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ORIGINAL INVESTIGATION

Beyond attention: methylphenidate reduces dishonesty in healthy adults

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Abstract

Rationale Healthy adults increasingly use drugs to enhance cognitive performance. However, these drugs influence brain systems that have also been associated with dishonesty. Given the prevalent use of potentially performance-enhancing drugs in contexts susceptible to cheating, it is crucial to ascertain whether they have adverse effects on honesty.

Objectives Our primary objective was to compare the effects of methylphenidate with those of placebo to determine the direction and magnitude of its potential influence on dishonest behavior. We furthermore examined the intuitions of people who use smart drugs about the effects of methylphenidate on cheating in a US representative sample.

Methods We conducted a double-blind, placebo-controlled experiment to compare the effects of methylphenidate (Ritalin), a popular performance-enhancing drug, and compared its effects with atomoxetine (Strattera), another performance-enhancing drug with a distinct pharmacological mechanism. Participants were randomly assigned to receive either a placebo ($n=52$), methylphenidate ($n=49$), or atomoxetine ($n=50$). Subsequently, they performed a die-rolling task in which they could increase their earnings by dishonestly misreporting their outcomes. Additionally, a representative sample of 575 American participants indicated their performance-enhancing drugs use and intuitions about the effects of these drugs on dishonesty.

Results Our findings show that, compared to the placebo condition, methylphenidate reduced dishonesty. This effect was not attributable to statistical fluctuations, demand effects, or domain-general mechanisms such as mood or attention. In addition, individuals who use drugs to enhance performance have limited intuitions about the impact of methylphenidate on dishonest behavior.

Conclusion These results reveal an unforeseen consequence associated with methylphenidate and may have policy implications regarding the paradoxical relationship between the use of drugs for performance enhancement and their potential impact on honesty.

Keywords Methylphenidate · Atomoxetine · Performance-enhancing drugs · Cheating · Attention · Bioethics

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Introduction

Around the world, more and more healthy adults are taking prescription drugs in the belief that these drugs will increase their cognitive performance despite doubts about the effectiveness of these drugs to enhance performance (Bowman et al. 2023). In the latest global survey, 14% of the general population reported taking drugs like methylphenidate and atomoxetine to enhance cognitive performance in the past year, marking a significant increase from 5% in 2015 (Maier et al. 2018). In the US alone, more than 5 million individuals reported using drugs in the hope of improved performance in 2018 (Board et al. 2020), and estimates of such drug use in the country range from 2.1% to 58.7% among the sampled population (Faraone et al. 2020). Similarly, European countries like France and the UK are also witnessing a surge in use of potentially performance enhancing drugs, indicating a global trend of drug use to increase performance (Daubner et al. 2021). Although potentially performance-enhancing drugs are consumed by a diverse range of individuals in various contexts (Franke et al. 2011, 2013, 2014; Dietz et al. 2013), their popularity is particularly notable in academic and professional settings. A recent review found that between 5% and 43% of college students have used drugs with the hope to improve their performance within the past year (Sharif et al. 2021), with estimates as high as 55% among specific student populations such as fraternity members (DeSantis et al. 2009). While precise figures for professionals are less available, research indicates that performance enhancing drugs are regularly used in the workplace (Gesundheitsreport 2015; no date), in the financial industry (Bowman et al. 2020), or by economists (Dietz et al. 2016). Moreover, the use of drugs has a long-standing history in military contexts, aiming to enhance soldier performance in combat, primarily to lessen fatigue and improve attention (Saniotis and Kumaratilake 2020; Ehlert and Wilson 2021; Wingelaar-Jagt et al. 2021; Van Puyvelde et al. 2022).

