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Expectation for Stimulant Type Modifies Caffeine's Effects on Mood and Cognition Among College Students

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Caffeine is regularly used by college students to enhance mood and academic performance. Although high doses confer risk for negative consequences, moderate doses of caffeine may lead to acute improvements in mood and cognitive functioning. Notably, the pharmacological effects of caffeine may be enhanced by expectancy effects. College students may also engage in nonmedical prescription stimulant use for similar purposes, as students expect strong cognitive enhancement from prescription stimulants and consider them to be more efficacious than caffeine. The purpose of the current study was to examine whether the pharmacological effects of caffeine on mood/drug effects and cognitive performance are enhanced when expecting a conceivably stronger stimulant (i.e., Adderall) compared to when expecting caffeine. Sixty-five undergraduate students were randomized to condition across two variables: drug ingested (placebo or 200 mg caffeine) and drug expected (caffeine or Adderall). Participants completed self-report measures of mood and drug effects pre- and post-drug, as well as cognitive assessments post-drug. There were significant main effects of drug ingested and drug expected on several post-drug measures. Subjects receiving caffeine reported feeling more high, stimulated, anxious, and motivated than subjects receiving placebo. Further, subjects expecting Adderall reported stronger amphetamine effects and feeling more high, and performed better on a working memory test, than those expecting caffeine. Effects tended to be strongest in participants receiving caffeine and expecting Adderall. Modifying expectancies, in conjunction with the pharmacological properties of caffeine at moderate doses, may be one mechanism by which college students may experience differential effects of caffeine.

Public Health Significance
This study found that mood and cognitive performance are influenced by both the acute pharmacological effects of a moderate dose of caffeine and by expectancies, and most strongly by expectation to ingest a prescription stimulant. Thus, expectancies likely play a role in the overall caffeine experience, particularly for college students within the academic environment. Future research is warranted to further understand how expectancies may be modified to increase the benefits of caffeine, while simultaneously reducing risk for negative consequences.

Keywords: caffeine, Adderall, expectancy, mood, cognition

Caffeine is reportedly used regularly by over 80% of adults in the United States (Childs & deWit, 2012), across several modes of administration including coffee, tea, soda, energy drinks, and caffeine pills. College students are particularly likely to use caffeine, with one study indicating 98% of students sampled reported lifetime use and 89% reported past-month use (Norton et al., 2011). Nationally representative data in the U.S. indicate that adults consume an average of 211 mg of caffeine daily (Fulgoni et al., 2015), while college students report up to 850 mg daily, or three to five times the recommended daily dose of caffeine (McIlvain et al., 2011). Such elevated rates of caffeine use among college students are likely informed by specific motives for use. Namely, college students most commonly report use of caffeine for cognitive enhancement purposes, including to increase alertness, energy, and concentration; while also being motivated to use caffeine for mood enhancement (Irons et al., 2014).

Consistent with these motives, experimental studies indicate that caffeine does acutely and dose-dependently enhance several objective cognitive enhancement outcomes, including vigilance, cognitive control, working memory, and reaction time at low (40 mg) to moderate (300 mg) doses (Giles et al., 2012; McLellan et al., 2016; Ruxton, 2008). For college students in particular, caffeine has been found to enhance vigilance, increase executive control of visual attention, enhance arousal, and improve memory performance (Brunyé et al., 2010; Sherman et al., 2016). Similarly, low to moderate doses of caffeine (20–200 mg) also increase sociability,

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happiness, and well-being (Griffiths et al., 2003). However, caffeine may produce negative consequences when used in excess of 400 mg daily. Among college students, elevated caffeine use has been linked to poorer academic performance (Pettit & DeBarr, 2011), as well as poorer overall sleep quality and greater daytime sleepiness (Roehrs &, Roth, 2008; Stasio et al., 2011). Higher doses of caffeine may also lead to feelings of anxiety, jitteriness, and upset stomach (Griffiths et al., 2003). Moreover, extremely high daily doses (>500–600 mg) can lead to caffeine intoxication, resulting in anxiety, insomnia, tachycardia, and psychomotor agitation (Cappelletti et al., 2015). Despite the potential for some adverse consequences, caffeine is generally considered to be relatively safe to use in doses up to 400 mg per day (U.S. Food and Drug Administration, 2018), and is widely used without negative incident among healthy adults, including college students (Mitchell et al., 2014; Temple et al., 2017).

Caffeine's pharmacological mechanism of action to produce positive stimulatory effects, including cognitive and mood enhancement, is related to blocking of adenosine receptors and indirectly stimulating dopaminergic activity in the prefrontal cortex (Advokat et al., 2014). However, it is likely that caffeine's cognitive and mood enhancement effects are also simultaneously influenced by expectation for the drug, which may result in the production of placebo effects. Specific to caffeine, several studies find that both caffeine and expectation for caffeine's effects uniquely enhance cognitive performance and mood (e.g., Anderson & Horne, 2008; Dawkins et al., 2011; Elliman et al., 2010; Fillmore & Vogel-Sprott, 1994; Lotshaw et al., 1996). Few studies examining the effect of caffeine expectation separate from its pharmacological effects have been conducted with college students, which is greatly needed given the propensity of college students to use caffeine. Further, expectancies for drug-related benefits are associated with more frequent drug use; for example, strong cognitive and mood/social enhancement expectancies for caffeine are related to daily caffeine use (Huntley & Juliano, 2012). Students may be likely to hold strong, positive caffeine expectancies, which may increase their caffeine use and consequently explain their heightened risk for negative consequences (McIlvain et al., 2011), despite that at least some of the perceived benefits of caffeine use may be due to expectancy. Thus, further examination of the ways in which expectations align with improvements in performance and modulate the outcomes of caffeine use among college students is recommended, given the ubiquity of caffeine use in this population.

