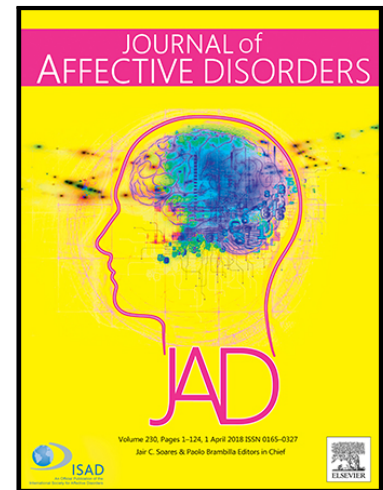


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An ecological momentary assessment study of the role of emotional dysregulation in co-occurring ADHD and internalising symptoms in adulthood

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Highlights

- Internalising problems and emotional dysregulation (ED) are common in ADHD
- We collected affect four times a day for two weeks to estimate ED
- ED mediated the association between ADHD symptoms and internalising problems

Abstract

Previous ecological momentary assessment (EMA) research in children has suggested that emotional dysregulation problems are commonly associated with ADHD symptoms and may help explain their relatively strong co-occurrence with anxiety and depression (collectively referred to as 'internalising problems'); however, this has yet to be replicated for adults. In

this study, we used data from a n=260 longitudinal cohort and EMA study, to evaluate the hypothesis that emotional dysregulation mediates the association between ADHD symptoms and internalising problems in emerging adulthood. Emotional dysregulation was based on affect data collected in near real time and in ecological context over a 14-day period, providing a measure of emotional lability in the context of participants' daily lives. Cross-sectional mediation was tested using structural equation modelling. Emotional lability significantly mediated the association between ADHD symptoms and internalising problems. Results suggest that interventions that address the emotional dysregulation aspects of ADHD are likely to be beneficial for preventing and managing secondary internalising symptoms.

Keywords: attention-deficit/hyperactivity disorder; emotional dysregulation; depression; anxiety; internalising problems; ecological momentary assessment

Emotional lability, defined as sudden and marked shifts in emotion that are inappropriate to setting and/or developmental stage, is recognised as a common associated feature of ADHD symptoms (Posner et al., 2014; Shaw et al., 2015). It is assumed to reflect emotional dysregulation problems and has been proposed to play a significant role in many of the difficulties associated with ADHD in childhood, including anxiety and depression ; collectively referred to as internalising symptoms (Anastopoulos et al., 2011; Rosen & Factor, 2015). However, despite the fact that ADHD symptoms and their sequelae remain common in adulthood (Kessler et al., 2006; Simon et al., 2009), less is known about the role of emotional lability in co-occurring internalising symptoms during this developmental phase, with studies investigating its role using emotion data collected in the context of daily life particularly lacking. In this study, we use data from the community-ascertained n=260 D2M study (an ecological momentary assessment sub-study of the Zurich Project on Social Development from Childhood to Adulthood; z-proso) to evaluate whether emotional dysregulation, as indicated by higher levels of emotional lability, mediates the association between ADHD symptoms and a common sequela, namely internalising problems in emerging adulthood.

Emotional dysregulation is commonly associated with ADHD symptoms in childhood. Estimates vary but suggest that approximately 25% children with ADHD show severe emotional dysregulation, and another 50% show moderate emotional dysregulation problems (Shaw et al., 2015; Sobanski et al., 2010). Such is its prevalence in individuals with ADHD that there have been ongoing debates concerning whether emotional dysregulation should be considered a core rather than associated feature of the disorder (Faraone et al., 2019; Caroline Skirrow & Asherson, 2013). While it previously served as a marker for ADHD

in older editions of the Diagnostic and Statistical Manual of Mental Disorders (DSM), in the most recent editions, only behavioral dysregulation is recognised as a core feature of ADHD (American Psychiatric Association, 2013).

The significance of emotional dysregulation in ADHD is also in its proposed role in many of the behavioural, emotional and psychosocial sequelae of ADHD, including internalising problems (Anastopoulos et al., 2011; Rosen & Factor, 2015). Both anxiety and depression are frequently associated with ADHD symptoms (Angold et al., 1999; Biederman et al., 2008; Jarrett & Ollendick, 2008; Schatz & Rostain, 2006). A commonly advanced explanation is that the psychosocial problems associated with ADHD, such as peer victimisation/rejection and academic/occupational failures undermine self-esteem and increase the risk of developing anxiety and/or depression (Roy et al., 2015; Schatz & Rostain, 2006; Yip et al., 2013). However, there is preliminary evidence that issues with emotional regulation also play an important role in co-occurring internalising problems (Anastopoulos et al., 2011; Leaberry et al., 2017; Rosen & Factor, 2015).

