The role of executive functions in mediating the relationship between adult ADHD symptoms and hyperfocus in university students

Garcia Pimenta, Miguel; Gruhnert, Rixa Käthe; Fuermaier, Anselm B.M.; Groen, Yvonne

Published in:
Research in Developmental Disabilities

DOI:
10.1016/j.ridd.2023.104639

Research in Developmental Disabilities 144 (2024) 104639

Contents lists available at ScienceDirect

Research in Developmental Disabilities

journal homepage: www.elsevier.com/locate/redevdis

The role of executive functions in mediating the relationship between adult ADHD symptoms and hyperfocus in university students

Miguel Garcia Pimenta [a,*,1], Rixa Käthe Gruhnert [a,b], Anselm B.M. Fuermaier [a], Yvonne Groen [a,2]

[a] *University of Groningen, Clinical and Developmental Neuropsychology, Grote Kruisstraat 2/1, 9712 TS Groningen, the Netherlands*
[b] *University of Vienna, Department of Cognition, Emotion and Methods in Psychology, Liebiggasse, 51010 Vienna, Austria*

ARTICLE INFO

Keywords:
Adult ADHD
Executive functions
Hyperfocus

ABSTRACT

Background: Hyperfocus, a state of intense, narrow and prolonged attentional focus, has been associated with symptoms of attention-deficit/hyperactivity disorder (ADHD) in both clinical and non-clinical populations. Hyperfocus may be explained by difficulties in executive control, typically observed in ADHD.
Aims: To investigate (1) whether ADHD and executive functions (EF) are associated with hyperfocus and (2) whether EF mediate the relationship between ADHD symptoms and hyperfocus.
Methods and procedures: A non-clinical sample of 380 university students (264 females) completed self-reports of ADHD, EF, hyperfocus and hyperfocus during rewarding activities.
Outcomes and results: Increased difficulties in EF and severity of ADHD symptoms were significantly and positively correlated with a higher frequency of hyperfocus. Moreover, EF difficulties partially mediated the relationship between ADHD and hyperfocus (after controlling for sex and substance use), but not the relationship between ADHD and hyperfocus during rewarding activities.
Conclusions and implications: Difficulties in EF partially explained the higher frequency of hyperfocus, but not of hyperfocus during rewarding activities, among university students reporting more severe ADHD symptoms. Future research should investigate whether and how specific EF and other ADHD-related neurocognitive difficulties (e.g., reward sensitivity) contribute to various types of hyperfocus experiences in ADHD.
What this paper adds?: This paper is a first attempt to explain the relationship between adult ADHD symptoms and hyperfocus experiences. Our findings suggest that, although highly correlated, existing self-reports of hyperfocus measure different aspects of this experience: hyperfocus and reward-related hyperfocus. We replicate previous findings that indicated a greater frequency of both types of hyperfocus in ADHD. Additionally, we demonstrate a connection between EF difficulties and different aspects of hyperfocus. Finally, we extend previous findings by proposing that EF difficulties partially explain the relationship between ADHD and hyperfocus, but not the relationship between ADHD and reward-related hyperfocus. We hypothesize that other

* Correspondence to: Faculty of Behavioral and Social Sciences, Grote Kruisstraat 2/1, 9712 TS Groningen, the Netherlands.
E-mail address: m.garcia.pimenta@rug.nl (M. Garcia Pimenta).
[1] https://orcid.org/0000-0002-3691-2314
[2] https://orcid.org/0000-0002-7242-0317

https://doi.org/10.1016/j.ridd.2023.104639
Received 26 October 2021; Received in revised form 23 October 2023; Accepted 12 November 2023
Available online 30 November 2023
0891-4222/

neurocognitive difficulties (e.g., reward sensitivity) may contribute to explain the relationship between ADHD and different aspects of hyperfocus.

1. Introduction

Attention-deficit/hyperactivity disorder (ADHD) is a childhood neurodevelopmental disorder characterized by symptoms of inattention, hyperactivity, and impulsivity (American Psychiatric Association, 2013), which persists through adolescence and adulthood (Caye et al., 2016). The prevalence of adult ADHD varies from 0.6% to 7.3% across low- to high-income countries (Fayyad et al., 2017) and it is estimated to affect from 2% to 8% of college students in the United States (DuPaul et al., 2009). ADHD symptoms have been shown to have a dimensional structure with those who are diagnosed with the disorder falling at the extreme end of a continuum (e.g., Marcus & Barry, 2011). ADHD is commonly recognized as an heterogeneous disorder characterized by multiple neurocognitive difficulties, including executive functions (EF), delay aversion and reward sensitivity, and temporal information processing (e.g., Sonuga-Barke et al., 2010). The EF construct describes a class of higher-order, effortful and goal-oriented cognitive process that regulate lower-order cognitive functions, behavior, emotions and motivation (e.g., Miyake & Friedman, 2012). More specifically, EF are implicated in attention control and in attentional focus self-regulation (Nigg, 2017, pp. 12675). There is a wide consensus in the literature regarding the strong association between ADHD and impaired performance in EF tests in both children and adults. For example, ADHD has been associated with difficulties in response inhibition (Fosco et al., 2019) and task-switching (Dibbets et al., 2010). Additionally, the severity of ADHD symptoms has been associated with self-reported EF difficulties during daily life activities in adults (Barkley & Murphy, 2011; Silverstein et al., 2020) and more specifically in college students (Dehili et al., 2017). To our knowledge, there has been no investigation into the potential effects of ADHD-related neurocognitive difficulties, which include executive functions, on hyperfocus.

Hyperfocus has been defined as a state of intense and narrow attentional focus on a stimulus, object or task (Luck et al., 2019; Ozel-Kizil et al., 2016), which is accompanied by diminished awareness of the self, time and the surroundings (Ashinoff & Abu-Akel, 2019; Hupfeld et al., 2019). While hyperfocusing, individuals often experience difficulties in disengaging and switching attention to other stimuli or tasks (Hupfeld et al., 2019), which can result in excessively prolonged periods of sustained attention. The implications of hyperfocus for mental health are still unknown. An association with increased cognitive performance has been speculated in high-functioning ADHD adults (Sedgwick et al., 2019). According to this attention enhancement perspective, hyperfocus may result from heightened motivation during interesting, rewarding or novel activities (Ashinoff & Abu-Akel, 2019), such as pursuing one's hobbies, completing school assignments, or consuming screen content (Hupfeld et al., 2019). Conversely, an excessively intense allocation of attentional resources and narrow focus, irrespective of motivational factors, may explain difficulties encountered across a broad range of cognitive domains (e.g., visual spatial attention and working memory) in people with schizophrenia (e.g., Luck et al., 2019). In line with this cognitive impairment perspective, hyperfocus may exacerbate core ADHD symptoms (e.g., not listening when addressed by someone else because of excessive focus on something one is doing) and difficulties in daily life (e.g., managing time and postponing other tasks) often associated with the disorder.