One widely-used drug, methylphenidate, is commonly prescribed to alter concentration in individuals with ADHD (Wolraich et al. 2019), and improves attention and inhibitory control in healthy adults as well (Linssen et al. 2014; Ilieva et al. 2015; Roberts et al. 2020), aligning with the expectations of users. The mechanism behind this improvement lies in methylphenidate's ability to impede dopamine and norepinephrine reuptake, thereby augmenting extracellular dopaminergic and noradrenergic activity in cortical and striatal brain regions (Volkow et al. 2001, 2005; van den Bosch et al. 2022). Given the broad impact of methylphenidate on neurotransmitter function, it is pertinent to consider its broader behavioral effects beyond improving attention and inhibitory control. We chose to investigate its effects on dishonesty, given the escalating use of methylphenidate in academic, business, and military environments where opportunities for dishonesty are prevalent and where the consequences of dishonest behavior are significant. For example, a recent survey of more than 70,000 undergraduate students in the US reveals that 68% admitted to engaging in academic cheating on tests or written assignments (Ballentine et al. 2019). No studies to date have investigated the impact of methylphenidate on dishonest behavior in healthy adults, despite its relevance to the very contexts in which methylphenidate is commonly used. However, one study tested the effect of methylphenidate on cheating in 22 medicated boys with ADHD diagnosis, comparing their academic cheating on a day when they received methylphenidate with a day when they received a placebo (Hinshaw et al., 1992). Methylphenidate increased cheating in boys with ADHD who received methylphenidate on the first day of testing, but not in participants who received the placebo on the first day of testing. While these mixed results might suggest that methylphenidate has the potential to impact cheating, the significant differences in how a single dose of methylphenidate impacts healthy adults compared to children with an ADHD diagnosis and regular drug use (Busardò et el, 2016; Linssen et al. 2014) make it hard to generate an implication for the present research.

The neurochemical modulation induced by methylphenidate also influences brain regions associated with dishonest behavior. The decision-making process involving the prioritization of self-interest over adherence to honesty norms engages fronto-striatal circuits (Buckholtz et al. 2015; FeldmanHall et al. 2015; Crockett et al. 2017; Carlson and Crockett 2018; Qu et al. 2019; van Baar et al. 2019; Zoh et al. 2022), which are sensitive to drugs targeting the dopamine system (Pedroni et al. 2014; Crockett et al. 2015; Sáez et al. 2015; Soutschek et al. 2017). While existing research suggests that methylphenidate may affect dishonest behavior, the specific direction of this effect is hard to predict. The impact of dopaminergic activity on social behavior appears to be contingent, at least in part, on the particular drug manipulation used to increase or decrease dopaminergic activity. For instance, augmenting dopamine function through the administration of the dopamine precursor levodopa diminishes prosocial behavior in healthy adults (Pedroni et al. 2014; Crockett et al. 2015), while the Catechol O-Methyltransferase inhibitor tolcapone, which heightens prefrontal dopaminergic tone, promotes egalitarian behavior (Sáez et al. 2015). Similarly, elevating dopaminergic activity via levodopa reduces self-interest in male participants (Pedroni et al. 2014). However, attenuating mesolimbic dopaminergic activity through amisulpride increases self-interest in men but diminishes it in women (Soutschek et al. 2017; Artigas et al. 2019). Consequently,

it is plausible to hypothesize that drugs such as methylphenidate, used for cognitive enhancement purposes, may have side effects on dishonesty, although the specific effects may depend on the precise pharmacological mechanism of the drug and the context in which it is taken.

To investigate the impact of methylphenidate on dishonesty, we conducted a double-blind, placebo-controlled experiment. Our primary objective was to compare the effects of methylphenidate with those of placebo to examine the direction and magnitude of its potential influence on dishonest behavior. However, given that different cognitive-enhancing drugs increase attention and concentration through different pharmacological mechanisms, it seems unlikely that all will have similar side effects on dishonest behavior. Therefore, in the same study, we additionally examined the effects of another cognitive-enhancing drug, atomoxetine (Strattera), to explore whether its impact on dishonest behavior aligns with that of methylphenidate. Atomoxetine has also been shown to impact attention and working memory (Hernaus et al. 2017), albeit via mechanisms that are different from methylphenidate (Marquand et al. 2011). This comparative analysis is valuable as methylphenidate and atomoxetine operate through distinct pharmacological mechanisms. While methylphenidate acts as a dopaminergic and noradrenergic reuptake inhibitor, atomoxetine functions as a selective noradrenergic reuptake inhibitor (Simpson and Perry 2003; Gilbert et al. 2005; Nandam et al. 2014; Shang et al. 2016). By comparing the effects of these two drugs, we can gain insights into the generalizability of their side effects on dishonest behavior and gain information about potential neuromodulatory mechanisms. If methylphenidate alone affects dishonesty, we can infer a dopaminergic mechanism, while if both drugs affect dishonesty, we cannot rule out a noradrenergic mechanism.

