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ORIGINAL ARTICLE

Living "in the zone": hyperfocus in adult ADHD

Kathleen E. Hupfeld[1] · Tessa R. Abagis[2] · Priti Shah[2]

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Abstract
Adults with ADHD often report episodes of long-lasting, highly focused attention, a surprising report given their tendency to be distracted by irrelevant information. This has been colloquially termed "hyperfocus" (HF). Here, we introduce a novel assessment tool, the "Adult Hyperfocus Questionnaire" and test the preregistered a priori hypothesis that HF is more prevalent in individuals with high levels of ADHD symptomology. We assess (1) a pilot sample ($n=251$) and (2) a replication sample ($n=372$) of adults with or without ADHD. Participants completed highly validated scales, including the Conners' Adult ADHD Rating Scale, to index ADHD symptomology. Those with higher ADHD symptomology reported higher total and dispositional HF and more frequent HF across each of the three settings (school, hobbies, and screen time) as well as on a fourth subscale describing real-world HF scenarios. These findings are both clinically and scientifically significant, as this is the first study to comprehensively assess HF in adults with high ADHD symptomology and to present a means for assessing HF. Moreover, the sizable prevalence of HF in adults with high levels of ADHD symptomology leads to a need to study it as a potentially separable feature of the ADHD syndrome.

Keywords Hyperfocus · Attention-deficit/hyperactivity disorder (ADHD) · Adult ADHD · Flow · Internet addiction

Introduction

While the estimated 8 million adults in the USA affected by attention-deficit/hyperactivity disorder (ADHD) might find it nearly impossible to sit still in a lecture hall or excruciatingly challenging to focus on writing a term paper, these same individuals might find themselves spending hours at a time composing a new song, tinkering with their car, writing computer code, or watching television (Kessler et al. 2006). The term "hyperfocus" (HF) has been used to characterize this state of heightened, focused attention that individuals with ADHD frequently report (Brown 2006; Conner 1994; Ozel-Kizil et al. 2016). However, while HF is often described anecdotally by clinicians and individuals diagnosed with ADHD (Brown 2006; Doyle 2007; Fitzsimons et al. 2016) and is discussed as a facet of ADHD in popular media articles (Flippin 2005; Maucieri 2014; Nerenberg 2016), HF is not currently a component of the diagnostic criteria for ADHD (American Psychiatric Association 2013). This lack of clinical evidence is surprising, given that a search on google.com for "ADHD hyperfocus" yields 104,000 hits. It is also a cause for concern, as notions of HF derived from anecdotal case studies and popular media sources are likely influencing clinicians' treatment decisions and therapeutic approaches for those with ADHD, even though HF has yet to be well-characterized in the ADHD literature. Research on HF is necessary to fill this clear gap in our knowledge of ADHD.

Most of the scant literature on HF in ADHD comes from clinical reports of patients describing instances of falling under "hypnotic spells" as they become immersed in an activity (Brown 2006), but empirical support for this idea is minimal. Only one previous group has attempted to empirically examine HF in neurotypical adults (Ozel-Kizil et al. 2013) and in individuals with ADHD (Ozel-Kizil et al. 2016). However, their work suffers from several limitations. Their scale (Ozel-Kizil et al. 2013) includes only 11 items

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✉ Kathleen E. Hupfeld
khupfeld@ufl.edu

[1] Department of Applied Physiology and Kinesiology, University of Florida, 1864 Stadium Road, Gainesville, FL 32603, USA

[2] Department of Psychology, University of Michigan, Ann Arbor, USA

that overlap closely with ideas of executive dysfunction (Barkley 2011b) and focus solely on the negative consequences of HF, despite the fact that those with ADHD often report both positive and negative features of HF. Further, the scale was originally administered in Turkish, and the published English language version (Ozel-Kizil et al. 2013) includes confusing wording that would be challenging for a sample of native English speakers to interpret. These clear shortcomings of the only published HF questionnaire to date suggest a dire need for the development of a new, comprehensive HF questionnaire that is appropriate for use with broader samples.

The most commonly reported HF experiences occur when an individual is engaging in something related to their hobbies, using a computer, or watching TV (Brown 2006; Conner 1994; Doyle 2007). This raises questions over the role of environmental cues on ADHD behaviors—whether, similar to findings regarding hyperactive ADHD symptoms (Kofler et al. 2016), only certain situations induce HF. Many descriptions of HF experiences by those with ADHD include common qualities such as distorted time perception, failure to notice the world, and difficulty stopping an activity and switching to a new task (Brown 2006); this suggests that HF may be multi-dimensional. However, while some of these potential features of HF have been examined in isolation through laboratory-based tasks in ADHD samples (Barkley et al. 2001; Oades and Christiansen 2008; Panagiotidi et al. 2017), they have yet to be empirically investigated in the real-world contexts that we examine here. A better understanding of these features of HF is critical. For instance, understanding whether HF is domain specific could guide treatment approaches; clinicians could coach those with ADHD to avoid situations that might induce negative HF experiences (e.g., spending hours playing a videogame) and seek situations that might induce positive HF experiences (e.g., completing a school assignment).

Moreover, empirical investigation of HF carries substantial clinical significance because HF may warrant consideration as an independent symptom of ADHD. If replicated studies indicate that HF is indeed associated with high levels of ADHD symptomology, then inclusion of HF as an ADHD symptom may improve the sensitivity of diagnostic criteria—especially for adult ADHD, which is often underdiagnosed (Asherson et al. 2012). Better characterizing HF also has more general scientific significance, as investigation of the underlying cognitive mechanisms of HF might lead to a greater understanding of the dysfunctional attentional regulation processes associated with ADHD. In the present study, we sought to establish a measure of HF, which we showed was able to properly distinguish people with and without ADHD symptomology.

Our approach was to first characterize HF. By (1) completing a comprehensive review of the current HF literature and (2) conducting interviews with individuals with diagnosed ADHD, we developed a strong theoretical basis for a novel HF questionnaire and identified several possible settings and dimensions of HF, which are outlined in Table 1. We present these settings and dimensions as the core features of HF and wish to establish the following working definition of HF:

> A state of heightened, intense focus of any duration, which most likely occurs during activities related to one's school, hobbies, or "screen time" (i.e., television, computer use, etc.); this state may include the following qualities: timelessness, failure to attend to the world, ignoring personal needs, difficulty stopping and switching tasks, feelings of total engrossment in the task, and feeling "stuck" on small details.

Based on this working definition, we developed the Adult Hyperfocus Questionnaire, which comprehensively assesses each of these settings and dimensions of HF (Table 2; Online Resource 1–2), and we tested whether this measure of HF is associated with ADHD symptomology in two independent samples.

We conducted an initial pilot study (Study 1), followed by a preregistered replication study (Study 2) with a larger sample size and targeted recruitment of ADHD individuals. Given the anecdotal reports of real-world HF experiences and the several laboratory experiments that have identified potentially related behavioral deficits in ADHD samples, such as difficulty with task-switching (Oades and Christiansen 2008), we hypothesized that those with high ADHD symptomology (based on the Conners' Adult ADHD Rating Scales, CAARS) would report more frequent instances of HF than those with low ADHD symptomology. We further predicted those with high ADHD symptomology would not only exhibit higher overall HF, but also higher HF across several subscales: dispositional, settings, and scenarios, as defined below. As flow (i.e., full immersion in an intrinsically enjoyable activity) (Csikszentmihalyi 1997) and Internet addiction (Yen et al. 2007, 2009; Yoo et al. 2004) may overlap with HF and with ADHD symptoms, we also included scales to examine these behaviors to identify whether HF is a separable construct from these behaviors.

Methods

All participants were provided informed consent, and this work was classified as "exempt" by the Univeristy of Michigan IRB.