The association between ADHD and hyperfocus has been suggested by several recent research findings. Ozel-Kizil et al. (2016) showed that, in comparison to healthy controls, both medicated and non-medicated adults with ADHD exhibited significantly more specific hyperfocus, hyperfocus-related time management difficulties and hyperfocus-related procrastination, as measured by the corresponding subscales of the Hyperfocusing Scale (HS, Ozel-Kizil et al., 2013). They also found that the level of ADHD severity in their sample of medicated and non-medicated individuals with ADHD displayed moderate positive correlations with both specific hyperfocus and general hyperfocus (measured by the composite score of the three HS subscales). Hupfeld et al. (2019) developed the Adult Hyperfocus Questionnaire (AHQ) to measure hyperfocus in adults with ADHD. Participants falling within the clinical range for ADHD reported a greater frequency of hyperfocus in three specific settings (school, hobbies and screen-time activities) and during rewarding activities (henceforth called reward-related hyperfocus), compared to those falling outside the clinical range. Reward-related hyperfocus, as measured by the Dispositional Hyperfocus Subscale (DHS-AHQ), showed moderate positive correlations with two different ADHD self-report scales in a mixed community sample of self-reported ADHD and non-ADHD adults (Hupfeld et al., 2019). Finally, Groen et al. (2020) concluded that hyperfocus frequency (broadly defined as engagement in a task or activity to the point of being unaware of time and surroundings) correlated weakly with ADHD symptoms in a large sample of healthy adults. However, they failed to observe significant differences between individuals with ADHD and matched controls in hyperfocus frequency, duration and pervasiveness. It is important to acknowledge that the use of a single-item hyperfocus measure, the psychometric validity of which is uncertain, calls for caution when interpreting the latter findings. Collectively, these results imply that ADHD symptoms are significantly associated with hyperfocus in both clinical and non-clinical populations. However, the strength of this relationship may differ based on the definition and operationalization of hyperfocus.

Previous studies speculated that EF may be involved in hyperfocus. Hupfeld et al. (2019) advanced the hypothesis that hyperfocus reflects difficulties in attentional control and EF, such as inhibition and task-switching. Individuals with EF difficulties in inhibition may be less efficient in overriding automatic attention capture and dominant response tendencies (Miyake & Friedman, 2012) thus leading to excessive focus on irrelevant stimuli. EF difficulties in task-switching between global and local processing of visual stimuli have also been implicated in the tendency to hyperfocus on details observed in ADHD (Ozel-Kizil et al., 2016). Individuals with ADHD consistently exhibit a diminished Navon effect (e.g., Song & Hakoda, 2015), which refers to the tendency to process the overall shape (global level) relative to the constitutive elements (local level) of a letter stimulus compound pattern (Navon, 1977). This excessive focus on details relative to global patterns may, in turn, be explained by specific impairment in shifting (slow reaction times and higher task-switching costs) between global and local features in individuals with ADHD (Luna-Rodriguez et al., 2018). Hyperfocus may correspond to a state in which certain stimuli (e.g., local features, rewarding activities) are given priority, and regaining cognitive flexibility (through inhibition, updating and set shifting) may require attentional effortful control. Although previous research suggests that EF difficulties underpin hyperfocus states, especially in individuals with ADHD, no studies to date investigated this question.

The aim of the current research is to examine the relationship between ADHD, EF and hyperfocus. In line with previous studies, we predicted positive associations between ADHD symptom severity and hyperfocus (Hupfeld et al., 2019; Ozel-Kizil et al., 2016) and between ADHD and EF (Barkley & Murphy, 2011; Silverstein et al., 2020) in our sample of university students. Given the association between EF difficulties and excessive attention selectivity and narrowing (e.g., Luna-Rodriguez et al., 2018), we predicted that individuals with greater difficulties in EF would have a higher propensity for hyperfocus. Finally, we explored whether EF difficulties mediate the relation between ADHD and hyperfocus. To assess the robustness of our findings, we conducted several mediation analyses using different measures of hyperfocus (i.e., general hyperfocus, specific hyperfocus and reward-related hyperfocus). A related goal of the study was to investigate the convergent validity of those hyperfocus measures. Finally, we controlled for the possible influence of cognitive enhancers on hyperfocus and EF, as prior research has indicated that stimulant medication may induce hyperfocus in naïve-stimulant children with ADHD (Wigal et al., 2012) and enhance EFs in healthy adults (Roberts et al., 2020). Among university students, the use of cognitive enhancers, including stimulant medications (e.g., methylphenidate), stimulant substances (e.g., methamphetamines), and other substances (e.g. cannabis) to enhance alertness, sustained attention, and motivation, is estimated to have a lifetime prevalence ranging from 6% to 20% worldwide (Sharif et al., 2021) and of approximately 16% in the Netherlands where the current study was conducted (Fuermaier et al., 2021). A better understanding of the mechanisms underpinning hyperfocus in ADHD may lay the foundations to prevent hyperfocus-related daily life difficulties and to promote compensatory attentional focus enhancement strategies (e.g., use of intrinsic motivation) in individuals with ADHD and at-risk of ADHD (including university students).

2. Methods

2.1. Participants

Participants were recruited from a convenience sample of first-year students enrolled in the English track of the Bachelor in Psychology of the University of Groningen in three consecutive academic years (from September 2018 to March 2021). Participants accessed the study through the SONA-system participation pool and received course credits compensation proportioned to time investment. The initial sample consisted of 628 participants who provided informed consent. Participants were excluded from the analysis if they met at least one of the following criteria: being younger than 18 years of age, repeated participation, missing data in any of the variables included in the analyses, admitting to have responded untruthfully or carelessly, reporting difficulties in understanding or interpreting the questions, and incorrectly responding to any of the instructed response items. Application of these criteria led to the exclusion of 248 participants. Out of the 380 participants (mean age 20 years, ranging from 18 to 39) entered in the analysis, 264 identified as female (69.5%), 115 as male (30.3%), and one as other (0.2%). The participants were Dutch (52.9%), German (27.1%) or had other nationalities (20%). The majority of participants (68.7%) indicated they were never diagnosed with a neuropsychiatric disorder or other medical condition, 7.1% were previously diagnosed with ADHD or ADHD with comorbidity, 6.4% were previously diagnosed with anxiety or depression, and the remaining 17.8% had been diagnosed with other medical conditions including psychiatric (2.9%) or neurological disorders (0.5%). Among all the participants, 29 (7.6%) indicated the use of stimulant medication, 28 (7.4%) used stimulant substances (e.g., cocaine, methamphetamines or amphetamines), and 57 (15%) used other recreational substances (e.g., cannabis, hallucinogens) in the past six months.

2.2. Materials

Reward-related hyperfocus was assessed by the DHS-AHQ (Hupfeld et al., 2019). In the initial validation study, the DHS-AHQ emerged as a separate hyperfocus factor and was able to discriminate between self-diagnosed ADHD and non-ADHD participants with a medium effect size (Hupfeld et al., 2019; Study 2). The DHS-AHQ includes 12 items scored on a 6-point scale (1 =“Never”, 2 =“1–2 times every 6 months”, 3 =“1–2 times per month”, 4 =“Once a week”, 5 =“2–3 times a week”, 6 =“Daily”) measuring the general tendency to experience hyperfocus during enjoyable and rewarding activities (e.g., “Generally, when I am very focused on something or doing something that I find especially rewarding, I can feel totally captivated by or “hooked” on the activity.”). Sum scores of all 12 items composing the DHS-AHQ were computed. Cronbach's alpha for the scale in the current sample indicated excellent internal consistency ($\alpha = .90$) in line with the initial ADHD and non-ADHD validation samples (Hupfeld et al., 2019).