Participants ($N=151$) were randomly assigned to one of three conditions: placebo ($n=53$), a 30 mg dose methylphenidate ($n=50$), or a 60 mg dose of atomoxetine ($n=53$) in a double-blind design. The methylphenidate and atomoxetine doses conform to standard levels used in research with healthy adults, assumed to be of equivalent effects (Chamberlain et al. 2007; Hester et al. 2012; Nandam et al. 2014). The study employed measures to ensure blinding of both participants and experimenters. Cognitive enhancing effects were assessed by measuring sustained attention before and 80 min after drug administration, while participants' mood was also assessed during these time points. Subsequently, approximately ninety minutes after drug administration (corresponding to peak plasma levels for both drugs) (Müller et al. 2005; Sauer et al. 2005; Dockree et al. 2017), participants engaged in a die-rolling task designed to measure dishonesty, alongside other incentivized economic games that were implemented to discern the specificity of the effects on dishonest behavior while also concealing the purpose of the study (Fig. 1). It is worth noting that behavior in this task has been shown to predict real-world dishonesty in various contexts, including educational settings (Cohn and Maréchal 2018), prison misconduct (Cohn et al. 2015), fare-dodging on public transport (Dai et al. 2017), and corrupt behavior among civil servants (Hanna and Wang 2017).

While many people perceive taking drugs in the hope to improve performance as dishonest (Schermer 2008; Goodman 2010; Bell et al. 2013), a question arises: do they also anticipate that the use of such drugs itself might have side-effects on honest behavior? To investigate this, we explored in a second study the intuitions of previous drugs users and non-users regarding the impact of methylphenidate on dishonest behavior. We recruited a nationally representative sample of US participants ($N=574$), ensuring representation across gender, age, and race. Participants were provided with a description of the pharmacological study procedures, including the observed level of dishonest misreporting in the placebo condition. Subsequently, they were asked to make predictions about the extent of dishonest misreporting in the methylphenidate condition, with incentives provided for accurate predictions.

Methods

Participants

We ran simulations to determine the target sample size and statistical power for our study. Finance constraints allowed us to test 150 participants. And we expected the effect of the drugs on dishonest behavior to be around 6% since Cohn et al. show that reminding prison inmates of their criminal identity increased success rates by 6% percentage points (Cohn et al. 2015). Hence, we aimed to increase statistical power to an optimum by increasing the trials on the die rolling task (i.e., reducing the measurement error, Blake and Gangestad 2020). To estimate statistical power, we performed 10,000 simulations of placebo samples, each consisting of 50 subjects rolling the die multiple times. We assumed that each die roll follows a binomial process with a success rate of 50%. Similarly, we simulated 10,000 samples for methylphenidate and atomoxetine, with 50 subjects per sample, assuming success rates ranging from 50% to 70% in 1% increments. Using rank-sum tests, we compared each pair of drug and placebo samples to determine if the difference in successful die rolls is statistically significant. The proportions of hypotheses rejected at a two-sided 5% significance level provided estimates of statistical power for different numbers of die rolls. The simulation results indicate that a sample size of 50 subjects per treatment group is

