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Testing the relation between ADHD and hyperfocus experiences

Yvonne Groen [a], Ulrike Priegnitz [a], Anselm B.M. Fuermaier [a], Lara Tucha [b], Oliver Tucha [b], Steffen Aschenbrenner [c,d], Matthias Weisbrod [c,e], Miguel Garcia Pimenta [a,*]

[a] University of Groningen, Clinical and Developmental Neuropsychology, Grote Kruisstraat 2/1, 9712 TS, Groningen, the Netherlands
[b] Department of Psychiatry and Psychotherapy, University Medical Center Rostock, Gehlsheimer Str. 20, 18147, Rostock, Germany
[c] Department of Psychiatry and Psychotherapy, SRH Clinic Karlsbad-Langensteinbach, 76307, Karlsbad, Germany
[d] Clinical Psychology and Neuropsychology, SRH Clinic Karlsbad-Langensteinbach, 76307, Karlsbad, Germany
[e] Department of General Psychiatry, Center of Psychosocial Medicine, University of Heidelberg, Germany

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ABSTRACT

Background: Attention-deficit/hyperactivity disorder (ADHD) has been associated with hyperfocus, a transient experience of enhanced attentional focus and diminished awareness of time and the environment.
Aims: This study aims to investigate the association between the frequency, duration and pervasiveness of hyperfocus across different situations in adults with and without ADHD.
Method and procedures: Within a healthy sample ($n = 1124$), we analysed correlations between scores on the ADHD Rating Scale and self-reports of frequency, duration and pervasiveness of hyperfocus. An ADHD patient group ($n = 78$) was compared to matched healthy participants on all hyperfocus variables.
Outcomes and results: In healthy adults, the frequency of hyperfocus was positively correlated with ADHD traits; older age and higher education were correlated with fewer hyperfocus occurrences in a smaller number of situations. ADHD patients and matched controls did not differ in the occurrence, frequency, duration and pervasiveness of hyperfocus, but hyperfocus was less likely to occur in educational and social situations in ADHD patients.
Conclusions and implications: Hyperfocus experiences are not specific of ADHD patients. The divergent findings might reflect multiple hyperfocus dimensions (situational and motivational) assessed in different studies which need to be addressed in future research.

What this paper adds?

This paper is the first to report on the duration and pervasiveness of hyperfocus in adults with and without ADHD. Although ADHD and controls did not differ in terms of overall hyperfocus frequency, duration and pervasiveness, our results suggest a crucial role for motivational and situational aspects in eliciting the phenomenon. Hyperfocus was less likely to occur in situations that are typically felt as problematic (and consequently as less rewarding) by people with ADHD, such as educational and social activities. Interestingly, in previous studies, the conceptualisation of hyperfocus as a clinical phenomenon (Ozel-Kizil et al., 2016) and as being associated with intrinsily rewarding activities (Hupfeld, Abagis, & Shah, 2019) might have been related to its higher frequency in adults with ADHD.

* Corresponding author at: 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).

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The current study additionally highlights the role of age and educational level in the duration and pervasiveness of hyperfocus. Taken together our results propose a fundamental role for situational, motivational, clinical but also demographics variables in determining the hyperfocus experience in adults with ADHD which should be explicitly addressed in future studies.

1. Introduction

Hyperfocus experiences in patients with attention-deficit/hyperactivity disorder (ADHD) are frequently reported in the popular science press (e.g. Maucieri, 2014; Kolberg & Nadeau, 2016). Popular media describe hyperfocus as a "laser fixated [concentration] on a specific event or topic", with a "type of focus [that] is narrower and more intense than most of us have experienced when we concentrate on something" (Maucieri, 2014). In the self-help literature patients with ADHD are advised to find constructive ways to use hyperfocus to their advantage and to limit their negative consequences by setting reminders (Kolberg & Nadeau, 2016). Although the occurrence of hyperfocus in patients with ADHD is a known symptom in clinical practice, it is not included in diagnostic manuals as an official symptom of ADHD. The present study sets out to explore the relationship between self-reported hyperfocus and ADHD in adults with and without ADHD.

The numerous reports of hyperfocus in ADHD in the popular media seem counterintuitive, considering that ADHD is defined by symptoms of inattention and/ or hyperactive-impulsive behaviour (American Psychiatric Association, 2000). ADHD has its onset in childhood with a prevalence between 5.9 % and 7.1 % in children and adolescents (Willcutt, 2012) and persists into adulthood in around two-thirds of the cases (Kooij et al., 2010). Inattention is a predominant symptom affecting up to 93 % of adult patients with ADHD (Millstein, Wilens, Biederman, & Spencer, 1997). Cognitive studies objectified that adult patients with ADHD present with impairments in multiple components of attention (Fuermaier et al., 2015; Hervey, Epstein, & Curry, 2004; Mostert et al., 2015; Schoechlin & Engel, 2005; Tucha et al., 2008). Some studies point to particular difficulties in sustaining attention to one or more stimuli during prolonged periods of time, which leads to stronger performance decrements with time-on-task compared to healthy participants (Marchetta, Hurks, De Sonneville, Krabbendam, & Jolles, 2008; Tucha et al., 2017).

Perhaps counterintuitively, the presence of inattention symptoms and impairments in sustained attention do not exclude the possibility of experiencing hyperfocus. According to several theoretical accounts of ADHD these phenomena can be explained by deficits in attention regulation. Kaufmann, Kalbfleisch, and Castellanos (2000) proposed that "ADHD is not characterized by an inability to sustain attention, but rather by the inability to appropriately regulate the application of attention to tasks that are not intrinsically rewarding and/or that require effort" (p. 14). In a similar vein, state regulation deficit models such as the cognitive-energetic model (CEM) suggest that neuropsychological deficits in ADHD are due to an under- or over-activation of an optimal energetic state (Sergeant, 2005; Van der Meere, 2005). According to this model, if task demands do not match with the energetic state, effort is required to adjust arousal and activation to a more optimal performance level (Sergeant, 2005; Sonuga-Barke, Wiersema, van der Meere, & Roeyers, 2010; Van der Meere, 2005). Patients with ADHD may present a disturbed and lower involvement of effort allocation, particularly in an under-activated state. Therefore, they show symptoms of inattention during tasks with a slow presentation rate of stimuli (Van der Meere, Stemerdink, & Gunning, 1995). However, the CEM model predicts that in situations of overactivation and that do not require effortful control, these patients would experience increased attentional focus, which can be equated as a state of hyperfocusing.