Numerous measures have been developed to assess emotional dysregulation (e.g., see Faraone et al., 2019 for a review); however, those that capture emotional dysregulation in the context of daily life (e.g., Helfer et al., 2019) are especially valuable in illuminating its role in internalising problems. In particular, ecological momentary assessment (EMA) studies can provide measures of emotional functioning in the context of real life and 'in the moment', that are more ecologically valid and that are considerably less vulnerable to issues such as recall bias that commonly affect questionnaire measures (e.g., Bolger & Laurenceau, 2013). Ecological momentary assessment studies involve administering small sets of items frequently (e.g., 3-10 times a day over several days or weeks), often via participants' own

smartphones, in order to capture momentary affective states, cognitions, behaviours, and experiences as they occur in a real-life context. There is a growing literature on using EMA methodologies to measure manifestations of emotional dysregulation; however, their application in ADHD research has been relatively limited (Miguel-Fernandez et al., 2018). Only a handful of studies have employed this methodology to evaluate its role in internalising symptoms associated with ADHD symptoms (Rosen et al., 2013, 2015) and all studies to date have explored these links in child samples.

Leaberry et al. (2017) used EMA to evaluate the relations between emotional lability and comorbid internalising problems in $n=58$ 8-12 year olds. They found that participants with ADHD and a comorbid internalising disorder showed more EMA-derived emotional lability than those with ADHD alone. However, Rosen et al., (2015), in a sample of $n=102$ 8-12 year olds ($n=56$ with ADHD) found that emotional lability was associated with internalising problems but not directly with ADHD diagnostic status. In another study, in a sample of $n=27$ 8-12 year-olds with ADHD, Rosen and Factor (2015) found that EMA-derived emotional impulsivity was correlated with internalising problems at $r=.54$ ($p<.001$) based on parent reports. Thus, further work is required to clarify the role of emotional lability in the relation between ADHD and internalising symptoms. Furthermore, given the risk of Berkson's bias (i.e., the over-estimation of symptom co-occurrence) in clinical samples (e.g., Pearce & Richiardi, 2014), studies utilising community-ascertained samples will be an important complement to the clinically diagnosed studies used in previous studies. Finally, although there have been informative EMA studies of emotion dysregulation in adults (Skirrow et al., 2014), none have yet addressed its role in co-occurring internalising problems. Internalising problems remain a common issue associated with ADHD symptoms

in adulthood (e.g., Krone & Newcorn, 2015), that may be partially explained by the emotional dysregulation features of ADHD. In this study we thus evaluated the hypothesis that emotional dysregulation mediates the relation between ADHD symptoms and internalising problems in adults using a measure of emotional dysregulation based on an EMA design that captures emotional dysregulation as it occurs in the context of daily life. Given that ADHD symptoms and internalising symptoms show meaningful variation both above and below clinical cut-offs, we used a general population sample.

Methods

Ethics

Ethical approval was obtained from the Ethics Committee from the Faculty of Arts and Social Sciences of the University of Zurich (ECFASSUZH). Participants provided informed consent before participating. The study information instructed participants not to answer prompts during times where it would not be safe to do so (e.g., while driving).

Procedure

Data come from the 'Decade-to-minutes' (D2M) study which is a combined longitudinal and EMA study. Specifically, the D2M sample is a subsample of the z-proso longitudinal study (e.g., M. Eisner & Ribeaud, 2007; N. L. Eisner et al., 2018). Data were collected at the age 20 measurement wave of z-proso. The main age 20 z-proso data collection consisted of a questionnaire that included measures of ADHD symptoms and internalising problems. These were administered in the context of a range of other constructs related to psychosocial development, including substance use, behavioural

problems and criminality, sexual experiences, and victimisation. A separate EMA survey was conducted to measure emotional symptoms in the context of daily life.