More specifically, college students may be the most likely population to seek out external enhancements within the academic environment due to insufficient sleep patterns and the need to study for exams (Maulinauskas et al., 2007). Given that caffeine is a freely available stimulant with some cognitive and mood enhancement properties, students may be particularly likely to use caffeine to boost performance. In fact, Mahoney et al. (2019) found that most college students report consuming caffeine specifically to feel more awake, improve their mood, and alleviate stress. Although, students have their choice of cognitive enhancers. For example, prescription stimulant medications commonly used to treat attention-deficit hyperactivity disorder (ADHD; e.g., Ritalin, Adderall) are taken nonmedically (i.e., without a prescription or in ways other than prescribed) for cognitive and mood enhancement by college students (Benson et al., 2015; Blevins et al., 2017). Rates of nonmedical prescription stimulant use (NPS) among college students have increased in recent years, despite simultaneous decreases or leveling out of misuse of other prescription medications (e.g., opioids; McCabe et al., 2014). Although college students tend to deny that NPS is dangerous or detrimental (Desantis & Hane, 2010), it is associated with myriad negative consequences (Arria et al., 2008, 2013; McCabe & Teter, 2007), and more serious psychological and physical symptoms at higher doses, including depression, elevated body temperature, arrhythmia, cardiovascular failure, and seizures (National Institute on Drug Abuse [NIDA], 2011). Importantly, the benefit-to-risk ratio for NPS is much more unfavorable than for caffeine, given that there is no good evidence that prescription stimulants meaningfully enhance cognition in healthy adults without ADHD (Advokat, 2010; Cropsey et al., 2017; Chamberlain et al., 2011; Ilieva et al., 2013; Smith & Farah, 2011). Despite lack of evidence, students report strong cognitive enhancement expectancies for prescription stimulants (Looby & Earleywine, 2010) and believe that they are more efficacious and have enhancement properties above and beyond the simple wake-promoting effects of caffeine (Franke et al., 2011).

It is possible that some college students may not expect caffeine to produce much benefit, and may instead seek out assistance from drugs that have a greater risk of negative outcomes, such as prescription stimulants. For this reason, it is necessary to better understand how expectations for caffeine are aligned with various cognitive- and mood-related outcomes, and importantly how this effect is modified when active caffeine is present, and when expectation is shifted to a conceivably more powerful cognitive enhancer (i.e., a prescription stimulant). A more nuanced understanding of under what conditions stimulant expectation produces enhancements may have important implications for recommendations to maximize the benefits of caffeine and/or minimize its consequences. Thus, the purpose of the current study was to examine whether subjective mood/drug effects and cognitive performance vary as a function of type of drug ingested (i.e., placebo vs. caffeine) and drug expected (i.e., Adderall vs. caffeine). We hypothesized significant main effects of both drug ingested and expectation, in that ingesting caffeine (compared to placebo) would enhance mood and cognition, and expecting Adderall, which is typically associated with stronger cognitive enhancement beliefs compared to caffeine (Franke et al., 2011), would do the same. Further, we anticipated that subjects who both expected Adderall and received caffeine would demonstrate superior cognitive performance and report the strongest drug effects.

Method

Participants

Undergraduates were recruited via flyers posted on a Rocky Mountain West campus and via a Psychology Department Subject Pool. An online screening survey assessed eligibility, including age between 18 and 25 years, current undergraduate enrollment, past-month caffeine use with no history of adverse effects, no lifetime history of a prescription stimulant for any purpose (to enhance the credibility of, or limit suspicion regarding the placebo, based on prior experience), and reported willingness to ingest caffeine or a prescription stimulant in the laboratory. Participants were excluded if they self-reported a current psychiatric diagnosis, used nicotine

daily, reported history of medical problems for which caffeine use or fasting may be contraindicated, or were currently pregnant or breastfeeding.

Sixty-five students participated in the study. Participants were predominantly female (60%) with a mean age of 19.43 years (SD = 1.57). Most (89.2%) participants were non-Hispanic. The most common race reported was White (90.8%), followed by Asian (4.6%), mixed race (3.1%), and Black (1.5%).

Measures

Substance Use Questionnaire

Participants reported on frequency of past-month use of nicotine, alcohol, caffeine, and marijuana; and presence of lifetime and past-month use of cocaine, methamphetamine, hallucinogens, heroin, and other recreational opioids. Denial of lifetime prescription stimulant use for any purpose was also confirmed. Specifically, participants were presented with examples of common prescription stimulants (e.g., Adderall, Ritalin, Concerta, Vyvanse) and asked to indicate if they had ever used these drugs in their lifetime, including without a prescription.

