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The Journal of Child Psychology and Psychiatry

Journal of Child Psychology and Psychiatry **:* (2021), pp **–** doi:10.1111/jcpp.13556

A symptom level perspective on reactive and proactive aggressive behaviours and ADHD symptoms in childhood

Lydia Gabriela Speyer,[1,2] Manuel Eisner,[3,4] Denis Ribeaud,[4] Michelle Luciano,[1] Bonnie Auyeung,[1,5] and Aja Louise Murray[1]

[1]Department of Psychology, University of Edinburgh, Edinburgh, UK; [2]Department of Psychology, University of Cambridge, Cambridge, UK; [3]Violence Research Centre, Institute of Criminology, University of Cambridge, Cambridge, UK; [4]Jacobs Center for Productive Youth Development, University of Zurich, Zurich, Switzerland; [5]Autism Research Centre, Department of Psychiatry, University of Cambridge, Cambridge, UK

Objective: Attention-Deficit/Hyperactivity Disorder (ADHD) is one of the most prevalent childhood disorders, affecting around 3.4% of children worldwide. A common and impairing correlate of ADHD is aggressive behaviour. ADHD symptoms and aggression are both heterogeneous and it has been speculated that certain symptoms of ADHD might be more important in aggressive behaviours of different types than others. This study uses a symptom-level analysis to investigate the concurrent and temporal links between ADHD symptoms and aggressive behaviours. **Methods:** Using Gaussian Graphical Models and Graphical Vector Autoregression Models, longitudinal and cross-sectional networks of ADHD symptoms and aggressive behaviours, measured using parent-reported Social Behaviour Questionnaires, were estimated. Participants included 1,246 children taking part in the longitudinal Swiss z-proso cohort study at ages 7, 9 and 11. **Results:** The longitudinal network highlighted that ADHD symptoms and aggressive behaviours share a multitude of reciprocal temporal relations, with inattentive ADHD symptoms preceding both reactive and proactive aggression. Cross-sectional networks suggested that hyperactive/impulsive symptoms were predominantly connected to reactive aggressive behaviours but also to a form of proactive aggression, namely dominating other children. **Conclusion:** Findings provide preliminary evidence which specific symptoms are the most promising targets for reducing aggressive behaviours in children with ADHD. They also highlight the potential importance of targeting feedback loops resulting from aggressive behaviours. Future research is needed to better understand the mechanisms through which ADHD and aggressive behaviours become linked. **Keywords:** ADHD; reactive aggression; proactive aggression; longitudinal network modelling; z-proso.

Introduction

Attention-Deficit/Hyperactivity Disorder (ADHD) is one of the most prevalent childhood disorders, affecting around 3.4% of all children worldwide (Polanczyk, Salum, Sugaya, Caye, & Rohde, 2015) and as many as 23% at the sub-clinical level (Balázs & Keresztény, 2014). A common and impairing correlate of ADHD is aggressive behaviour, particularly affecting those with hyperactive/impulsive symptoms and with a severity that tends to track the number of ADHD symptom a child exhibits (Connor, Chartier, Preen, & Kaplan, 2010). It has been proposed to act as a major contributor to a range of negative outcomes associated with ADHD and often drives initial treatment referrals to health care practitioners (Connor & Doerfler, 2008; King & Waschbusch, 2010). This makes aggression a key treatment target in children affected by ADHD symptoms.

Aggression can be subtyped on the basis of its function into proactive and reactive aggression and this distinction may be important in the context of ADHD. Though proactive and reactive aggression are highly correlated suggesting shared bases, studies have suggested that they emerge as separate dimensions in factor analytic studies and show differential patterns of development (e.g. Babcock, Tharp, Sharp, Heppner, & Stanford, 2014; Cui, Colasante, Malti, Ribeaud, & Eisner, 2016; Murray, Obsuth, Zirk-Sadowski, Ribeaud, & Eisner, 2020; Raine et al., 2006). Proactive aggression refers to emotionally 'cold' aggression, that is goal-oriented, whereas reactive aggression refers to emotionally 'hot' aggression, that is impulsive and represents a reaction to stimuli such as a perceived threat or provocation (Dodge, 1991). In terms of where proactive and reactive aggression diverge in their aetiology, following social learning theory, proactive aggression has been hypothesised to develop when children learn that aggression may lead to positive rewards, for example, through interactions with or observing parents or peers. The continuing expectations of these positive rewards may then lead to the maintenance of proactive aggressive behaviours (Bennett, Pitale, Vora, & Rheingold, 2004; Slaughter, Leaberry, Fogleman, & Rosen, 2020). Reactive aggression, on the other hand, is hypothesised to be an emotion-driven behaviour. Individuals showing high levels of reactive aggressive behaviours commonly show a hostile attributional bias and have deficits in

Conflict of interest statement: No conflicts declared.