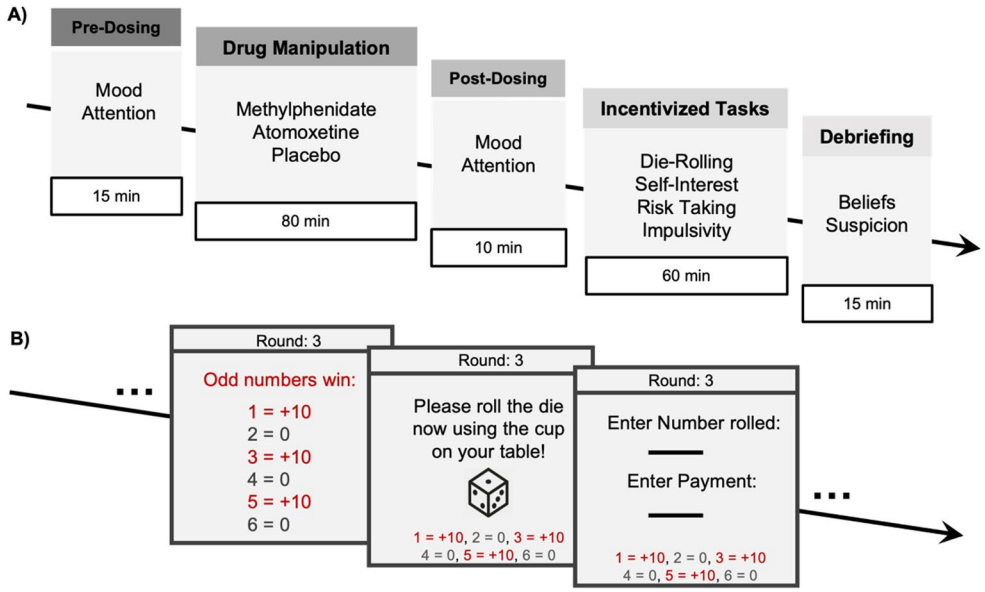

Fig. 1 **A** At the beginning of the testing session, participants' mood and sustained attention were measured. Subsequently, participants were randomly assigned to receive either placebo, methylphenidate (30 mg), or atomoxetine (60 mg). Participants then waited for a duration of 80 min. After the waiting period, participants' mood and sustained attention were measured once again. The subsequent phase involved participants completing a series of incentivized tasks, including measures of dishonesty, self-interest, risk-taking, and impulsivity. These tasks were administered in a randomized order. Finally, participants answered questions regarding their beliefs about which drug they received, its potential effects, and the nature of the experiment itself. **B** To measure dishonest behavior, participants engaged in a die-rolling task consisting of 25 rounds. Prior to each roll, participants were informed by the computer which outcomes would result in a payoff of 10 tokens (equivalent to £1). Subsequently, participants rolled the die under a cup and reported the outcome obtained

sufficient to detect an increase or decrease in success rates of 6% points with 87% or 84% power, respectively, if they roll the die 25 times.

Participants ($N=156$) were randomly assigned to one of three conditions: placebo ($n=53$), methylphenidate ($n=50$), or atomoxetine ($n=53$). Four participants discontinued the study due to experiencing nausea (one in the methylphenidate condition, three in the atomoxetine condition) and an additional participant was excluded due to a computer failure (placebo condition). This resulted in a final sample of 151 participants. We did not find differences between conditions for age, gender, income, and education (see Table S1). The study had a double-blind design such that neither participants nor experimenters knew in which condition the participant was.

Before participating in the study, people interested in participating completed a survey that assessed potential exclusion factors. People were excluded from participating if they self-reported having a diagnosis of ADHD or ADD, or if they reported currently using or having a history of using ADHD drugs or any other potentially cognitive-enhancing substances. Furthermore, people were also excluded if their score on the Beck Depression Inventory – II (Beck et al. 1996) exceeded 12, if they had prior experience with experiments involving similar tasks, if they had a history of illicit drug use, if they were taking specific medications such as blood thinners, epinephrine medications for high blood pressure, diet pills, antidepressants or anti-seizure medications, if they smoked more than five cigarettes per day, if their answers on the Alcohol Use Disorders Identification Test (Reinert and Allen 2007) indicated hazardous drinking (score of eight or higher), or if they had a history of mental illness. Participants were also instructed to refrain from excessive caffeine consumption on the morning of the experiment, and to abstain from alcohol consumption the night before.