The EMA survey was conducted over a 14-day period with measurements occurring four times a day at quasi-random intervals between 10am and 10pm. Measures were administered via an application provided by *LifeDataCorp LLC*, which participants downloaded on their smartphone device. At each measurement instance, participants received a notification that directed them to a brief set of items. Incentives were scaled to level of compliance, with participants receiving a maximum of 50 CHF for a response rate of at least 70% over both week 1 and week 2. Fieldwork was carried out by Decision Science Laboratory (DeSciL) at the ETH Zurich: <https://www.descil.ethz.ch/>. As well as the measures utilised in the current study, the survey included measures of momentary substance use, aggression, provocations, stress, and context (i.e., who a person was with and what they were doing at the time of responding to a prompt).

Participants

D2M participants were a $n=260$ ($n=100$ male) subsample of the z-proso study: <https://www.jacobscenter.uzh.ch/en/research/zproso/aboutus.html> with a median age of 20. The z-proso sample is a school-year cohort sample, first recruited when entering first grade (median age 7) and followed up at ages 8,9,10,11,12,13,15,17 and 20. All participants entering first grade in the year 2004 from across 56 schools in the Zurich, Switzerland area at age 7 were invited to participate. At the latest wave, $n=1620$ had provided data for at least one measurement wave (from a target sample of $n=1675$). Previous studies have suggested that the sample is mostly representative of the underlying same-aged population (Eisner et al., 2018). The main exception was an initial slight under-representation of

participants whose parents did not speak German as their first language; however, this effect diminished after consent procedures switched from being parent-based to participant-based.

An inclusion criterion for D2M was that z-proso participants were required to have access to a smartphone running iOS or android; however, as this accounts for 99.6% of all smartphones (Thai & Page-Gould, 2017), this was not thought to be a significant biasing factor. Most importantly in the context of the current study, levels of ADHD symptoms ($p=.17$) and internalising symptoms ($p=.20$) did not differ between D2M and non-D2M participants i.e., those participating in the broader z-proso study but not the D2M sub-study. We did not impose compliance thresholds as doing so is likely to introduce missingness related to the constructs of interest, such as internalising problems (Silvia et al., 2013) and thus bias parameter estimates by creating non-random missingness (Rubin, 1976).

Measures

ADHD symptoms

ADHD symptoms were measured using an adapted self-reported version of the ADHD subscale from the Social Behavior Questionnaire (SBQ; Tremblay et al., 1991), modified to be more developmentally appropriate for emerging adults. This was collected as part of the main age 20 z-proso survey. The scale included nine items measuring both inattention and hyperactivity/impulsivity symptoms, including restlessness, being easily distracted, having difficulties concentrating, acting without thinking, forgetfulness, difficulties paying attention, being hectic and fidgety, being unable to settle to anything for

long, and internal feelings of restlessness. Responses were recorded on a five-point Likert-type scale from *never* to *very often*. The psychometric properties of versions of this questionnaire have been examined in previous studies, supporting its reliability, structural validity, and criterion validity of its scores (Murray, Eisner, Obsuth, et al., 2017; Murray, Eisner, & Ribeaud, 2017; Murray, Obsuth, et al., 2017; Tremblay et al., 1991). In the current sample, omega reliability (McDonald, 1999) was good at .87.

Internalising problems

Internalising problems were also measured using the SBQ (Tremblay et al., 1991) administered as part of the main age 20 wave of data collection. The internalising subscale of the SBQ includes 14 items measuring both anxiety and depression. Items refer to symptoms including boredom, anhedonia, crying frequently, lethargy, feeling fearful, feeling unhappy, feeling as if one is doing everything wrong, loneliness, insomnia, feeling useless, feeling sad without reason, worrying, hating oneself, and self-harm. Responses were recorded on a five-point Likert-type scale from *never* to *very often*. Previous research using similar versions of the SBQ has also supported the reliability and validity of the internalising scores (Murray, Eisner, Obsuth, et al., 2017; Murray, Eisner, & Ribeaud, 2017; Murray, Obsuth, et al., 2017; Tremblay et al., 1991). In the current sample, omega reliability was good at .92.

Emotional lability

Emotional lability scores were derived from the ecological momentary assessment component of D2M using an abbreviated version of the negative affect schedule of the *Positive Affect Negative Affect Schedule Expanded* (PANAS-X; Watson & Clark, 1999).

