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Attention, Motivation, and Study Habits in Users of Unprescribed ADHD Medication

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Abstract

Objective: Despite the limited effectiveness of ADHD medications on healthy cognition, prescription stimulants' cognitive enhancement use is increasing. This article examines enhancement users' attention, motivation, and study habits. **Method:** A total of 61 users of unprescribed stimulants and 67 controls (no history of prescription stimulant use) completed tests of objectively measured and subjectively reported attention. Self-reports on study habits, as well as motivation during laboratory attention testing, were also administered. **Results:** Our data replicated previous findings of relatively lower self-reported attention functioning in users. Extending past research, we showed that user-control differences in attention were still present but less pronounced on objective measures than on self-report. In addition, we obtained evidence of lower motivation during cognitive testing and less optimal study habits among users, as compared with their non-using peers. **Conclusion:** Unprescribed stimulant use is more strongly related to compromised study habits, low motivation, and a subjective perception of attention problems than to objective attention performance. *(J. of Att. Dis. 2019; 23(2) 149-162)*

Keywords

inattention, impulsivity, motivation, cognitive performance enhancement, stimulants

Recent research has cast doubt on the magnitude of cognitive enhancement possible with prescription stimulants for people without ADHD (Chamberlain et al., 2010; Ilieva, Boland, & Farah, 2013; Ilieva, Hook, & Farah, 2015). Yet, the use of stimulant medication among healthy people is common, especially on college campuses (see Smith & Farah, 2011, for a review). Thus, it remains an open question what drives the enhancement use of medications like Adderall and Ritalin. Given the public health implications of the widespread stimulant use without medical supervision, a better understanding of the people who use stimulants for enhancement and their reasons for doing so is essential. This article will focus on four non-mutually exclusive candidate explanations of stimulant enhancement use among college students. These are the possibility that use is related to users' real attention problems, self-perceived attention problems, low motivation, or suboptimal study habits. Our goal is to determine which of these dimensions users and non-users differ on—a question with important implications for the reasons for enhancement stimulant use: Do users self-medicate undiagnosed attention difficulties? Do they seek to treat perceived attention problems despite objectively normal attention? Do they use stimulants to overcome low motivation? Or do they use them to compensate for inefficient approaches to learning?

Attention Problems (Real or Perceived) and Unprescribed Stimulant Use

Several researchers have suspected attention problems among non-medical stimulant users. This hypothesis has received support from a number of studies on college students, finding higher self-reported inattention and/or impulsivity in users, compared with their non-using peers (Arria et al., 2011; Peterkin, Crone, Sheridan, & Wise, 2011; Rabiner et al., 2009; Rabiner et al., 2010). Moreover, longitudinal data have shown that self-reported attention difficulties in the beginning of college predict prospectively the onset of enhancement use (Rabiner et al., 2010), consistent with the self-medication hypothesis.

Nevertheless, evidence of attention problems in non-medical stimulant users is qualified by a research limitation in past investigations. Previous studies have relied purely on self-report assessments of attention—measures susceptible to bias (e.g., see Hunt, Momjian, & Wong, 2011). For

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instance, users might consciously or unconsciously exaggerate their symptoms to justify self-medication. Alternatively, students surrounded by high-achieving peers might perceive their normal attention abilities as deficient. Thus, without converging evidence from objective neuropsychological testing, it is difficult to conclusively infer users' attentional impairment.

The most widely used objective test of attention is the Test of Variables of Attention (TOVA). The TOVA is a continuous performance test, which presents participants with a sequence of simple geometric figures signaling either a "go" or a "no-go" response. Several strengths of this instrument make it suitable for the objective assessment of attention. Age- and gender-normed standard scores are automatically generated, allowing an inference about the clinical significance of participants' performance. Malingering is detectable through an index of symptom exaggeration, considered positive if relevant conditions are met (e.g., if post-commission responses are quicker than the mean reaction time). The TOVA has better sensitivity and specificity than standard continuous performance tests: Its 22-min duration prevents above-threshold performance purely due to a compensatory strategy when actual attention difficulties are present. In addition, the test's non-verbal stimuli help differentiate attention problems from reading disorder (Forbes, 1998; Hunt et al., 2011). Thus, this test is a suitable instrument to evaluate whether enhancement stimulant users have *objectively* lower attention performance, given their previously documented *subjectively reported* attentional difficulties.

Motivation and Unprescribed Stimulant Use

Aside from optimal attention, non-medical stimulant users might be seeking increased motivation to study. Motivation encompasses a variety of facets, including, but not limited to, liking (e.g., enjoying a task) and wanting (e.g., ascribing value to the task outcome, expending effort in a task). Several lines of research have converged to suggest that stimulants are beneficial for improving motivation. Animal research shows that stimulants increase activity in the mesolimbic dopamine system, which is central to motivation (Butcher, Fairbrother, Kelly, & Arbuthnott, 1988; Drevets et al., 2001; Volkow et al., 2004). Double-blind, placebo controlled laboratory experiments on stimulant effects in humans have documented drug-related elevations in a number of motivation-related variables, such as (a) enjoyment of viewing emotionally valenced images (Wardle & de Wit, 2012), (b) expenditure of effort for reward in a laboratory task (Wardle, Treadway, Mayo, Zald, & de Wit, 2011), (c) self-reported energy (e.g., Costa et al., 2012; de Wit et al., 2000), and (d) self-reported interest in a mathematical task, an effect correlated with change in striatal extracellular dopamine (Volkow et al., 2004). Recent survey research has indicated that enhancement users rate stimulants' motivational effects as at least as pronounced as the cognitive ones (Ilieva & Farah, 2013). Thus, a number of experiments, using self-report, behavioral and neural measures, have supported the effects of ADHD medications on motivation in non-clinical samples.

Research on enhancement users' experiences has found that that stimulants' motivational properties are highly sought after. A recent study, based on semi-structured interviews and qualitative analyses, showed that users particularly value these drugs' effects on drive and task enjoyment (Vrecko, 2013). As a representative participant noted, "[on Adderall] I didn't want to stop what I was doing until it was completed up to a certain level of my satisfaction," and "You're interested in what you're doing even if it's boring." Accordingly, structured surveys asking participants to choose among candidate motives for unprescribed stimulant use have found that a majority of users indicate stimulant-driven increases of energy and task enjoyment as reasons for seeking these drugs (e.g., Bavarian, Flay, Ketcham, & Smit, 2013; DeSantis, Webb, & Noar, 2008; Teter, McCabe, Cranford, Boyd, & Guthrie, 2005). These data converge to demonstrate users' interest in stimulants' motivational properties.