Table 1 Proposed settings and dimensions of HF and example statements by adults with ADHD

School	Hobbies	Screen time
3 HF settings		
"This doesn't always happen, but if I have a coding project for class that I am really interested in, I can focus on it for hours and hours at a time"	"I do experience hyperfocus sometimes, but only with things I really enjoy doing, like pleasure reading and organizing things"	"I can watch TV for hours… more than what I think is 'normal' for people who enjoy TV. I just don't realize that the time is passing"
6 HF dimensions		
Losing track of time	Failing to notice the world around you	Failing to attend to personal needs
"I get super carried away reading about new projects I want to do…I'll stay up all night and not notice how late it's gotten until I see the sun coming up"	"Especially when I was little, I used to zone out completely when watching TV. You could shout my name or wave your hands in my face and I wouldn't notice"	"I can't always tell when it's happening…I think I've actually forgotten to go to sleep and missed meals"
Difficulty stopping and moving on to a new task	Feeling totally engrossed in the task	Getting "stuck" on small details
"This definitely happens…I get hooked into Netflix, and I'm not able to stop easily to get work done"	"When I'm working on motorcycles, I forget the world… my mind just goes crazy on 'overdrive,' and I can't think of anything else"	"I will definitely get 'stuck' on small details when I'm trying to get something 'just right'…I want everything to be perfect"

These settings and dimensions were identified from statements made during open-ended interviews with adults diagnosed with ADHD. Statements listed above are direct quotations from interview participants

Adult Hyperfocus Questionnaire

We first developed a comprehensive questionnaire to assess HF. Reviews of the literature, including the only other empirically tested HF questionnaire (Ozel-Kizil et al. 2013, 2016), and responses from open-ended interviews with ADHD individuals were used to develop the novel Adult Hyperfocus Questionnaire. These methods are described in more detail in Online Resource 1, and a paper-and-pencil version of the entire questionnaire is presented in Online Resource 2. Briefly, to develop the questionnaire, we identified three primary settings in which HF is most likely to occur (i.e., school, hobbies, and screen time) and six primary dimensions of HF (i.e., losing track of time, failing to notice the world around you, failing to attend to personal needs, difficulty stopping and moving on to a new task, feeling totally engrossed in the task, and getting "stuck" on small details). These settings and dimensions were used to develop five quantitative subscales, with the goal of comprehensively characterizing HF and examining possible global and domain-specific features of HF: (1) dispositional HF (general tendency for one to experience HF); HF during activities related to (2) school, (3) hobbies, and (4) screen time; and (5) descriptive scenarios in which HF is likely to occur. Every subscale included multiple questions for each HF dimension. Table 2 presents an overview of the items asked on these subscales. The final section (6) included qualitative short-answer responses about past HF experiences; these short answers were included for later comparison with our identified HF settings and dimensions to examine the content validity of our questionnaire (i.e., that the questionnaire fully assesses all aspects of HF).

Participants received six HF scores: one score for each of the five quantitative subscales, in addition to a "total HF" score, which consisted of the sum of all HF scores except for the scenario score. The scenario HF subscale score was kept separate here to later test the convergent (construct) validity of our questionnaire (i.e., that two different measures of the same construct, HF, are indeed related). That is, while the dispositional and setting HF subscales asked more abstractly about HF tendencies (e.g., "Feeling like you can't stop doing your hobby, even if you have other more important responsibilities"), the scenario HF subscale included similar questions but instead asked participants to relate their own experiences to items which discussed concrete contexts in which HF might occur (e.g., "For me, it's writing. I get so into my personal creative writing that I can't stop…I've been late to class many times because I've just had to finish that last paragraph or sentence"). Because participants were asked to rate their HF tendencies in two different ways on the dispositional/setting subscales versus the scenario subscale, we were able to later look at the correlation between total HF score and scenario HF score to examine convergent validity.

Table 2 Adult Hyperfocus Questionnaire items, sorted by subscale and dimension

Dimension	Dispositional HF subscale item	School HF subscale item	Hobby HF subscale item	Screen time HF subscale item
Losing track of time	Generally, when I am busy doing something I enjoy or something that I am very focused on, I tend to completely lose track of the time	Completely losing track of time while doing work for the class	Completely losing track of time while doing something related to your hobby	Completely losing track of time while doing the screen time activity
	In general, when I am very focused on something or I am doing something that I find especially rewarding, I can be unsure of what time of day it is or how much time has passed since I started the activity	Not realizing how much time has passed since you started your homework or studying	Not realizing how much time has passed since you started doing something related to your hobby	Not realizing how much time has passed since you started doing the screen time activity
Failing to notice the world around you	Generally, when I am busy doing something I enjoy or something that I am very focused on, I don't react to any distractions (e.g., if someone talks to me)	Not attending to distractions (e.g., not hearing someone talking to you) when you're doing homework or studying	Not attending to distractions (e.g., not hearing someone talking to you) while working on something related to your hobby	Not attending to distractions (e.g., not hearing someone talking to you) while doing the screen time activity
	In general, when I am very focused on something or I am doing something that I find especially rewarding, I do not notice the world around me, and I won't realize if someone calls my name or if my phone buzzes	Not noticing the world around you (e.g., not realizing if someone calls your name or if your phone buzzes) if you're working on homework or studying	Not noticing the world around you (e.g., not realizing if someone calls your name or if your phone buzzes) while doing something related to your hobby	Not noticing the world around you (e.g., not realizing if someone calls your name or if your phone buzzes) while doing the screen time activity
Failing to attend to personal needs	Generally, when I am very focused on something or doing something that I find especially rewarding, I might accidentally miss meals, stay up all night, or keep doing the activity until I absolutely must get up to go to the bathroom	Accidentally missing meals, staying up all night, or continuing to study or do work for the class until you absolutely must get up to go to the bathroom	Accidentally missing meals, staying up all night, or continuing to do something related to your hobby until you absolutely must get up to go to the bathroom	Accidentally missing meals, staying up all night, or continuing to do something related to the screen time activity until you absolutely must get up to go to the bathroom
	In general, when I am busy doing something I enjoy or something that I am very focused on, I forget to attend to my personal needs (e.g., I forget to sleep or eat or I wait until the last minute to go to the bathroom)	Forgetting or failing to attend to your personal needs (e.g., not sleeping, missing meals, waiting to going to the bathroom) while you're doing homework or studying	Forgetting or failing to attend to your personal needs (e.g., not sleeping, missing meals, waiting to going to the bathroom) when you're doing something related to your hobby	Forgetting or failing to attend to your personal needs (e.g., not sleeping, missing meals, waiting to going to the bathroom) when you're doing the screen time activity
Difficulty stopping and moving on to a new task	Generally, when I am very focused on something or doing something that I find especially rewarding, I feel like I can't stop doing the activity, even if I have other more important responsibilities	Feeling like you can't stop doing your schoolwork, even if you have other more important responsibilities (e.g., an assignment that is due sooner for another class)	Feeling like you can't stop doing your hobby, even if you have other more important responsibilities (e.g., getting ready to go to class or your job)	Feeling like you can't stop the screen time activity, even if you have other more important responsibilities (e.g., getting ready to go to class or your job)

Table 2 (continued)