Specifically, data were collected on the following affective states: afraid, scared, nervous, hostile, guilty, ashamed, and distressed. Participants were asked to record on a five-point scale from *Very slightly or not at all* to *Extremely*. The prompt-wise response rates for these variables was 67%. Mean squared successive differences (MSSDs; Von Neumann et al., 1941) were calculated for each of the affect items separately based on the data available for each individual, to obtain a measure of the variability in each affective state for each individual over the ecological momentary assessment period. These were then used as indicators in a confirmatory factor analysis (described in the *Statistical Procedure* section) to derive a measure of overall emotional lability.

Statistical Procedure

A structural equation model was estimated to test the mediating role of emotional lability in the relations between ADHD symptoms and internalising problems. Emotional lability, ADHD, and internalising problems were all specified as latent variables. The indicators for the emotional lability latent variable were the above-described MSSDs for each negative affect item. The indicators for ADHD, internalising problems were the above-described SBQ items. Scaling and identification were achieved by fixing the loading for one reference indicator per latent factor to one.

A mediation model was specified with the ADHD latent variable as the predictor, the emotional lability latent variable as the mediator, and the internalising latent variable as the outcome. Direct effects of ADHD on the outcome were also modelled. The model is summarised in Figure 1. The statistical significance of the indirect effects of ADHD internalising problems was evaluated using the bootstrapped confidence intervals for 1) the product of the regression of internalising problems on emotional lability and the regression

of emotional lability on ADHD. Missingness was dealt with using full information maximum likelihood estimation. All models were fit using lavaan (Rosseel, 2012) in R Statistical software.

Results

The initial model fit did not fit well according to incremental fit indices, though it fit reasonably well according to SRMR and RMSEA (CFI=.83, TLI=.84, RMSEA=.08, SRMR=.07), Modification indices and expected parameter changes suggested that residual covariances between some of the emotional lability items and a cross-loading of the internalising factor on an ADHD item would improve fit. The cross-loading was included to reduce the risk that the latent internalising-ADHD association would be inflated. The residual covariances were also included for the emotional lability items as they pertained to lability in emotional states that could feasibly show excess correlations, over and above a generalised emotional lability tendency.

The modified structural equation model fit reasonably well (CFI=.91, TLI=.90, RMSEA=.06, SRMR=.06). Fully standardised parameter estimates are provided in Figure 1 (residual variances and covariances and factor variances are not shown for visual clarity). All parameters were significant at $p < .05$. Results show that there was a significant direct effect of ADHD symptoms on internalising problems ($r = .54$), and a significant effect of emotional lability on internalising problems ($r = .27$) and a significant effect of ADHD symptoms on emotional lability ($r = .37$). Based on bootstrapped confidence intervals, emotional lability significantly mediated the association between ADHD symptoms and internalising problems ($b = .07$, 95% CI = .03-.14; standardised $b = .10$). The mediation was partial and accounted for 16% of the total effect of ADHD symptoms on internalising problems.

Discussion

Emotional dysregulation issues have previously been shown to be associated with ADHD symptoms and have been proposed to contribute to the tendency for individuals with ADHD symptoms to experience co-occurring anxiety and depression (Rosen & Factor, 2015). In this study we evaluated this hypothesis in an $n=260$ sample of community-ascertained adults, using EMA to obtain measures of emotional dysregulation as it occurs in near real time and in the context of daily life. Our results suggest that emotional dysregulation partially mediates the association between ADHD symptoms and internalising problems.

Our findings are consistent with previous EMA studies in children which have shown that emotional dysregulation problems are associated with higher levels of internalising problems (Leaberry et al., 2017; Rosen & Factor, 2015). However, despite the continuing prevalence of ADHD symptoms and co-occurring internalising problems in adults, equivalent studies in adults have not been conducted prior to the current study. Our results thus provide important evidence that emotional dysregulation remains an important factor in the co-occurrence of anxiety/depression with ADHD symptoms in adulthood.

Our results suggest that interventions targeting emotional dysregulation problems could help reduce the overall symptom burden associated with ADHD by preventing the development of secondary internalising problems. There is already some evidence that emotional dysregulation symptoms respond positively to standard ADHD treatments; however, the effects are not as large as for symptoms that are currently regarded as 'core' ADHD symptoms (Faraone et al., 2019; Posner et al., 2014). In a systematic review and meta-analysis of the effects of pharmacological treatments for ADHD in adults, the standardised effect sizes for methylphenidate, atomoxetine, and lisdexamfetamine were in

only the small-to-moderate range (Lenzi et al., 2018). Thus, approaches more specifically tailored to the management of emotional dysregulation symptoms could have even stronger effects. There is some preliminary evidence showing positive effects of mindfulness-based interventions for emotional dysregulation in children with ADHD (Huguet et al., 2019). However, a range of therapeutic approaches could be relevant, including dialectal behaviour therapy, which includes emotion regulation skill components (Neacsiu et al., 2014).