Procedure

On the day of the experiment, participants were again provided with the participant information sheet to ensure their understanding of the study's procedures and risks, after which they signed the consent form. Subsequently, various physiological measurements were taken, including blood pressure, heart rate, weight, height, mood, and attention. Following this, the drug administration took place under the supervision of a medical attendant. Participants received three pills containing either 30 mg of methylphenidate, 60 mg of atomoxetine[1], or a placebo composed of sugar. The dosage levels were determined based on previous

[1] Most studies using single-dose atomoxetine manipulations employ a dosage of 60 mg (e.g., Chamberlain et al. 2006, 2007; Nandam et al.

studies that have demonstrated cognitive effects (Chamberlain et al. 2007; Nandam et al. 2014).

After a lapse of eighty minutes from the drug administration, a second round of measurements was conducted, encompassing blood pressure, heart rate, mood, and attention. The battery of incentivized economic tasks was administered ninety minutes post-drug administration. The timing of these tasks was determined in consideration of the timeframe within which peak plasma levels are typically observed for the three drugs (90–180 min) subsequent to oral ingestion in adults (Chamberlain et al. 2006; Nandam et al. 2011, 2014; Hester et al. 2012).

Randomization, blinding and code-breaking procedures

Participants were randomly assigned to one of three groups (methylphenidate, atomoxetine, or placebo) using a pre-generated list. Gender balance was ensured by recruiting an equal number of male and female participants. The randomization lists for men and women were generated using a standard software package for random number generation in MATLAB. To maintain blinding, the researcher responsible for data collection was unaware of the treatment group assigned to each participant. Blinding was achieved by encapsulating the methylphenidate, atomoxetine, and placebo tablets in identical form. The randomization codes and schedule were held by a researcher who was not involved in drug administration or data analysis. At the end of the study, participants were informed whether or not they had received a drug, and if so, which one they were assigned to. There were no significant differences between conditions for education level, $\chi^2(2) = 2.35$, $p = 0.309$, income, $\chi^2(2) = 3.05$, $p = 0.218$, or age, $F(2, 146) = 1.34$, $p = 0.265$. (Table S1).

Measures

The instructions for every task can be found at https://osf.io/uv5ke/?view_only=ce44a28f86d543e3a5839b7fda79acb8.

Attention

To measure sustained attention, we employed a Rapid Visual Information Processing task (Sarter et al. 2001). In this task, participants had to detect specific number sequences (e.g., 1, 3, 5) within a rapid succession of single digits. A white square was displayed on the screen, within which from 1 to 9 appeared randomly at a rate of 100 digits per minute. Participants were instructed to identify and respond to target sequences of digits, such as 13 − 5, 2–4-6, 3–5-7, and 4–6-8, by pressing the space key as quickly as possible.

Mood

To assess participants' mood, we utilized a self-report measure before and 80 min after the drug administration, consisting of 16 items adapted from (Crockett et al. 2015). Participants were asked to indicate their feelings on a slider scale from 0 to 1. The scale included opposing endpoints for each dimension, such as sociable-withdrawn or incompetent-proficient. The 16 items were factor analyzed, resulting in two factors: energy (reflecting feelings of being energetic, alert, quick-witted) and contentment (reflecting feelings of calmness, contentment, and happiness).

Dishonesty

To measure dishonesty, participants rolled a six-sided die for a total of 25 rolls. Participants were informed that they would roll a die 25 times, with a 50% chance of winning 10 tokens (equivalent to £1) and a 50% chance of winning nothing on each roll. Prior to each roll, participants were informed which outcome would yield the 10-token payoff (e.g., rolling an odd or even number). Participants then rolled the die under a cup and reported their outcome on the computer. This task was conducted privately in an isolated room to eliminate concerns about being caught while misreporting outcomes. However, dishonest behavior is detectable at the group level by comparing the percentage of reported successful die rolls to the honesty benchmark of 50% in each of the three conditions.