Dimension	Dispositional HF subscale item	School HF subscale item	Hobby HF subscale item	Screen time HF subscale item
	In general, when I am busy doing something I enjoy or something that I am very focused on, I find it very difficult to quit and move on to doing something else, even if I have a lot of other important things I should be doing instead	Difficulty quitting or moving on from your schoolwork and starting a new task, even if this new task is more important or urgent	Difficulty quitting or moving on from the hobby activity and starting a new task, even if this new task is more important or urgent (e.g., to finish work for school or your job)	Difficulty quitting or moving on from the activity and starting a new task, even if this new task is more important or urgent (e.g., to finish work for school or your job)
Feeling totally engrossed in the task	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	Feeling totally captivated by or "hooked" on completing your schoolwork or studying	Feeling totally captivated by or "hooked" on doing things related to your hobby	Feeling totally captivated by or "hooked" on the screen time activity
	In general, when I am busy doing something I enjoy or something that I am very focused on, I can feel completely engrossed or fixated with the activity	Feeling completely engrossed or fixated with your schoolwork or studying	Feeling completely engrossed or fixated with the hobby activity	Feeling completely engrossed or fixated with the screen time activity
Getting "stuck" on small details	Generally, when I am very focused on something or doing something that I find especially rewarding, I can get "stuck" on little details that keep me from finishing other important parts of the task	Getting "stuck" on little details that keep you from finishing other important parts of the task (e.g., spending too much time trying to come up with one better word to use when writing a paper instead of focusing on the paper as a whole)	Getting "stuck" on little details that keep you from finishing other important parts of the task (e.g., spending too much time practicing playing one part of a song, instead of practicing the entire song)	Getting "stuck" on little details that keep you from finishing other important parts of the task (e.g., spending too much time looking up recipe ideas online trying to find the "perfect" dish)
	In general, when I am busy doing something I enjoy or something that I am very focused on, I sometimes focus for far too long on a small detail of the task and avoid other important parts	Finding yourself too focused on a small detail of a task while avoiding other important parts of the task (e.g., spending too much time formatting your document instead of concentrating on writing the content of your paper)	Finding yourself too focused on a small detail of a task while avoiding other important parts of the task (e.g., spending too much time redrawing one portion of your art piece instead of concentrating on the piece as a whole)	Finding yourself too focused on a small detail of a task while avoiding other important parts of the task (e.g., spending too much time comparing prices and reviews online and putting off a decision about something to buy)

Participants answered each item on a Likert 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." For the school, hobby, and screen time HF subscales, participants answered each item based on their favorite academic course, hobby, and screen time activity. All items were presented to participants in a randomized order online through the survey software Qualtrics (https://www.qualtrics.com). See Online Resource 2 for a suggested format for paper-and-pencil administration of the questionnaire and for the full text of the scenario HF subscale items (not included in the table here due to space constraints)

Study 1: pilot study

We first tested the Adult Hyperfocus Questionnaire in a smaller pilot sample of individuals who did ($n = 23$) and did not ($n = 228$) self-report ADHD. This pilot study aimed to: (1) test our online recruitment and questionnaire administration methods; (2) allow participants to provide feedback about confusing questions; (3) obtain pilot data regarding associations between HF and ADHD symptomology and diagnosis on which to base our preregistered a priori hypotheses for a larger study of our HF questionnaire. See Online Resource 4 for further discussion of the Study 1 methods.

Study 2: replication study

Study 2 aimed to replicate the HF results identified in Study 1 in a larger sample with targeted recruitment of those with ADHD. Our hypotheses for Study 2 were preregistered with the Open Science Framework (see preregistration: https://osf.io/ta92r/register/565fb3678c5e4a66b5582f67. Importantly, preregistration, which is completed *before* any data is collected, involves the creation of a time-stamped document of one's hypotheses and data collection/analysis plan. This provides evidence that our primary hypotheses were indeed a priori and were not formed after we had analyzed the data ("hypothesizing after the results are known"; HARKing) (Kerr 1998).

Procedure

Data collection for Study 2 took place on TurkPrime, Amazon's update to MTurk, which has been successfully used by others to assess symptoms of psychological disorders (Arditte et al. 2016; Shapiro et al. 2013), including ADHD (Wymbs and Dawson 2015). Of note, others have demonstrated that MTurk respondents provide a sample that is comparable in age, sex, and race distribution to large representative national surveys (Huff and Tingley 2015) and that MTurk respondents pay equal or more attention than undergraduate students on similar tasks (Hauser and Schwarz 2016; Weinberg et al. 2014). All questionnaires were administered online via Qualtrics (https://www.qualtrics.com). Data collection took place in two parts: (1) screening to recruit participants with self-reported ADHD (corroborated by high, clinically significant ADHD symptomology scores) and without self-reported ADHD (corroborated by minimal or no report of ADHD symptomology) and (2) replication of the pilot results (i.e., questionnaires to assess HF, ADHD symptoms, and related constructs).

Part 1: screening

To identify participants with a likely ADHD diagnosis, the screening included three brief parts: (1) the Adult ADHD Self-Report Scale-Screener (ASRS-S) (Kessler et al. 2007); (2) the Self-Report Habit Index for Reading (Schmidt and Retelsdorf 2016); (3) mental health and demographic questions. The ASRS-S has been successfully used in the past to screen MTurk participants for ADHD (Wymbs and Dawson 2015) and is highly sensitive for detecting general population cases (Ustun et al. 2017). As recommended for general population samples, we used ≥ 14 as the clinical cutoff for ADHD (Kessler et al. 2007). Thus, our ADHD group includes only those who self-reported a past ADHD diagnosis by a healthcare professional and scored ≥ 14 on the ASRS-S. The reading habit questionnaire was included to blind participants to the fact that they were being screened for ADHD. Mental health questions asked about multiple conditions to allow for omission of pre-planned comorbid diagnoses (e.g., schizophrenia) and to maintain participants' blindness.

Part 2: replication of pilot results

After screening, we invited all participants with high, clinically significant levels of ADHD symptomology and a randomly selected control group to complete several questionnaires to assess the following: (1) HF; (2) flow; (3) Internet addiction; (4) current ADHD symptoms; (5) childhood ADHD symptoms; (6) demographics, ADHD characteristics, and mental health conditions. These questionnaires are summarized in Table 3.

HF, flow, and Internet addiction

Participants first completed our Adult Hyperfocus Questionnaire (see Table 2 for a list of questionnaire items and Online Resource 2 for a full paper-and-pencil version of the questionnaire). Next, participants completed the LONG Dispositional Flow Scale-2-General (Jackson and Eklund 2002; Jackson et al. 2008) to assess tendencies to experience "flow" in a specific activity. Participants identified a general activity that usually causes them to have "peak experiences" (e.g., cooking, hiking, writing reports for work) and responded to items such as "[when I am doing this activity]…my attention is focused entirely on what I am doing…" Participants then completed the Internet Addiction Test (Young 1998) to assess Internet addiction tendencies. Here, "Internet use" was broadly defined to include use of any device with Internet access to engage in activities related to school, work, online shopping, social media, online dating, watching media online, online gaming, and miscellaneous "surfing the web."

Table 3 Questionnaires used in the pilot study (Study 1) and replication study (Study 2)

Scale	Description
Adult Hyperfocus Questionnaire	Comprised of six parts in total: four 12-item subscales (dispositional, school, hobby, and screen time HF), one 18-item subscale with descriptions of HF scenarios, and a short-answer section about past HF experiences; participants receive a score for each subscale and a total HF score; a full paper-and-pencil version of this questionnaire is available in Online Resource 2
LONG Dispositional Flow Scale-2-General (Jackson and Eklund 2002; Jackson et al. 2008)	36 items to assess tendency to experience flow in a specific activity chosen by the participant (i.e., an activity that usually causes them to have "peak experiences"); a total global flow score is calculated for each participant
Internet Addiction Test (Young 1998)	20 items to assess the severity of problematic Internet use; each participant receives a total Internet addiction score
Conners' Adult ADHD Rating Scales (CAARS)—Screening version (Conners et al. 1999)	30 items to assess self-report of current (adult) ADHD symptoms; each participant receives four subscale scores: Inattention, Hyperactivity/Impulsivity, ADHD Symptoms Total, and ADHD Index
Barkley Adult ADHD Rating Scale-IV (Barkley 2011a)	18 items to assess self-report of childhood ADHD symptoms (i.e., symptoms between ages 5–12); each participant receives three subscale scores: Inattention, Hyperactivity/Impulsivity, and Total Symptoms; *(completed by participants in Study 2 only)*
Demographics	Questions asking about participant age, sex, ethnicity, race, education, and household income
ADHD diagnosis	Self-report of past ADHD diagnosis by a healthcare professional
Other mental health conditions	Self-report diagnosis of depression, anxiety, autism, PTSD, bipolar disorder, OCD, alcohol or substance abuse, eating disorder, schizophrenia, schizoaffective disorder, borderline personality disorder, and free entry of other mental health conditions