behavioural inhibition and emotion regulation with such deficits being amplified by emotional urgency (Bennett et al., 2004; Slaughter et al., 2020). Research on aggressive behaviours in children with ADHD has shown that they present with higher levels of both reactive and proactive aggression than their unaffected peers, with reactive aggression being the more strongly associated with ADHD (Bennett et al., 2004; Murray et al., 2020). The stronger co-occurrence of reactive aggression with ADHD has been hypothesised to be related to the fact that ADHD and reactive aggression likely share a common neurocognitive basis through deficits in impulse control and emotion regulation (Saylor & Amann, 2016; Slaughter et al., 2020). In contrast, proactive aggression has been suggested to be more indirectly linked to ADHD through processes such as peer deviancy training whereby children with ADHD symptoms are rejected by their normative peers and therefore socialise with anti-social peers, leading them to copy their aggressive behaviours (Bennett et al., 2004; Saylor & Amann, 2016).

Previous research into links between aggressive behaviours and ADHD has mostly focused on associations at the disorder level (e.g. Bennett et al., 2004; Hammad & Awed, 2016; Slaughter et al., 2020) with a few studies also examining differences within the various dimensions of ADHD symptomatology, that is, predominantly hyperactive/impulsive, predominantly inattentive or combined ADHD presentations (Connor et al., 2010; Evans & Fite, 2019). One study examining the differential relations of proactive/reactive aggression and different ADHD subtypes found that proactive aggression was only more prevalent in children with combined inattentive and hyperactive/impulsive ADHD compared to a control group without ADHD, while both the combined subtype and the inattentive subtype showed higher reactive aggression than controls (Connor et al., 2010). To date, however, no study has gone beyond domain level associations to investigate the links between proactive and reactive regression at the symptom level.

Symptom level analyses are critical for shedding light on specific symptoms that are most strongly associated with particular outcomes and which are therefore likely to be priority targets for intervention (Borsboom, 2017). In the context of links between ADHD and reactive/proactive aggression, symptom level analyses can, for instance, provide insights into whether symptoms relating to impulsivity are more strongly related to reactive aggression than proactive aggression, or whether symptoms relating to inattentiveness might share stronger associations with aggressive behaviours than symptoms of hyperactivity/impulsivity. This can offer valuable information to inform psychological interventions for children with ADHD that are better targeted towards an individual's risk for specific aggressive behaviours.

Another gap in the literature on ADHD and aggression relates to their longitudinal relations. Most studies have only investigated their associations cross-sectionally (e.g. Bennett et al., 2004; Evans, Fite, Hendrickson, Rubens, & Mages, 2015; Slaughter et al., 2020). While previous research has established that trajectories of aggressive behaviours closely follow ADHD trajectories, with reactive aggression trajectories following ADHD trajectories more closely than proactive aggression trajectories (Murray et al., 2020), little is known about how the developmental interrelations between ADHD symptoms and proactive and reactive aggression unfold over time. In particular, it is not yet known whether specific ADHD symptoms precede increased aggressive behaviour or whether certain aggressive behaviours might be early indicators of ADHD symptomatology, particularly at the within-person level. The focus on the within-person level is crucial because only if associations between ADHD symptoms and aggression reflect developmental processes occurring *within* children over time (as opposed to reflecting confounding due to stable between-person differences) should we have good reason to expect that interventions targeting those symptoms would lead to improvements within individuals on downstream symptoms (Hamaker, Kuiper, & Grasman, 2015). Indeed, understanding within-person relations between aggressive behaviours and ADHD symptoms is clinically important given that interventions aiming to reduce aggressive behaviours are targeted at the within-person level. If an individual is liable to develop aggressive behaviours as a result of ADHD symptoms (or vice versa), then important intervention targets lie in the pathways that link these two domains. As such, being informed about which specific symptoms engender risk for specific others will be highly informative for research focusing on identifying potential pathways that can be targeted in interventions. For instance, knowledge of whether certain hyperactive symptoms are likely to lead to the development of future aggressive behaviours could increase the efficacy and efficiency of interventions. These interventions, such as classroom behavioural interventions or parenting training, can place greater emphasis on targeting these specific antecedent symptoms over those that do not show evidence of downstream effects. This knowledge may also benefit the earlier and more accurate identification of children most at risk of developing secondary problems based on their symptom patterns, facilitating early preventive intervention.

In the current study, we map symptoms of hyperactivity/impulsivity and inattention onto reactive and proactive aggressive behaviours in a large community-based study of $N = 1{,}246$ children to investigate whether specific ADHD symptoms are particularly strongly connected to specific aggressive behaviours longitudinally as well as concurrently (ages 7, 9 and 11). Based on previous research, we

hypothesised that hyperactive/impulsive symptoms, such as acting without thinking and fidgeting, would be more strongly connected to reactive aggressive behaviours than inattentive symptoms would be. For proactive aggression, previous literature has proposed both direct links with ADHD as well as indirect links through reactive aggression and associated peer problems. However, the evidence for such links is mixed, thus we took an exploratory approach to studying the relations between proactive aggressive behaviours and ADHD symptoms.