As regards pharmacological interventions, it is not clear whether medications for internalising symptoms (antidepressants and mood stabilisers) are more promising for reducing emotional dysregulation and/or associated internalising problems in unmedicated adults with ADHD symptoms than ADHD medications themselves, especially considering the potential side effects of medications typically prescribed for anxiety and depression (Lenzi et al., 2018). Further research will be required to directly compare the impacts of these different types of medication on emotional dysregulation and internalising symptoms in the context of ADHD, as well as identify factors that may moderate treatment impact, such as ADHD symptom profiles (inattentive, hyperactive/impulsive or combined) and severity.

Interventions targeting emotional dysregulation in ADHD will also benefit from an improved understanding of which of the mechanisms underlying emotional control are particularly impaired in ADHD. As several authors have previously noted, a multitude of processes could be involved, including both those involved in the generation of affective states and those involved in the management of existing affective states (Faraone et al., 2019; Posner et al., 2014).

Our findings also indicate that both ADHD symptoms and internalising problems are frequently associated with emotional dysregulation problems and thus support previous suggestions that adults presenting with emotional dysregulation issues be screened for ADHD (Skirrow & Asherson, 2013). They similarly suggest that patients presenting with either ADHD symptoms or internalising problems could benefit from being screened for emotional dysregulation issues: doing so could identify a potentially important source of functional impairment and help make better sense of symptoms. Given that smartphone use is embedded in the daily lives of many adults and that user-friendly EMA applications are becoming increasingly available (e.g., Hofmann & Patel, 2015; Thai & Page-Gould, 2017), it would be feasible to conduct these screens via similar methods as employed in the current study i.e., over a period of a couple of weeks or more, using participants' own smartphones. This would help to better capture emotional functioning as it occurs in the context of a person's daily life, as compared to using questionnaire measures which have more limited ecological validity and rely on retrospective recall.

However, the fact that the mediation of the ADHD-internalising problems relation by emotional dysregulation was only partial suggests that there are additional mechanisms linking ADHD symptoms to internalising problems. Several such mechanisms have previously been proposed. For example, it has been suggested that the negative psychosocial sequelae of ADHD can foster a negative self-concept, placing an individual at greater risk of developing anxiety or depression (Schatz & Rostain, 2006). Consistent with this, several studies have found parent or peer problems to be mediators of the ADHD-internalising associations (Humphreys et al., 2013; Ostrander & Herman, 2006; Roy et al., 2015; Yip et al., 2013). For example, Yip et al. (2013) found that peer problems mediated the association

between attention problems and anxiety, while Humphreys et al. (2013) found that the ADHD-depression relation was mediated by both peer and parent-child problems. It is also likely that the ADHD-internalising problems association at least partly reflects genetic, neurobiological, and cognitive factors that are common to both ADHD symptoms and internalising problems (e.g., Levy, 2004). For example, previous research has suggested that young people with depression and young people with ADHD have similar memory and executive functioning deficits (Matthews et al., 2008; Rhodes et al., 2012). Whether these factors also help account for the shared emotion dysregulation issues between internalising problems and ADHD is not yet clear.

Future Directions

While emotional dysregulation may appear to have particular relevance for internalising problems, where emotional issues are prominent, it is likely that the impairing effects of emotional dysregulation are much broader in terms of ADHD sequelae. Future research could assess the mediating role of EMA-derived measures of emotional dysregulation in the relation between ADHD symptoms and other adulthood outcomes robustly associated with ADHD symptoms, e.g., substance use, intimate partner problems, and behaviour problems (Buitelaar et al., 2015; Graziano et al., 2015; Lee et al., 2011). Further illumination of the relations between emotional dysregulation and cognitive factors with established relations to ADHD, such as mind-wandering and neuropsychological impairments will also be valuable. It is not clear, for example, whether cognitive factors in ADHD underpin emotional dysregulation, or are independent or interactive factors which – together with emotional dysregulation – contribute to the risk of outcomes such as internalising problems and other sequelae. The development and evaluation of

interventions for emotion dysregulation in the context of ADHD symptoms also represents an important future direction.