Contrary to the popular media, only few scientific sources mentioned hyperfocus in relation to ADHD. A first demonstration of this relation came from a study in which patients with ADHD reported being more engaged, showed greater distorted time perception and unawareness of their surroundings while playing a video game when compared to healthy participants (Sklar, 2013). More recently, Ozel-Kizil et al. (2016) reported a higher level of hyperfocus in adult patients with ADHD compared to healthy controls in a newly developed 11-item clinical measure of hyperfocus. According to the factorial analysis, their Hyperfocusing Scale (HS; Ozel-Kizil et al., 2013) assesses hyperfocus as well as associated functional impairments in time management and procrastination. However, as recently pointed out by Hupfeld et al. (2019), some items of this scale (e.g., "It is often not to complete work which I have started") might reflect either executive dysfunctions typically observed in ADHD or negative consequences of hyperfocus more than the phenomenon *per se*. Importantly, Ozel-Kizil et al. (2016) found that patients using psychostimulant medication were not more prone to experience hyperfocus than those not taking medication, an important distinction since hyperfocus has been reported as a side-effect of amphetamines in children with ADHD (Wigal et al., 2012). Thus, despite some methodological limitations, Ozel-Kizil et al. (2016) provide scientific support for the popular claim of an association between ADHD and hyperfocus independent from the effects of psychostimulant medication.A study recently published during the final preparation of the current study provided further confirmation of the association between hyperfocus and ADHD. Hupfeld et al. (2019) developed the Adult Hyperfocus Questionnaire (AHQ) measuring dispositional hyperfocus (defined as the proneness to experience a heightened state of attentional focus during enjoyable or rewarding activities irrespective of the situation) and situational hyperfocus (defined as the frequency of the phenomenon in specific situations) in three different settings: "school", "hobbies" and "screen time". Hyperfocus was defined as an experience of complete focus on a task to the point of becoming difficult to switch attention from it and getting "stuck" on its details, failure to attend to the self and the world, and loss of the sense of time. Using this questionnaire in two large samples with and without (self-reported) ADHD, the authors showed that participants that reported ADHD in childhood and adulthood experienced more frequent dispositional and situational hyperfocus compared to controls. The AHQ thus seems to represent a significant progress in validating the construct of hyperfocus and in measuring its frequency in ADHD and non-ADHD populations. However, by limiting the number of hyperfocus situations to three, the instrument might not be representative of the range of activities in which adults experience hyperfocus (e.g., work or social activities). For instance, a measure recently developed by our group measuring situational variations in attention focus and intensity in nine different daily activities has been shown to be sensitive to attentional problems experienced by adults diagnosed with ADHD in

everyday life activities (Fuermaier et al., 2019; Groen et al., 2018). Thus, similarly to deficits in attentional focus, it is possible that hyperfocus is more pervasive (i.e., occurs in more situations) than the three situations assessed by the AHQ.

The present study aimed to further test the relationship between ADHD and hyperfocus. Based on the assumption that hyperfocus may be associated with the level of activation and effort implied by a given activity or situation, and more so in individuals with deficits in attention regulation, we set out to investigate whether ADHD trait severity in a large sample of healthy adults would be associated with the frequency, duration and pervasiveness of hyperfocus. Based on previous empirical findings, we further predicted increased frequency, duration and pervasiveness of hyperfocus in a sample of adult patients with ADHD compared to matched healthy controls.

2. Method

2.1. Participants and design

The data set includes two independently recruited samples: a group of patients with ADHD and a group of healthy participants. Participation was voluntary and not paid. Before starting the survey, participants were given information about the confidentiality and gave their informed consent. The study was approved by the ethical committees of the institutions where participants were recruited.

2.1.1. Healthy participants group

The data of healthy adults (18 years +) was recruited within a 4-year period as part of a larger project developed at the Department of Clinical and Developmental Neuropsychology at the University of Groningen. The initial dataset included 1490 healthy participants. Participants with incomplete data entries for the variables of interest of this study were excluded ($n = 286$). Participants who reported a psychological disorder or reported taking psychotropic drugs were also excluded ($n = 80$). After applying these exclusion criteria 1124 participants ranging from 18 to 86 were included (see Table 1 for the group characteristics).

2.1.2. ADHD patient group

The data of 93 patients with ADHD was collected via the inpatient and outpatient clinic of the Department of Psychiatry and Psychotherapy of the SHR clinic Karlsbad-Langensteinbach in Germany. For the diagnostic assessment, clinical psychiatric interviews developed by Barkley and Murphy (1998) were used. These included both a retrospective diagnosis of ADHD in childhood as well as current symptoms according to DSM-IV criteria (American Psychiatric Association, 2000). Diagnostic assessments were performed by experienced clinicians and diagnoses were made by mutual agreement between at least two clinicians experienced in the assessment and treatment of adults with ADHD. The diagnostic assessment also included identifying objective impairments supporting the diagnosis of ADHD (e.g. evidence derived from school reports, failure in academic and/or occupational achievement) and comprised multiple informants, such as employer evaluation and partner- or parent-reports. Due to the high occurrence of comorbidities in patients with ADHD (Sherman & Tarnow, 2013), the patients with another diagnosis ($n = 45$, e.g. depression, posttraumatic stress disorder, obsessive compulsive disorder, personality disorders) and/or patients who were using medication ($n = 46$, e.g. psychostimulants, antidepressants) were not excluded from the data set in order to have a sample that is representative of the ADHD population. Only participants with missing data such as incomplete questionnaires were excluded. After this exclusion criterion had been applied, the data set comprised information of 78 participants with ADHD (32 females). The age ranged from 18 to 63 years (see Table 1 for more detailed group characteristics).

2.1.3. Matched comparison groups

In order to compose a matched comparison group for the ADHD patient group, 78 healthy participants were selected from the dataset of healthy participants with similar characteristics in age, sex and level of education as the group of patients with ADHD ('matched controls 1'). Matching was performed manually by ordering the data according to the matching variables and then picking the best match in the order of sex, level of education, and age. Prior to the matching procedure, healthy participants who were at risk for having ADHD were excluded (based on ADHD Rating Scale, see Measures section). In order to allow matching for education

Table 1
Group characteristics.

	Healthy participants ($n = 1124$)	ADHD patients ($n = 78$)	Matched controls 1 ($n = 78$)	Test statistics ADHD patients vs. Matched controls 1
Sex (female/male)	684/440	34/44	32/46	$\chi^2(1, N = 156) = 0.105$, $p = .746$
Age in years *M(SD)*	35.8 (15.6)	32.8 (12.3)	32.0 (11.2)	$t(154) = 0.382$, $p = .703$
Educational level (low/ medium/high)	165/554/398	19/21/38	14/27/37	$\chi^2(1, N = 156) = 1.521$, $p = .467$
ADHD subtype (H/I/C)	n.a.	1/12/57	n.a.	n.a.
Medication (yes/no)	n.a.	46/32	n.a.	n.a.
Comorbidities (yes/no)	n.a.	45/33	n.a.	n.a.