Methods

Participants

Participants in this study were children taking part in the Zurich Project on the Social Development from Childhood to Adulthood (z-proso) at (median) ages 7, 9 and 11 (51% male). Z-proso is a Swiss longitudinal cohort study that has been following children's development across 10 measurement waves from primary school entry in 2004 at age 7 up until age 20 with data collection ongoing. Children were recruited based on a stratified sampling procedure selecting 56 schools based on location and school size to ensure representativeness in terms of area-based deprivation. Participants were from ethnically and culturally diverse backgrounds, with less than 50% of caregivers having been born in Switzerland. Thus, in order to recruit and retain as many of the parents whose first language was not German (the official language of the study site), contact letters and parent interviews were translated into an additional nine languages. At the first wave of data collection, 1,239 parents provided information on their children's development. Of these, 4.5% dropped out before the second wave (N = 1,192) with a further 2.0% lost to attrition in the third wave (N = 1,180). A number of families entered the study after the first wave, resulting in a final sample of 1,246 children that had data available at least at one wave. Previous analyses of attrition in z-proso have found that dropout was related to primary caregivers speaking a minority language but not to children's behaviour after adjustment for multiple comparisons (Eisner, Murray, Eisner, & Ribeaud, 2019). Sample demographics are presented in Table S1. While information on clinical diagnosis of ADHD was not collected in z-proso, self-reports on medication use suggested that around 5% of participants may have taken medications typically prescribed for the treatment of ADHD symptoms (Murray et al., 2018). For further details on recruitment, assessment procedures, retention and attrition, see the relevant literature (Eisner & Ribeaud, 2005, 2007; Eisner et al., 2019; Ribeaud, Murray, Shanahan, Shanahan, & Eisner, 2021) and the z-proso website (https://www.jacobscenter.uzh.ch/en/research/zproso/aboutus.html).

Ethical considerations

Ethical approval for the z-proso study was obtained from the Ethics Committee from the Faculty of Arts and Social Sciences of the University of Zurich. Up until age 12, active informed consent for participating in the study was obtained via the participants' parents.

Measures

The ADHD symptoms and aggressive behaviours were measured using an adapted version of the Social Behavior Questionnaire (SBQ) (Tremblay et al., 1991). Parents completed the SBQ via a computer assisted personal interview when children were (median-) aged 7, 9 and 11. The SBQ measures children's psycho-social development in five domains: ADHD symptoms, aggression, anxiety/depression, non-aggressive conduct problems, and prosocial behaviour. The SBQ has been shown to reliably distinguish moderately low to very high levels of psychopathology in community samples and has shown developmental invariance, as well as factorial and criterion validity in the current sample (Murray, Eisner, Obsuth, & Ribeaud, 2017; Murray, Eisner, & Ribeaud, 2019). SBQs administered to parents in the z-proso study included five items relating to symptoms of inattentiveness, four items relating to symptoms of hyperactivity/impulsivity, four items relating to proactive aggressive behaviour and three items relating to reactive aggressive behaviours. All items were rated on a five-point Likert scale from *Never* to *Very Often* with higher scores indicating more problem behaviours. For English phrasings of the administered items and descriptive statistics, see Tables S2 and S3.

Statistical analysis

To analyse the longitudinal relations between aggressive behaviours and ADHD symptoms, a multilevel Graphical Vector Autoregression (GVAR) model was built using the R package *psychonetrics* (Epskamp, 2020). Multilevel GVAR models enable the modelling of temporal and concurrent relations between multiple repeatedly measured variables while accounting for between-person differences through also estimating cross-sectional between-person differences (Epskamp, 2020). These different levels of the data structure (within-person temporal effects, within-person concurrent effects and between-person effects) can be visualised using Gaussian Graphical Models (GGMs). In GGMs, the dependence structures between multiple variables are visualised in the form of a partial correlation network. These networks are made up of nodes, representing individual variables connected through undirected or directed edges (encoding directional effects over time), representing the relations between variables (Epskamp, Waldorp, Mõttus, & Borsboom, 2018). If two variables are not connected by an edge, they are conditionally independent, that is, any relation between them is due to their common relation with other variables in the model. Edge weights (ω) quantify the strength of these relations in the form of partial correlations. Prior to building the GVAR model, data were detrended for age-related effects and standardised across time points to satisfy the stationarity assumption of GVAR models. For the present analysis, this was considered appropriate since only the correlational structure – and not the mean structure – was of interest. Missing data were accounted for using Full Information Maximum Likelihood (FIML) estimation which, under the assumption that the data is missing at random, provides unbiased estimates. To minimise the risk of over-fitting and to control model complexity, the GVAR model was regularised using Bayesian Information Criterion (BIC) as the model selection criterion. Model fit was judged to be acceptable if Comparative Fit Index (CFI) was >.90, Tucker Lewis Index (TLI) >0.90 and Root Mean Square Error of Approximation (RMSEA) <.05 (Kline, 2005). Networks were visualised using the R package *qgraph* (Epskamp, Cramer, Waldorp, Schmittmann, & Borsboom, 2012) which uses the Fruchterman–Reingold algorithm to place nodes that share stronger connections closer together. To identify the symptoms that may be most likely to lead to the development of difficulties in another area of psychosocial functioning (i.e. bridge symptoms), we further estimated bridge influence indices using the R package *networktools* (Jones, Ma, & McNally, 2021). Finally, we estimated a series of cross-sectional models to complement the results of our longitudinal analysis using the R package *EGAnet* (Golino & Epskamp, 2017). This employs a community detection algorithm to identify clusters of symptoms that share the strongest