Addiction Research Center Inventory (ARCI)

The 49-item short form of the ARCI (Martin et al., 1971) assessed drug-related effects. Participants were instructed to respond to each true/false item according to whether they presently experienced each effect. The ARCI short form assesses five effects: euphoria (MBG scale), anxiety and restlessness (LSD scale), intellectual energy and efficiency (BG scale), amphetamine effects (AMPH scale), and sedation (PCAG scale). The ARCI subscales have been found sensitive to placebo-related stimulant effects among undergraduates (Looby & Earleywine, 2011).

Visual Analogue Scales (VAS)

Seven VASs were used to assess current mood state: "good," "bad," "attentive," "focused," "high," "stimulated," and "motivated." Each scale consisted of a 100 mm line, anchored at each end by *not at all* and *extremely*. Participants were instructed to complete each scale in accordance with how they were feeling at that moment. Similar VASs have been found sensitive to placebo-related stimulant effects among undergraduates (Looby & Earleywine, 2011).

Cognitive Assessments

The California Verbal Learning Test–Second Edition (CVLT II; Delis et al., 2000) was used to assess memory. Participants were read 16 words across five trials and asked to recall them immediately and again after short- and long-delay. Total words correctly recalled at each time point (i.e., immediate, short-delay, long-delay) was used as the outcome for this measure. The Coding subtest from the Wechsler Adult Intelligence Scale-IV (Wechsler, 2008) assessed accuracy of processing speed. Participants were provided with a key that matches nine symbols with a digit and asked to draw in the matching symbol as quickly as they can in 120 seconds. Number of correct symbols was used as the outcome for this measure. The Paced Auditory Serial Addition Test (PASAT; Gronwall, 1977) assessed working memory, divided attention, and information processing speed. This test was computer-administered using Inquisit 5. Participants listened to an auditory presentation of digits and consecutively added pairs of numbers such that each number was added to the one immediately prior. Participants selected the current sum from a circle of visually presented numbers (1–18). Participants completed four trials of 61 items; the interstimulus interval of auditory digit presentation on each trial was incrementally shortened (i.e., 2400 ms, 2000 ms, 1600 ms, 1200 ms). Total number of correct responses summed across the four trials was used as the outcome for this measure. The Wisconsin Card Sorting Test (WCST; Grant & Berg, 1948) assessed set-shifting and ability to modulate impulsive responding. This test was also computer-administered using Inquisit 5. Participants were required to sort cards categorically without further instruction. Feedback on accuracy following each card was provided; however, categorization rules changed without prior warning following 10 consecutive correct responses. The task ended when participants successfully completed six categories, or when 128 cards had been attempted. Number of trials to complete the first category, number of perseverative responses, percent errors, and percent conceptual level responses (i.e., consecutive correct responses occurring in runs of three) were the outcome measures for this assessment.

Manipulation Check

Participants were asked to rate along two 10-point scales (0 = *not at all*; 9 = *extremely*) to what extent they believed they received Adderall and caffeine during the study. Participants were also asked to categorically select which drug they thought they received: Adderall, caffeine, or neither.

Procedure

Eligible individuals were invited to participate in a study assessing the effects of cognitive enhancers on mood and cognition. Participants were informed that participation in the study would require them to ingest either a 200 mg caffeine or 10 mg Adderall pill, which would be determined during their study visit. Participants were also told that they would complete questionnaires assessing mood and drug effects, and a battery of cognitive tests.

Study visits were completed in the morning following an overnight fast for at least 8 hr, including refraining from use of any psychoactive substance. Upon arrival at the laboratory, participants provided informed consent and self-reported their last use of food and beverage, alcohol, caffeine, nicotine, and illicit drugs to verify their abstention, and that they had engaged in past-month caffeine use. Participants then completed baseline ARCI and VAS measures. At this time, participants were randomized to condition across two variables, using a single-blind procedure: drug expected (i.e., told either caffeine or Adderall) and drug received (i.e., ingested either placebo or 200 mg caffeine), resulting in four groups. We utilized a block randomization procedure to ensure equal representation of gender across conditions. Drug (placebo or 200 mg caffeine) was disguised in a strawberry flavored capsule, with a cover story that the flavored capsule would aid participants in swallowing the pill. During a 20-min delay to allow the medication to take effect, participants reported on their demographics and substance use history. After the delay, participants completed the cognitive

assessments (i.e., CVLT-II, Coding, PASAT, WCST), followed by post-test ARCI and VAS measures of mood and drug effects. The assessment battery took approximately 40 min; thus, participants ingesting caffeine likely reached peak drug levels during the testing (Liguori et al., 1997). Participants then completed the manipulation check to assess the credibility of the deception, followed by a full debriefing of the study and the true substance consumed. Participants were compensated with either cash or psychology course credit. This study was approved by the university's IRB.

Data Analysis

Analyses of covariance (ANCOVAs) examined the main effects of drug ingested and drug expected on post-test subjective mood and drug effects while controlling for baseline measure of that effect. Analyses of variance (ANOVAs) were used to examine the main effects of drug ingested and drug expected on cognitive performance. Due to the small sample size, we were underpowered to detect significant expectation x drug ingested effects. Thus, the models examined the main effects entered simultaneously; when significant main effects emerged, planned contrasts comparing the expect Adderall/receive caffeine group to the other three groups were examined. Significance of the planned contrasts was evaluated at a Bonferroni-corrected $p < .017$.