Note: Educational level low = primary school or lower secondary school; Educational level medium = Secondary Vocational Education; Educational level high = academic high school, University Bachelor or University Master; H = Hyperactive–impulsive subtype; I = Inattentive subtype; C = Combined subtype; n.a. = not applicable.

between the two samples, the level of education was recoded into the three groups "low education", "medium education" and "high education" (see Table 1 for the coding). Group comparisons indicated that the ADHD patient group and the matched control group did not differ significantly with regard to the variables age, sex and level of education (see Table 1). In order to check for the reliability of our findings, we matched a second independent control group from the dataset of healthy participants ('matched controls 2') and repeated our analyses with that group.

2.2. Procedure and measures

Participants were asked to complete a survey as part of a psychometric study of a newly developed attention questionnaire, which took approximately 40 min to complete. Participants completed the survey either on paper or online via Qualtrics (Qualtrics, 2005). The ADHD patient group completed the survey during their assessment for ADHD, however the information was not used to inform the diagnosis but for research purposes only. For each participant, informed consent was obtained before starting the study. The questionnaires were completed as part of a larger study, but only measures of interest are described in this context.

2.2.1. Demographics

Participants were asked 20 questions about demographic characteristics including sex, age, level of education, psychological or psychiatric diagnoses and use of medication.

2.2.2. ADHD rating scale (ARS)

The ARS (Kooij et al., 2005) is a self-report measure for DSM-IV ADHD symptoms. It has been shown to be a reliable instrument that adequately predicts a clinical diagnosis of ADHD (Kooij et al., 2008). The ARS was completed twice by the healthy participant group (and not by the patient group); once for childhood symptoms and once for current symptoms. The form for current symptoms consists of 23 items referring to DSM-IV symptoms of hyperactivity/ impulsivity (e.g. "When I am sitting in a chair, I often move my hands or feet in a restless manner") and inattention (e.g. "I often fail to give close attention to details in my work) as experienced in the last six months (Kooij et al., 2005). For childhood symptoms, the items refer to the age up until 12. Response categories range from 0 to 3 (0 = rarely or never, 1 = sometimes, 2 = often, 3 = very often), with 2 and 3 being regarded as symptomatic scores. If 6 or more hyperactivity/impulsivity or inattention symptoms were present for the childhood version, and 5 or more for the adulthood version, the healthy participant was considered to be at risk for having ADHD (according to the DMS-5 criteria). These at-risk participants were excluded for the matching procedure. These participants were kept in the healthy participants group analysis in order not to artificially skew the normal distribution of scores of the ARS in line with the dimensional approach to ADHD (Coghill & Sonuga-Barke, 2012). For the healthy participants group, the total adult ARS scores were computed by summing up scores for the adulthood inattention traits, hyperactivity/impulsivity traits and combined traits.

2.2.3. Hyperfocus experiences

Four questions were included for measuring the occurrence, frequency, duration and pervasiveness of hyperfocus experiences: (1) "Do you ever have periods in which you are completely caught up in a task or activity, in such a way that you do not even notice time or the world around you?" *[hyperfocus occurrence]*, (2) "If yes, how often do you experience these periods?" *[hyperfocus frequency]*, (3) "How long do these periods last?" *[minimum duration* and *maximum duration]*, (4) "For which kind of tasks or activities do you have these periods?" *[hyperfocus situations]*. The first question was answered dichotomously ("Yes"/" No"). For the second question, the frequency of hyperfocus was assessed on the following Likert scale: once a year (1), couple of times a year (2), once a month (3), couple of times a month (4), once a week (5), couple of times a week (6), daily (7). For the analyses, "never" (0) was added to the frequency variable for the participants who indicated to not experience hyperfocus. For the third question, the participant had to indicate the minimum and maximum duration of hyperfocus in minutes. With regard to the fourth question, participants could freely enter the situations in which they experience hyperfocus.

The question about the different hyperfocus situations ("For which kinds of tasks or activities do you have these periods?") was coded by two independent raters into ten different categories: "Consuming media", "Creative work", "House work", "Educational activities", "Leisure time activities", "Social activities"," Spiritual", "Sports", "Video games", "Work" (see Table 2). Unspecific

Table 2
Coding scheme for categorizing the hyperfocus situations.

Hyperfocus category	Hyperfocus situations
Consuming media	Reading books; Listening to music; Watching TV; Surfing on the internet; Going to the cinema; Reading the newspaper/ magazines
Creative work	Playing an instrument; Knitting; Drawing; Doing handcrafts; Creative writing; Video and photo editing
House work	Cooking; Cleaning; Tidying
Educational activities	Studying; Exam preparations; Reading for university
Leisure time activities	Playing board games; Walking with dog; Car driving; Sex; Gardening; Solving (crossword) puzzles; Going to the theatre
Social activities	Talking with friends/ family/ colleagues; Having discussions, Talking on the phone; Chatting online
Spiritual	Meditation; Yoga; Praying
Sports	Running; Wall climbing; Cycling; Skateboarding; Football
Video games	Playing with the games console; Playing computer games; Playing games with a mobile/ tablet
Work	Administration for work; Appointments with clients; Giving lectures/ teaching

responses of participants ($n = 11$) were not counted (e.g. "diverse" or "anything"). We created a variable called *hyperfocus pervasiveness* by adding up the number of situations in which hyperfocus was experienced. To minimize errors in the coding procedure, the coding was performed independently by two trained research assistants. Interrater reliability for the codings of hyperfocus situations was high (Cohen's $\kappa = 0.95$, 95 % CI, .300–.886), $p < .001$). For the analyses, the count of one research assistant was used.

2.3. Statistical analyses

Statistical analyses were carried out by means of the Statistical Package for the Social Sciences (SPSS), Version 23. Within the healthy participants group, we tested whether ARS scores for the adulthood inattention traits, hyperactivity/impulsivity traits and combined traits correlated with *hyperfocus frequency, minimum* and *maximum hyperfocus duration,* and *hyperfocus pervasiveness*. Log transformations resulted in approximately normal distributions for the variables *minimum* and *maximum hyperfocus duration* but not for *hyperfocus frequency* and *hyperfocus pervasiveness*. Therefore, Spearman correlations were used for these two variables. Similar analyses were performed to explore the association between the hyperfocus variables and age, sex and level of education.

Group comparisons were performed between the ADHD patient group and the 'matched controls 1' for seven hyperfocus variables: *hyperfocus occurrence* (dichotomous variable: χ^2 test), *hyperfocus frequency* (interval variable: independent samples *t*-test), *minimum* and *maximum hyperfocus duration* (interval variable: independent samples *t*-test after log transformation), *hyperfocus situations* (dichotomous variable: χ^2 test) and *hyperfocus pervasiveness* (interval variable: independent samples *t*-test after log transformation). In order to check the reliability of our findings, we repeated these analyses with a second, independently matched, comparison group ('matched controls 2'). These analyses can be found in Supplement 1. For all analyses, the assumptions of normality, homoscedasticity and independence were checked. Parametric and nonparametric Levene's tests were used to verify the equality of variances in the samples. Log transformations were performed for variables that did not fulfil the assumptions for parametric tests. If the log transformation did not result in a normal distribution and homoscedasticity, nonparametric tests were carried out. Because of the exploratory nature of the study, an alpha level of 0.05 was adopted and two-tailed p-values are presented. For significant effects, Cohen's *d* effect sizes were calculated and evaluated.