Given this self-reported pursuit of a motivational boost, perhaps lower motivation for cognitive tasks is what distinguishes users from controls. To address this question, we examined users' and controls' subjective experience of the TOVA, focusing on how boring they found the task and how driven they were to do well. This measure is useful in distinguishing the subjective experience of motivation from attention during cognitive testing.

Study Habits and Unprescribed Stimulant Use

Whether they have an attention disorder or low motivation for their schoolwork, stimulant enhancement users may also seek medication to compensate for poor study habits. We use the term *study habits* to describe study practices that either facilitate or impede successful and efficient learning. Here, we are interested in study habits at a behavioral level, without attempting to parse out the relative causal contributions of psychopathology, lack of proper instruction and training, low achievement motivation, low self-control, or unfavorable situational factors.

Several lines of research converge to suggest the possibility of suboptimal study habits among non-medical stimulant users. Previous work has indicated that users spend less time studying and skip more classes than their non-using peers (Arria et al., 2011, 2013). Cramming for exams and improving study skills have been identified as common motives for unprescribed ADHD medication use (DeSantis et al., 2008; Hildt, Lieb, & Franke, 2014; Peterkin et al., 2011). An inverse relationship has been documented between trait Conscientiousness and unprescribed stimulant use (Benotsch et al., 2013). Trait Conscientiousness reflects, in part, a combination of self-discipline, personal organization, and dutifulness—facets that can be crucial for maintaining effective study practices. Taken together, these data raise the possibility that use is associated with the quality of students' study habits—a construct more specific to academic behavior than trait Conscientiousness but, as shown below, more comprehensive than the isolated student behaviors examined previously.

Previous research has identified a number of study practices beneficial for learning. Spaced practice of to-be-learned material leads to longer-term retention than massed practice. Retrieval practice improves memory relative to no practice or to repeated exposure to the same material. Critical analysis of the studied material (e.g., interpreting and interconnecting information) is another strategy shown to benefit retrieval (see Bjork, Dunlosky, & Kornell, 2013; Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013; Roediger & Pyc, 2012, for reviews of the solid body of research that supports the effectiveness of these approaches). Other activities found to correlate with successful learning outcomes in school and at work include persistence despite failure or boredom, time management, and the tendency to work in distraction-free environments, as well as planning and monitoring one's goal-directed behavior (Credé & Phillips, 2011; Sitzman & Ely, 2011). The small to moderate size of the correlations with learning outcomes does not necessarily discount the importance of these study practices: They may be an important determinant of success, although acting only in conjunction with intelligence and other factors and effective only if applied properly (Bjork et al., 2013).

We asked whether users and controls differ on this broader, more comprehensive array of study habits. To address this question, we compiled our own set of self-report items borrowed from several existing scales (see the Appendix), with the aim of assessing (a) study habits previously shown to effectively promote learning and achievement, and (b) study habits (e.g., note-taking and class participation) that appeared important for academic success to three independent research staff members who reviewed the published scales. Despite the availability of a multitude of published measures of study habits in the literature (e.g., Biggs, 1987; Christopoulos, Rohwer, & Thomas, 1987; Gredler & Garavalia, 2000; Kornell & Bjork, 2007; Nonis & Hudson, 2010; Pintrich, Smith, Garcia, & McKeachie, 1991; Schmeck, Geisler-Brenstein, & Cercy, 1991, etc.), we decided against directly using one of these measures, because none met fully our first and main aim, as described above.

The Present Study

The goals of the present study were to examine attention, motivation, and study habits in stimulant enhancement users, relative to controls with no history of ADHD medication use. We conducted a multimodal assessment of attention, combining a subjective measure with an objective neuropsychological test. We predicted lower self-reported attention among users, while making two alternative hypotheses about user-control differences on objectively measured attention. If use relates to true attention problems, we expected to see lower TOVA performance in users than in controls. Alternatively, if use is more strongly driven by perceived attention functioning than by objective problems, we expected an interaction pattern, indicating lower ratings on self-report in users than in controls, despite comparable objective performance in the two groups. We further predicted lower level of self-reported motivation among users for the duration of the TOVA, as well as less optimal self-reported study habits, relative to controls. We were interested in whether these outcomes distinguish users from controls and whether they remain significant even after holding constant previously documented group differences on depression, anxiety, and substance use (Arria et al., 2013; Dussault & Weyandt, 2011; McCabe et al., 2005; McCabe & West, 2013; Rabiner et al., 2010; Teter, Falone, Cranford, Boyd, & McCabe, 2010; Weyandt et al., 2009). By understanding how enhancement users differ from non-users, we are better positioned to understand the likely motives for enhancement use, a significant public health concern.

Method

Participants

The analyzed data are from 128 participants, a sample size selected to attain 87.5% power of detecting medium-sized effect (Cohen's $d = 0.5$) in our main analyses, given a $p = 0.05$ significance threshold (one-tailed, given our directional hypotheses). The sample consisted of 67 controls (37 female, 30 male), who reported no lifetime prescription stimulant use and 61 enhancement users of prescription stimulants (27 female, 34 male). All participants were young adults (age range 18-28, $M = 20.95$, $SD = 2.05$) who denied history of ADHD diagnosis. Participants were recruited through university-affiliated recruitment websites and flyers on university campuses in Philadelphia. The project was advertised as "a research study comparing users of unprescribed ADHD medication to people who have never used such drugs."

In addition to this final sample of 128 participants, 48 more participants began the study without completing it or without being included in the analyses. Of these 48, 24 participants (14 users and 10 controls) dropped out after completing part of the study.[1] Additional 24 participants were excluded for the following reasons: possible symptom exaggeration on the TOVA ($n = 4$); inconsistent self-report of ADHD diagnosis history at different assessment points ($n = 1$); inconsistent self-report on enhancement use (admitted vs. denied) at different assessment points ($n = 5$); five or more alcoholic drinks the evening before the TOVA ($n = 7$); four or fewer hours of sleep the night before the TOVA ($n = 3$); the equivalent of a cup of coffee or more before the TOVA, given no regular caffeine intake[2] ($n = 3$); and runs of sequential omission errors (a rare pattern of performance typical of narcolepsy and seizure disorders, $n = 1$). Participants who took medications with stimulant properties (e.g., stimulant medications, modafinil, atomoxetine, bupropion) before the TOVA were ineligible, but none presented to the lab meeting this criterion.