Participants entered the outcomes of each roll into the computer interface. In each round, half of the rolled numbers (e.g., 1, 2, 3) resulted in a payoff of 10 tokens (£1), while the remaining numbers yielded no payoff. Prior to each round, participants were informed on the computer screen which numbers would result in a payoff. Using a cup, participants physically rolled the die and then entered the resulting outcomes into the computer. To ensure comprehension of the task rules, participants also reported the corresponding payoffs. This task was conducted individually in a separate room, ensuring privacy and absence of observation. If the random computer draw at the end of the experiment indicated that the die rolling task was selected for payment, participants received the earnings accumulated from all 25 rounds.

Risk preferences

In order to assess participants' risk preferences, we employed a task involving trade-offs between risky and

2011, 2014) or 40 mg (Tona et al., 2020; Warren et al., 2017; Lim et al., 2025).

certain payments (Falk, et al., 2016). Participants were presented with two tables, each containing 21 rows. Within each row, participants had to choose between a guaranteed payment and a lottery option that had a 50% chance of yielding 200 Tokens (£20) and a 50% chance of yielding nothing. The lottery option remained the same across all rows in both tables, while the safe payment varied. The safe payment decreased in increments of 10 token (£1) steps from 200 tokens (£20) to 0 token (£0). In the second set of tables, we introduced random variations by adding or subtracting up to 3 tokens to each safe payment option. If this task was randomly selected for payment at the end of the experiment, one of the participants' choices was randomly selected for payment. The row at which participants switched from preferring the lottery to preferring the safe payment indicates their individual risk preferences.

Material self-interest

Each participant was given an endowment of 200 tokens (£20) and had to make a decision regarding the amount they wished to donate to different charities: Red Cross, UNICEF, and Doctors Without Borders. The order of presentation for these options was randomized to mitigate potential order effects.

Impulsivity

Participants made a series of binary choices, where they had to decide between receiving a specified number of tokens at a later date or obtaining an equal or smaller amount (e.g., 120 tokens or £12) at an earlier date. We implemented three different scenarios: "today vs. in 3 months", "today vs. in 6 months", and "in 3 months vs. in 6 months." Within each scenario, participants were given a list with 25 choice situations involving the delayed payment and an earlier payment. The first row of the list featured an earlier payment amount equivalent to the delayed payment (e.g., 120 token). In subsequent rows, the amount of the delayed payment increased by 5 tokens, with slight variations of plus or minus one or two tokens. Participants' level of impulsivity was determined by the average point at which they switched from selecting the earlier payment to opting for the delayed payment across all three scenarios. If this task was randomly selected for payment, the computer randomly chose one row within a scenario. If participants chose an "today" payment option in that row, they received the corresponding amount immediately after the testing session. Alternatively, if they chose the delayed payment (i.e., in 3 months or in 6 months), they could choose between receiving the amount by mail or picking it up in person.

Drug administration beliefs

Following the conclusion of the experiment, participants were presented with a series of questions aimed at gathering insights into their experiences during the study, as well as their beliefs regarding the drug manipulation and the tasks. Specifically, participants were asked whether they believed they had received a drug or a placebo, and if they believed they had received a drug, they were further queried about their perception of which specific drug they had received.