3. Results

3.1. Healthy participants group

A frequency analysis showed that 82.7 % of the healthy participants ($n = 929/1124$) indicated to have *hyperfocus occurrences*. Those who indicated to have hyperfocus occurrences reported a mean frequency between once a month to a couple of times a month (see Table 3 and Fig. 1), and a median frequency of couple of times a month. These experiences lasted on average between 18 and 78 min. There was a significant but weak positive Spearman correlation between *hyperfocus frequency* and the ARS total score ($r_s = 0.064$, $p = .031$; 1000 bootstrapped CI-95 = 0.006 to 0.121) as well as the ARS hyperactive-impulsive score ($r_s = 0.076$, $p = 0.010$; 1000 bootstrapped CI-95 = 0.017 to 0.133) (see Table 3) as indicated by the bootstrapping confidence intervals. No significant correlations were found for the parametric tests examining the relation between the different ARS scores and *minimum* and *maximum hyperfocus duration*. In addition, no significant relationship was found for *hyperfocus pervasiveness* (see Table 3).

As shown in Table 4, the exploratory correlation analyses with age, sex and level of education revealed only small significant associations with *hyperfocus occurrence (*all *ps* $< .01$*)*, *minimum* (all *ps* $< .05$ except for sex) *and maximum hyperfocus duration* (all *ps* $< .01$ except for sex) and *hyperfocus pervasiveness (*all *ps* $< .01$*)*. Specifically, older age and higher education were related to more frequent occurrences of hyperfocus with a shorter duration and in less situations ($-0.013 < r_s < -0.201$). Also small correlations ($-0.006 < r_s < 0.089$) were found for sex, with females having fewer hyperfocus occurrence but in more situations.

3.2. ADHD patients vs. matched controls

The comparisons between the ADHD patients and the matched controls 1 revealed no significant differences for the *hyperfocus occurrence, hyperfocus frequency, minimum* and *maximum duration of hyperfocus* and *hyperfocus pervasiveness* (see Table 5). Around 75 % of the participants of both groups reported the occurrence of hyperfocus with an average frequency between once and a couple of times

Table 3
Descriptives of the hyperfocus variables and Spearman (r_s) and Pearson (r) correlations between the hyperfocus variables and ADHD traits.

	M (*SD*)	ARS Total	ARS Inattention	ARS Hyperactive-impulsive
Hyperfocus frequency (Likert scale) [a]	3.67 (2.19)	$r_s = 0.064$*	$r_s = 0.040$	$r_s = 0.076$*
Minimum hyperfocus duration (minutes)[b]	17.83 (27.26)	$r = -0.006$	$r = -0.018$	$r = 0.005$
Maximum hyperfocus duration (minutes)[b]	77.54 (136.24)	$r = 0.019$	$r = 0.009$	$r = 0.026$
Hyperfocus pervasiveness (number) [a]	1.66 (1.28)	$r_s = 0.023$	$r_s = -0.008$	$r_s = 0.042$

Note: a = never (0), once a year (1), couple of times a year (2), once a month (3), couple of times a month (4), once a week (5), couple of times a week (6), daily (7); b = Pearson correlations were computed with log−transformed values of this variable in order to improve normality of the distribution; for the variables Hyperfocus frequency and Hyperfocus pervasiveness, log transformations did not results in normality, therefore nonparametric test results are reported for these variables. * = $p < .05$; ARS = ADHD Rating Scale – adult scores.

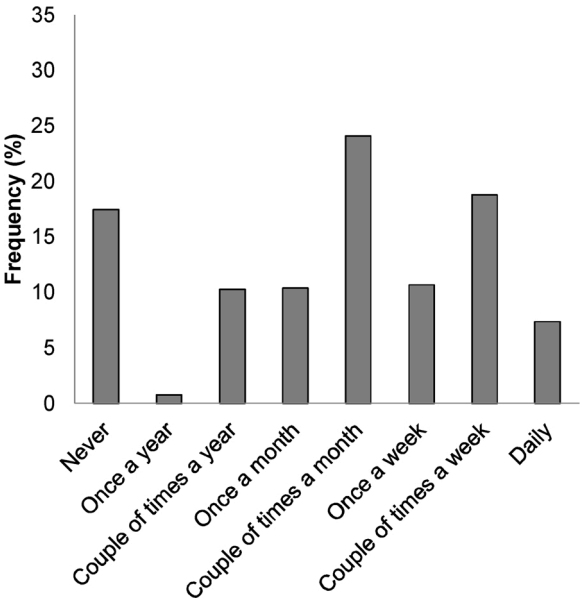

Fig. 1. Reported frequency of hyperfocus in the healthy participants group ($N = 1124$).

Table 4
Spearman correlations between the matching variables age, sex and level of education and the hyperfocus variables in the healthy participants group ($N = 1124$).

	Age	Sex	Level of education
Hyperfocus occurrence (yes/ no)	$r_s = 0.124$**	$r_s = -0.080$**	$r_s = 0.07$**
Hyperfocus frequency (Likert scale)	$r_s = -0.036$	$r_s = 0.034$	$r_s = -0.013$
Minimum hyperfocus duration (minutes)	$r_s = -0.097$**	$r_s = 0.052$	$r_s = -0.069$*
Maximum hyperfocus duration (minutes)	$r_s = -0.201$**	$r_s = -0.006$	$r_s = -0.150$**
Hyperfocus pervasiveness (number)	$r_s = -0.168$**	$r_s = 0.089$**	$r_s = -0.135$**

Note: * = $p < .05$; ** = $p < .01$.

a month, but ranging widely from a couple of times a year to daily. As shown in Fig. 2, compared to matched controls a higher percentage of ADHD patients reported experiencing hyperfocus daily and couple of times a week, even though the overall *t*-test was not significant. In these samples, the duration of hyperfocus ranged from minimally 8–12 min to maximally 48–69 min and did not statistically differ between the groups (see Table 5).

The analysis of the *hyperfocus situations* revealed that fewer patients with ADHD (4/78) than healthy matched controls (13/78) experienced hyperfocus during Educational activities ($\chi^2(1, N = 156) = 5.347, p = .037, \varphi = 0.19$). Also, fewer patients with ADHD (2/78) than healthy matched controls (10/78) reported experiencing hyperfocus in Social situations ($\chi^2(1, N = 156) = 5.778, p = .032, \varphi = 0.19$). Effect sizes were small for both significant effects. See Fig. 3 for a frequency distribution of hyperfocus experiences per situation in the ADHD and in the matched control group 1. No significant group differences in the frequencies were found for the remaining eight situations (Consuming media, Creative work, House work, Leisure activities, Spiritual activities, Sports, Videogames,

Table 5
Descriptives and test statistics of hyperfocus for the ADHD patient group and matched control group.