Procedure

The study began with an anonymous screening survey, excluding people with an ADHD diagnosis, as well as people outside of the 18 to 30 age range. Potential participants were also asked about lifetime use of prescription stimulants (yes vs. no). Depending on user status, they were directed to two separate sign-up lists. This early distinction between users and non-users allowed us to keep the number of enrolled participants roughly equal between groups.

The initial phase of the actual study consisted of an online battery of self-report assessments of study habits, attention, anxiety, depression, and substance use, administered in that order. A separate second session began with the TOVA and continued with participants' self-report on their motivation during the computerized test. A self-report on the incidence of their enhancement stimulant use followed. The session concluded with a report on medication use, caffeine intake, alcohol and illicit substance intake, amount of sleep before testing, and history of ADHD diagnosis. A day prior to the study, participants had been contacted with instructions to take their usual amount of sleep before testing and to refrain from taking more caffeine than usual on the test day. In all, 74 participants (36 users) were tested in lab by blind experimenters; for the remaining 54 participants (25 users), testers were not blind to user status.[3]

Materials

Main measures

Enhancement stimulant use. Participants indicated the number of occasions of unprescribed ADHD medication use in the past month, past year, and in their lifetime. The measure, adapted from Teter et al. (2010), read as follows: "On how many occasions have you used **ADHD medication** (e.g., Adderall, Ritalin, or other), ***without* a prescription**, to help you **do well at school** and/or work?" Our main analyses were based on the incidence of lifetime use (given its greatest range among the three measures). Sensitivity analyses using data on past-year and past-month use were also conducted.

Barkley & Murphy ADHD Current Symptom Scale. This self-report ADHD assessment instrument incorporates scales of inattention (nine items) and impulsivity (nine items). The scale items correspond to ADHD symptoms as defined in the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; *DSM-IV*; American Psychiatric Association, 1994), with wording adapted for adult populations. Participants indicated the frequency of each symptom on a 0 ("never or rarely") to 4 ("very often") scale. An indication of frequent or very frequent manifestation of at least six inattention *or* six hyperactivity symptoms meets the scale's cutoff for clinically significant impairment. The scale has demonstrated excellent positive predictive value (0.8-1) but limited negative predictive value (0.3) in previous research (O'Donnell, McCann, & Pluth, 2001). Thus, diagnosis cannot be established purely based on the results of the scale, in the absence of report from other informants on the nature, severity, pervasiveness, and childhood onset of the difficulties (Murphy & Adler, 2004).

TOVA. The TOVA is a 21.6-min continuous performance test. Participants are presented with a sequence of briefly flashed simple geometric figures, requiring participants either to press a button as quickly as possible or to withhold responding. The first half of the test taxes inattention, given infrequent target presentation, based on a target: non-target ratio of 1:3.5. The second half taxes impulsivity, given frequent target presentation, based on the reverse target:non-target ratio of 3.5:1. Throughout the test, stimulus presentation is 100 ms, and interstimulus interval is 2 s. The TOVA provides a symptom exaggeration index, which is considered positive if at least two of the following criteria are met: quick post-commission responses, slow commission errors, extreme omission, commission, or reaction time variability scores. The TOVA's specificity and sensitivity in identifying ADHD have been estimated to range between 67% to 86% (Forbes, 1998; Greenberg & Waldman, 1993; Schatz, 2001).

Our dependent variables on the TOVA included three measures of inattention: omission errors, reaction time variability, and reaction time; one measure of impulsivity: commission errors; and the test's overall attention performance index: the API score. The API reflects a linear combination of reaction time in the first half of the test, sensitivity (d') in the second half of the test, and reaction time variability over the duration of the total test. This is a combination of variables, previously indicated to best predict ADHD (Greenberg & Waldman, 1993). The API falls on a –10 to +10 scale, where negative numbers are suggestive of clinically significant attention problems. The remaining dependent measures are automatically reported as standard scores ($M = 100$, $SD = 15$), with higher standard scores indicating better performance.

Motivation and perceived difficulty of the TOVA. Participants rated their experience of completing the TOVA test on six scales. Four of these items assessed two aspects of motivation: boredom ("unpleasant"–"enjoyable," "very fun"–"very boring,") and drive ("not motivated to do well"–"very motivated," effort invested in the task: "as much as possible"–"none at all"). Two items assessed how difficult and how tiring participants found the test ("easy"–"difficult," "very-exhausting"–"not tiring at all"). All items were scored on 5-point scales. These measures were completed twice: once at the end of the short TOVA practice test and once at the end of the full actual TOVA test.

Study habits. A 34-item self-report measure assessed a variety of study habits, including self-testing and rehearsal, spaced practice, effort and persistence, critical analysis of the material, time management, preference for work-appropriate spaces, self-monitoring of goal-directed activities, class attendance, assignment completion, and time spent studying, among others. Participants were presented with statements, each describing a study habit, and asked to indicate how frequently they rely on that study habit, using a 0 (*never*) to 4 (*always*) scale. Items were compiled from previously published scales on study habits. In our sample, the scale had good-to-excellent internal consistency: Cronbach's alpha = .88. Furthermore, in this sample, the measure of study habits was significantly associated with grade point average (GPA; r = .38, $p < 0.01$), depression (BDI: r = –0.31, Spearman's rho = –0.23, both ps < 0.01), trait anxiety (STAI–general: r = –0.30, Spearman's rho = –0.30, both ps < 0.01), and self-reported attention (Current Symptom Scale–Total Score: r = –0.35, Spearman's rho = –0.29, both ps < 0.01; Current Symptom Scale–Inattention Subscale: r = –0.47, Spearman's rho = –0.40, both ps < 0.01; Current Symptom Scale–Impulsivity Subscale: r = –0.17, p = 0.06, Spearman's rho = –0.20, p = 0.03. We found no correlations between Study Habits and any of the TOVA indexes.