relations. For additional details regarding the estimation of cross-sectional networks, see the Appendix S1.

Results

Longitudinal network analyses

The regularised longitudinal GVAR model showed good fit (*CFI* = .92; *TLI* = 0.92; *RMSEA* = 0.035, 90% *CI*: .034 to .037) and an improvement over the saturated GVAR model (Δ*BIC* = 1963.81; *CFI* = .94, *TLI* = 0.90; *RMSEA* = .040, 90% *CI*: .038 to .042). In this model (see Figure 1), aggressive behaviours and ADHD symptoms shared relatively strong temporal connections within their respective broad domains. ADHD symptoms were also linked to a number of aggressive behaviours. In particular, *child has difficulty awaiting turn in games or groups*, *child cannot concentrate, cannot pay attention for long*, *child is inattentive* and *child gives up easily* were positively associated with proactive and reactive aggressive behaviours over time. All proactive aggressive behaviour items as well as *child reacts in an aggressive manner when something was taken* were further associated with higher ADHD symptoms over time. According to bridge influence indices (presented in full in the Tables S4 and S5), *child is inattentive* had the strongest direct and indirect influence on aggressive behaviours whereas *child encourages other children to pick on a particular child* had the strongest influence on ADHD symptoms.

The within-person concurrent effects network suggested that ADHD and aggressive symptoms were associated within time points (see Figure 2). Bridge influence indices suggested that the ADHD item *child is inattentive* shared the strongest direct and indirect associations with aggressive behaviours while *child encourages other children to pick on a particular child* shared the strongest direct and indirect associations with ADHD symptoms.

Finally, the between person network highlighted that children who are high on inattentive ADHD symptoms are also high on aggressive behaviours. In particular these children are more likely to *react in an aggressive manner when being teased* and to *encourage other children to pick on a particular child* compared to children who are low on inattentive ADHD symptoms (see Figure 3).

Cross-sectional network analyses

Cross-sectional networks also indicated that aggressive behaviours and ADHD symptoms share a