	Matched controls 1 ($n = 78$) *M (SD)*	ADHD patients ($n = 78$) *M (SD)*	Test statistics ADHD patients vs. Matched controls 1
Hyperfocus occurrence (yes/ no)	58/20	61/17	$\chi^2(1, N = 156) = 0.319$, p = .572
Hyperfocus frequency (Likert scale[a])	3.50(2.43)	4.01(2.62)	$t(154) = 1.268, p = .207$
Minimum hyperfocus duration (minutes)[b]	12.42(15.53)	7.63(12.10)	$t(154) = -1.831, p = .069$
Maximum hyperfocus duration (minutes)[b]	68.81(82.45)	47.51(76.30)	$t(154) = -0.999, p = .319$
Hyperfocus pervasiveness (number)[b]	1.71(1.38)	1.37(1.28)	$t(138) = -1.223, p = .223$

Note: a = never (0), once a year (1), couple of times a year (2), once a month (3), couple of times a month (4), once a week (5), couple of times a week (6), daily (7); b = Parametric test comparisons were computed with log–transformed values of this variable in order to improve normality of the distribution.

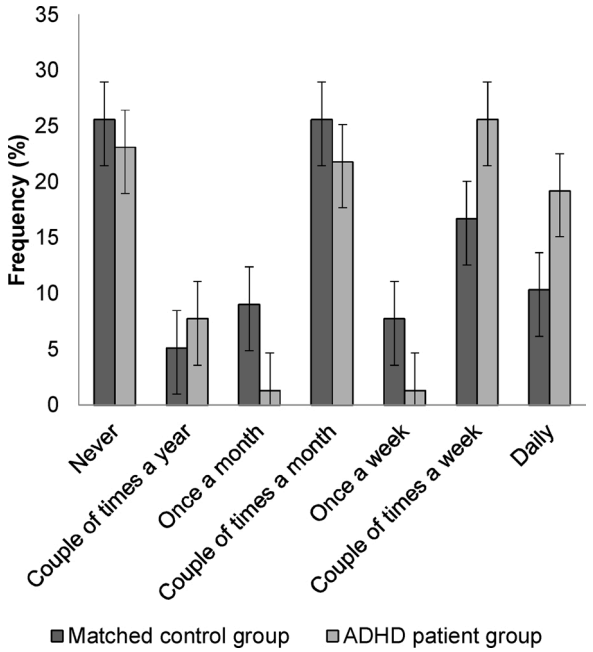

Fig. 2. Reported mean frequency (%) of hyperfocus by patients with ADHD and the matched control group. Error bars are shown with a 95 % confidence interval.

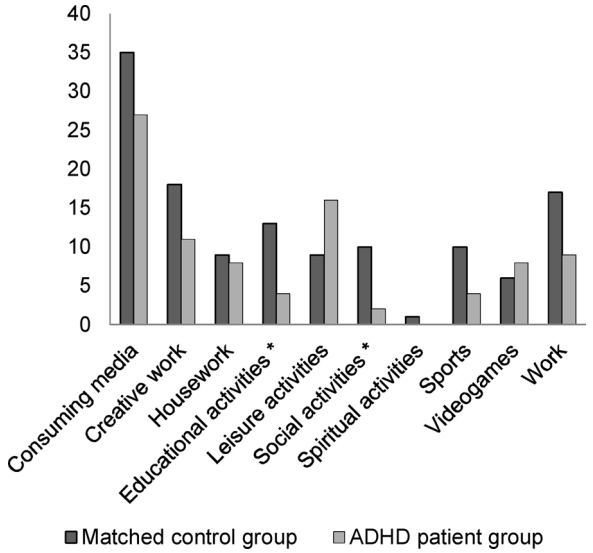

Fig. 3. Number of participants in the ADHD patient group and matched control group reporting hyperfocus per situation. Significant group differences were found for the social and educational situations (indicated by *).

Work).

We repeated the analyses with a second independently matched control group. Contrary to the initial analyses, ADHD patients showed significantly higher *hyperfocus frequency* and significantly lower *minimum duration of hyperfocus* relative to matched controls. Similarly to previous analyses, ADHD and matched control groups did not differ significantly in terms of *hyperfocus occurrence*, *maximum duration of hyperfocus* and *hyperfocus pervasiveness*. For a full report of these results see Supplement 1.

4. Discussion

The current study contributed to a better understanding of of hyperfocus in both healthy individuals and ADHD patients. The analyses of a large healthy sample revealed that 83 % of the people do experience hyperfocus in their everyday life. In line with

previous findings (Hupfeld et al., 2019), we found a small positive correlation between the frequency of hyperfocus and self-reported ADHD scores in our healthy sample. However, we found no evidence that the severity of ADHD symptoms would be positively correlated with the duration and pervasiveness of hyperfocus. Interestingly, we provided first evidence that demographic variables such as age, sex and educational level play a role in the experience of hyperfocus, even though correlations were generally small. In the healthy sample, both age and educational level were associated with a higher *hyperfocus occurrence*, but lower *hyperfocus pervasiveness* and lower *minimum* and *maximum hyperfocus duration*. These results suggest that higher expertise resulting from increased age and education may contribute to experiencing hyperfocus in a smaller number of activities (possibly the areas of expertise) and for shorter periods of time (possibly indicating more efficient problem solving).

Using a matched comparison sample, we demonstrated that the occurrence of hyperfocus was almost as likely in ADHD patients (78 %) as it is in a matched control group (74 %). These results were confirmed when using a second matched control group (70 %). However, our results were inconclusive regarding the higher frequency of hyperfocus in ADHD patients relative to healthy controls. In fact, a slightly higher frequency of hyperfocus was reported by ADHD patients (on average a couple of times a month) which was significant when compared to the second but not to first matched control group (once a month and between once a month and a couple of times a month, respectively). Thus, we failed to corroborate previous observations (Hupfeld et al., 2019; Ozel-Kizil et al., 2016) that ADHD patients experience hyperfocus more frequently than healthy control participants when matched for sex, age and educational level. On average, the duration of hyperfocus in patients with ADHD and matched controls ranged from minimally 8−12 min to maximally 48−69 min. Interestingly and contrary to predicted, ADHD patients reported a lower minimum duration of the hyperfocus episodes compared to matched controls, although this difference only reached statistical significance relative to the second matched control group. It must be noted that the reliability of the estimation of hyperfocus duration could have been hindered both by distortions of temporal duration judgements, which have been observed in ADHD patients (Marx et al., 2010), and errors of measurement inherent to retrospective self-reports. In both groups (taking together the two matched control group analyses), participants reported experiencing hyperfocus in one to two situations on average, most often during work, creative work and consuming media. Thus, our results could not provide strong support for the claims that hyperfocus has a significantly higher occurrence, frequency, duration or pervasiveness in ADHD patients relative to typically developing individuals. Based on our results we can conclude that hyperfocus experiences are also common in the healthy population.