Secondary measures. Secondary measures reflected demographics, as well as several control variables (e.g., depression, anxiety, substance use).

Beck Depression Inventory–II (BDI-II). The BDI is a measure of depression severity, tailored to reflect the *DSM-IV* diagnostic criteria. Each of the 21 items on the BDI is rated on a 0 to 3 severity scale for a maximum score of 63. Conventionally, scores in the ranges 0 to 9, 10 to 19, 20 to 29, and 30 to 63 reflect, respectively, minimal, mild, moderate, and severe depression. The BDI has excellent reliability and validity (e.g., Steer, Ball, Ranieri, & Beck, 1999; Storch, Roberti, & Roth, 2004).

State Trait Anxiety Inventory (STAI). The STAI is a widely used self-report assessment of anxiety, from which we selectively focused on the 20-item subscale reflecting trait anxiety. Participants were asked to rate the extent to which they experience various anxiety symptoms (e.g., nervousness, insecurity) on a 0 (*not at all*) to 3 (*very much so*) scale. The test has high test–retest reliability and correlates highly with other anxiety questionnaires (Spielberger et al., 1983), although it does not consistently differentiate anxiety from depression (Bados, Gómez-Benito, & Balaguer, 2010; Balsamo et al., 2013).

Substance use. To assess substance use, participants were given a list of addictive, commonly abused substances, some of which were also identified with a street name. These included tobacco, marijuana, MDMA ("molly" or "ecstasy"), cocaine, hallucinogenic mushrooms, LSD, heroin, methamphetamine, opioids, unprescribed opioid painkillers, PCP ("angel dust"), hashish, unprescribed barbiturates or benzodiazepines, and inhalants. For each substance, participants indicated the number of occasions of use in their lifetime.

Other demographic and control variables. Data were also collected on participants' gender, undergraduate institution, GPA, and current occupation. To examine some situational factors, potentially affecting TOVA performance, we administered a list of open-ended questions about medication intake (type and dose) within 24 hr before the TOVA; caffeine intake (type and amount of caffeinated drink) on the day of the TOVA, as well as on a typical day; and alcohol and substance use (type and amount of substance) within 24 hr before the TOVA. We also inquired about the number of hours participants slept the night before the TOVA. All participants confirmed that their vision was normal or corrected-to-normal at the time of the objective test.

Results

Data Distributions and Choice of Parametric Versus Non-Parametric Tests

Several of our main variables of interest had non-normal distributions, as indicated by a series of significant Shapiro–Wilk tests. Non-normally distributed variables included all indexes of objective attention (TOVA: omissions, commissions, reaction time variability, reaction time, and API) and subjective attention (Current Symptom Scale: Inattention subscale, Impulsivity subscale, and total score), as well as the BDI, STAI–general, our measures of substance use incidence, and amount of sleep pre-TOVA. These distributions were skewed, in some cases pronouncedly so: A majority of data points indicated uniformly high functioning, while increasingly fewer participants showed (or reported) increasingly greater problem severity. We attempted several transformations (square root, square, ln, and log10) of the raw or the reversed scores, but without attaining normality. Hence, our main analyses relied on non-parametric tests. Secondarily, we conducted parametric procedures, in which, for the sake of interpretability, we used untransformed data. Measures of study habits and motivation were normally distributed, allowing analyses using parametric procedures only.

Handling of Outliers

To minimize the effect of extreme values in the analyses that follow, we Winsorized the data by substituting the three highest and three lowest data points with the next most extreme data point for each measure. This resulted in replacing the most extreme 4.7% of the data overall (i.e., 6 out of the total of 128 values from 128 participants).

Handling of External Variables

Based on consistent past findings (Arria et al., 2013; Dussault & Weyandt, 2011; McCabe et al., 2005; McCabe & West, 2013; Rabiner et al., 2010; Teter et al., 2010; Weyandt et al., 2009), we assumed that elevated levels of depression, anxiety, and substance use are characteristic of users. Thus, in our main analyses, we do not statistically control for these variables, in order not to partial meaningful group variance out of the analyses. If we hold constant the values of depression, anxiety, and substance use between groups, we run the risk of obtaining findings unrepresentative of a substantial proportion of users (Miller & Chapman, 2001). However, in a secondary set of analyses, we do enter third variables as predictors in the model, to assess the separate question of whether users and controls differ on attention, motivation, and study habits above and beyond their previously documented differences on depression, anxiety, and substance use.

Subsets of Data Analyzed

Our main analyses, which are reported below, were conducted based on the full sample of eligible participants. In addition, we replicated these analyses in two subsets of participants. First, we excluded participants ($n = 5$) who disclosed having used enhancement medication only once in their lifetime. Our reasoning was that one-time users might be unrepresentative of people who use continually; for instance, one-time users might find stimulants unhelpful or differ in some other way from the majority of users. Second, we replicated our analyses in users with API scores within normal limits ($n = 109$). User-control differences on motivation and study habits were most likely to be detected in this subsample, as would be disparities between perceived and objectively measured attention. The results of these two sets of secondary analyses are only reported when different in direction or significance from the findings of the main analyses.

Characteristics of Enhancement Users

A chi-square test for independence indicated a non-significant relationship between gender and user status (chi sq = 1.53, $p = 0.22$). There was a borderline significant trend for users to report more time having slept the night before testing ($M = 7.40$, $SD = 1.19$) than non-users ($M = 7.02$, $SD = 0.97$), $t(122) = 1.93$, $p = 0.06$. Users were more likely than controls to have taken a cup of coffee or more (or a roughly equivalent amount of another caffeinated drink) on the test day, chi sq (1) = 5.29, $p = 0.02$. Frequency of stimulant enhancement use within our sample is described in Table 1.

Table 1. Frequency of Non-Medical Stimulant Use Within the Present Sample.