Results

Thirty-three participants were randomly assigned to ingest a placebo pill, while 32 ingested caffeine. Thirty-three participants also were randomly assigned to expect Adderall, while 32 expected caffeine. Broken down into groups, 17 subjects were assigned to expect Adderall/receive placebo, while 16 subjects were assigned to each of the following groups: expect caffeine/receive placebo, expect caffeine/receive caffeine, and expect Adderall/receive caffeine. Demographic subject information is provided in Table 1. There were no significant demographic differences among groups.

Credibility of the Deception

Belief that subjects truly ingested the drug they were told to expect was generally high. Mean believability scores were 7.34 ($SD = 2.04$) for subjects expecting caffeine and 6.73 ($SD = 2.71$) for subjects expecting Adderall. There was not a significant difference in believability scores between drug expectation conditions ($t(63) = 1.03$, $p = .305$). Subjects also tended to categorically select that they believed they ingested the drug they had expected. Specifically, 81% of subjects expecting caffeine/receiving placebo believed they ingested caffeine; 88% of subjects expecting caffeine/receiving caffeine believed they ingested caffeine; 76% of subjects expecting Adderall/receiving placebo believed they ingested Adderall; and 88% of subjects expecting Adderall/receiving caffeine believed they ingested Adderall. There were no significant group differences for likelihood of selecting the drug they were told to expect ($\chi^2(3) = 1.01$, $p = .799$).

Subjective Effects

On the ARCI subscales, there was a significant main effect of drug ingested on anxiety and restlessness (LSD scale), such that subjects ingesting caffeine reported stronger effects than those ingesting a placebo ($F_{(1,61)} = 15.01$, $p < .001$, $\eta_p^2 = .20$). Planned contrasts demonstrated that subjects expecting Adderall/ingesting caffeine reported significantly stronger anxiety and restlessness effects than subjects expecting caffeine/receiving placebo ($p = .001$, 95% CI: 1.05, 4.00, $d = 1.21$) and those expecting Adderall/receiving placebo ($p = .001$, 95% CI: 1.19, 4.10, $d = 1.26$). There was also a significant main effect of expectation on amphetamine effects (AMPH scale), such that subjects expecting Adderall reported stronger effects than those expecting caffeine, regardless of drug ingested ($F_{(1,61)} = 4.18$, $p = .045$, $\eta_p^2 = .06$). Examination of planned contrasts revealed that subjects expecting Adderall/receiving caffeine reported significantly stronger amphetamine effects compared to subjects expecting caffeine/receiving caffeine ($p = .011$, 95% CI: 0.48, 3.53, $d = 0.95$). There were no

Table 1
Demographic Information for the Total Sample and by Group

	Expect caffeine/receive placebo ($n = 16$)[a]	Expect caffeine/receive caffeine ($n = 16$)[a]	Expect Adderall/receive placebo ($n = 17$)[a]	Expect Adderall/receive caffeine ($n = 16$)[a]	Total sample ($n = 65$)[a]		
	M (SD) or %					F/χ^2	p
Age	19.50 (1.32)	19.25 (1.65)	18.88 (1.11)	20.13 (1.96)	19.43 (1.57)	1.89	.14
Gender	38% M	38% M	41% M	44% M	40% M	0.19	.98
Race/ethnicity	88% WNH	75% WNH	71% WNH	94% WNH	82% WNH	3.77	.29
Years of education	13.19 (1.17)	12.63 (0.81)	12.59 (0.94)	13.31 (0.95)	12.92 (1.00)	2.42	.08
Caffeine use	279.25 (175.49)	358.25 (350.82)	312.24 (348.90)	354.56 (346.68)	325.86 (309.40)	0.23	.88
Alcohol use	11.19 (17.71)	7.97 (11.11)	13.29 (25.18)	16.57 (30.90)	12.20 (22.07)	0.41	.75
Illicit drug use	25%	63%	41%	56%	46%	5.43	.14

Note. Caffeine use refers to past-month use in ounces. Alcohol use refers to past-month number of drinks. Illicit drug use is reported dichotomously and indicates percent of subjects reporting any lifetime use of marijuana, cocaine, methamphetamine, hallucinogens, heroin, or other recreational opioids. M = men. WNH = white, non-Hispanic.
[a] Values are *M* (*SD*) or %.

significant main effects for any other subscale. See Table 2 for full ARCI results and descriptive statistics.