The reasons for the different results observed between the current and previous studies can be both methodological and conceptual. One important methodological consideration is the influence of third variables. As shown in the current study, age and educational level were both significantly correlated with hyperfocus occurrence, duration and pervasiveness. Differently from the current study that used matched controls, previous studies showing higher frequency of hyperfocus in patients with ADHD may have insufficiently controlled for these variables. The findings of study 2 of Hupfeld et al. (2019) may be explained by a significant difference in age and a nearly significant difference in educational level between self-reported ADHD and non-ADHD groups. Also, the conclusion of Ozel-Kizil et al. (2016) that hyperfocus is a distinctive feature of ADHD needs reconsideration in light of the differences in age and educational level between their ADHD and healthy control groups. Although the authors reported that the higher hyperfocus scores in the ADHD groups persisted even after correcting for age and educational level differences, the use of ANCOVA is questionable in this case (Miller & Chapman, 2001) as it cannot be assumed that age and educational level are independent from ADHD nor from the ability to maintain attentional focus.

A conceptual reason for the divergent findings might be the varying definitions and operationalisations of the hyperfocus construct across studies. In line with the recently proposed consensus operationalisation of the construct (Ashinoff & Abu-Akel, 2019), the current study minimally defined hyperfocus as a period of complete engagement in a task accompanied by failure to notice time and the world. Other definitions of hyperfocus emphasized the difficulty in stopping and switching tasks, feeling stuck in small details (Hupfeld et al., 2019), failure to attend to personal needs (Hupfeld et al., 2019; Ozel-Kizil et al., 2016), that the experience needs to be felt as fun, enjoyable, interesting or rewarding (Ashinoff & Abu-Akel, 2019; Hupfeld et al., 2019; Ozel-Kizil et al., 2016) and improvements in task performance (Ashinoff & Abu-Akel, 2019), while also possibly leading to impairments in managing time such as procrastinating or not finishing other tasks (Ozel-Kizil et al., 2016). The overlapping operationalisation of hyperfocus and executive dysfunctions (including difficulties in stopping, task switching and time management) commonly observed in ADHD, (Barkley & Murphy, 2011), might explain the association between ADHD and hyperfocus observed in previous studies and the weak evidence in the current study. Moreover, the items of one previous hyperfocus questionnaire (Ozel-Kizil et al., 2016) were developed by clinicians based on hyperfocus descriptions of ADHD patients and often emphasized its negative consequences. This might have biased the questions towards the type of hyperfocus experiences most commonly observed in ADHD but not necessarily as it is experienced in individuals not suffering from this disorder. This is especially problematic in light of our findings that the experience of hyperfocus is fairly common even in typically developing individuals. On the other hand, it must be acknowledged that our operationalisation of hyperfocus did not contemplate the possibility that hyperfocus experience may be often accompanied by clinically significant distress and functional impairments in personal, occupational and social domains. Since clinical populations might be more prone to experience the negative consequences of hyperfocus, the failure to address this clinical dimension of hyperfocus might have explained the lack of differences between ADHD patients and healthy controls in the present study.

Another conceptual difference between studies concerns the rewarding nature of hyperfocus. For example, the lower frequency of hyperfocus in educational activities in the ADHD group found in the present study is in sharp contrast with the findings obtained by Hupfeld et al. (2019) who described a significantly higher propensity to hyperfocus at school in the self-reported ADHD group relative to controls. These divergent findings may be explained by the clear emphasis on the rewarding nature of activity (e.g., favourite course in school) implicit in the operationalisation of hyperfocus provided by Hupfeld et al. (2019), in contrast with the neutral definition used in the current study. This explanation is consistent with multiple reports and theories suggesting that patients with ADHD only

differ from healthy people in their ability to focus when the task is effortful and not "continuously reinforcing and automatic" (Kaufmann et al., 2000) and is not associated with reward incentives and intrinsic motivation (Goldstein & Brooks, 2012). Although academic activities might in general be less enjoyable for those with higher ADHD traits, in part due to problems in controlled attention and executive functioning (Daley & Birchwood, 2010), this might not be the case once attention is automatically engaged by intrinsically motivating tasks. Additionally, we found that individuals with ADHD experienced significantly less hyperfocus during social interactions. Although no previous studies investigated the concept of hyperfocus in the social domain, we speculate that this might be related to ADHD patients experiencing social interactions as more effortful and less intrinsically rewarding in face of their conspicuous social difficulties (de Boo & Prins, 2007; Groen, den Heijer, Fuermaier, Althaus, & Tucha, 2017). It is noteworthy that in the current study, patients with ADHD showed a trend to be less prone to hyperfocus across all situations with the exception of those presumably more intrinsically rewarding and requiring less effort, i.e. leisure activities and videogames (although non-significant). Taken together these results seem to suggest that the extent to which patients with ADHD experience hyperfocus might critically depend on whether that particular experience is felt as rewarding.

4.1. Limitations and suggestions for future research

As no validated measurement tools were available at the outset of the study, we relied on single items to assess hyperfocus experiences, which exhibit a lower reliability than scales. Recently, two clinical measures of hyperfocus have been introduced in the context of ADHD: The HS (Ozel-Kizil et al., 2013) and the AHQ (Hupfeld et al., 2019). Future research needs to investigate the divergent validity of these questionnaires relative to the functional impairments in executive functioning and the intrinsic rewarding nature of the situations in which hyperfocus is assessed (as outlined above). In contrast to the operationalisation of hyperfocus of the current study, these questionnaires addressed the possibility that hyperfocus might be associated with some degree of functional impairment and were sensitive to difference in ADHD and healthy controls. Therefore, future measures of hyperfocus would do well in assessing not only its fundamental features but also its negative impact on personal, social and occupational functioning.

We checked the reliability of our findings by selecting a second matched comparison group. It is interesting to note that in this replication the matched controls reported a lower frequency of hyperfocus than the ADHD patients as well as a longer minimum duration of the hyperfocus experience. This demonstrates that the selected comparison group makes a crucial difference for the interpretation of the findings. Therefore, further studies are needed to replicate our findings with carefully matched comparison groups. On the other hand, the vulnerability of the above measures to the selection of specific groups is suggestive of the low reliability of retrospective self-reports of frequency and duration of hyperfocus. The use of experience sampling methods (Larson & Csikszentmihalyi, 2014) in future studies might increase the reliability of these measures.