The severity of general and specific hyperfocus was measured by the 11-item HS (Ozel-Kizil et al., 2013). A pilot study (Garcia Pimenta et al., 2019), using a sample of 323 first-year Psychology students of the University of Groningen, identified several language difficulties in the English version of the scale published by Ozel-Kizil et al. (2016). Therefore, an adapted translation of the HS was used in the current study. Similar to the original version, the items were scored on a 4-point scale (1 =“Totally disagree”, 2 =“Disagree”, 3 =“Agree”, 4 =“Totally agree”). In line with the original scale (Ozel-Kizil et al., 2016), the exploratory factor analysis (EFA) suggested the retention of three factors with only small differences in the item composition of each factor after elimination of one item. For a full report of the adaptation and exploratory factor analysis, see the Supplementary Material. The three factors were named HS hyperfocus (5 items) measuring specific hyperfocus, HS procrastination (3 items) measuring hyperfocus-related procrastination and delaying other tasks, and HS time perception (2 items) measuring hyperfocus-related changes in time perception. The HS total scale, composed of all 10 items, measured general hyperfocus. Sum scores for the adapted HS total scale and the three subscales were computed. The internal consistency was acceptable for the HS total scale (α = .78) and HS hyperfocus subscale (α = .76). Because the internal consistencies were below the acceptable .70 threshold, the HS procrastination (α = .63) and the HS time perception subscales (α = .64) were not included in the analysis.

General EF difficulties in daily life were measured by the 20-item Barkley Deficits in Executive Functioning Scale- Short Form (BDEFS-SF; Barkley, 2011). Items were scored on a 4-point scale (1 =“Never or rarely”, 2 =“Sometimes”, 3 =“Often”, 4 =“Very often”). A sample item is “I have trouble doing what I tell myself to do”. Barkley (2011) reported robust psychometric properties of the complete scale, including good discriminant and convergent validity with various measures of difficulties in daily life activities (e.g., family and academic functioning), test-retest reliability, and internal consistency. Factorial analyses (Barkley, 2011; Lace et al., 2020) suggested that the BDEFS-SF assesses five EF domains (i.e., self-motivation, self-management to time, self-restraint, self--organization/problem-solving, and self-regulation of emotion). However, a recent examination of the factorial structure of the scale indicated that one general factor accounted for the large majority of the variance (Clauss et al., 2021). In line with the latter recommendation, responses to the BDEFS-SF were summed to compute a full-scale score. In the current sample, the BDEFS-SF full-scale showed good internal consistency (α = .88).

The Adult ADHD Self-Report Scale (ASRS; Kessler et al., 2005) was used to assess the severity of the 18 ADHD symptoms defined by the DSM-IV diagnostic criteria (American Psychiatric Association, 2000) in the past 6 months. Nine of these items assess symptoms of inattention, while the remaining assess hyperactivity and impulsivity. Participants are requested to self-rate the severity of each symptom on a 5-point Likert scale (0 =“never”, 1 =“Rarely”, 2 =“Sometimes”, 3 =“Often”, and 4 =“Very often”). Responses to the ASRS were summed to compute a full-scale score. The ASRS showed moderate sensitivity (56.3%) and high specificity (98.3%) in the general population (Kessler et al., 2005). Cronbach’s alpha for the ASRS in the current sample was α = .87, indicating good internal consistency.

Additionally, participants were asked whether they were ever diagnosed with a neurological, psychiatric or medical disorder that could affect the ability to concentrate (Yes/No). Furthermore, the participants were asked about the use of substances (i.e., medication and substances with potential cognitive enhancement effects) in the last 6 months (Yes/No). In the event of a positive response, participants were subsequently asked to indicate which substance(s) they used from a list of common or commercial names of medications and drugs (e.g., stimulant medication for ADHD, cocaine, hallucinogens). The responses were categorized as stimulant medication (Stim Med), stimulant substances (Stim Subs), and recreational substance use other than stimulants (Other Subs). Based on these categories, three dichotomous variables were computed for each participant.

2.3. Procedure

The study was approved by the Ethics Committee of Psychology affiliated with the University of Groningen, the Netherlands. The study was part of a larger survey administered online and took about 20 min to complete. Participants were informed about the goals and procedures of the study and provided active informed consent by selecting a specified option in the online form. Participants were made aware that the data would be stored and processed anonymously, that participation was voluntary and that withdrawal was allowed at any point. Upon starting the survey, participants completed the HS, the DHS-AHQ and a measure of flow state in randomized order to prevent order effects between measures of similar constructs. Then, participants completed the BDEFS-SF, followed by the ASRS. One instructed response item was embedded in each of the scales to detect careless responding. This was followed by

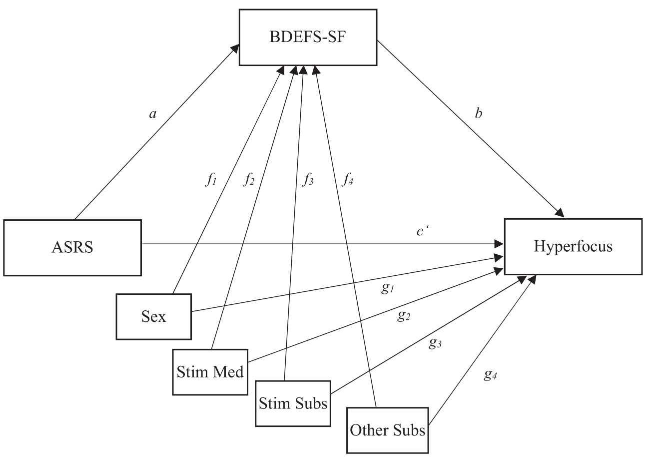

Fig. 1. Simple mediation model using ASRS (total scores) as predictor, BDEFS-SF (total scores) as mediator and Hyperfocus as the outcome variables. The same mediation model was used for the three hyperfocus variables (HS total, HS hyperfocus and DHS-AHQ). Sex, stimulant medication use (Stim Med), stimulant substance use (Stim Subs) and recreational substance use other than stimulants (Other Subs) were included as covariates in the three models.

completing information about previous diagnoses. In the event of a positive response, participants were requested to specify their diagnosis, to indicate when they received it and when it was first suspected. Next, they were asked about the use of substances. If the participants indicated the use of stimulant medication, they were then questioned about whether these were medically prescribed, or if they were used for recreational and/or cognitive enhancement purposes. Finally, participants completed demographic information (age, sex assigned at birth, educational level, nationality and professional status), answered an honesty check ("Did you try to answer all questions seriously and honestly?" (Yes/No)), reported on difficulties understanding the items or instructions ("Did you experience difficulties interpreting any of the questions?" (Yes/No)) and were debriefed.