Participants completed the questionnaires in the order specified above in both the Pilot Study (Study 1) and Replication Study (Study 2); the same questionnaires were used in both cases, with the exception that only Study 2 participants completed the BAARS

ADHD symptoms, demographics, and mental health history

Participants completed the CAARS—Screening Version to assess current ADHD symptoms (Conners et al. 1999). The CAARS is a frequently used and well-validated questionnaire for measuring ADHD symptomology. CAARS subscale scores have been demonstrated to have high test–retest reliability (Erhardt et al. 1999), high sensitivity and specificity (diagnostic efficiency rate of 85%) (Erhardt et al. 1999), high internal consistency (Cronbach's alpha = 0.74–0.95) (Adler et al. 2008), and high reliability in predicting changes in psychiatric symptoms and functioning (Adler et al. 2008). Participants also completed the Barkley Adult ADHD Rating Scale-IV (BAARS-IV), which indexes childhood ADHD symptoms with high test–retest reliability (0.79) and high internal consistency (Cronbach's alpha = 0.95) (Barkley 2011a). Importantly, as we had already asked participants during the screening portion of the study to self-report any past ADHD diagnoses and included only those who scored above the ASRS-S clinical cutoff of ≥ 14 (Kessler et al. 2007), we did not use any clinical cutoffs for the CAARS or BAARS scales. That is, we were primarily interested in how severity of ADHD characteristics on the different CAARS and BAARS scales (e.g., inattention versus hyperactivity versus general ADHD symptoms) would associate with HF, so once individuals had been selected into the ADHD group based on the screening study, we did not further stratify the ADHD group based on CAARS or BAARS clinical cutoff scores. Lastly, participants provided demographics and information about mental health and ADHD diagnoses they had previously received from a healthcare professional.

Statistical analyses

Statistical analyses were performed in R 3.3.1 (R Core Team 2016). For all analyses, significance was defined at the conservative level of $p < 0.01$, and trends were defined at the level of $p < 0.05$.

Results

In both the Pilot Study (Study 1) and Replication Study (Study 2), greater severity of ADHD symptoms was associated with higher total HF score and higher scores on each of the HF subscales. Moreover, those who self-reported an ADHD diagnosis (which was corroborated with the ASRS-S clinical cutoff of ≥ 14) reported higher total HF and scored significantly higher on each of the HF subscales (with the exception of dispositional and school HF in Study 1). Each HF subscale had high internal reliability (Cronbach's alpha = 0.87–0.99; Online Resource 3), suggesting the utility of our novel Adult Hyperfocus Questionnaire in measuring HF in both ADHD and non-ADHD samples.

Study 1: pilot study

Full results for the pilot study, including associations of HF and ADHD status with flow and Internet addiction, are presented in Online Resource 4, Tables 7–9. Briefly, in this pilot sample in which those with higher levels of ADHD symptomology were not specifically recruited, 23 adults reported high levels of ADHD symptomology and an ADHD diagnosis, and 228 did not report high ADHD symptoms or a diagnosis. More severe ADHD characteristics on each of the CAARS subscales showed low-to-moderate significant correlations with greater total, dispositional, school, hobby, screen time, and scenario HF scores ($r = 0.24$–0.49; Table 8). Those who reported ADHD had greater total HF scores and greater scores on all subscales (Table 9), with the exception of a trend for dispositional HF ($p = 0.022$) and, unexpectedly, no significant difference in school HF based on ADHD diagnosis ($p = 0.065$); however, after square root transformation to improve data normality, the ADHD group trended toward higher transformed school HF scores ($p = 0.010$). These findings directly support the notion that, as expected, more severe ADHD symptomology is associated with greater HF. Overall, these findings provided strong rationale to proceed to a second experiment to replicate these results using larger and approximately equal samples of individuals with and without self-reported ADHD (corroborated with high, clinically significant ADHD symptom scores).

Study 2: replication of study 1 results

Given the Study 1 results, we hypothesized that more severe ADHD symptom scores would associate with higher total and subscale HF scores and that those with self-reported ADHD (corroborated with high levels of ADHD symptomology) would report greater HF on all subscales except for school HF.

ADHD screening

A total of 3,673 participants completed the screening study. Those who reported schizophrenia ($n = 13$), schizoaffective disorder ($n = 2$), and borderline personality disorder ($n = 12$) were omitted. Those who declined to answer any of the questions were removed ($n = 60$). In line with Wymbs and Dawson, who also screened MTurk participants for ADHD, 8.47% ($n = 304$) of the remaining participants ($n = 3{,}586$) self-reported an ADHD diagnosis from a healthcare professional (Wymbs and Dawson 2015). Of these individuals, 282 (56.4% female) self-reported ADHD and also scored in the clinically significant range (≥ 14) on the ASRS-S, which fits with the ADHD population estimations of 2.1–5.4% in males and 1.1–3.2% in females (Bitter et al. 2010; Kessler et al. 2006). All of the ADHD individuals were invited by email to complete Study 2. A randomly selected sample ($n = 282$) of individuals without self-report of ADHD diagnosis or clinically significant ADHD symptoms from the remaining respondents were also invited to complete the study and comprised the control group.

Study 2 participants

One hundred and ninety-nine ADHD (i.e., those who self-reported an ADHD diagnosis and scored ≥ 14 on the ASRS-S) and 221 non-ADHD control individuals (i.e., those who did not self-report a diagnosis and scored < 14 on the ASRS-S) completed Study 2. Exclusion criteria included inconsistent reporting of gender ($n = 4$) or ADHD diagnosis ($n = 35$) between the screening and replication surveys. This resulted in final samples of 162 with ADHD and 210 without ADHD; see Online Resource 5, Table 10 for complete Study 2 demographics.

Association between ADHD symptoms and HF scores

As predicted a priori, more severe adult ADHD characteristics on each of the CAARS subscales were correlated with higher total HF scores ($r = 0.36$–0.46; Fig. 1; Table 4) and higher scores on each of the HF subscales ($r = 0.22$–0.49). Similarly, as predicted a priori, more severe childhood ADHD characteristics on each of the BAARS subscales were correlated with higher total HF scores ($r = 0.32$–0.37) and higher scores on each of the HF subscales ($r = 0.23$–0.36).

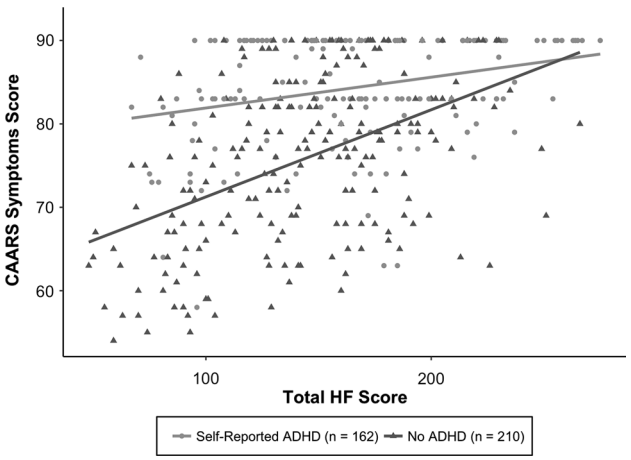

Fig. 1 Association between total HF score, ADHD symptomology, and self-reported ADHD status in Study 2. ADHD symptoms are reported as CAARS Symptom score. Those with ADHD ($n = 162$) scored higher on the CAARS Symptom scale than those without ADHD ($n = 210$). A moderate positive correlation ($r = 0.44$) emerged between CAARS Symptom score and total HF score. HF indicates hyperfocus; ADHD, attention-deficit/hyperactivity disorder; CAARS, Conners' Adult ADHD Rating Scales (CAARS)-Screening Version

Table 4 Replication study (Study 2) association of HF subscale scores with CAARS, BAARS, flow, and Internet addiction score