Limitations

It is important to consider the limitations of the current study. First, while part of a longitudinal study, the measures available in the current study allowed only cross-sectional mediation tests. Longitudinal EMA studies remain rare but as more longitudinal EMA data becomes available, future replications using repeated measures of ADHD symptoms, emotional dysregulation, and internalising problems will be valuable to provide a longitudinal test of our hypotheses. Second, while our sample did not differ from its (same-aged population-representative parent sample) on ADHD or internalising problems, it was not a random draw from this sample. Future replications in population-representative samples will be helpful to ensure the generalisability of results.

Conclusions

Emotional dysregulation is associated with both ADHD symptoms and internalising problems and partially mediates their association. Interventions targeting emotional dysregulation could, therefore, be beneficial for reducing the development of anxiety and depression secondary to ADHD symptoms.

Contributors:

Aja Murray conceived the study, co-designed and oversaw the data collection with Manuel Eisner and Denis Ribeaud, conducted the data analysis and took the lead on drafting the manuscript.

Siu Ching Wong contributed to the drafting of the manuscript.

Ingrid Obsuth contributed to the drafting of the manuscript.

Sinead Rhodes contributed to the drafting of the manuscript.

Manuel Eisner co-designed the study with Aja Murray, helped oversee the data collection, and contributed to drafting the manuscript.

Denis Ribeaud co-designed the study with Aja Murray, helped oversee the data collection, and contributed to drafting the manuscript.

All authors saw and approved the final manuscript before submission.

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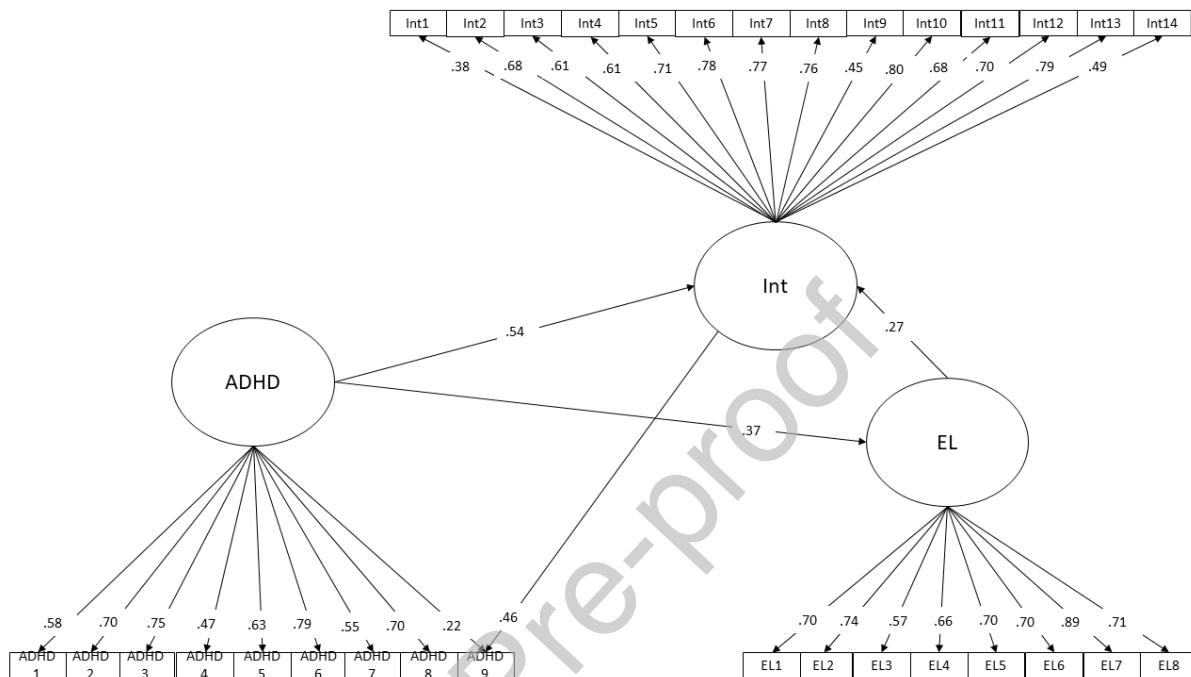
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Figures

Figure 1: Structural equation model of ADHD, emotional lability and internalising problem relations



Note. Int= internalising problems; EL= emotional lability. All structural paths were significant at $p < .05$. Residual factors not shown for visual clarity.