2.4. Design and statistical analysis

Statistical analyses were performed using the IBM Statistical Package for the Social Sciences (SPSS, version 27). As shown in Fig. 1, we conducted three simple mediation analyses using the HS total, the HS hyperfocus and the DHS-AHQ as outcome variables measuring general hyperfocus, specific hyperfocus and reward-related hyperfocus, respectively. The predictor variable, ASRS total score, measured the ADHD symptom severity, while the mediating variable, BDEFS-SF total score, measured EF difficulties in all three mediation analyses. The variables Stim Med (Yes/No), Stim Subs (Yes/No) and Other Subs (Yes/No) were included as covariates in the three analyses. Additionally, we included Sex (male/female/other) as a covariate variable to correct statistically for the imbalance between males and females in our sample.

The mediation analyses were conducted in PROCESS (Hayes, 2018) using the bias-corrected 95% CI bootstrapping method with 10000 bootstrap resamples to test for the indirect effect (*ab*). Effect sizes for the mediation analyses were given by the completely standardized total effect (c_{cs}), the completely standardized direct effect (c'_{cs}) and the completely standardized indirect effect (ab_{cs}) (Preacher & Kelley, 2011). Reported correlations are Pearson correlations (*r*) and Point-Biserial Correlations (r_p) for correlations including binary categorical variables. Hochberg-correction method was used to correct for multiple comparisons. A significance alpha level of .05 (two-tailed) was used for all analyses. For the predictive relationships, regression assumptions of linearity, normality, and homoscedasticity were checked. Because of heteroscedasticity observed between the predictor and the mediator, as well as between the covariates, the mediator and the outcome variables, we applied Davidson-MacKinnon heteroscedasticity-consistent regression estimate (HC3), as recommended by Cribari-Neto et al. (2005).

3. Results

Descriptive statistics and correlations (Hochberg-correction for multiple comparisons) between predictor, mediating, outcome and covariate variables included in the three mediation models are shown in Table 1. The ASRS showed moderate to strong positive correlations with the three hyperfocus measures (HS total, HS hyperfocus and DHS-AHQ), a strong correlation with BDEFS-SF, and a small correlation with Other Subs. The three hyperfocus measures were strongly correlated with each other. We found high positive correlations between the HS total and the HS hyperfocus subscale (with a shared variance of R^2 =0.77), between the HS total and the

Table 1
Pearson (r) and Point-Biserial (rp) Correlations, p-values and Descriptive Statistics for predictor, mediating, outcome, and covariate variables. Means, standard deviations (SD) and number of participants with valid responses in each variable (N).

Variables		1.	2.	3.	4.	5.	6.	7.	8.
1. ASRS		-							
2. HS total	r	.55*	-						
	p	.000	-						
3. HS hyperfocus	r	.48*	.88*	-					
	p	.000	.000	-					
4. DHS-AHQ	r	.47*	.70*	.61*	-				
	p	.000	.000	.000	-				
5. BDEFS-SF	r	.74*	.50*	.43*	.39*	-			
	p	.000	.000	.000	.000	-			
6. Sex	r_p	.06	.00	-.04	-.05	.12	-		
	p	.232	.966	.398	.321	.019	-		
7. Stim Med	r_p	.11	.11	.08	.03	.13	-.01	-	
	p	.027	.030	.118	.576	.015	.901	-	
8. Stim Subs	r_p	.08	.05	.04	.01	.07	-.12	.37*	-
	p	.140	.361	.397	.814	.163	.018	.000	-
9. Other Subs	r_p	.16*	.06	.00	.08	.17*	-.16*	.35*	.56*
	p	.002	.278	.988	.129	.001	.002	.000	.000
Mean		30.83	24.76	10.43	41.58	39.30	-	-	-
SD		10.21	4.45	2.80	11.42	9.80	-	-	-
N		380	380	380	380	380	379	380	380

Notes: HS = Hyperfocusing Scale; ASRS = Adult ADHD Self-Report Scale; DHS-AHQ= Dispositional Hyperfocus Scale of the Adult Hyperfocus Questionnaire; BDEFS-SF = Barkley Deficits in Executive Functioning Scale-Short Form; Stim Med = Stimulant medication use; Stim Subs = Stimulant substance use; Other Subs = Recreational substance use other than stimulants. * =Hochberg correction for multiple comparisons p < .05 (first significant p-value=0.002).

Table 2
Ordinary least squares regression model unstandardized coefficients (standard errors in parenthesis), p-values and 95% confidence intervals [CIs] for three simple mediation analyses with predictor (ASRS), mediator (BDEFS-SF), three outcomes (HS total, HS hyperfocus and DHS-AHQ) and four covariates (Sex, Stim Med, Stim Subs and Other Subs).

	Mediator				Outcome									
	BDEFS-SF				HS total				HS hyperfocus			DHS-AHQ		
Predictor		*B* (SE)	*p*	95% CI		*B* (SE)	*p*	95% CI	*B* (SE)	*p*	95% CI	*B* (SE)	*p*	95% CI
ASRS	*a*	*.693*(.035)	< .001	[.621;.760]	*c'*	*.178*(.031)	< .001	[.118;.238]	*.101*(.020)	< .001	[.061;.140]	*.432*(.080)	< .001	[.276;.588]
					c	*.243*(.021)	< .001	[.202;.285]	*.137*(.014)	< .001	[.110;.165]	*.531*(.053)	< .001	[.427;.635]
BDEFS-SF					*b*	*.095*(.029)	.001	[.037;.152]	*.053*(.020)	.008	[.014;.093]	*.143*(.081)	.080	[− .017;.303]
Sex	f_1	*1.780*(.735)	.016	[.335;3.224]	g_1	*-.563*(.424)	.185	[− 1.237;.448]	*-.636*(.284)	.026	[− 1.194;.078]	*-2.280*(1.169)	.052	[− 4.302;.260]
Stim Med	f_2	*.990*(1.509)	.512	[− 1.977;3.957]	g_2	*1.033*(.792)	.193	[− .408;2.660]	*.500*(.516)	.332	[− .429;1.536]	*-.908*(2.251)	.687	[− 5.080;3.547]
Stim Subs	f_3	*-.850*(1.858)	.648	[− 4.505;2.804]	g_3	*.317*(.910)	.728	[− 1.513;1.986]	*.636*(.579)	.273	[− .521;1.702]	*-1.464*(2.349)	.533	[− 6.029;2.857]
Other Subs	f_4	*1.954*(1.147)	.148	[− .694;4.602]	g_4	*-1.066*(.724)	.142	[− 2.330;.569]	*-1.230*(.484)	.011	[− 2.085;− .167]	*-.241*(1.815)	.984	[− 3.044;4.086]

Notes: ASRS = Adult ADHD Self-Report Scale total score; BDEFS-SF = Barkley Deficits in Executive Functioning Scale-Short Form; DHS-AHQ= Dispositional Hyperfocus Scale of the Adult Hyperfocus Questionnaire; HS = Hyperfocusing Scale; Stim Med = Stimulant medication use; Stim Subs = Stimulant substance use; Other Subs = Recreational substances other than stimulants. Paths *a, b, c'*, f_1 *to* f_4 *and* g_1 *to* g_4 are identified in Figure 1. Path *c* = total effect.