Scale	Total HF			Dispositional HF			School HF			Hobby HF			Screen time HF			Scenario HF		
	r	DF	*p*	*r*	DF	*p*	*R*	DF	*P*	*R*	DF	*P*	*R*	DF	*P*	*R*	DF	*P*
CAARS[a]																		
Inattention[b]	0.36	327	< 0.001**	0.40	327	< 0.001**	0.22	327	< 0.001**	0.26	327	< 0.001**	0.40	327	< 0.001**	0.30	327	< 0.001**
Hyperactivity/impulsivity[b]	0.40	355	< 0.001**	0.39	355	< 0.001**	0.30	355	< 0.001**	0.30	355	< 0.001**	0.36	355	< 0.001**	0.39	355	< 0.001**
ADHD symptoms	0.44	370	< 0.001**	0.40	370	< 0.001**	0.30	370	< 0.001**	0.33	370	< 0.001**	0.43	370	< 0.001**	0.39	370	< 0.001**
ADHD Index[b]	0.46	346	< 0.001**	0.41	346	< 0.001**	0.30	346	< 0.001**	0.35	346	< 0.001**	0.49	346	< 0.001**	0.43	346	< 0.001**
BAARS[c]																		
Inattention	0.32	370	< 0.001**	0.31	370	< 0.001**	0.26	370	< 0.001**	0.23	370	< 0.001**	0.28	370	< 0.001**	0.32	370	< 0.001**
Hyperactivity/impulsivity	0.36	370	< 0.001**	0.34	370	< 0.001**	0.32	370	< 0.001**	0.25	370	< 0.001**	0.27	370	< 0.001**	0.35	370	< 0.001**
Total ADHD score	0.37	370	< 0.001**	0.36	370	< 0.001**	0.31	370	< 0.001**	0.26	370	< 0.001**	0.30	370	< 0.001**	0.36	370	< 0.001**
Flow	0.23	370	< 0.001**	0.26	370	< 0.001**	0.18	370	0.001*	0.24	370	< 0.001**	0.10	370	0.053	0.23	370	< 0.001**
Internet addiction	0.30	370	< 0.001**	0.26	370	< 0.001**	0.22	370	< 0.001**	0.22	370	< 0.001**	0.30	370	< 0.001**	0.32	370	< 0.001**

Scale	Flow			Internet addiction		
	r	DF	*p*	*r*	DF	*p*
CAARS[a]						
Inattention[b]	−0.18	327	**0.001***	0.21	327	< 0.001**
Hyperactivity/impulsivity[b]	−0.08	355	0.127	0.25	355	< 0.001**
ADHD symptoms	−0.13	370	0.011	0.24	370	< 0.001**
ADHD Index[b]	−0.08	346	0.154	0.18	346	< 0.001**
BAARS[c]						
Inattention	−0.03	370	0.669	0.15	370	0.004*
Hyperactivity/impulsivity	0.01	370	0.867	0.24	370	0.001*
Total ADHD score	−0.01	370	0.871	0.21	370	< 0.001**

CAARS Conners' adult ADHD rating scales, *BAARS* Barkley adult ADHD rating scale

*$p < 0.01$; **$p < 0.001$

[a]Raw CAARS scores were converted to t-scores based on age and sex

[b]The data were positively skewed on three CAARS subscales: inattention, hyperactivity/impulsivity, and ADHD Index. The data showed a normal distribution after excluding all participants who answered "Not at all, never" for every question (Inattention: $n = 39$ with ADHD, $n = 4$ without ADHD; Hyperactivity/impulsivity: $n = 12$ with ADHD, $n = 3$ without ADHD; ADHD Index: $n = 21$ with ADHD, $n = 3$ without ADHD). The data presented here incorporate these exclusions

[c]BAARS percentile scores were not normally distributed, so raw scores are presented here instead. As a non-normal distribution of BAARS percentile scores was not anticipated, this choice to use raw scores instead was not included in the preregistration

Association between ADHD diagnosis and HF scores

The ADHD self-report group had higher total HF than the non-ADHD control group, as well as higher scores on each of the HF subscales, including school HF (Fig. 2; Table 5). We predicted each of these group differences a priori, except for the group difference in school HF; as there was no significant difference based on ADHD diagnosis for school HF in Study 1, we did not predict a priori that a significant difference in school HF score would emerge in Study 2.

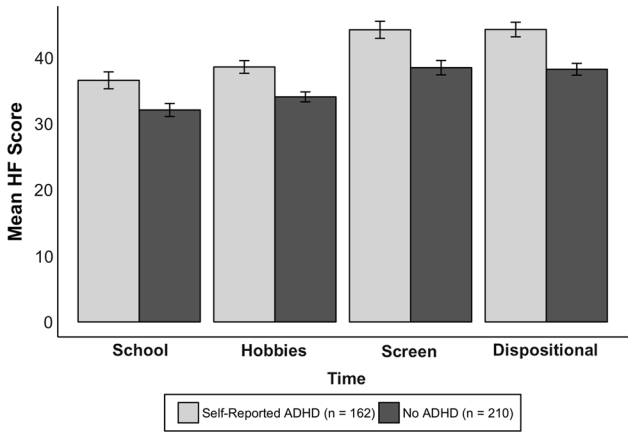

Fig. 2 Mean HF scores across the three setting subscales and dispositional ("dispos.") HF subscale for participants with ($n=162$) and without ($n=210$) self-reported ADHD (corroborated with high ADHD symptomology scores) in Study 2. Those with ADHD scored significantly higher than those without ADHD on every subscale. Error bars represent standard error. HF indicates hyperfocus; ADHD, attention-deficit/hyperactivity disorder

Factor structure

Post hoc, we conducted an exploratory factor analysis (EFA) to examine the factor structure of the 66 items from each of the five HF subscales using the responses from Study 2 participants ($n=372$ total). We ultimately selected an eight-factor solution, which explained 49.3% of the variance in HF responses and had the best model fit qualities. The first five factors represented each of the HF subscales: (Factor 1) School HF; (Factor 2) Screen Time HF; (Factor 3) Scenario HF; (Factor 4) Hobby HF; (Factor 5) Dispositional HF. The other three factors represented three of the six HF dimensions: (Factor 6): Failing to Notice the World; (Factor 7): Failing to Attend to Personal Needs; (Factor 8): Getting "Stuck" on Small Details. The questionnaire items loaded most strongly onto the five HF subscale factors, with fewer items loading onto the three HF dimension factors. See Online Resource 6 for further details on the EFA methods.

Overall, this factor structure suggests that: (1) each HF subscale tests a unique, separable quality of HF and (2) all questionnaire items are relevant for measuring these qualities. As no single "global HF" factor emerged and the first five factors represented each of the five HF subscales, this suggests that considering each HF subscale separately as part of an individual's "HF profile" is potentially more useful than considering only their total HF score. Of note, we conducted this factor analysis post hoc, and we had predicted a priori that total HF score would associate with ADHD symptoms and diagnosis. Thus, in the present work we examined these associations with total HF score and with each subscale HF score; however, future work might exclude analysis of total HF score and focus primarily on the HF subscale scores. Further, all questionnaire items had moderate to high factor loadings, with the exception of only one item on the hobby HF subscale for which the factor

Table 5 Dispositional, setting, and scenario HF scores for the replication study (Study 2)

Scale	Self-reported ADHD ($n=162$)		No self-reported ADHD ($n=210$)		$F(1, 370)$	P	Cohen's d
	Mean	SD	Mean	SD			
Dispositional HF	44.25	14.07	38.23	13.00	18.25	< 0.001**	0.45
School HF[a]	36.56	16.29	32.07	14.33	7.96	0.005*	0.30
Hobby HF	38.58	12.22	34.05	10.85	14.26	< 0.001**	0.39
Screen time HF	44.20	16.44	38.47	15.84	11.59	< 0.001**	0.36
Total HF	163.59	49.33	142.82	44.80	17.98	< 0.001**	0.44
Scenario HF	62.79	22.54	53.07	19.66	19.68	< 0.001**	0.46
Flow	145.47	20.61	145.14	18.25	0.028	0.087	0.02
Internet addiction	30.62	35.69	26.73	32.70	1.19	0.028	0.11