Follow-up studies need to develop a better picture of the possible influence of individual differences in hyperfocus. The current study concluded that the variables age, sex and education play a role in the relationship between hyperfocus and ADHD. There is also preliminary research suggesting that gifted males with ADHD may be most challenged to shift focus and predisposed to experience hyperfocus (Kalbfleisch, 2000). This may imply that the level of intelligence has an influence on the likelihood to experience hyperfocus.

The continued investigation of the relation between hyperfocus and ADHD may present potential advantages to this patient population. Given that the present research demonstrated that ADHD patients are at least as likely to experience hyperfocus as healthy controls, it remains to be investigated whether they can be taught to strategically control hyperfocus to improve performance. An important factor for behaviour is the effectiveness of positive or negative reinforcers. In certain situations, such as when working with deadline pressure, the reinforcement strength may be substantially greater in ADHD adults compared to controls. This has previously been termed the "ADHD advantage zone". Under these circumstances, adults with ADHD may be more able to engage their maximum attention and energy on the urgent task than healthy controls (Glickman & Dodd, 1998). In contrast, when the consequence is delayed, such as when studying for a test in a month of time, the effects of the reinforcer or consequence are weaker in patients with ADHD than in controls (Sagvolden, Aase, Zeiner, & Berger, 1998). Manipulating deadlines and reinforcers may therefore be a way to elicit hyperfocus in patients with ADHD. Understanding and defining hyperfocus in ADHD could therefore contribute to improving interventions.

5. Conclusions

The proposed relationship between ADHD symptoms and the frequency, duration and pervasiveness of hyperfocus was not supported by our correlational analysis in a large healthy sample nor by group differences between ADHD patients and matched controls. These results are in contrast with previous reports of more frequent hyperfocus episodes in patients with confirmed ADHD diagnoses and self-reported ADHD (Hupfeld et al., 2019; Ozel-Kizil et al., 2016). Our findings further indicate that motivation, age, sex and educational level might play a role in the occurrence, duration and pervasiveness of hyperfocus. Future studies ought to clarify whether divergent findings might be explained by varying conceptualizations of hyperfocus and/or methodological differences in controlling for the influence of third variables.

CRediT authorship contribution statement

Yvonne Groen: Conceptualization, Methodology, Resources, Investigation, Formal analysis, Writing - original draft, Writing - review & editing, Supervision, Project administration. **Ulrike Priegnitz:** Conceptualization, Methodology, Resources, Investigation,

Formal analysis, Writing - original draft, Writing - review & editing. **Anselm B.M. Fuermaier:** Conceptualization, Methodology, Resources, Investigation, Formal analysis, Writing - review & editing. **Lara Tucha:** Conceptualization, Methodology, Writing - review & editing. **Oliver Tucha:** Conceptualization, Methodology, Writing - review & editing. **Steffen Aschenbrenner:** Conceptualization, Methodology, Resources, Investigation, Formal analysis, Writing - review & editing. **Matthias Weisbrod:** Conceptualization, Methodology, Resources, Investigation, Formal analysis, Writing - review & editing. **Miguel Garcia Pimenta:** Conceptualization, Methodology, Writing - review & editing.

Declaration of Competing Interest

Matthias Weisbrod holds contracts for development of neuropsychological diagnostic and training tools with different enterprises. Miguel Garcia Pimenta is guest lecturer in courses of neurofeedback and ADHD. The other authors do not report conflicts of interest.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ridd.2020.103789.

References

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: Author. https://doi.org/10.1176/ajp.152.8.1228

Ashinoff, B. K., & Abu-Akel, A. (2019). Hyperfocus: The forgotten frontier of attention. *Psychological Research, 1*, 3. https://doi.org/10.1007/s00426-019-01245-8

Barkley, R. A., & Murphy, K. R. (1998). *Attention-deficit hyperactivity disorder : a clinical workbook*. Guilford Press.

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

Coghill, D., & Sonuga-Barke, E. J. S. (2012). Annual Research Review: Categories versus dimensions in the classification and conceptualisation of child and adolescent mental disorders - implications of recent empirical study. *Journal of Child Psychology and Psychiatry, 53*(5), 469–489. https://doi.org/10.1111/j.1469-7610.2011.02511.x

Daley, D., & Birchwood, J. (2010). ADHD and academic performance: why does ADHD impact on academic performance and what can be done to support ADHD children in the classroom? *Child: Care, Health and Development, 36*(4), 455–464. https://doi.org/10.1111/j.1365-2214.2009.01046.x

de Boo, G. M., & Prins, P. J. (2007). Social incompetence in children with ADHD: Possible moderators and mediators in social-skills training. *Clinical Psychology Review, 27*(1), 78–97. https://doi.org/10.1016/j.cpr.2006.03.006

Fuermaier, A. B. M., Groen, Y., Tucha, L., Weisbrod, M., Aschenbrenner, S., & Tucha, O. (2019). Everyday Life Attention Scale (ELAS): Normative data of n=1,874 Dutch participants. *Applied Clinical Neuropsychology*. https://doi.org/10.1080/23279095.2019.1605994

Fuermaier, A. B. M., Tucha, L., Koerts, J., Aschenbrenner, S., Kaunzinger, I., Hauser, J., & Tucha, O. (2015). Cognitive impairment in adult ADHD – Perspective matters! *Neuropsychology, 29*(1), 45–58. https://doi.org/10.1037/neu0000108

Glickman, M. M., & Dodd, D. K. (1998). GUTI: A measure of urgent task involvement among adults with attention-deficit hyperactivity disorder. *Psychological Reports, 82*(2), 592–594. https://doi.org/10.2466/pr0.1998.82.2.592

Goldstein, S., & Brooks, R. B. (Eds.). (2012). *Handbook of resilience in children*. New York, NY: Springer. https://doi.org/10.1007/978-1-4614-3661-4.

Groen, Y., den Heijer, A. E., Fuermaier, A. B. M., Althaus, M., & Tucha, O. (2017). Reduced emotional empathy in adults with subclinical ADHD: Evidence from the empathy and systemizing quotient. *ADHD Attention Deficit and Hyperactivity Disorders*, 1–10. https://doi.org/10.1007/s12402-017-0236-7

Groen, Y., Fuermaier, A. B. M., Tucha, L., Weisbrod, M., Aschenbrenner, S., & Tucha, O. (2018). A situation-specific approach to measure attention in adults with ADHD: The everyday life attention scale (ELAS). *Applied Neuropsychology: Adult*. https://doi.org/10.1080/23279095.2018.1437730

Hervey, A. S., Epstein, J. N., & Curry, J. F. (2004). Neuropsychology of adults with attention-deficit/hyperactivity disorder: A meta-analytic review. *Neuropsychology, 18*, 485–503. https://doi.org/10.1037/0894-4105.18.3.485

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

Kalbfleisch, M. L. (2000). *Electroencephalographic differences between males with and without ADHD with average and high aptitude during task transitions*. Unpublished doctoral dissertation. Charlottesville: University of Virginia.