DHS-AHQ (with a shared variance of R^2 =0.49) and between the HS hyperfocus and the DHS-AHQ (with a shared variance of R^2 =0.37) suggesting convergent validity. However, the moderate shared variances between the two HS scales and the DHS-AHQ (37% and 49%) suggest that they measure different attributes of hyperfocus. Importantly, all three hyperfocus measures exhibited moderate correlations with BDEFS-SF. Additionally, increased use of other substances exhibited significant correlations with higher BDEFS-SF scores, being male, and a higher frequency of both stimulant medication and stimulant substances use. However, stimulant medication use and stimulant substance use were not significantly correlated with ASRS scores, BDEFS-SF scores or hyperfocus scores in any of the three measures. Biological sex assigned at birth was not significantly correlated with ASRS, BDEFS-SF or hyperfocus scores. Overall, these correlations are consistent with the hypothesized mediation.

All three simple mediation analyses indicated that the ASRS scores predicted hyperfocus. As shown in Table 2, the total effects (path *c*) of ASRS scores on hyperfocus were significant for the three outcome measures (HS total: R^2 =.31, B=.243, t = 11.585, $p < .001$, c_{cs}=0.559); HS hyperfocus: R^2 = .25, B= .137, t = 9.906, $p < .001$, c_{cs}= 0.502; DHS-AHQ: R^2 = .23, B= .531, t = 10.043, $p < .001$, c_{cs}= 0.475), when accounting for the effect of BDEFS scores and controlling for Sex, Stim Med, Stim Subs and Other Subs. When controlling for the mediator and confounding variables, the direct effect between ADHD and hyperfocus measures (path *c'*) was significant for all outcome measures (HS total: R^2 =.33, B=.178, t = 5.835, $p < .001$, c'_{cs}=0.409); HS hyperfocus: R^2 = .27, B= .101, t = 4.981, $p < .001$, c'_{cs}= 0.367; DHS-AHQ: R^2 = .23, B= .432, t = 5.423, $p < .001$, c'_{cs}= 0.386).

The bootstrapping of indirect effects *ab* based on 10000 bootstrap samples indicated that the 95% confidence interval was entirely above zero when the outcome variables were HS total (*ab*=0.066, *Boot* SE=0.020, CI [0.025,0.106], ab_{cs}=0.150) and HS hyperfocus (*ab*=0.037, *Boot* SE=0.014, CI [0.010,0.064], ab_{cs}=0.135), but included zero when the outcome variable was the DHS-AHQ (*ab*=0.099, *Boot* SE=0.056, CI [−0.010,0.212], ab_{cs}=0.089). When the hyperfocus measure was the HS total, the effect sizes can be interpreted as follows: people who are one standard deviation higher in ADHD scores are estimated to be 0.409 standard deviations higher in general hyperfocus (c'_{cs}); people who are one standard deviation higher in ADHD scores will differ by about 0.150 standard deviations in general hyperfocus as a result of EF deficits (ab_{cs}), which corresponds to 26.8% of the overall effect (c_{cs}=0.559). When the hyperfocus measure was the HS hyperfocus scale, the effect sizes can be interpreted as follows: people who are one standard deviation higher in ADHD scores are estimated to be 0.367 standard deviations higher in specific hyperfocus (c'_{cs}); people who are one standard deviation higher in ADHD scores will differ by about 0.135 standard deviations in specific hyperfocus as a result of EF deficits (ab_{cs}), which corresponds to 26.9% of the overall effect (c_{cs}=0.502). In summary, for the analyses in which the HS total and the HS hyperfocus were taken as outcomes, the indirect effect explained only a similarly small proportion (about one-quarter) of the total effect and the direct effects between ASRS and the hyperfocus measures were still significant thus suggesting partial mediation. We repeated the mediation analyses using the original 11-item HS total and the 5-item HS hyperfocus subscales proposed by Ozel-Kizil et al. (2016) as outcome variables. No differences were found between these additional analyses and the results reported above.

Additionally, Table 2 shows that the predicted relationship between ASRS and BDEFS-SF (path *a*) was significant when controlling for covariates. Being female significantly predicted higher BDEFS–SF scores. As can also be seen in Table 2, the predicted relations between BDEFS-SF scores and the three hyperfocus measures (path *b*) were significant for the HS total and HS hyperfocus scales, but did not reach statistical significance for the DHS-AHQ, when controlling for ASRS scores and covariate variables. Being male and decreased use of other substances significantly predicted HS hyperfocus. Being male marginally predicted higher scores on the DHS-AHQ. Other influences of covariates in the three mediation models did not reach statistical significance.

4. Discussion

We examined the relation between ADHD symptoms, EF and hyperfocus in three simple mediation analyses using different hyperfocus measures. Crucially, the existing hyperfocus scales, although strongly correlated, shared less than 50% of variance suggesting that they measure different attributes of the same construct. Based on the item content (see Supplementary Material for details on the development of the scales), we propose that the HS measures hyperfocus while the DHS-AHQ assesses reward-related hyperfocus. Consistent with the hypothesized mediation, ADHD symptoms and EF difficulties were moderately to strongly associated with both hyperfocus and reward-related hyperfocus. The mediation analysis supported the prediction that ADHD symptoms were indirectly associated with general hyperfocus through EF difficulties. A sensitivity analysis confirmed the significant mediation when using a measure of specific hyperfocus as the outcome variable, which exhibited a weaker correlation with EF difficulties and ADHD symptoms compared to the measure of general hyperfocus. However, in both analyses, the indirect effect of EF could only account for approximately one-quarter of the association between ADHD and hyperfocus, thereby indicating the possibility of other neurocognitive processes playing a mediating role in this relationship. Interestingly, EF difficulties did not serve as a significant mediator in the relationship between ADHD symptoms and reward-related hyperfocus, indicating that reward sensitivity may be a crucial factor in the association between ADHD and hyperfocus.

We replicated previous findings, showing that a higher severity of ADHD symptoms was associated with a greater frequency of hyperfocus (Groen et al., 2020; Hupfeld et al., 2019; Ozel-Kizil et al., 2016). This association was strong for general hyperfocus and moderate-to-strong for specific hyperfocus and reward-related hyperfocus in our non-clinical sample of university students. These results are generally in line with previous studies showing that ADHD symptoms were moderately correlated with hyperfocus in individuals with ADHD (Ozel-Kizil et al., 2016) and with reward-related hyperfocus in a mixed community sample of self-reported ADHD and non-ADHD adults (Hupfeld et al., 2019). Notably, the correlation between ADHD and general hyperfocus was considerably stronger in the current study (r = .55) than in the original study (r = .41) by Ozel-Kizil et al. (2016). Since both studies used the same ADHD scale, this difference may be explained by other factors. First, the measures of general hyperfocus differed between the two studies. In fact, we adapted the item content to allow the assessment of a broader spectrum of hyperfocus experiences and eliminated one item of the original HS (for details see Supplementary Material). Additionally, there are demographic and linguistic differences between the two studies. Considering that hyperfocus frequency may decline with age (Groen et al., 2020), the younger age of our participants might explain its higher frequency in the current study relative to that reported by Ozel-Kizil et al. (2016). Moreover, Ozel-Kizil et al. (2016) participants filled the HS in their native Turkish language, while English was not the native language for the majority of our participants. Although we controlled for item understanding, it remains possible that this factor still contributed to the overreporting of hyperfocus in the current sample. Finally, compared to the general and clinical populations, university students often encounter situations demanding intense concentration, potentially leading to an overreporting of hyperfocus. Therefore, more research is necessary to ascertain the sensitivity of different hyperfocus scales to ADHD symptoms in university students and non-students, different age groups, and clinical and non-clinical populations.