Non-medical stimulant use	Number of participants	%
Never	67	52.3
1 occasion	5	3.9
2 occasions	2	1.6
3-5 occasions	18	14.1
6-9 occasions	8	6.3
10-19 occasions	15	11.7
20-39 occasions	9	7.0
40 or more occasions	4	3.1

Hypotheses with directional predictions were tested next. Consistent with past findings (Arria et al., 2013; Dussault & Weyandt, 2011; McCabe et al., 2005; McCabe & West, 2013; Rabiner et al., 2010; Teter et al., 2010; Weyandt et al., 2009), users reported higher levels of depression, $t(126) = 3.28$, $p < 0.01$, one-tailed (Mann–Whitney $U = 2{,}633.50$, $z = 2.82$, $p < 0.01$, one-tailed); trait anxiety, $t(127) = 3.35$, $p < 0.01$, one-tailed (Mann–Whitney $U = 2{,}677.50$, $z = 3.03$, $p < 0.01$, one-tailed); and substance use, $t(127) = 5.75$, $p < 0.01$, one-tailed (Mann–Whitney $U = 3{,}141.50$, $z = 5.28$, $p < 0.01$, one-tailed), than did controls. Finally, self-reported GPA was lower among enhancement users ($M = 3.29$, $SD = 0.38$) than among controls ($M = 3.55$, $SD = 0.41$), $t(124) = 3.67$, $p < 0.01$, one-tailed (see Table 2 for descriptive statistics).

Stimulant Enhancement Use and Self-Reported Attention

Non-parametric and parametric procedures consistently showed higher level of self-reported inattention, replicating earlier research ($U = 2{,}619.50$, $z = 2.76$, $p < 0.01$, one-tailed, $d = 0.50$, $t(126) = 2.95$, $p < .01$, one-tailed, $d = .52$), and impulsivity ($U = 2{,}637$, $z = 2.99$, $p < 0.01$, one-tailed, $d = 0.54$, $t(126) = 3.26$, $p < 0.01$, one-tailed, $d = 0.57$) on the Current Symptom Scale among users than controls. Accordingly, users had higher total scores on this self-report scale: $U = 2{,}669.50$, $z = 2.99$, $p < 0.01$, one-tailed, $d = 0.54$; $t(126) = 3.36$, $p < 0.01$, one-tailed, $d = 0.59$ (see Table 2 for descriptive statistics). Lifetime enhancement use correlated with subjectively perceived attention problems: $r = 0.31$,

Table 2. Attention, Depression, Anxiety, and GPA Among Users and Controls.

	Non-users (N = 67)		Users (N = 61)	
	M	*SD*	*M*	*SD*
Barkley & Murphy ADHD Current Symptom Scale–Total score	9.61	6.74	14.66	10.05
Barkley & Murphy ADHD Current Symptom Scale–Inattention	4.66	3.89	7.20	5.57
Barkley & Murphy ADHD Current Symptom Scale–Hyperactivity	4.96	3.40	7.46	5.10
TOVA: Omissions	99.28	17.32	95.78	18.59
TOVA: Commissions	102.95	13.52	102.91	13.14
TOVA: Reaction time variability	102.90	17.43	101.11	16.94
TOVA: Reaction time	119.03	13.12	118.25	13.24
TOVA: API	3.37	2.55	2.75	2.42
BDI-II	6.42	5.45	10.72	9.08
STAI–General	16.85	10.17	23.26	11.46
GPA	3.55	0.41	3.29	0.38

Note. GPA = grade point average; TOVA = Test of Variables of Attention; API = attention performance index; BDI-II = Beck Depression Inventory–II; STAI = State Trait Anxiety Inventory.

Spearman's rho = 0.28, ps < 0.01, one-tailed, for the Inattention subscale of the Current Symptom Scale; r = 0.35, Spearman's rho = 0.29, ps < 0.01, one-tailed, for the Impulsivity subscale of the Current Symptom Scale; r = 0.35, Spearman's rho = 0.31, ps < 0.01, one-tailed, for the total score of this scale. Qualitatively similar patterns emerged when correlating the measures of attention with past-year and past-month enhancement use.

We further asked whether clinically significant self-reported attention problems appear more common in users of unprescribed stimulants than in controls. Nine users and two controls scored in the clinical range of the Current Symptom Scale. A significant chi-square test for independence showed that users are significantly more likely to have above-threshold self-reported attention difficulties (chi sq = 5.63, p = 0.01, one-tailed).

Stimulant Enhancement Use and Objectively Measured Attention

Results thus far reported are consistent with previous findings associating stimulant enhancement use with self-reported attention difficulties. Here, we address the question of whether enhancement use is also associated with objective measures of attention. Independent-samples Mann–Whitney tests on TOVA performance showed a higher number of omission errors (the measure with the most pronouncedly skewed distribution) among users than controls (U = 1,610, z = 2.09, p = 0.02, one-tailed, d = 0.38), as well as lower overall API among users (U = 1,693, z = 1.67, p = 0.05, one-tailed, d = 0.30). Descriptive statistics are presented in Table 2. These differences emerged, even though, as shown above, users had slept slightly longer the night before testing and were more likely to have taken the equivalent of a cup of coffee before testing.[4]

We also examined the correlations between incidence of enhancement use and each index of objective attention. According to the results of non-parametric tests, omission errors were weakly correlated with lifetime enhancement use (Spearman's rho = 0.15, p = 0.05, one-tailed) and past-year use (Spearman's rho = 0.19, p = 0.02, one-tailed). The relationship with past-month use did not reach significance, possibly due to the restricted range of this measure. No other correlations between enhancement use and the remaining indexes of objective attention emerged significant, based on either non-parametric or parametric tests (all ps > 0.08, one-tailed) and irrespective of controlling for sleep and caffeine before the TOVA in corresponding parametric regression analyses.

In contrast to the continuous measures of attention functioning from the TOVA, incidence of clinically elevated API scores did not differ between the groups, with 9 users and 10 controls performing outside of normal limits (chi sq < 0.01, p = .49, one-tailed). In sum, although enhancement users are not more likely to perform in the clinical range than non-users, they do show elevated attentional problems on an objective test of attention.

Perceived difficulty of the TOVA. Self-reports on participants' experience of the TOVA showed positive correlations between the tendency to describe the test as difficult, on one hand, and the incidence of past-year use (r = 0.19, p = 0.02, one-tailed; Spearman's rho = 0.19, p = 0.02, one-tailed) and past-month use (r = 0.17, p = 0.03, one-tailed; Spearman's rho = 0.18, p = 0.03, one-tailed). No significant correlations with lifetime use emerged. In addition, no correlation emerged between incidence of use (lifetime, past year, and past month) and participants' tendency to describe the attention test as tiring.