On the VASs, there was a significant main effect of drug ingested on feeling high, such that subjects ingesting caffeine reported feeling more high than those ingesting placebo, regardless of expectation ($F_{(1,61)} = 8.45$, $p = .005$, $\eta_p^2 = .12$). There was also a significant main effect of expectation on feeling high, such that subjects expecting Adderall reported feeling more high than those expecting

Table 2
Descriptive Statistics by Group and ANCOVA Main Effect Results for Subjective Mood and Drug Effects

	Expect caffeine/receive placebo[a] ($n = 16$)	Expect caffeine/receive caffeine[a] ($n = 16$)	Expect Adderall/receive placebo[a] ($n = 17$)	Expect Adderall/receive caffeine[a] ($n = 16$)			
	EMM (SE)				*F*	*p*	η_p^2
Euphoria (MBG)	6.97 (0.80)	5.54 (0.80)	6.92 (0.77)	6.83 (0.80)			
Drug ingested					0.90	.346	.02
Drug expected					0.58	.450	.01
Sedation (PCAG)	2.82 (0.70)	2.88 (0.70)	3.51 (0.68)	1.70 (0.70)			
Drug ingested					1.58	.213	.03
Drug expected					0.10	.749	.00
Intellectual energy (BG)	7.56 (0.69)	7.55 (0.70)	7.07 (0.67)	8.08 (0.70)			
Drug ingested					0.57	.455	.01
Drug expected					0.00	.997	.00
Amphetamine (AMPH)	4.81 (0.52)	3.85 (0.53)	5.05 (0.50)	5.85 (0.53)			
Drug ingested					0.01	.912	.00
Drug expected					4.18	.045	.06
Anxiety (LSD)	3.50 (0.52)	4.87 (0.52)	3.39 (0.51)	6.03 (0.52)			
Drug ingested					15.01	<.001	.20
Drug expected					0.98	.326	.02
Feeling good	67.56 (3.52)	79.97 (3.52)	68.03 (3.44)	75.07 (3.55)			
Drug ingested					1.82	.182	.03
Drug expected					0.62	.433	.01
Feeling bad	21.26 (3.71)	15.20 (3.71)	16.26 (3.61)	19.27 (3.73)			
Drug ingested					0.16	.690	.00
Drug expected					0.02	.885	.00
Feeling attentive	70.28 (4.35)	70.47 (4.32)	68.99 (4.19)	77.26 (4.32)			
Drug ingested					1.01	.319	.02
Drug expected					0.40	.530	.01
Feeling focused	69.16 (4.54)	68.24 (4.54)	68.64 (4.39)	75.04 (4.52)			
Drug ingested					0.40	.531	.01
Drug expected					0.48	.493	.01
Feeling high	7.69 (5.27)	16.41 (5.31)	14.06 (5.11)	35.71 (5.32)			
Drug ingested					8.45	.005	.12
Drug expected					5.67	.020	.09

(*table continues*)

Table 2 (*continued*)

	Expect caffeine/receive placebo[a] (n = 16)	Expect caffeine/receive caffeine[a] (n = 16)	Expect Adderall/receive placebo[a] (n = 17)	Expect Adderall/receive caffeine[a] (n = 16)			
	EMM (SE)				F	p	η_p^2
Feeling stimulated	40.96 (5.96)	55.76 (5.98)	40.89 (5.79)	55.58 (5.97)			
Drug ingested					6.31	.015	.09
Drug expected					0.00	.983	.00
Feeling motivated	62.80 (5.09)	70.78 (5.11)	51.83 (4.94)	73.79 (5.13)			
Drug ingested					8.71	.004	.13
Drug expected					0.66	.419	.01

Note. Estimated marginal means (EMMs) indicate post-test responses while controlling for baseline scores. Main effects of drug ingested and drug expected were entered into each model simultaneously.
[a] Values are EMM (*SE*).

caffeine, regardless of drug ingested ($F_{(1,61)} = 5.67$, $p = .02$, $\eta_p^2 = .09$). Examination of planned contrasts demonstrated that subjects expecting Adderall/receiving caffeine reported feeling more high compared to all three groups (expecting caffeine/receiving placebo: $p < .001$, 95% CI: 13.03; 43.02, $d = 1.32$; expecting caffeine/receiving caffeine: $p = .013$, 95% CI: 4.14, 34.48, $d = 0.91$; expecting Adderall/receiving placebo: $p = .005$, 95% CI: 6.90, 36.40, $d = 1.02$). There was a significant main effect only of drug ingested on feeling motivated, such that subjects ingesting caffeine reported feeling more motivated ($F_{(1,61)} = 8.71$, $p = .004$, $\eta_p^2 = .13$) than those ingesting placebo, regardless of expectation. Planned contrasts demonstrated that subjects expecting Adderall/receiving caffeine reported feeling significantly more motivated ($p = .003$, 95% CI: 7.69, 36.24, $d = 1.07$) than subjects expecting Adderall/receiving placebo. Finally, there was a significant main effect only of drug ingested on feeling stimulated, such that subjects ingesting caffeine reported feeling more stimulated than those ingesting placebo, regardless of expectation ($F_{(1,61)} = 6.31$, $p = .015$, $\eta_p^2 = .09$). Planned contrasts did not reveal any significant pairwise differences, however. There were no significant main effects for any other scale. See Table 2 for full VAS results and descriptive statistics.