The current study provides the first evidence that hyperfocus is associated with EF difficulties. This is line with the previous proposals suggesting that hyperfocus partly reflects functional difficulties in inhibiting and overriding automatic response tendencies, in task-switching and in shifting between global and local features (Hupfeld et al., 2019; Ozel-Kizil et al., 2016). Future studies should explore the relationship between hyperfocus and specific EF domains by employing a combination of both self-reports and objective measures across various EF domains. Different EF measures have been shown to provide distinct information (Barkley & Fischer, 2011) and reflect different EF theories (Chan et al., 2008), which relevance to hyperfocus is worth exploring in future studies.

The current study enhances our comprehension of the neurocognitive processes mediating the relationship between ADHD and hyperfocus. We offer support for the hypothesis that difficulties in EF mediate the relationship between ADHD and both general and specific hyperfocus, as measured by the HS. In both analyses, the indirect effect of EF could explain approximately one-quarter of the relationship between ADHD and hyperfocus. An explanation for this indirect influence is that HS total scores partly measure other ADHD characteristics (e.g., procrastination) that are also mediated by EF (Bolden & Fillauer, 2020). This interpretation is in line with previous criticism of the HS scale being conflated with EF difficulties (see Hupfeld et al., 2019) and the structural validation in the current sample (see Supplementary Material). While our sensitivity analysis suggested that the mediation effect was still significant when using a hyperfocus measure less conflated with procrastination and time perception difficulties (i.e., the HS hyperfocus subscale measuring specific hyperfocus), these findings call for a careful interpretation. Furthermore, EF did not significantly mediate the relationship between ADHD and reward-related hyperfocus as measured by the DHS-AHQ. This scale also exhibits a weaker correlation with EF than the HS scales. Taken together, EF difficulties accounted for about one-quarter of the relationship between ADHD and hyperfocus (general and specific), but not for the relationship between ADHD and reward-related hyperfocus.

Since EF difficulties did not mediate the relation between ADHD and reward-related hyperfocus, we hypothesize that reward sensitivity could serve as an additional neurocognitive mediator in the relationship between ADHD and hyperfocus. In line with the multiple-pathway model (e.g., Sonuga-Barke et al., 2010), both children and adults with ADHD were previously shown to have a greater preference for immediate over delayed rewards and to respond positively to immediate reward by improving attentional performance and persistence (e.g., Bubnik et al., 2015; Luman et al., 2008). The heightened sensitivity to immediate rewards in ADHD may explain the increased concentration above individual baseline levels, which may be perceived as hyperfocus. High self-reported reward sensitivity in ADHD has also been linked to tendencies to approach intense positive affect experiences (e.g., Mitchell, 2010), which, in turn, may contribute to the higher intensity, increased duration and narrowness of attentional focus (e.g., Gable & Harmon-Jones, 2008). Moreover, rewards seem to attenuate and even compensate EF difficulties experienced by individuals with ADHD (Marx et al., 2013). Reward sensitivity is thus a potential mediating processes between ADHD and hyperfocus that requires further exploration in future studies.

4.1. Strengths and limitations

The present findings must be interpreted in light of the study's strengths and limitations. The strengths of the current study are the large sample with sufficient statistical power and the statistical control for the effects of substances with cognitive enhancement effects, the consumption of which is becoming increasingly prevalent among university students (Sharif et al., 2021) and may mimic the effects of hyperfocus. This study also has a number of limitations. First, the current findings can only be generalized to similar populations of first-year Psychology students, where there is an overrepresentation of female participants. Given that hyperfocus is more likely to occur in younger age than in older age and in less educated adults compared to their more educated counterparts (Groen et al., 2020), it is advisable to replicate these findings in samples that encompass a wider range of ages and educational backgrounds. While our dimensional approach to ADHD has contributed to advancing knowledge about the mechanism of hyperfocus in ADHD, it is important to note that the current findings also warrant replication in a clinical sample of adults with ADHD. Second, English was not the native language of the large majority of the participants in this study. This might have influenced the interpretation of items and introduced bias into the self-report ratings. This is particularly relevant regarding the complexity of the items in the two hyperfocus scales (see Materials and Supplementary Material for examples). Some of the HS and DHS-AHQ items are double-barrelled (e.g., ask about hyperfocus and its negative consequences) and contain long behavioural descriptions, which may have contributed to the interpretation difficulties. While all participants possessed an adequate command of the English language, a prerequisite for enrolment in the English-taught university program, and we made efforts to mitigate this limitation by excluding participants who reported difficulties in interpreting survey items, it is advisable to replicate the current findings in the participants' native language. Third, the current findings relied solely on self-reports, which are susceptible to bias. In future studies, taking into account objective measures of EF and hyperfocus (e.g., behavioural performance in the Navon task) may help overcome the bias inherent in self-evaluations. Moreover, our adapted translation of the HS has a number of differences in terms of content and structural validity relative to the original version (see Supplementary Material), which might have influenced the comparability to prior studies. While we offer initial evidence of satisfactory convergent validity among different hyperfocus measures, further research is required to investigate their structural and external validity in larger and more heterogeneous samples. A final limitation pertains to the data collection period, which partially overlapped with several COVID-19 pandemic lockdowns. During this period, university students at a higher risk of ADHD exhibited more problematic internet use compared to those at a lower risk (Zhao et al., 2021), which could have been associated with increased levels of hyperfocus (Ishii et al., 2023). Hence, it is plausible that, some participants may have experienced a greater frequency of hyperfocus during the period of the study. This underscores the importance of considering external variables that could potentially influence the reliability of self-reports of hyperfocus in future studies.

5. Conclusions

The goal of this study was to understand the neurocognitive mechanisms that could account for the relationship between ADHD and hyperfocus. Our findings indicate that university students who exhibit more severe ADHD symptoms and greater EF difficulties also experience hyperfocus and reward-related hyperfocus more frequently. Furthermore, our results provide support to the idea that EF difficulties partially mediate the relationship between ADHD and hyperfocus, explaining about one-quarter of the effect, but not the relationship between ADHD and reward-related hyperfocus. Additional research is required to investigate the neurocognitive functions, including specific EF and reward sensitivity, which might mediate the relationship between ADHD and different aspects of hyperfocus in both clinical and non-clinical populations. This exploration should encompass both subjective and objective measures of neurocognitive functions and hyperfocus, as well as the further validation of the hyperfocus construct. Enhancing our comprehension of the neurocognitive processes underlying hyperfocus could establish the foundations for preventing hyperfocus-related daily life difficulties and promote attention compensation strategies in individuals with ADHD.

CRediT authorship contribution statement

Miguel Garcia Pimenta: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing – original draft, Writing – review & editing, Supervision, Project administration, Resources; **Rixa Käthe Gruhnert:** Investigation, Formal analysis, Writing – original draft, Writing – review & editing; **Anselm B. M. Fuermaier:** Conceptualization, Writing – review & editing; **Yvonne Groen:** Conceptualization, Writing – review & editing. All authors revised the article and approved the final version to be published.

