001
predictor + confounder	writing	.840	0,0033	102%	-0,0290	0,0357	7505,307	2123,117	551,680	< .001
	attention	< .001*	0,4507		0,4191	0,4823	7505,307	2123,117	551,680	< .001
predictor + confounder + interaction	writing	.890	0,0023		-0,0301	0,0347	7504,541	2121,169	1,948	.163
	attention	< .001*	0,4575		0,4249	0,4901	7504,541	2121,169	1,948	.163
	interaction	.097	0,0255		-0,0046	0,0555	7504,541	2121,169	1,948	.163
predictor only	writing	< .001*	-0,1415		-0,1760	-0,1071	8.199,505	2.674,796	57,533	< .001
predictor + confounder	writing	< .001*	-0,0567	60%	-0,0885	-0,0249	7.588,647	2.182,642	492,155	< .001
	hyperact.	< .001*	0,4126		0,3815	0,4436	7.588,647	2.182,642	492,155	< .001
predictor + confounder + interaction	writing	< .001*	-0,0560		-0,0877	-0,0244	7.569,670	2.167,504	15,137	< .001
	hyperact.	< .001*	0,4397		0,4067	0,4727	7.569,670	2.167,504	15,137	< .001
	interaction	< .001*	0,0719		0,0412	0,1027	7.569,670	2.167,504	15,137	< .001
predictor only	writing	< .001*	-0,1415		-0,1760	-0,1071	8.199,505	2.674,796	57,533	< .001
predictor + confounder	writing	< .001*	-0,0926	35%	-0,1227	-0,0625	7.352,100	2.017,892	656,905	< .001
	impulsivity	< .001*	0,4694		0,4400	0,4988	7.352,100	2.017,892	656,905	< .001
predictor + confounder + interaction	writing	< .001*	-0,0929		-0,1230	-0,0628	7.353,438	2.017,449	0,443	.506
	impulsivity	< .001*	0,4709		0,4413	0,5005	7.353,438	2.017,449	0,443	.506
	interaction	.416	0,0122		-0,0172	0,0417	7.353,438	2.017,449	0,443	.506

Table 5 (continued)

model		**model parameters**					**model comparisons**			
	predictor	***p***	***estimate***	***estimate change***	***95% CI (low)***	***95% CI (high)***	***AIC***	***deviance***	***deviance diff.***	***p***
predictor only	math	< .001*	-0,1409		-0,1753	-0,1065	8.189,119	2.670,154	57,055	< .001
predictor + confounder	math	.743	0,0054	104%	-0,0269	0,0378	7.495,926	2.119,652	550,502	< .001
	attention	< .001*	0,4510		0,4194	0,4826	7.495,926	2.119,652	550,502	< .001
predictor + confounder + interaction	math	.751	0,0052		-0,0271	0,0376	7.493,601	2.116,610	3,042	.081
	attention	< .001*	0,4602		0,4274	0,4929	7.493,601	2.116,610	3,042	.081
	interaction	.038	0,0315		0,0018	0,0613	7.493,601	2.116,610	3,042	.081
predictor only	math	< .001*	-0,1409		-0,1753	-0,1065	8.189,119	2.670,154	57,055	< .001
predictor + confounder	math	< .001*	-0,0806	43%	-0,1120	-0,0493	7.563,811	2.167,984	502,170	< .001
	hyperact.	< .001*	0,4125		0,3819	0,4431	7.563,811	2.167,984	502,170	< .001
predictor + confounder + interaction	math	< .001*	-0,0801		-0,1114	-0,0487	7.563,046	2.165,994	1,990	.158
	hyperact.	< .001*	0,4194		0,3878	0,4511	7.563,046	2.165,994	1,990	.158
	interaction	.097	0,0268		-0,0048	0,0583	7.563,046	2.165,994	1,990	.158
predictor only	math	< .001*	-0,1409		-0,1753	-0,1065	8.189,119	2.670,154	57,055	< .001
predictor + confounder	math	< .001*	-0,1096	22%	-0,1395	-0,0797	7.326,294	2.003,538	666,616	< .001
	impulsivity	< .001*	0,4715		0,4423	0,5007	7.326,294	2.003,538	666,616	< .001
predictor + confounder + interaction	math	< .001*	-0,1095		-0,1394	-0,0796	7.328,144	2.003,438	0,100	.752
	impulsivity	< .001*	0,4710		0,4417	0,5004	7.328,144	2.003,438	0,100	.752
	interaction	.699	-0,0060		-0,0362	0,0243	7.328,144	2.003,438	0,100	.752

Notes. * significant after FDR correction; AIC = Akaike information criterion; diff. = difference; hyperact. = hyperactivity.