*$p<0.01$; **$p<0.001$

[a]School HF scores were positively skewed. After square root transformation, those with ADHD ($M=5.89$, $SD=1.39$) still scored significantly higher than those without ADHD ($M=5.52$, $SD=1.26$), $F(1, 370)=7.00$, $p=0.009$, $d=0.28$

loading was 0.398, which fell just below our 0.400 cutoff. This suggests that all items (with the possible exception of the single hobby HF subscale item) are relevant for measuring HF, and thus, likely, no items should be excluded from the questionnaire. Finally, each of the HF subscale factors contributed similarly to the overall variance in HF; that is, the percent of variance explained by the first five factors was similar: 5.9–10.1%, with school HF explaining the most variance and dispositional HF explaining the least variance. This suggests that these five HF subscale factors similarly contribute to an individual's HF profile, as no single HF subscale factor explains substantially more of the variance than the other HF subscale factors. The three HF dimension factors explained less of the variance in HF (2.6–3.7%) and should be further explored to determine whether these three HF dimensions contribute more strongly to an individual's HF profile than the other three HF dimensions which did not emerge as factors.

Strongest predictor of ADHD diagnosis status: scenario HF

Post hoc, we performed a binary multiple logistic regression to test which of the five HF subscale scores was most predictive of ADHD diagnosis status. We set ADHD self-report diagnosis as the binary dependent variable and the five subscale scores as the independent variables. Using the step() function in R (R Core Team 2016), we performed stepwise regression to determine the strongest predictor(s) of ADHD diagnosis status. The final model included only scenario HF score ($\chi^2(1) = 17.80$, $p < 0.001$) as a predictor. This suggests that the scenario HF score is most predictive of ADHD status; however, future work is needed to validate whether the scenario HF subscale can function as a short-form assessment of HF in ADHD, or if instead a combination of items from each subscale would serve as a better short form of our questionnaire.

Convergent validity

As described in Methods, we included the scenario HF subscale in order to examine the convergent (construct) validity of our questionnaire by examining the correlation between scenario HF and total HF. Scenario HF was highly correlated with total HF, $r(370) = 0.86$, $p < 0.001$, which provides compelling support for the convergent validity of the questionnaire in measuring HF. That is, participants responded similarly when presented with more abstract questions on the first four HF subscales (e.g., "Generally, when I am very focused on something…I can feel totally captivated by… the activity") as they did when presented with the concrete real-world quotations about HF provided in the scenario subscales (see Online Resource 3 for a complete list of the scenario HF questions).

Content validity

Tables 11 and 12 in Online Resource 5 present short-answer responses from Study 2 participants to open-ended questions about their HF experiences. We have categorized these responses according to the HF setting or dimension with which they fit best. Many of the short-answer responses from Study 2 participants matched well with our proposed settings and dimensions of HF. Thus, this further supports the content validity of our questionnaire (i.e., that we are fully assessing all aspects of HF). However, it is beyond the scope of the present work to methodically code and analyze these short-answer responses.

Flow

In Study 2, higher flow scores showed low correlations with higher total HF and higher subscale HF ($r = 0.18$–0.26; Table 4) on each of the subscales except for screen time HF ($r = 0.10$; $p = 0.053$). While the lack of association for screen time followed our predictions, the rest of these significant correlations were somewhat unexpected, as in Study 1. For Study 2, we predicted that the correlations between flow and HF would not persist in a well-powered sample with similarly sized groups of those with and without ADHD. We examine this further in the Discussion. As we found in Study 1 and as we predicted a priori, flow scores were not associated with adult ADHD characteristics on the CAARS subscales ($p > 0.01$), although a trend emerged for the ADHD Symptoms subscale ($p = 0.011$), and a significant difference emerged for the Inattention subscale ($p = 0.001$; Table 4), which we did not predict. Similarly, as we predicted a priori, flow scores were not associated with childhood ADHD characteristics for any of the BAARS subscales ($p > 0.01$). Finally, as anticipated a priori, flow was not associated with ADHD diagnosis ($p = 0.087$; Table 5). As in Study 1, these results support the notion that HF is generally associated with flow; that is, those who more frequently experience HF may also more frequently experience flow. Further, we again show that, because flow is not related to adult or childhood ADHD symptomology, there seems to be a unique relationship between HF and high ADHD symptomology; however, future research is needed to explore this relationship, a point which we elaborate on in the Discussion.

Internet addiction

In Study 2, as predicted a priori, higher Internet addiction scores were associated with higher total HF and higher subscale HF on each of the subscales ($r = 0.22$–0.32) and with more severe ADHD characteristics on each of the CAARS subscales ($r = 0.18$–0.25; Table 4). Similarly, as predicted a priori, higher Internet addiction scores were associated

with more severe childhood ADHD characteristics for each of the BAARS subscales ($r = 0.15$–0.24; Table 4). Finally, Internet addiction was not associated with ADHD diagnosis ($p = 0.028$; Table 5); although this matches our finding from Study 1, this remains surprising, given the relatively equal group sizes tested here and the body of literature which has associated Internet addiction tendencies with ADHD (Yen et al. 2007, 2009; Yoo et al. 2004). Thus, again, similar to Study 1 and to the flow results, these findings demonstrate that HF is generally associated with Internet addiction. However, as in Study 1, while more severe Internet addiction was associated with more severe adult and childhood ADHD symptoms, it did not predict ADHD diagnosis, suggesting a more complicated relationship of Internet addiction and ADHD.

Anxiety and depression

As depression and anxiety were frequently reported in the Study 2 sample and were highly comorbid with ADHD (Online Resource 5, Table 10), we conducted a post hoc examination of the relationships between these conditions and HF to determine whether HF is uniquely related to ADHD symptomology or is rather a more general component of multiple mental health conditions. Mental health conditions other than anxiety and depression were less prevalent (affecting fewer than 10% of the participants) and had too few participants for a well-powered analysis. We conducted a Tukey HSD test on four groups: (1) self-report anxiety diagnosis only ($n = 52$); (2) self-report ADHD diagnosis only ($n = 122$); (3) self-report anxiety and ADHD diagnosis ($n = 40$); and (4) self-report of neither diagnosis ($n = 158$). Here, the only significant difference in total HF score emerged between those with only an ADHD self-report diagnosis (corroborated with high ADHD symptomology scores) ($M = 162.95$, $SD = 50.52$) and those with neither diagnosis ($M = 139.80$, $SD = 45.40$) ($p < 0.001$). Given that no post hoc associations emerged for either subgroup which included anxiety, these results suggest that the relationship between HF and ADHD symptomology is independent of anxiety.

Similarly, for depression, we conducted a follow-up Tukey HSD test on four groups: (1) self-report depression diagnosis only ($n = 64$); (2) self-report ADHD diagnosis only ($n = 65$); (3) self-report depression and ADHD diagnosis ($n = 97$); (4) self-report of neither diagnosis ($n = 146$). Here, a significant difference in total HF score emerged only between those with comorbid self-report ADHD and depression ($M = 167.04$, $SD = 48.21$) and those with neither diagnosis ($M = 140.60$, $SD = 44.75$) ($p < 0.001$). Thus, there may be a tendency for those with comorbid ADHD and depression to experience HF more often than those with either ADHD or depression alone. Importantly, both the anxiety and depression results presented here suggest that those with high HF scores are not merely over-reporting their symptoms on all self-report scales they complete, and that this HF effect is particularly associated with ADHD symptomology and not associated with self-report of mental health conditions in general.