Conflicts of interest

The authors report no conflicts of interest.

Data Availability

Data will be made available on request. The datasets generated during and /or analysed during the current study are available from the corresponding author on reasonable request.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ridd.2023.104639.

References

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders* (fourth ed.). Washington, DC: Author. https://doi.org/10.1176/ajp.152.8.1228. Text Revision.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (fifth ed.). Arlington, VA: Author. https://doi.org/10.1176/appi.books.9780890425596

Ashinoff, B. K., & Abu-Akel, A. (2019). Hyperfocus: The forgotten frontier of attention. *Psychological Research, 1*, 1–19. https://doi.org/10.1007/s00426-019-01245-8

Barkley, R. A. (2011). *Barkley Deficits in Executive Functioning Scale (BDEFS for adults)*. Guilford Press.

Barkley, R. A., & Fischer, M. (2011). Predicting impairment in major life activities and occupational functioning in hyperactive children as adults: Self-reported Executive Function (EF) deficits versus EF tests. *Developmental Neuropsychology, 36*(2), 137–161. https://doi.org/10.1080/87565641.2010.549877

Barkley, R. A., & Murphy, K. R. (2011). The nature of executive function (EF) deficits in daily life activities in adults with ADHD and their relationship to performance on EF tests. *Journal of Psychopathology and Behavioral Assessment, 33*(2), 137–158. https://doi.org/10.1007/s10862-011-9217-x

Bolden, J., & Fillauer, J. P. (2020). " Tomorrow is the busiest day of the week ": Executive functions mediate the relation between procrastination and attention problems. *Journal of American College Health, 68*(8), 854–863. https://doi.org/10.1080/07448481.2019.1626399

Bubnik, M. G., Hawk, L. W., Jr, Pelham, W. E., Jr, Waxmonsky, J. G., & Rosch, K. S. (2015). Reinforcement enhances vigilance among children with ADHD: Comparisons to typically developing children and to the effects of methylphenidate. *Journal of Abnormal Child Psychology, 43*, 149–161. https://doi.org/10.1007/s10802-014-9891-8

Caye, A., Swanson, J., Thapar, A., Sibley, M., Arseneault, L., Hechtman, L., Arnold, L. E., Niclasen, J., Moffitt, T., & Rohde, L. A. (2016). Life span studies of ADHD—conceptual challenges and predictors of persistence and outcome. *Physiology & Behavior, 18*(12), 111. https://doi.org/10.1007/s11920-016-0750-x.Life

Chan, R. C. K., Shum, D., Toulopoulou, T., & Chen, E. Y. H. (2008). Assessment of executive functions: Review of instruments and identification of critical issues. *Archives of Clinical Neuropsychology, 23*(2), 201–216. https://doi.org/10.1016/j.acn.2007.08.010

Clauss, K., Witte, T. K., & Bardeen, J. R. (2021). Examining the factor structure and incremental validity of the barkley deficits in executive functioning scale – Short form in a community sample. *Journal of Personality Assessment, 102*(3), 415–427. https://doi.org/10.1080/00223891.2021.1887879

Cribari-Neto, F., Ferrari, S. L. P., & Oliveira, W. A. S. C. (2005). Numerical evaluation of tests based on different heteroskedasticity-consistent covariance matrix estimators Numerical evaluation of tests based on different heteroskedasticity-consistent covariance matrix estimators. *Journal of Statistical Computation and Simulation, 75*(8), 611–628. https://doi.org/10.1080/00949650410001729427

Dehili, V. M., Prevatt, F., & Coffman, T. P. (2017). An analysis of the barkley deficits in executive functioning scale in a college population: Does It predict symptoms of ADHD better than a visual-search task? *Journal of Attention Disorders, 21*(7), 567–574. https://doi.org/10.1177/1087054713498932

Dibbets, P., Evers, E. A. T., Hurks, P. P. M., Bakker, K., & Jolles, J. (2010). Differential brain activation patterns in adult attention-deficit hyperactivity disorder (ADHD) associated with task switching. *Neuropsychology, 24*(4), 413–423. https://doi.org/10.1037/a0018997

DuPaul, G. J., Weyandt, L. L., O'Dell, S. M., & Varejao, M. (2009). College students with ADHD current status and future directions. *Journal of Attention Disorders, 13*, 234–250. https://doi.org/10.1177/1087054709340650

Fayyad, J., Sampson, N. A., Hwang, I., Adamowski, T., Aguilar-Gaxiola, S., Al-Hamzawi, A., Andrade, L. H. S. G., Borges, G., de Girolamo, G., Florescu, S., Gureje, O., Haro, J. M., Hu, C., Karam, E. G., Lee, S., Navarro-Mateu, F., O'Neill, S., Pennell, B. E., Piazza, M., & Wojtyniak, B. (2017). The descriptive epidemiology of DSM-IV Adult ADHD in the World Health Organization World Mental Health Surveys. *ADHD Attention Deficit and Hyperactivity Disorders, 9*(1), 47–65. https://doi.org/10.1007/s12402-016-0208-3

Fosco, W. D., Kofler, M. J., Alderson, R. M., Tarle, S. J., Raiker, J. S., & Sarver, D. E. (2019). Inhibitory control and information processing in ADHD: Comparing the dual task and performance adjustment hypotheses. *Journal of Abnormal Child Psychology, 47*(6), 961–974. https://doi.org/10.1007/s10802-018-0504-9

Fuermaier, A. B. M., Tucha, O., Koerts, J., Tucha, L., Thome, J., & Faltraco, F. (2021). Feigning ADHD and stimulant misuse among Dutch university students. *Journal of Neural Transmission, 128*(7), 1079–1084. https://doi.org/10.1007/s00702-020-02296-7

Gable, P. A., & Harmon-Jones, E. (2008). Approach-motivated positive affect reduces breadth of attention. *Psychological Science, 19*(5), 476–482.

Garcia Pimenta, M., Fuermaier, A. B. M., Tucha, L., Tucha, O., & Groen, Y. (2019). The role of executive functions in hyperfocusing and flow experiences in people with ADHD Traits [Poster]. *7th World Congress on ADHD*.

Groen, Y., Priegnitz, U., Fuermaier, A. B. M., Tucha, L., Tucha, O., Aschenbrenner, S., Weisbrod, M., & Garcia Pimenta, M. (2020). Testing the relation between ADHD and hyperfocus experiences. *Research in Developmental Disabilities, 107*, Article 103789. https://doi.org/10.1016/j.ridd.2020.103789

Hayes, A. F. (2018). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach (2nd Ed.)*. Guilford Press,.