Kaufmann, F., Kalbfleisch, M. L., & Castellanos, F. X. (2000). *Attention deficit disorders and gifted students: What do we really know? (Senior scholars series)*. Storrs: University of Connecticut, The National Research Center on the Gifted and Talented.

Kolberg, J., & Nadeau, K. (2016). *ADD-friendly ways to organize your life: Strategies that work from an acclaimed professional organizer and a renowned ADD clinician*. New York, NY: Brunner-Routledge.

Kooij, S. J., Bejerot, S., Blackwell, A., Caci, H., Casas-Brugué, M., Carpentier, P. J., … Gaillac, V. (2010). European consensus statement on diagnosis and treatment of adult ADHD: The European Network Adult ADHD. *BMC Psychiatry, 10*(1), 67. https://doi.org/10.1186/1471-244X-10-67

Kooij, J. J. S., Boonstra, A. M., Swinkels, S. H. N., Bekker, E. M., de Noord, I., & Buitelaar, J. K. (2008). Reliability, validity, and utility of instruments for self-report and informant report concerning symptoms of ADHD in adult patients. *Journal of Attention Disorders, 11*(4), 445–458. https://doi.org/10.1177/1087054707299367

Kooij, J. J. S., Buitelaar, J. K., van den Oord, E. J., Furer, J. W., Rijnders, C. A. T., & Hodiamont, P. P. G. (2005). Internal and external validity of attention-deficit/hyperactivity disorder in a population-based sample of adults. *Psychological Medicine, 35*, 817–827. https://doi.org/10.1017/s003329170400337x

Larson, R., & Csikszentmihalyi, M. (2014). The experience sampling method. *Flow and the foundations of positive psychology: The collected works of Mihaly Csikszentmihalyi* (pp. 21–34). Netherlands: Springer. https://doi.org/10.1007/978-94-017-9088-8_2

Marchetta, N. J., Hurks, P. M., De Sonneville, L. J., Krabbendam, L., & Jolles, J. (2008). Sustained and focused attention deficits in adult ADHD. *Journal of Attention Disorders, 11*(6), 664–676. https://doi.org/10.1177/1087054707305108

Marx, I., Hübner, T., Herpertz, S. C., Berger, C., Reuter, E., Kircher, T., … Konrad, K. (2010). Cross-sectional evaluation of cognitive functioning in children, adolescents and young adults with ADHD. *Journal of Neural Transmission, 117*(3), 403–419. https://doi.org/10.1007/s00702-009-0345-3

Maucieri, L. (2014). *ADHD hyperfocus: What is it and how to use it. Adapting hyperfocus for your relationship.*. Retrieved from. PsychologyToday https://www.psychologytoday.com/blog/the-distracted-couple/201411/adhd-hyperfocus-what-is-it-and-how-use-it.

Miller, G. A., & Chapman, J. P. (2001). Misunderstanding analysis of covariance. *Journal of Abnormal Psychology, 110*(1), 40–48.

Millstein, R. B., Wilens, T. E., Biederman, J., & Spencer, T. J. (1997). Presenting ADHD symptoms and subtypes in clinically referred adults with ADHD. *Journal of Attention Disorders, 2*(3), 159–166. https://doi.org/10.4088/JCP.08m04785pur

Mostert, J. C., Onnink, A. M. H., Klein, M., Dammers, J., Harneit, A., Schulten, T., … Franke, B. (2015). Cognitive heterogeneity in adult attention deficit/hyperactivity disorder: A systematic analysis of neuropsychological measurements. *European Neuropsychopharmacology, 25*(11), 2062–2074. https://doi.org/10.1016/j.euroneuro.2015.08.010

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*, 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., … 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

Sagvolden, T., Aase, H., Zeiner, P., & Berger, D. (1998). Altered reinforcement mechanisms in attention-deficit/hyperactivity disorder. *Behavioral Brain Research, 94*, 61–71. https://doi.org/10.1016/S0166-4328(97)00170-8

Schoechlin, C., & Engel, R. R. (2005). Neuropsychological performance in adult attention-deficit hyperactivity disorder: Meta-analysis of empirical data. *Archives of Clinical Neuropsychology, 20*, 727–744. https://doi.org/10.1016/j.acn.2005.04.005

Sergeant, J. A. (2005). Modeling attention-deficit/hyperactivity disorder: A critical appraisal of the cognitive-energetic model. *Biological Psychiatry, 57*(11), 1248–1255. https://doi.org/10.1016/j.biopsych.2004.09.010

Sherman, J., & Tarnow, J. (2013). Comorbidities in ADHD. *The Psychiatric Times, 30*(8), 16H-16H.

Sklar, R. H. (2013). *Hyperfocus in adult ADHD: An EEG study of the differences in cortical activity in resting and arousal states (Unpublished Master's Thesis)*. University of Johannesburg, South Africa.

Sonuga-Barke, E. J., Wiersema, J. R., van der Meere, J. J., & Roeyers, H. (2010). Context-dependent dynamic processes in attention deficit/hyperactivity disorder: Differentiating common and unique effects of state regulation deficits and delay aversion. *Neuropsychology Review, 20*(1), 86–102. https://doi.org/10.1007/s11065-009-9115-0

Tucha, L., Tucha, O., Laufkötter, R., Walitza, S., Klein, H. E., & Lange, K. W. (2008). Neuropsychological assessment of attention in adults with different subtypes of attention-deficit/hyperactivity disorder. *Journal of Neural Transmission, 115*(2), 269–278. https://doi.org/10.1007/s00702-007-0836-z

Tucha, L., Fuermaier, A. M., Koerts, J., Buggenthin, R., Aschenbrenner, S., Weisbrod, M., … Tucha, O. (2017). Sustained attention in adult ADHD: Time-on-task effects of various measures of attention. *Journal of Neural Transmission, 124*(1), 39–53. https://doi.org/10.1007/s00702-015-1426-0

Van der Meere, J. (2005). State regulation and attention deficit hyperactivity disorder. *Attention deficit hyperactivity disorder* (pp. 413–433). Humana Press. https://doi.org/10.1385/1-59259-891-9:413

Van der Meere, J., Stemerdink, N., & Gunning, B. (1995). Effects of presentation rate of stimuli on response inhibition in ADHD children with and without tics. *Perceptual and Motor Skills, 81*(1), 259–262. https://doi.org/10.2466/pms.1995.81.1.259

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

Willcutt, E. G. (2012). The prevalence of DSM-IV attention-deficit/hyperactivity disorder: A meta-analytic review. *Neurotherapeutics, 9*(3), 490–499. https://doi.org/10.1007/s13311-012-0135-8

Qualtrics. (2005). *Qualtrics software* (2012th ed.)). Provo, UT: Author. Retrieved from http://www.qualtrics.com.