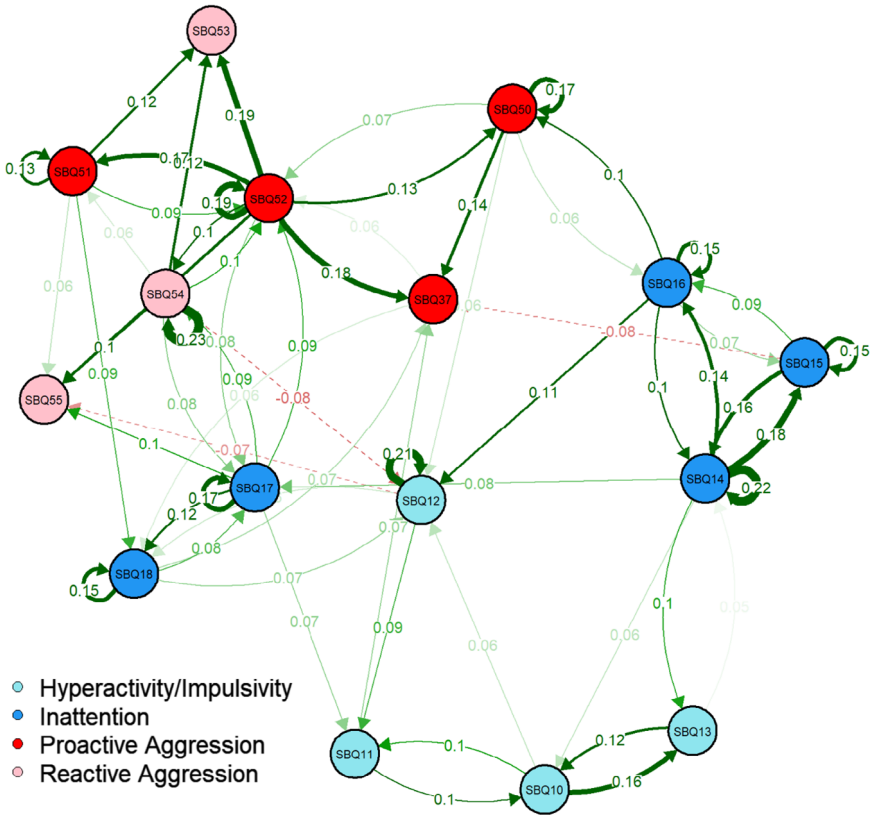

Figure 1 Temporal network for ADHD symptoms and aggressive behaviours standardised to directed partial correlations. Green edges (solid lines) indicate positive effects; red edges (dashed) indicate negative effects. Edge widths are indicative of the strength of association with wider edges representing stronger effects. SBQ10: *impulsive*, SBQ11: *difficulty awaiting turns*, SBQ12: *restless*, SBQ13: *fidgets*, SBQ14: *cannot settle to anything*, SBQ15: *distractible*, SBQ16: *cannot concentrate*, SBQ17: *inattentive*; SBQ18: *gives up easily*; SBQ37: *threatens people*; SBQ50: *encourages other children to pick on a particular child*; SBQ51: *tries to dominate other kids*; SBQ52: *scares others for own benefit*; SBQ53: *aggressive when teased*; SBQ54: *aggressive when something is taken*; SBQ55: *aggressive when contradicted*

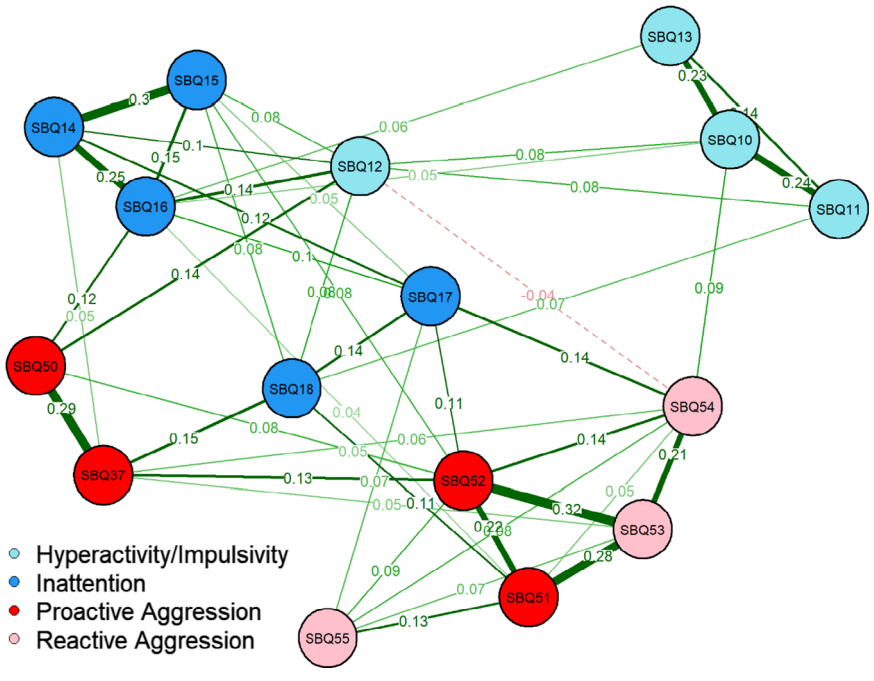

Figure 2 Contemporaneous within-person network for parent-reported symptoms standardised to partial correlations. Green edges (solid lines) indicate positive effects. Red edges (dashed lines) indicate negative effects. Edge widths are indicative of the strength of association with wider edges representing stronger effects. SBQ10: *impulsive*, SBQ11: *difficulty awaiting turns*, SBQ12: *restless*, SBQ13: *fidgets*, SBQ14: *cannot settle to anything*, SBQ15: *distractible*, SBQ16: *cannot concentrate*, SBQ17: *inattentive*; SBQ18: *gives up easily*; SBQ37: *threatens people*; SBQ50: *encourages other children to pick on a particular child*; SBQ51: *tries to dominate other kids*; SBQ52: *scares others for own benefit*; SBQ53: *aggressive when teased*; SBQ54: *aggressive when something is taken*; SBQ55: *aggressive when contradicted*