Objective and Self-Reported Attention: Differential Relations With Enhancement

Are the discrepancies between users' and controls' attention significantly more pronounced on subjective than on objective tests? We conducted a series of three mixed-model ANOVAs with test type (subjective vs. objective) as a repeated-measures factor and user status (users vs. controls) as a between-subjects factor. Dependent measures in each of these three analyses were the following pairs of indexes: (a) total score of the Current Symptom Scale and API (TOVA), (b) Inattention subscale (Current Symptom Scale) and a linear composite of Omissions plus Reaction Time (RT) Variability (TOVA), and (c) Impulsivity (Current Symptom Scale) and Commissions (TOVA). To convert the objective and subjective data to a common scale, we converted all outcomes to *z*-scores with consistent directionality. We found a significant interaction on the tests of impulsivity, such that objective scores were very similar between users and controls, while users described themselves as more impaired than controls on self-report, $F(1, 126) = 4.48$, $p = 0.02$, one-tailed. The same trends emerged on tests of inattention and of overall attention performance, and the interactions were near-significant ($0.051 < p < 0.08$ for all *p*s, one-tailed).

When participants who had used unprescribed stimulants only once were excluded, the interactions between user status and attention test type emerged significant on all three measures—impulsivity, inattention, and overall attention performance—showing comparable performance on the objective test between the two groups but lower perceived attention among users than controls: for inattention subtests, $F_{\text{interaction}}(1, 121) = 4.78$, $p = 0.02$, one-tailed; for impulsivity subtests, $F_{\text{interaction}}(1,121) = 7.91$, $p < 0.01$, one-tailed; and for overall attention performance, $F_{\text{interaction}}(1, 121) = 3.83$, $p = 0.03$, one-tailed (see Figure 1).

Stimulant Enhancement Use and Motivation

An independent-samples *t* test indicated that users reported lower overall motivation during the TOVA test than did controls, $t(126) = 3.09$, $p < 0.01$, one-tailed, $d = 0.54$, based on a composite of the four motivation-related items. A closer look at specific sub-groups of items indicated that, relative to controls, users described the test as more boring, $t(126) = 2.83$, $p < 0.01$, one-tailed, $d = 0.50$ (based on a composite of the items "very fun"–"very boring" and "unpleasant"–"enjoyable"), and reportedly, were less driven to do well, $t(126) = 2.11$, $p = 0.02$, one-tailed, $d = 0.37$ (based on a composite of the items "not motivated to do well"–"very motivated" and effort expended on the task: "as much as possible"–"none at all"). Accordingly, the incidence of lifetime stimulant enhancement use was inversely correlated with the motivation composite score ($r = –0.26$, Spearman's rho = –0.28, *p*s < 0.01, one-tailed), as well as with its components: task enjoyment ($r = –0.24$, Spearman's rho = –0.28, *p*s < 0.01, one-tailed) and drive ($r = –0.17$, $p = 0.03$, one-tailed; Spearman's rho = –0.18, $p = 0.03$, one-tailed). All relationships reported above remained significant after controlling for participants' objective TOVA performance (i.e., their API scores) and the TOVA test's perceived difficulty. Correlations between these motivation indexes and past-year use replicated the reported findings, whereas correlations with past-month use failed to reach significance, possibly due to the more restricted range of this measure.

Another way of examining users' motivation during the TOVA entails asking whether their motivation ratings' linear composite dropped more dramatically over the duration of the test, relative to the control group. We conducted a mixed-model ANOVA with user status as a between-subjects factor and motivation assessment time point (after TOVA practice, after the full test) as a within-subjects factor. No significant interaction emerged either based on the full sample or after one-time users were excluded ($ps_{\text{interaction}} > 0.10$, one-tailed). However, when only analyzing data from people with API scores within normal limits, the interaction between user status and pre-post assessment emerged significant, $F(1, 105) = 4.21$, $p = 0.02$, one-tailed. This interaction revealed that the drop in motivation from the beginning to the end of the TOVA was greater among users with normal objective attention than among controls with normal objective attention.

Stimulant Enhancement Use and Study Habits

An independent-samples *t* test indicated that users reported less optimal study habits than controls, $t(126) = 2.65$, $p < 0.01$, one-tailed, $d = 0.48$. Accordingly, ratings of study habits quality correlated inversely with the incidence of lifetime stimulant enhancement use, $r = –0.20$, $p = 0.01$, one-tailed, and past-year enhancement use, $r = –0.23$, $p < 0.01$, one-tailed. No significant correlation with past-month use emerged ($r = –0.13$, $p = 0.07$, one-tailed), possibly due to the relatively more restricted range of this scale.

Analyses Controlling for External Variables

In addition to describing the relationships between unprescribed stimulant use, on one hand, and attention, motivation, and study habits, on the other hand, we asked whether these associations are significant after holding constant factors that have been previously documented to differ between users and controls: depression, anxiety, and substance use. In other words, we were interested in whether use is associated with attention, motivation, and study habits over and above what could be accounted for by depression, anxiety, and substance use. We conducted a series of between-subjects ANOVAs for each outcome, with the control variables (trichotomized to circumvent distribution skewness) and user status as between-subjects factors. For analyses with TOVA indexes as outcomes, we additionally entered caffeine use (dichotomous) and sleep before the TOVA (trichotomized) as control