Summary of results

This well-powered, preregistered study successfully replicated our results from Study 1 and supported our main hypotheses. Greater adult and greater childhood ADHD symptom severity were associated with greater total and setting-specific HF scores. Further, those with a self-reported ADHD diagnosis (corroborated with ASRS-S ≥ 14) scored higher on all HF subscales. Unlike Study 1, those with self-reported ADHD scored higher on the school subscale, suggesting that the increased frequency of HF experiences in ADHD also translates to academic settings. The EFA results suggest that each HF subscale uniquely contributes to an individual's HF profile and thus all subscales should be used to gain a complete picture of one's HF tendencies. Regression analyses indicated that scenario HF most strongly predicts ADHD status. Questionnaire validity was demonstrated by the high correlation between total HF and scenario HF scores and through examining participant short-answer responses. While higher flow was associated with higher HF on most HF subscales, flow did not associate with ADHD symptoms or diagnosis, suggesting that HF is uniquely related to ADHD. Higher Internet addiction also associated with higher HF; however, Internet addiction correlated with adult and childhood ADHD symptoms, but not with ADHD diagnosis, suggesting that further investigation of the relationship between Internet addiction and ADHD is needed. Finally, HF status was more strongly related to ADHD symptomology than to anxiety or depression. All of these results are especially compelling, given that participants were blind to the goals of the study.

Discussion

In one of the first empirical studies to do so, we have presented a novel questionnaire to assess HF and demonstrated through a pilot study (Study 1) and preregistered replication study (Study 2) that those with higher ADHD symptomology experience more frequent instances of HF. This was the case for dispositional HF, across three settings (i.e., school, hobbies, and screen time), and when participants were asked to relate to a variety of descriptive HF scenarios. Taken together, this provides strong support that HF may be an independent feature of adult ADHD.

Potential mechanisms, emotional valence, and consequences of HF

While HF does occur in the general population (as indicated by the distribution of HF scores in those without self-reported ADHD), more research is needed to understand what aspects of the ADHD cognitive profile make those with ADHD generally more susceptible to HF. Perhaps the higher prevalence of HF in ADHD is an issue of attentional control—that ADHD may not be an attention deficit, but rather an attention dysfunction (Doyle 2007) or a "maldistribution of attention" (Leimkuhler 1994). Future studies should investigate potential mechanisms of HF, such as attentional control (Banich et al. 2009), inhibition (Woltering et al. 2013), difficulty task-switching (Oades and Christiansen 2008), and perseveration (Boucugnani and Jones 1989). Further work should also address how HF relates to the findings that individuals with ADHD are more likely to suffer from addictive behaviors (Fatséas et al. 2016; Lee et al. 2017), OCD (Abramovitch et al. 2015), or autism-spectrum features (Joshi et al. 2013).

Those with ADHD may have greater difficulty focusing their attention on tasks that are not intrinsically rewarding (Kaufmann et al. 2000); however, strong incentives normalize executive function performance in ADHD (Dovis et al. 2012). Here, we asked about HF during participants' favorite activities, so these results associate HF with a certain level of enjoyment. Further studies may address whether other factors, such as an impending deadline or monetary incentives, are able to induce HF in those with ADHD during less intrinsically enjoyable situations.

Relatedly, it is unclear whether HF in ADHD is primarily problematic or productive and desirable. The qualitative short-answer responses here indicated potential positive and negative connotations of HF. Multiple participants noted tangible products resulting from HF episodes (e.g., completed musical composition or finished product for their job). However, others noted negative outcomes that ranged from physical consequences (e.g., stiff neck from staring at a computer screen) to substantial wastes of time, as one participant describing a videogame stated: "I accomplished feats in the game, but I accomplished nothing in the real world." Future work may explore factors that influence whether those with ADHD typically view HF experiences as positive or negative.

Relationship of HF with flow, addiction, and mental health conditions

Unlike HF, flow is typically presented with only positive connotations and is used to describe when someone is having an "optimal experience" (Carpentier et al. 2012; Csikszentmihalyi 1997). Here, we identified low-to-moderate correlations between higher flow score and higher HF score on all HF subscales except for school (Study 1) and screen time (Study 2). However, no associations emerged between flow scores and ADHD symptoms or ADHD diagnosis, suggesting that HF, but not flow, is related to high ADHD symptomology. Potentially, HF is a type of "deep" flow—a more intense flow experience that encompasses feelings of isolation or detachment from one's environment (Moneta 2012). On the other end of the spectrum is "shallow" flow, a more common flow state that does not encompass detachment from the environment (Moneta 2012). The majority of items on the flow questionnaire used here (Jackson and Eklund 2002; Jackson et al. 2008) ask about shallow, not deep, flow. Thus, we have demonstrated some correlation between shallow flow and HF experiences.

Additionally, past work has shown that more individuals report having experienced shallow flow as compared to deep flow, and very few individuals have experienced deep flow without having ever experienced shallow flow (Moneta 2012). As we have found a lack of association between the (shallow) flow scores we collected here and ADHD symptoms or self-report diagnosis, we suggest that those with ADHD might be uniquely able to experience deep flow (i.e., HF) without also experiencing shallow flow. Further research is needed to test these claims regarding shallow and deep flow and to more precisely examine the differences between HF and flow. Yet considering HF as a part of the flow spectrum and conceptualizing those with ADHD as superior deep "flow-ers" aids in interpreting the present findings and may aid those considering clinical interventions for individuals with ADHD.

Addictive behaviors, which are often comorbid with ADHD (Fatséas et al. 2016; Lee et al. 2017), may also be related to HF tendencies. Some evidence suggests that Internet addiction (Yen et al. 2007, 2009; Yoo et al. 2004) and Internet gaming disorders (Lee et al. 2017) are more prevalent in ADHD. Here, we identified a correlation between higher adult and childhood ADHD characteristics and higher Internet addiction scores, but no difference in Internet addiction score based on ADHD self-report. Further, higher HF across all subscales was correlated with higher Internet addiction score, suggesting that HF, and possibly ADHD symptomology, are likely at least somewhat associated with unhealthy Internet use. Further research is needed to uncover the mechanisms that underlie the relationship between addictive tendencies and HF in ADHD.

Those with ADHD who develop addictive behaviors and high HF may experience more profound impairments in executive control, including performance monitoring (Weigard et al. 2016), reward processing (Fosco et al. 2015), and salience processing (Tegelbeckers et al. 2015). Further, both the inattention (Sihvola et al. 2011) and the hyperactivity/impulsivity components of ADHD have been

associated with higher risk of addiction (Elkins et al. 2007). Here, greater HF was correlated with more severe symptom scores on both the CAARS Inattention and Hyperactivity/Impulsivity subscales. This suggests that, like susceptibility to addiction, HF may not depend on certain inattentive or hyperactive/impulsive symptoms, but is instead a global feature of ADHD. Thus, as those with higher susceptibility to addiction may also experience more frequent HF, further work is needed to identify the bases of these susceptibilities.

HF was particularly related to ADHD symptomology compared to other mental health conditions frequently self-reported by participants (i.e., anxiety and depression). When considering self-report anxiety, we found a unique relationship between HF and ADHD symptomology, as post hoc group differences emerged only between those with ADHD and those with no diagnosis, but no group differences emerged for those who also reported anxiety. Post hoc analyses indicated that those with comorbid depression and ADHD reported higher total HF than those with neither diagnosis. This suggests that a combination of ADHD and depression symptoms might make individuals most susceptible to HF. As we oversampled those with self-reported ADHD (combined with higher levels of ADHD symptomology) in Study 2 and did not specifically oversample those with depression, we cannot dismiss the possibility that an independent relationship might persist between HF and depression. Given that ADHD and depression are highly comorbid (McIntosh et al. 2009), and depression includes symptoms related to attentional regulation such as impaired concentration (Gonda et al. 2015) and perseveration of thought (Ruscio et al. 2011), HF tendencies might actually be expected as a particular feature of depression. Future work should specifically include depression questionnaires to better quantify the relationship between HF and depression.