Hupfeld, K. E., Abagis, T. R., & Shah, P. (2019). Living "in the zone": Hyperfocus in adult ADHD. *ADHD Attention Deficit and Hyperactivity Disorders, 11*(2), 191–208. https://doi.org/10.1007/s12402-018-0272-y

Ishii, S., Takagi, S., Kobayashi, N., Jitoku, D., Sugihara, G., & Takahashi, H. (2023). Hyperfocus symptom and internet addiction in individuals with attention-deficit/hyperactivity disorder trait. *Frontiers in Psychiatry, 14*, Article 1127777. https://doi.org/10.3389/fpsyt.2023.1127777

Kessler, R. C., Adler, L., Ames, M., Demler, O., Faraone, S., Hiripi, E., Howes, M. J., Jin, R., Scnik, K., Spencer, T., Ustun, T. B., & Walters, E. E. (2005). The World Health Organization adult ADHD self-report scale (ASRS): A short screening scale for use in the general population. *Psychological Medicine, 35*(2), 245–256. https://doi.org/10.1017/S0033291704002892

Lace, J. W., McGrath, A., & Merz, Z. C. (2020). A factor analytic investigation of the Barkley deficits in executive functioning scale, short form. *Current Psychology, 41* (4), 2297–2305. https://doi.org/10.1007/s12144-020-00756-7

Luck, S. J., Hahn, B., Leonard, C. J., & Gold, J. M. (2019). The hyperfocusing hypothesis: A new account of cognitive dysfunction in schizophrenia. *Schizophrenia Bulletin, 45*(5), 991–1000. https://doi.org/10.1093/schbul/sbz063

Luman, M., Oosterlaan, J., & Sergeant, J. A. (2008). Modulation of response timing in ADHD, effects of reinforcement valence and magnitude. *Journal of Abnormal Child Psychology, 36*, 445–456. https://doi.org/10.1007/s10802-007-9190-8

Luna-Rodriguez, A., Wendt, M., Kerner auch Koerner, J., Gawrilow, C., & Jacobsen, T. (2018). Selective impairment of attentional set shifting in adults with ADHD. *Behavioral and Brain Functions, 14*, Article 18. https://doi.org/10.1186/S12993-018-0150-Y

Marcus, D. K., & Barry, T. D. (2011). Does attention-deficit/hyperactivity disorder have a dimensional latent structure? A taxometric analysis. *Journal of Abnormal Psychology, 120*(2), 427–434. https://doi.org/10.1037/a0021405

Marx, I., Hö Pcke, C., Berger, C., Wandschneider, R., & Herpertz, S. C. (2013). The Impact of Financial Reward Contingencies on Cognitive Function Profiles in Adult ADHD. *PLoS ONE, 8*(6), 67002. https://doi.org/10.1371/journal.pone.0067002

Mitchell, J. T. (2010). Behavioral approach in ADHD: Testing a motivational dysfunction hypothesis. *Journal of Attention Disorders, 13*(6), 609–617. https://doi.org/10.1177/1087054709332409

Miyake, A., & Friedman, N. P. (2012). The nature and organisation of individual differences in executive functions: Four general conclusions. *Current Directions in Psychological Science, 21*(1), 8–14. https://doi.org/10.1177/0963721411429458.The

Navon, D. (1977). Forest before trees: The precedence of global features in visual perception. *Cognitive Psychology, 9*(3), 353–383. https://doi.org/10.1016/0010-0285(77)90012-3

Nigg, J. T. (2017). Annual Research Review: On the relations among self-regulation, self-control, executive functioning, effortful control, cognitive control, impulsivity, risk-taking, and inhibition for developmental psychopathology. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 58*(4), 361–383. https://doi.org/10.1111/jc

Ozel-Kizil, E., Demirbas, H., Bastug, G., Kirici, S., Tathan, E., Kasmer, N., & Baskak, B. (2013). P.7.b.012 A scale for the assessment of hyperfocusing in attention deficit and hyperactivity disorder. *European Neuropsychopharmacology, 23*(Supplement 2), S593. https://doi.org/10.1016/S0924-977X(13)70944-1

Ozel-Kizil, E. T., Kokurcan, A., Aksoy, U. M., Kanat, B. B., Sakarya, D., Bastug, G., Colak, B., Altunoz, U., Kirici, S., Demirbas, H., & Oncu, B. (2016). Hyperfocusing as a dimension of adult attention deficit hyperactivity disorder. *Research in Developmental Disabilities, 59*, 351–358. https://doi.org/10.1016/j.ridd.2016.09.016

Preacher, K. J., & Kelley, K. (2011). Effect size measures for mediation models: Quantitative strategies for communicating indirect effects. *Psychological Methods, 16* (2), 93–115. https://doi.org/10.1037/a0022658

Roberts, C. A., Jones, A., Sumnall, H., Gage, S. H., & Montgomery, C. (2020). How effective are pharmaceuticals for cognitive enhancement in healthy adults? A series of meta-analyses of cognitive performance during acute administration of modafinil, methylphenidate and D-amphetamine. *European Neuropsychopharmacology, 38*, 40–62. https://doi.org/10.1016/j.euroneuro.2020.07.002

Sedgwick, J. A., Merwood, A., & Asherson, P. (2019). The positive aspects of attention deficit hyperactivity disorder: A qualitative investigation of successful adults with ADHD. *ADHD Attention Deficit and Hyperactivity Disorders, 11*(3), 241–253. https://doi.org/10.1007/s12402-018-0277-6

Sharif, S., Guirguis, A., Fergus, S., & Schifano, F. (2021). The use and impact of cognitive enhancers among university students: A systematic review. *Brain Sciences, 11* (3), 1–44. https://doi.org/10.3390/brainsci11030355

Silverstein, M., Faraone, S., Leon, T., Biederman, J., Spencer, T., & Adler, L. (2020). The RelationShip Between Executive Function Deficits and DSM-5-Defined ADHD Symptoms. *Journal of Attention Disorders, 24*(1), 41–51. https://doi.org/10.1177/1087054718804347

Song, Y., & Hakoda, Y. (2015). Lack of global precedence and global-to-local interference without local processing deficit: A robust finding in children with attention-deficit/hyperactivity disorder under different visual angles of the Navon task. *Neuropsychology, 29*(6), 888–894. https://doi.org/10.1037/neu0000213

Sonuga-Barke, E., Bitsakou, P., & Thompson, M. (2010). Beyond the dual pathway model: Evidence for the dissociation of timing, inhibitory, and delay-related impairments in attention-deficit/hyperactivity disorder. *Journal of the American Academy of Child & Adolescent Psychiatry, 49*(4), 345–355. https://doi.org/10.1016/J.JAAC.2009.12.018

Wigal, S. B., Wong, A. A., Jun, A., Stehli, A., Steinberg-Epstein, R., & Lerner, M. A. (2012). Adverse events in medication treatment-naïve children with attention-deficit/hyperactivity disorder: Results from a small, controlled trial of lisdexamfetamine dimesylate. *Journal of Child and Adolescent Psychopharmacology, 22*(2), 149–156. https://doi.org/10.1089/cap.2010.0095

Zhao, Y., Jiang, Z., Guo, S., Wu, P., Lu, Q., Xu, Y., Liu, L., Su, S., Shi, L., Que, J., Sun, Y., Sun, Y., Deng, J., Meng, S., Yan, W., Yuan, K., Sun, S., Yang, L., Ran, M., & Shi, J. (2021). Association of symptoms of attention deficit and hyperactivity with problematic internet use among university students in Wuhan, China DURING THe COVID-19 pandemic. *Journal of Affective Disorders, 286*, 220–227. https://doi.org/10.1016/j.jad.2021.02.078