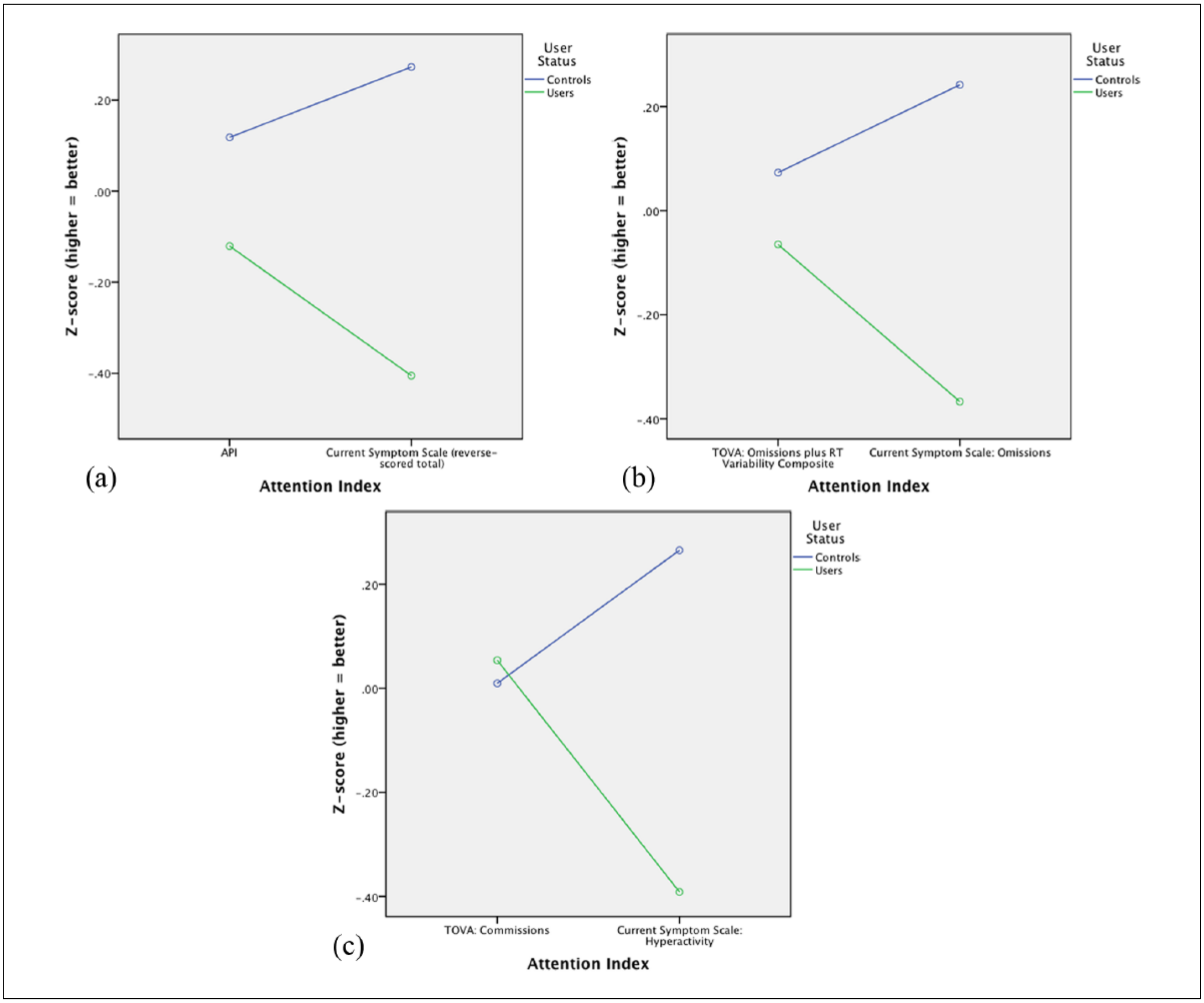

Figure 1. Discrepancy between subjectively reported and objectively measured attention in users of unprescribed stimulants and controls, based on data on (a) overall attention tests, (b) inattention subtests, and (c) impulsivity subtests.
Note. TOVA = Test of Variables of Attention.

variables. In these analyses, we found trend-level relationships between user status, on one hand, and subjective and objective attention and study habits, on the other hand ($0.07 > p > 0.16$ for all *p*s, one-tailed). The motivation composite remained related to user status after depression, anxiety, and substance use were held constant: $F(1, 127) = 4.96$, $p = 0.01$, one-tailed (for the main effect of user status).

Discussion

Are stimulant enhancement users self-medicating true attention difficulties or merely perceived attention problems? Are they compensating for low work motivation or poor study habits? The present findings are the first to document problems with motivation and objective attention in users in comparison with a control group, to replicate previous findings concerning self-rated attention and study habits, and to examine all these factors in a single study.

The psychological profile of users found here reflects elevated levels of objective attention problems. Although many earlier studies have shown increased self-reports of attention problems among users, it was unknown whether this reflected differences in subjective evaluation of attention functioning or a true difference. The present study provides the first evidence that enhancement users of stimulants indeed show objective signs of attentional dysfunction. However, the results also indicate that self-rated attentional dysfunction in users is disproportionately greater than objective dysfunction, consistent with a role of subjective factors in the decision to use stimulants for enhancement.

We also found that users describe their study habits as poorer than control participants, and rate their motivation during laboratory attention testing as lower. Previously observed associations between enhancement use, on one hand, and depression, anxiety, and substance use, on the other hand, were also found here. When controlling for these behavioral characteristics, attentional and study habit differences were reduced to non-significant trends while motivational differences between the two groups remained significant. Regardless of their relationship to these control variables, attention, motivation, and study habits are more compromised on average in users than controls.

Limitations

Several limitations of the present study require consideration. The current research design does not allow us to address the presence or direction of causality linking the use of stimulants for enhancement with the attentional, motivational, and study habit differences found here. The most obvious interpretation is that low levels of perceived attention, task motivation, and study habits lead to enhancement use. However, they may also result from enhancement use. For instance, some users might be justifying self-medication by perceiving or reporting attention difficulties; some might be deducing attentional impairment from the fact that the medication feels effective. Given the explicit aim of the research—to examine attention in enhancement stimulant users—stereotype threat might have compromised users' performance on the TOVA. The availability of Adderall as a study aid might be reducing the perceived need for maintaining self-regulated study habits. The experience of studying on stimulants might have made users less tolerant to tedious tasks, therefore explaining this group's lower motivation ratings. Furthermore, given our study's cross-sectional design, a third variable may be explaining some of the documented relationships. For instance, users—who have admitted to illicit medication use—may, on average, be less susceptible to socially desirable responding than our control sample. If so, this relatively lower proneness to socially desirable responding alone could explain users' tendency to rate the experiment as more boring and their own attention and study skills as more poor compared with controls. The present study cannot distinguish between these explanations but, as outlined below, paves the way for future longitudinal and intervention studies, which can establish the direction and causality of the examined relationships.

In addition, given that the majority of our sample consisted of students (124 out of 128) completing or having completed their undergraduate degree at a single university (114 out of 128 participants), the generalizability of our finding to other occupations or other undergraduate institutions is an open question. Finally, due to its specific focus on the enhancement use of stimulants, the study does not attempt to study these medications' recreational use, a similarly risky practice of substantial public health significance.