Cognitive Performance

There were no significant main effects of drug ingested or expectation on any outcomes from the CVLT, nor Coding. There was a significant main effect of drug ingested on two WCST outcomes: percent errors and percent conceptual level responses. Subjects receiving caffeine demonstrated more errors ($F_{(1,62)} = 4.77$, $p = .033$, $\eta_p^2 = .07$) and fewer consecutive runs of correct responses ($F_{(1,62)} = 4.80$, $p = .032$, $\eta_p^2 = .07$) on the WCST, regardless of expectation. Planned contrasts revealed that subjects expecting Adderall/receiving caffeine performed significantly worse than subjects expecting Adderall/receiving placebo on both indices (errors: $p = .021$, 95% CI: 1.18, 13.67, $d = 0.72$; conceptual level responses: $p = .012$, 95% CI: −21.10, −2.72, $d = 0.75$). There was neither a significant main effect of drug ingested on the other WCST outcomes, nor a main effect of expectation for any WCST outcome. There was, however, a significant main effect of expectation on the PASAT, such that subjects expecting Adderall performed better, regardless of drug ingested ($F_{(1,61)} = 4.73$, $p = .034$, $\eta_p^2 = .07$). Planned contrasts indicated that subjects who expected Adderall/received caffeine responded correctly on significantly more trials compared to participants who expected caffeine/received placebo ($p = .010$, 95% CI: 6.29, 43.35, $d = 0.90$). There was not a significant main effect of drug ingested on the PASAT. Table 3 displays results and descriptive statistics on all cognitive measures.

Discussion

This study is the first experimental test of the comparative expected effects of common cognitive enhancing drugs in college students, with a specific focus on identifying whether caffeine-related mood and cognitive effects are modulated by expectation for a conceivably more efficacious stimulant. Evidence that caffeine's pharmacological effects may be supplemented by expectancy for a conceivably stronger stimulant may inform recommendations for college student caffeine use. To support caffeine's pharmacological effects, we hypothesized significant main effects of a moderate dose of ingested caffeine on mood/drug effects and cognition, as we expected that compared to placebo, caffeine would produce elevations in mood, alertness, and cognition. In line with prior qualitative research demonstrating that college students report stronger expected effects for prescription stimulants compared to caffeine (Franke et al., 2011), we hypothesized significant main effects of expected Adderall on the same measures, compared to expected caffeine. Further, we expected the strongest effects in students who expected Adderall and received caffeine, who would benefit from combined pharmacological and psychological enhancement. Our hypotheses were supported on several specific measures of mood/drug effects and cognition.

Participants who ingested caffeine, regardless of drug expected, reported significantly more symptoms of anxiety and restlessness than participants who ingested placebo. This likely reflects the fact that caffeine is a central nervous system stimulant, and its effects on internal sensations such as increased heart rate may have been perceived by participants and interpreted as signs of anxiety or over-arousal. However, as expected, participants ingesting 200 mg

Table 3
Descriptive Statistics by Group and ANOVA Main Effect Results for Cognitive Effects

	Expect caffeine/receive placebo[a] (n = 16)	Expect caffeine/receive caffeine[a] (n = 16)	Expect Adderall/receive placebo[a] (n = 17)	Expect Adderall/receive caffeine[a] (n = 16)			
	M (SD)				F	p	η_p^2
CVLT—immediate recall	58.63 (9.03)	57.06 (7.00)	58.06 (6.71)	55.69 (12.64)			
Drug ingested					0.77	.383	.01
Drug expected					0.19	.669	.00
CVLT—short delay	12.69 (2.27)	12.31 (2.82)	13.41 (2.03)	11.81 (3.89)			
Drug ingested					2.02	.161	.03
Drug expected					0.03	.863	.00
CVLT—long delay	13.44 (2.22)	13.31 (2.30)	13.24 (1.86)	12.50 (3.37)			
Drug ingested					0.50	.482	.01
Drug expected					0.67	.416	.01
Coding	82.25 (9.16)	86.25 (10.58)	83.41 (9.07)	84.19 (9.06)			
Drug ingested					1.02	.317	.02
Drug expected					0.03	.856	.00
PASAT[b]	57.25 (16.21)	69.06 (21.06)	72.00 (26.74)	82.07 (35.69)			
Drug ingested					2.92	.092	.05
Drug expected					4.73	.034	.07
WCST—trials to complete 1st category	16.13 (14.45)	15.62 (7.04)	13.82 (7.71)	14.63 (6.97)			
Drug ingested					0.01	.946	.00
Drug expected					0.50	.483	.01
WCST—perseverations	7.75 (2.44)	9.19 (2.83)	9.12 (1.90)	9.13 (3.24)			
Drug ingested					1.18	.282	.02
Drug expected					1.02	.316	.02
WCST—% errors	16.75 (8.63)	19.00 (6.32)	14.51 (6.55)	21.93 (12.93)			
Drug ingested					4.77	.033	.07
Drug expected					0.02	.890	.00
WCST—% conceptual level responses	79.49 (11.44)	77.07 (8.28)	83.78 (8.89)	71.87 (20.59)			
Drug ingested					4.80	.032	.07
Drug expected					0.01	.908	.00

Note. Main effects of drug ingested and drug expected were entered into each model simultaneously. CVLT = California Verbal Learning Test. PASAT = Paced Auditory Serial Addition Test. WCST = Wisconsin Card Sorting Test.
[a] Values are *M* (*SD*).
[b] Data from only 15 participants in the expect Adderall/receive caffeine condition were included due to computer error.

caffeine also reported feeling significantly more motivated, stimulated, and high compared to participants ingesting placebo. Other studies have similarly found caffeine to elevate positive self-reported mood and drug effects (Childs & de Wit, 2006; Haskell et al., 2005); the present finding demonstrates that these likely sought-after effects can be successfully obtained by college students following a moderate dose of caffeine.