The concept of HF fits well with the emerging body of research on neurodiversity—the idea that diverse neurological conditions result from brain differences, not merely deficits (Armstrong 2010). Those with ADHD may be expressing a "different attentional style" that includes greater HF tendencies, as well as other strengths, such as greater creativity than neurotypical adults (Armstrong 2010; White and Shah 2006). Thus, it is possible that individuals with ADHD may thrive in some workplace and school environments that elicit these potential strengths.

Past HF literature

As discussed in Introduction, only one previous empirical study has explicitly evaluated HF in an ADHD sample. In line with our findings, Ozel-Kizil and colleagues identified greater HF in adults with ADHD versus controls and a correlation between ADHD symptoms and HF severity (Ozel-Kizil et al. 2016). They also found no influence of psychostimulant use on HF severity (Ozel-Kizil et al. 2016), which suggests that medication use (which we did not assess in the present work) might not be influencing our results here. Their study provides preliminary evidence that HF may be a symptom of ADHD and has several strengths, such as the inclusion of both a medicated and non-medicated sample of ADHD individuals.

However, the study had several limitations. The HF scale (Ozel-Kizil et al. 2013) included only 11 items that were derived from clinician reports of common complaints associated with ADHD. As such, these items focused on deleterious consequences for health, behavior, and relationships (e.g., being late for other activities) rather than on the subjective experience of HF. Individuals with ADHD often subjectively report both positive and negative features of HF, suggesting that this is essential to accurately index HF. Likewise, the Ozel-Kizil et al. (2016) scale did not consider different contexts in which HF might occur, or different aspects of HF. In fact, many of the items on the Ozel-Kizil et al. (2016) scale appear to overlap quite closely with items on the Barkley Deficits in Executive Functioning Scale (BDEFS), which aims to test executive function deficits in daily life activities (Barkley 2011b). For instance, the Ozel-Kizil et al. (2016) scale includes the statement, "It is not often to complete work which I have started," and the BDEFS includes the statement, "Have trouble completing one activity before starting into a new one" (Barkley 2011b). This item on the Ozel-Kizil scale is not probing HF according to our working definition, but rather probes more general executive dysfunction or difficulty with attentional distribution. Overall, we suggest that at least some of the items on the Ozel-Kizil scale are assessing deficits in executive functioning, rather than HF tendencies. As it is well established that individuals with ADHD exhibit greater deficits in executive functioning compared to their neurotypical peers (Sjöwall et al. 2013), it is perhaps not surprising that those with ADHD scored higher on the Ozel-Kizil scale.

Finally, and perhaps most importantly, while the scale was originally administered in Turkish, the English language version of the HF scale included wording that is not easily interpretable to our sample of native English speakers (e.g., "While I'm busy with something, I don't care if the world bemoans"). Work is currently underway to (1) translate the Ozel-Kizil et al. (2016) scale appropriately and (2) determine correlations between the two scales. The present study extends the Ozel-Kizil findings by considering the positive and negative consequences of HF, assessing the domain specificity or generality of HF, examining the relationship of HF and related constructs of flow and Internet addiction, and including a preregistered replication.

Questionnaire reliability and validity

In the present work, we have provided several metrics of reliability and validity of our Adult Hyperfocus Questionnaire; however, future work should further evaluate these qualities. We report high internal consistency reliability for all HF subscales (Cronbach's alpha 0.87–0.99). Future work may assess test–retest reliability over the course of several days to establish whether HF as measured by our questionnaire proves to be a stable construct. We have presented some data establishing content validity for our questionnaire by extracting common HF settings and dimensions from our interviews with adults with ADHD and from past ADHD literature. We compared these themes with those described by Study 2 participants in their short-answer responses. Although many short-answer responses closely matched with the identified settings and themes, it was beyond the scope of this work to more methodically analyze these responses.

We tested convergent validity through the scenario HF subscale; in the present work, we measured HF in two different ways: (1) by abstractly asking about HF tendencies on the dispositional and subscale (2) by asking participants to relate their own experiences to questions about concrete contexts in which HF might occur on the scenario HF subscale. As we identified a high correlation between total HF score and scenario HF score ($r = 0.86$), this established convergent validity and suggested that both the dispositional/setting subscales and the scenario subscale were measuring the same HF construct.

Limitations

There are several limitations of the present work. Some bias may have been introduced because participants were not clinically evaluated for ADHD, depression, or anxiety and instead self-reported these diagnoses, as well as adult and childhood ADHD symptoms. Despite this, participants were still blind to the fact that we were primarily interested in ADHD symptoms and diagnosis, so knowledge of our research interests did not influence their answers. In Study 2, we used a strict clinical cutoff (ASRS-S $\geq$ 14) to corroborate ADHD self-report (Kessler et al. 2007). Moreover, as ADHD is often under-diagnosed in adult populations and under-reported in self-reports by adults (Asherson et al. 2012), the use of self-report, perhaps counterintuitively, strengthens the present findings. Some individuals who do have (either diagnosed or undiagnosed) ADHD likely did not report a diagnosis and were thus included in the non-ADHD group; this likely added noise to the analyses. However, despite this, we still identified substantial group differences in HF score between the ADHD and non-ADHD groups, indicating a very strong association of HF with ADHD.

As the individuals who participated in preliminary interviews were young adults (i.e., those 20–31 years old), school emerged as an important setting for HF. School as an HF setting matched well with the scant clinical reports of HF in the literature; for instance, Fitzsimons et al. (2016) mentioned HF in the context of working with medical students and trainees with ADHD. While in the present work, we tested HF in adults aged 18–71, we still believe that schoolwork is a potentially important inducer of HF and carries clinical significance, as it is well established that those with ADHD usually perform worse than their peers in higher education settings (DuPaul et al. 2009). A better understanding of school HF in ADHD could provide important insight into treatment approaches. Participants were asked to answer the school section based on their favorite high school or college course; thus, participants did not need to be currently enrolled in academic courses to answer our questionnaire. Although the school HF responses could potentially be biased for the older participants included in the present work, we nonetheless identified significant associations between school HF, ADHD symptomology (Study 1 and Study 2), and ADHD diagnosis (Study 2).

Working definition of HF

The present results support the working definition of HF established in Introduction. We identified greater HF among those with ADHD across each of the three settings and based on questions related to each of the six dimensions. The factor analysis suggested that all of these questions were relevant, and our assessment of content validity suggested that our questions did indeed assess HF. Given the likely association between HF and deep flow, the working definition of HF might be edited to include a phrase such as, "Similar to a deep flow experience…"—although further work is needed to clearly understand the relationship between HF and flow.

Recommendations for use of the Adult Hyperfocus Questionnaire

The EFA results suggest that each of the five HF subscales is important in comprising an individual's HF profile. We thus recommend that those wishing to replicate or extend our work test participants on each subscale with all questions included. As regression analyses suggested scenario HF as the strongest predictor of ADHD diagnosis, a shorter clinical version of the questionnaire might include only the scenario HF subscale. However, future work is needed to validate any briefer form of the questionnaire.

Conclusions

In summary, the present work represents one of the first empirical studies to comprehensively examine HF in adult ADHD. We have proposed the first working definition of HF. We have demonstrated through a pilot (Study 1) and well-powered preregistered replication study (Study 2) that HF tendencies are higher in those with more severe ADHD symptomology across multiple settings, dimensions, and real-world scenarios. We also present the first English language scale for assessing HF and outline recommendations for future use of this questionnaire. This work provides strong scientific evidence that HF is an independent feature of adult ADHD and may have clinical implications for therapy and for addressing the under-diagnosis of adult ADHD (Asherson et al. 2012), as those with high HF are perhaps less likely to be diagnosed with an attention *deficit*, when their actual difficulty might be an attention *maldistribution*.

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Compliance with ethical standards

Ethical approval This study followed all ethical guidelines set forth by the University of Michigan IRB, and informed consent was obtained from all participants. All materials in this manuscript are original, have not been previously published or presented elsewhere, and are not in concurrent consideration by another journal. All of the authors have read this manuscript, and no ghost writing by others has occurred.

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