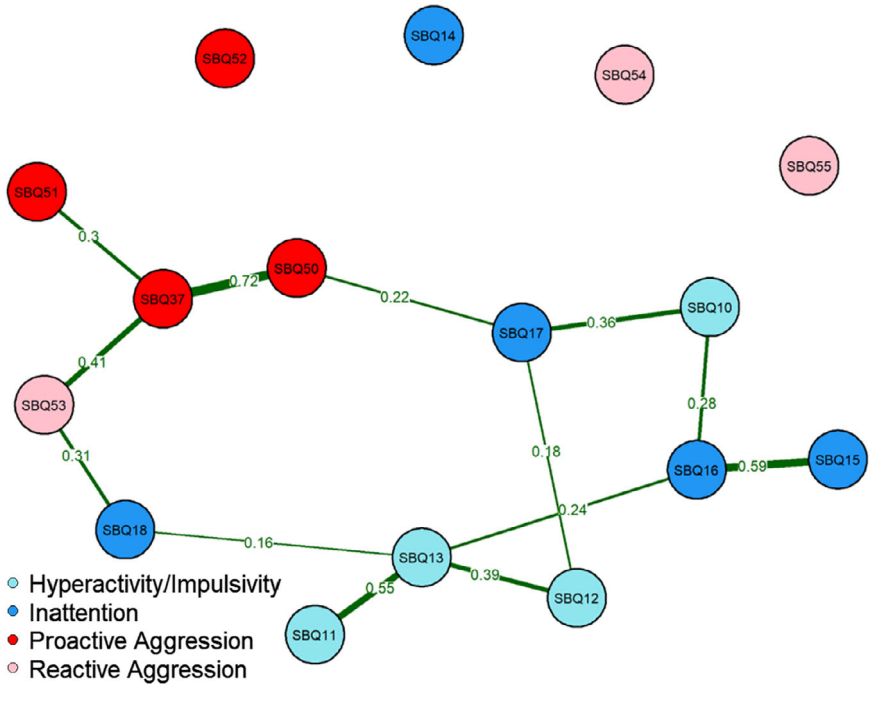

Figure 3 Between-person network for parent-reported symptoms standardised to partial correlations. Green edges (solid lines) indicate positive effects. Edge widths are indicative of the strength of association with wider edges representing stronger effects. SBQ10: *impulsive*, SBQ11: *difficulty awaiting turns*, SBQ12: *restless*, SBQ13: *fidgets*, SBQ14: *cannot settle to anything*, SBQ15: *distractible*, SBQ16: *cannot concentrate*, SBQ17: *inattentive*; SBQ18: *gives up easily*; SBQ37: *threatens people*; SBQ50: *encourages other children to pick on a particular child*; SBQ51: *tries to dominate other kids*; SBQ52: *scares others for own benefit*; SBQ53: *aggressive when teased*; SBQ54: *aggressive when something is taken*; SBQ55: *aggressive when contradicted*

multitude of relations. Hyperactive/impulsive symptoms were connected to predominantly reactive aggressive behaviours but also to a form of proactive aggression, namely *dominating other children*. Bridge influence indices indicated that, at age 7 and 9, the item *child is impulsive, acts without thinking* and at

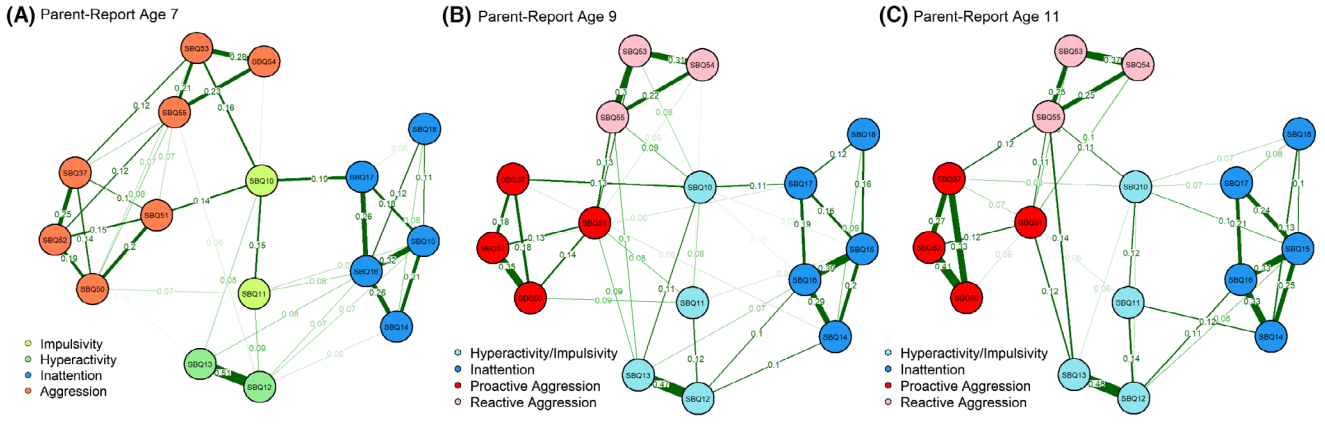

Figure 4 Cross-sectional partial correlation networks for ADHD symptoms and aggressive behaviours at ages (A) 7, (B) 9, and (C) 11. Green edges (solid lines) indicate positive effects. Edge widths are indicative of the strength of association with wider edges representing stronger effects. For better interpretability, edges smaller than .05 are not visualised. To facilitate comparisons, the network layout was kept constant based on the average layout of all cross-sectional networks. SBQ10: *impulsive*, SBQ11: *difficulty awaiting turns*, SBQ12: *restless*, SBQ13: *fidgets*, SBQ14: *cannot settle to anything*, SBQ15: *distractible*, SBQ16: *cannot concentrate*, SBQ17: *inattentive*; SBQ18: *gives up easily*; SBQ37: *threatens people*; SBQ50: *encourages other children to pick on a particular child*; SBQ51: *tries to dominate other kids*; SBQ52: *scares others for own benefit*; SBQ53: *aggressive when teased*; SBQ54: *aggressive when something is taken*; SBQ55: *aggressive when contradicted*