Surprisingly, there was a main effect of ingested caffeine on cognition in the opposite direction of what was expected. On two indices of the WCST, an executive functioning test assessing ability to form abstract concepts, shift and maintain set, and utilize feedback, participants who ingested caffeine performed more poorly than those ingesting placebo. Specifically, these participants made more errors and demonstrated poorer insight into learning the test rules. Though this finding was unexpected, it is not unprecedented. Prior research, including that on both caffeine and prescription stimulants, finds that stimulant administration can have an impairing effect on some cognitive abilities, likely due to increased arousal and anxiety (Advokat, 2010; Childs & de Wit, 2006; Loke et al., 1985). Given that participants reported significantly greater anxiety when ingesting caffeine, it is certainly possible that decrements in performance were consequently seen on the WCST. Interestingly, this was unique to this assessment, as performance was not otherwise significantly altered with caffeine use on tasks of memory or processing speed. Other studies examining the effect of caffeine on WCST performance have generally found no significant improvement effects at a range of doses (e.g., Franke et al., 2017; Killgore et al., 2009; Shulder et al., 2016), with one study finding improved WCST performance only in light caffeine users reporting consumption below 500 mg per week (Lyvers et al., 2004). Though we do not have data on caffeine in milligrams for participants in the present study, it is likely that the sample was not largely comprised of light users given that average days of past-month caffeine use were 18.25 (SD = 8.69). Thus, shifting and maintaining set based on feedback was likely not enhanced via 200 mg caffeine in this sample of fairly regular caffeine users, and may have conversely been negatively impacted via anxiety.

Regarding main effect of drug expected, participants expecting Adderall, regardless of drug ingested, reported feeling more high and experiencing more amphetamine-related effects (e.g., sharper

memory, faster movements) compared to participants expecting caffeine. These two indices were sensitive to prescription stimulant-related placebo effects among college students in prior research (Looby & Earleywine, 2011), and this finding is bolstered by the current results. It is surprising that main effects of expected Adderall were not seen on other subjective measures, such as feeling stimulated, attentive, or motivated. It is possible that these effects were more equally expected between Adderall and caffeine. Given the lack of comparison to a control group that did not expect any drug, we are not able to assess for this possibility. However, expecting to feel high and experience amphetamine-specific effects appears unique to prescription stimulants, and this expectation significantly modified the subjective experience of caffeine use, as there were significant enhancements in the expect Adderall/receive caffeine group compared to the expect caffeine/receive caffeine group.

Further, expecting Adderall, regardless of drug ingested, resulted in improved performance on the PASAT, a test of working memory under timed and increasingly difficult conditions. Prior research examining cognitive enhancement effects following expectation for a prescription stimulant found mixed evidence in support of objective enhancement. Looby and Earleywine (2011) found no significant cognitive enhancement following expectation to receive methylphenidate, while Cropsey and colleagues (2017) found enhancement only on certain measures of memory and attention following expectation to receive mixed amphetamine salts. Neither study assessed the effect of expectation on working memory, and it is possible that expectation for strong stimulant effects may have an enhancement effect only in specific domains, perhaps ones necessitating more effortful attention or cognitive resources. In fact, Looby and Earleywine (2011) hypothesized that college students may direct less effort towards cognitive tasks when taking or expecting to take a prescription stimulant. Thus, objective enhancement from stimulant expectancy may only be observed on tasks that demand active effort and engagement, such as tasks that are timed and increasingly difficult, as is the PASAT. Notably, main effects of expectancy on both mood and cognition were only found for Adderall, and never for caffeine, supporting prior research indicating that college students anticipate qualitatively different, and particularly stronger, effects from prescription stimulants (Franke et al., 2011).

Taken together, we were able to demonstrate enhanced mood/drug effects following administration of 200 mg caffeine, and enhanced mood/drug effects and cognitive performance following expectation to receive a prescription stimulant, across several measures. Importantly, our final hypothesis that participants expecting Adderall and receiving caffeine would experience the strongest mood and cognition effects was in part supported, in that these participants reported the strongest amphetamine and anxiety effects, feeling the most high and motivated, and they performed the best on the PASAT. These significant group differences were all large in effect, indicating a clinically meaningful impact of combining pharmacological stimulant effects with expectation to receive meaningful mood and cognitive enhancement (i.e., effects expected from a "stronger" stimulant like Adderall). Given that college students do not appear to expect strong cognitive and mood enhancement from caffeine (Franke et al., 2011), attempts to strengthen their positive caffeine expectancies may increase students' likelihood of effectively using caffeine, as mood and cognitive enhancements are potentially realized due to the combined pharmacological and expectancy effects on outcome.

On the other hand, there were several indices of mood and drug effects, and notably cognitive function, that were not enhanced via caffeine or expectancy. It is necessary to consider that moderate caffeine use, even when combined with enhancement expectations, may not function as an efficacious cognitive enhancer for many students. While combined Adderall expectation and 200 mg caffeine use did improve working memory, it did not appear to have an effect on measures of short- and long-term memory and processing speed, and it negatively impacted performance on a set shifting task. It is also unclear whether these improvements to working memory would generalize to real-world cognitive and academic tasks for which college students may be apt to use caffeine to enhance. Therefore, college students may benefit from the nuanced understanding that caffeine use may convey certain benefits (e.g., subjective stimulatory effects; potentially enhanced working memory), under certain conditions (e.g., alongside enhancement expectations; at moderate doses), for certain students (e.g., low-level caffeine users).