Future Directions

The present study opens up important avenues for future research. First, subsequent investigations can examine the relationship of unprescribed stimulant use to complementing measures of motivation and study habits. For a behavioral assessment of specific learning strategies, one could use (or modify) Son & Kornell's (2009) paradigm, which asks participants to study word pairs for a subsequent test and observes their learning strategies (e.g., spaced vs. massed practice) in the lab. Modifications of this procedure could evaluate the previously unexamined relationship of enhancement use to individual study habits, including time allocation for task-oriented activity and choice of self-testing versus passive review of the material. Analogously, subsequent research can assess the relationship of enhancement use with a comprehensive array of motivation-related functions. Motivation encompasses a number of facets, measurable through self-report and/or behavioral tests. Examples include the tendency to expend effort for reward (as measured through the behavioral EEfRT task, Treadway et al., 2009), trait drivenness (assessed by the Drive subscale of the Behavioral Activation scale), and positive expectancy for one's performance. Thus, the present study substantiates a more comprehensive assessment of the relationship of stimulant self-medication to motivation and study habits, using measures of various modalities.

In addition, future investigations may ask questions about the directionality and causality of the relationships examined here. Longitudinal research can examine whether objective attention, motivation, and study habits assessed in late adolescence prospectively predict the onset of non-medical stimulant use in young adulthood. Intervention studies can provide insights into the causal roles of motivation and study habits in non-medical stimulant use, while illuminating the approaches to reducing this risky behavior. Our study raises the possibility of several interventions potentially effective for reducing unprescribed stimulant use. Past research suggests that students harbor misconceptions about what study habits are optimal (Kornell & Bjork, 2008). A psychoeducational intervention addressing these misconceptions may improve study activities and, potentially, reduce non-medical stimulant use. Cognitive-behavioral interventions may also be helpful in enhancing users' motivation and study habits, while reducing academic impairment due to depression and anxiety. Research on the effects and mechanisms of these interventions (e.g., in comparison with a control condition, such as psychoeducation on the risks and uncertain benefits of stimulant self-medication) can be informative of the causal roles of motivation and study habits in enhancement stimulant use.

Finally, future studies can investigate other aspects of enhancement users' psychological profile, including possible weaknesses (e.g., planning and problem-solving) in need of intervention and potential strengths to draw from in compensating for these weaknesses.

Conclusion

The present study extends the previous literature on the correlates of stimulant enhancement in important ways. It shows that non-medical stimulant use is more strongly related to a subjective perception of attention difficulties than to objective attention difficulties (although the latter is also a factor), as well as to inefficient study habits and low task motivation. The present research has important implications for future research into the causal mechanisms of unprescribed ADHD medication use and into the interventions for discouraging this practice.

Appendix

Study Habits Questionnaire

1. I participate in class discussions even when the instructor does not call on me.
2. When I study for a class, I practice saying the material to myself over and over.
3. I ask myself questions to make sure I understand the material I have been studying.
4. I work through practice exercises and sample problems.
5. When working outside of class, I know how to plan my time to get everything done.
6. I don't take all the notes I should take.
7. When studying outside of class, I keep track of how much time I need to get the work done.
8. I review course material periodically
9. I cram for exams.
10. I spend more time studying than most of my friends
11. I wait till the last minute to complete homework and get ready for exams.
12. I make sure I keep up with the weekly readings and assignments.
13. I attend class regularly.
14. I usually study in a place where I can concentrate on my course work.
15. When reading about research, I like to try out several alternative ways of interpreting the findings
16. I rarely find time to review my notes or readings before an exam.
17. I find it difficult to make much sense of the notes that I take down in class.
18. I often find myself questioning things I hear or read to decide if I find them convincing.
19. When a theory, interpretation or conclusion is presented in class or in the readings, I try to decide if there is good supporting evidence.
20. When I study for a class, I pull together information from different sources, such as lectures, readings, and discussions.
21. I try to understand the course material by making connections between readings and the concepts from the lectures.
22. When I become confused about something I'm reading for a class, I go back and try to figure it out.
23. Before I study new course material thoroughly, I often skim it to see how it is organized.
24. I try to change the way I study in order to fit the course requirements and instructor's teaching style.
25. I try to think through a topic and decide what I am supposed to learn from it, rather than just reading it over when studying.
26. When studying, I try to determine which concepts I don't understand well.
27. When something presented in class is hard to understand, I get everything about it in my notes, so that I could figure it out later.
28. I feel so lazy or bored when I study for my classes that I quit before I finish what I planned to do.
29. I work hard to do well in my classes even if I don't like what we are doing.
30. When course work is difficult, I give up or only study the easy parts.
31. I carefully complete all course assignments.
32. I ask the instructor to clarify concepts I don't understand well.
33. When I can't understand the material, I ask another student in the class for help.
34. I can easily locate particular passages in a textbook when necessary.

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Authors' Note

Research material or data related to this article can be accessed by contacting the authors. The TOVA company provides a discounted rate for the use of the TOVA test for research (as opposed to clinical) purposes. The current research has benefitted from these lower rates.

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Notes

1. In the sample of 24 people who dropped out, users reported higher levels of depression (p = 0.04), anxiety (0.03 > ps > 0.04), substance use (p < 0.01), and attention problems (0.11 > ps > 0.08) than did controls. Users also reported less optimal study habits (p = 0.18) than did controls. As will be shown below, these trends suggest that user-control relationships in non-completers, at least based on these available data, are consistent with our findings among completers.
2. We based this exclusion criterion on past research showing that caffeine significantly affects TOVA performance only among people who do not regularly use caffeine (Hunt, Momjian, & Wong, 2011).
3. To assess possible experimenter effects on each of the TOVA indexes, we examined the interactions between user status and tester blindness, based on a series of two-way independent-samples ANOVAs. No significant interactions emerged. There were no effects of tester blindness on any of the TOVA variables within the separate subsamples of users and controls, according to the results of t tests and Mann–Whitney tests (all ps > 0.38).
4. Consistent with reduced sensitivity, when a series of between-subjects one-way ANOVAs were applied to the skewed data distributions, no significant differences emerged between the groups on any index of objective attention (irrespective of whether we controlled for sleep and caffeine before testing).

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