age 11 *child cannot sit still, is restless, or hyperactive* shared the strongest direct and indirect associations with aggressive behaviours. Results of the community detection algorithm indicated that, at ages 9 and 11, proactive and reactive aggressive behaviours formed relatively distinct sub-clusters within an overall aggressive behaviours cluster, whereas ADHD symptoms also clustered together, with inattentive symptoms being more closely connected to other inattentive symptoms than to hyperactive/impulsive symptoms (see Figure 4). At age 7, hyperactive/impulsive symptoms did not cluster as closely together but formed two separate sub-clusters whereas proactive and reactive aggressive behaviours only formed one general aggressive behaviour cluster.

Discussion

The aim of the current study was to gain insights into whether certain ADHD symptoms are particularly closely related to aggressive behaviours and would thus represent priority targets for the prevention of this common and impairing correlate of ADHD. We also explored possible reciprocal relations between ADHD and aggressive symptom domains. A key finding was that in longitudinal networks, inattentive symptoms shared reciprocal relations with both reactive and proactive aggression, highlighting that inattentive symptoms may play a central role in and may in fact be exacerbated by engagement in aggression.

Results of our cross-sectional models were mostly in line with previous literature, suggesting that hyperactive/impulsive symptoms are more strongly related to aggressive behaviours than inattentive symptoms (Connor et al., 2010). However, hyperactivity and impulsivity items did not cluster as closely as would be expected based on previous network analytic studies (Martel, Levinson, Langer, & Nigg, 2016), particularly at age 7. This could be because of the inclusion of a different set of symptoms or due to differences in participant characteristics. For example, Martel et al.'s study (2016) included a substantial number of children with a diagnosis of ADHD (~55%), which would have led to an over-representation of children with co-occurring symptoms relative to our purely community-ascertained sample.

In contrast, results of the longitudinal network analysis indicated that on the within-person contemporaneous as well as on the temporal level, inattentive symptoms were directly associated with higher aggressive behaviours whereas hyperactive/impulsive symptoms were only indirectly linked, thus, suggesting that associations between aggressive behaviours and hyperactive/impulsive symptoms can potentially be explained through shared relations with inattentive symptoms with such symptoms also playing an important role in the development of aggressive behaviours. This is in contrast to previous research which has suggested that hyperactive/impulsive symptoms and underlying deficits in emotion regulation are the driving factors for the high co-occurrence of ADHD and aggressive behaviours (e.g. Slaughter et al., 2020). This discrepancy illustrates the potential value of disaggregating within and between effects to better uncover the within-person processes that are likely to be the most fruitful targets for intervention.

One possible reason for these discrepant findings is that during the observed developmental period (i.e. the primary school years), inattentive symptoms are likely to play a relatively central role in ADHD presentations. Inattentive symptoms often only

become noticeable as children begin to struggle to fulfil the demands of school work due to attention deficits (Cherkasova, Sulla, Dalena, Pondé, & Hechtman, 2013) whereas hyperactive/impulsive symptoms tend to be most prominent during the preschool years and decline during the school years (Döpfner, Hautmann, Görtz-Dorten, Klasen, & Ravens-Sieberer, 2015; Miller, Loya, & Hinshaw, 2013). Inattentive behaviours, on the other hand, are less likely to decline (Murray et al., 2020). Alternatively, it may be that these findings are due to the included items on hyperactivity/impulsivity not capturing the whole spectrum of hyperactive/impulsive ADHD symptoms. It may be that the inclusion of additional hyperactive/impulsive symptoms would have led to different findings regarding the strength of their associations with aggressive behaviours.

In terms of mechanisms, social information processing differences may explain the links between inattention and aggression (King & Waschbusch, 2010). Difficulties in attention could, for example, lead children with ADHD to miss key social cues (e.g. that their behaviour is irritating a playmate), thus potentially leading to more instances where situations escalate to the point of an aggressive incident (Hammad & Awed, 2016). Alternatively, children with ADHD might successfully attend to social cues but then fail to encode them, undermining their ability to respond in a socially appropriate way (Andrade et al., 2012). In fact, our longitudinal models suggested that aggression can increase ADHD symptoms over time. This could reflect the operation of a vicious cycle whereby peer problems resulting from difficulties in social information processing lead to increased worries that consume attentional resources, exacerbating difficulties attending to/encoding social cues in the future. These feedback loops may represent particularly important targets for interventions.

While our longitudinal within-person findings suggested that inattention was related to both reactive and proactive aggression, these links may have different mechanisms. For example, while self-regulation difficulties may explain links with reactive aggression, the links with proactive aggression may be better explained by a tendency among children with ADHD to use aggression as an instrument to attain a desired goal that is more difficult to achieve using socially acceptable strategies requiring delay tolerance and sustained attention (Cherkasova et al., 2013). Similarly, since children with ADHD are more likely to be rejected by their peers, they may resort to dominance-type strategies to attain social status (e.g. Wehmeier, Schacht, & Barkley, 2010). It is thus possible that the apparent direct links observed in the current study are actually missing further unmeasured mediators such as peer problems. Future research will be valuable to examine these pathways.