Further, caution in promoting caffeine use among college students does need to be noted. Caffeine use should not be promoted for students with histories of adverse reactions to caffeine (e.g., anxiety, insomnia, gastrointestinal problems; Mora-Rodriguez et al., 2015; Winston et al., 2005), and it may also not be appropriate for students prone to anxiety in general (Yang et al., 2010), particularly as anxiety was increased via caffeine administration in our sample. Students for whom caffeine use may be appropriately suggested should be informed about the most effective and safest use of caffeine, which includes doses of approximately 38–400 mg per day (-0-.3 to four cups of coffee or one to eight cups of tea), used in moderation (Ruxton, 2008). Notably, moderate caffeine users receive more cognitive enhancing benefits from caffeine following brief abstinence than following regular daily use (Addicott & Laurienti, 2009; Haskell et al., 2005). Further, students should be encouraged to monitor other sources of caffeine in their diet so as not to inadvertently use too high of a dose of caffeine, as doses over 500–600 mg can lead to negative side effects such as anxiety, insomnia, tachycardia, and psychomotor agitation (Cappelletti et al., 2015). Students should also be cautioned against simultaneous use of caffeine and alcohol, which is associated with numerous consequences including increased risk-taking behaviors, elevated risk for continued drinking, reduced sensitivity to intoxication, and decreased reaction time (Heinz et al., 2013; O'Brien et al., 2008).

Several important limitations of this research must be considered. First, our results must be understood in the context of a small, homogenous sample of college students, where mood and cognitive functioning were assessed following administration of a single 200 mg dose of caffeine. As caffeine's effects are dose-dependent, the present results can only be considered relevant to this specific dose under study, and predominantly among white, female college students. Our results may not generalize to other doses of caffeine, other stimulant drugs, more diverse samples, nor to non-college individuals. Our small sample size limited our ability to examine interactive effects and effects smaller in magnitude. Despite our low power, we found several significant effects, highlighting that many effects of ingested caffeine and expected Adderall are quite large. Though there were a number of measures on which significant main effects were not found, examination of means in Table 2 reveals that participants expecting Adderall/ingesting caffeine tended to experience the strongest effects on many subjective measures, though

these are likely smaller in effect and thus did not reach significance in our small sample. We also did not recruit participants based on level of caffeine use outside any past-month use, and all participants were prescription stimulant-naïve, so we do not know if these effects would persist in participants with certain baseline levels of caffeine use (e.g., non-users, light users, heavy users) and in those with experience using other stimulant drugs. Moreover, we did not conduct baseline assessments on cognitive measures, nor did we assess information on baseline executive functioning abilities or ADHD symptoms, which is recommended in future research to understand whether these effects may be moderated in certain groups of individuals.

Further, we acknowledge several methodological limitations that may have affected some results. As noted previously, lack of a control group that did not expect to receive any drug limits our ability to fully appreciate effects of expectancy. However, the purpose of this study was to directly compare expected caffeine with expected Adderall, and not specifically to compare against no drug expectation. The assessment battery was not counterbalanced, which may have increased comparative likelihood of observing effects on latter tests if caffeine levels did not peak until later in the assessment. Use of a single-blind study also may have resulted in experimenter expectancy effects, resulting in over-estimation of placebo effects. Given that the effect of participant expectations on the outcome was primarily under study, and may have been influenced by the experimenter's knowledge, the present results should be interpreted cautiously with this in mind. In addition, we did not assess for sleep parameters in the present study. It is possible that marked differences in prior night sleep duration across groups may have influenced the impact of caffeine on cognitive performance. Finally, we were unable to biologically verify overnight abstinence from psychoactive drugs, and we relied on self-report to rule-out psychiatric diagnoses.

Nevertheless, this research adds to the growing body of literature on caffeine use and expectancy effects among college students, demonstrating that a nuanced understanding of the benefits of caffeine use for mood and cognitive enhancement is necessary. It seems clear that for certain indices (i.e., subjective stimulatory effects, working memory), a moderate dose of caffeine can exert incremental benefits when expectation for the drug's effects is modified. At the same time, 200 mg caffeine also appears likely to induce anxiety and may impair cognitive performance in certain domains. Further, expectancy modifies caffeine's pharmacological effects, though again inconsistently across mood and cognition. Importantly, expectancy for type of stimulant appears to matter, as mood and cognition were only enhanced via expectancy for Adderall, but never caffeine. Our results warrant continued investigation of related research questions in larger, more diverse samples to comprehensively understand under what conditions caffeine may be beneficially used by college students (e.g., by dose, by outcome, etc.), and how modifying expectations surrounding its stimulatory actions may augment its effects. Nevertheless, promoting alternative behavioral strategies for enhanced academic performance that are likely to have a stronger benefit-to-risk ratio, such as sleep hygiene (Wolfson et al., 2015), exercise (Keating et al., 2013), and stress reduction (Lumley & Provenzano, 2003), may best serve college students in meaningfully enhancing their cognitive and academic functioning.

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