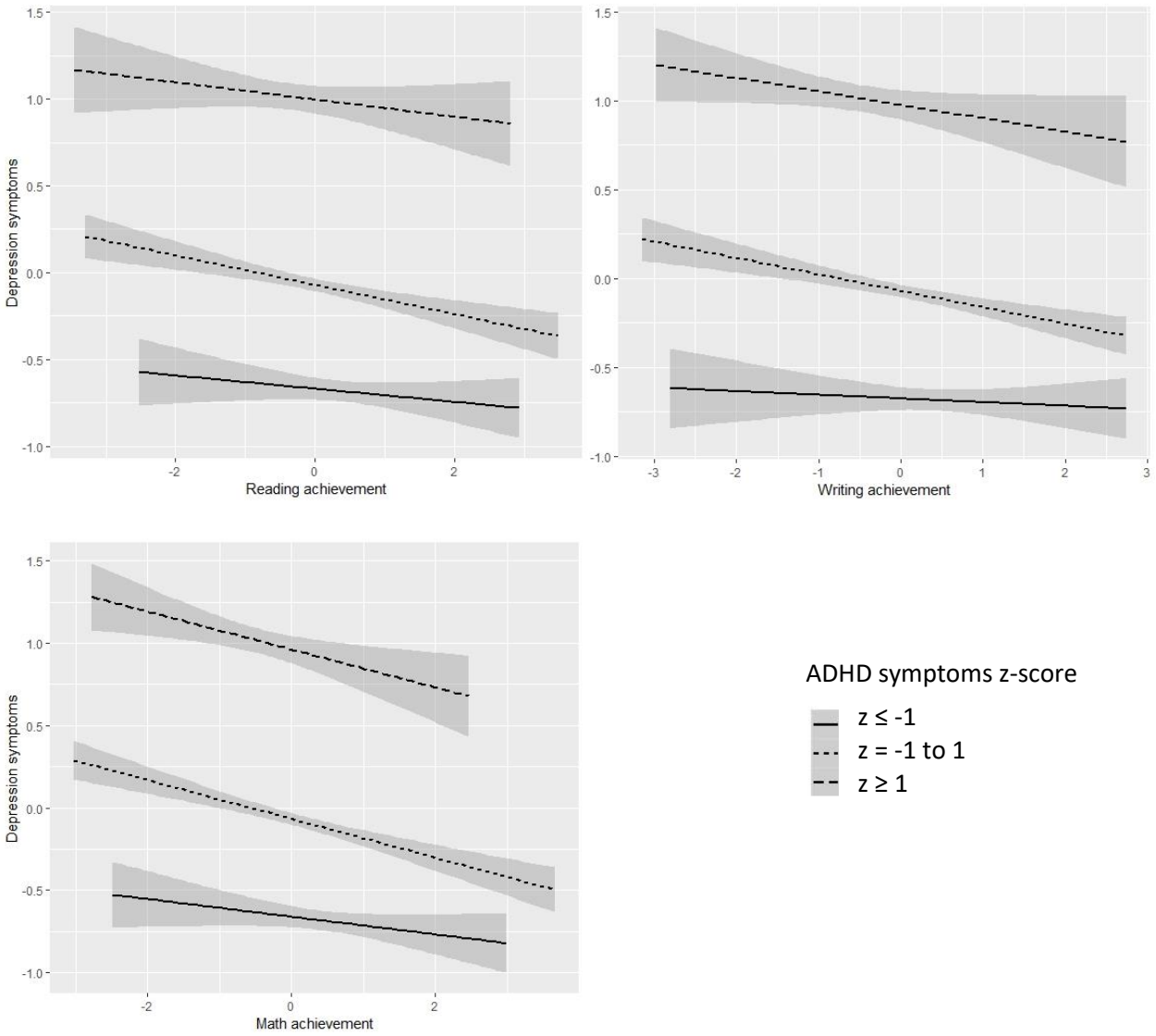

Figure 1. Interaction between reading / writing / math achievement and ADHD symptoms in predicting depression symptoms.