Findings of the current study also have potential clinical implications. Knowing which symptoms are most likely to lead to development of other problem behaviours may improve the identification of children most at risk of developing secondary difficulties. In particular, our results highlight that inattentive symptoms may increase the risk of engaging in aggressive behaviours, thus, children showing these difficulties may need particular attention when it comes to behavioural management at home or in the classroom. Further, targeting such symptoms might also increase the efficacy of interventions as they can be better hone in on the most relevant symptoms. Future research is needed to investigate whether the connections between ADHD symptoms and aggressive behaviours, and particularly feedback loops, can be effectively interrupted by pharmacological or psychological interventions, such as behavioural classroom management or behavioural parent training.

Future research is also needed to overcome the main limitations of the current study. First, we relied on a small number of symptoms. Ideally, future studies should include the full span of ADHD symptoms referred to in the DSM 5 (American Psychiatric Association, 2013) as well as commonly associated features. Second, due to limited statistical power, we were unable to investigate whether symptom networks might unfold differently in different genders. This would be valuable to explore in future research since previous research has highlighted gender differences in the co-occurrence between ADHD symptoms and aggressive behaviours (Levy, Hay, Bennett, & McStephen, 2005). Third, the current study relied on a community sample that mostly showed ADHD symptoms and aggressive behaviours within the normal range. This has some advantages, such as reducing the risk for overestimation of symptom co-occurrence (Berkson, 1946); however, it will be necessary for future studies to investigate whether the observed symptom-level relations would show different associations in children with clinically significant difficulties. Fourth, some of the included items were not normally distributed. Considering that temporal networks may be sensitive to normality violations (Epskamp et al., 2018), this may have impacted our results. Finally, the time intervals between measurement points in the current study spanned 2 years and thus studies should investigate shorter-term relations by assessing ADHD symptoms, aggressive behaviours (and candidate mediators) multiple times a year. In addition, short-term relations could be investigated using methods such as ecological momentary assessment to provide insights into the day-to-day dynamics that might result in aggressive behaviours (Murray, Lavoie, Booth, Eisner, & Ribeaud, 2021; Slaughter et al., 2020).

Conclusion

Numerous links can be observed between different ADHD symptoms and types of aggression; however, of particular note, inattentiveness symptoms are associated with increases in proactive and reactive aggression over time and may in fact be exacerbated by engagement in aggression. Future research is needed to better understand the mechanisms through which ADHD and aggressive behaviours become linked.

Supporting information

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

Table S1. Sample demographic information at baseline (age 7).
Table S2. ADHD and Aggressive Behaviours Items.
Table S3. Descriptive Statistics - ADHD and Aggressive Behaviours Items.
Table S4. Bridge Influence Indices for Cross-Sectional Networks.
Tables S5. Bridge Influence Indices for Longitudinal Networks.
Appendix S1. Statistical Analysis: Cross-sectional Models.

Acknowledgements

The authors are grateful to the children, parents and teachers who provided data for the z-proso study and the research assistants involved in its collection. The Zurich Project on Social Development from Childhood to Adulthood is supported by the Jacobs Foundation and the Swiss National Science Foundation. This work was further supported by the University of Edinburgh (L.G.S., Principal's Careers Development Scholarship); the European Union's Horizon 2020 research and innovation programme (B.A., Marie Skłodowska-Curie grant agreement No.813546); the Baily Thomas Charitable Fund (B.A., TRUST/VC/AC/SG/469207686); the UK Economic and Social Research Council (B.A., ES/N018877/1) and the Data Driven Innovation Initiative (B.A.). The authors have declared that they have no competing or potential conflicts of interest.

Ethical approval

The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

Data availability statement

Data and code available upon request.

Correspondence

Lydia Gabriela Speyer, Department of Psychology, University of Cambridge, Downing Site, Cambridge, CB2 3EA, United Kingdom; Email: ls945@cam.ac.uk

Key points

- Previous research has highlighted that ADHD commonly co-occurs with aggressive behaviours.
- ADHD symptoms and aggression are both heterogeneous and it has been speculated that certain symptoms of ADHD might map more closely to certain types of aggressive behaviour.
- Using a longitudinal symptom-level analysis, ADHD symptoms and aggressive behaviours were found to share a multitude of reciprocal temporal relations, with inattentive ADHD symptoms preceding both reactive and proactive aggressive behaviours.
- Findings highlight the importance of targeting inattentive symptoms in order to reduce aggressive behaviours in children with ADHD.
- Future research is needed to better understand the mechanisms through which ADHD and aggressive behaviours become linked.

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Accepted for publication: 10 November 2021