Data analysis

To examine the effects of methylphenidate and atomoxetine on cognitive performance and dishonest behavior, we analyzed data from two primary tasks: a sustained attention task and a die-rolling task. The dependent variables in the sustained attention task were participants' reaction times (RTs) and accuracy in detecting numerical sequences. These outcomes were analyzed using repeated-measures ANOVAs to test for interaction effects between drug condition (methylphenidate, atomoxetine, placebo) and time (pre- vs. post-dosing). Follow-up pairwise comparisons were conducted using ANOVAs or t-tests, where appropriate, to explore specific differences between conditions. Dishonest behavior was assessed using a die-rolling task, where participants self-reported the outcomes of private dice rolls. The primary dependent variable was the proportion of reported successful rolls, with higher proportions indicating greater dishonesty. We first compared observed success rates to the 50% benchmark for honest reporting using one-sample t-tests. Differences in dishonesty across drug conditions were assessed using non-parametric Kruskal-Wallis tests, followed by Bonferroni-adjusted pairwise comparisons using Mann-Whitney U tests. Additional analyses used simulation-based approaches and Bayesian methods to evaluate whether observed differences could plausibly arise from random variation alone. Highest Density Intervals (HDIs) were computed to determine whether observed distributions were consistent with honest reporting.

To assess alternative explanations, including demand effects and the potential role of mood, attention, impulsivity, risk-taking, and self-interest, we conducted a series of control analyses. These included regression analyses to test whether drug-induced changes in attention (as measured by changes in RTs) predicted dishonesty, and ANCOVAs to test whether the effect of methylphenidate on dishonesty remained significant when controlling for participants' beliefs about drug assignment, mood, and other psychological states.

Results

Did methylphenidate and atomoxetine enhance cognitive performance?

We first evaluated whether methylphenidate and atomoxetine indeed enhance cognitive performance using a sustained attention task (Sarter et al. 2001). In this task, participants had to identify sequences of numbers (e.g., 1, 3, 5, …) within rapid succession of single digits. Cognitive performance was measured based on reaction times and accuracy. We found a significant interaction effect of drug condition and time (pre versus post) on reaction times ($F(2,136)=9.288$, $P<0.001$). Specifically, participants in the methylphenidate condition exhibited significantly faster reaction times post-dosing (RT_{mean} = 338.42 ms) compared to the placebo condition (RT_{mean} = 379.42 ms, $F(2,93)=16.813$, $P<0.001$). Similarly, participants in the atomoxetine condition showed significantly faster reaction times post-dosing ($RT_{mean}=351.28$ ms) compared to the placebo condition ($F(2,93)=4.368$, $P=0.039$). However, there was no significant difference between two drug conditions in terms of their effects on reaction times ($F(1,87)=2.78$, $P=0.099$). Regarding changes in accuracy, no significant effect of drug condition was observed ($F(2,136)=1.80$, $P=0.16$). This lack of significance could be attributed to a ceiling effect, as participants already achieved nearly 90% accuracy in detecting targets prior to drug administration, leaving limited room for improvement.

Did methylphenidate and atomoxetine affect dishonest behavior?

In line with previous research (Abeler et al. 2019), we observed significant levels of dishonest behavior across all conditions, although not reaching maximal dishonesty. The average reported success rate in the die-rolling task across all conditions was 57.82% (SE = 1.23), which is significantly higher than the 50% honest benchmark ($t(150)=6.087$, $P<0.001$). Earnings from the task differed significantly across treatments, as determined by a non-parametric Kruskal-Wallis test ($H(2)=6.218$, $P=0.045$, Fig. 2A). Notably, in the placebo condition (Fig. 2B), participants reported 61% successful die rolls on average, which significantly exceeds the 50% honest benchmark ($t(51)=5.210$, $P<0.001$; 95% confidence interval: 57–65%). This finding suggests that dishonest misreporting occurred in 22% of all responses, assuming participants did not misreport to their disadvantage.

In stark contrast, participants in the methylphenidate condition reported successful die rolls in 53.7% of the rolls (Fig. 2C), which is not significantly different from the 50% honesty benchmark ($t(48)=1.88$, $P=0.066$; 95% confidence interval: 49%–57%) but is significantly lower than the rate observed in the placebo condition ($z=2.48$, $P=0.039$, Bonferroni adjusted). We estimate that participants in the methylphenidate condition misreported only on 6% of their trials, representing a 72% reduction compared to the placebo condition.

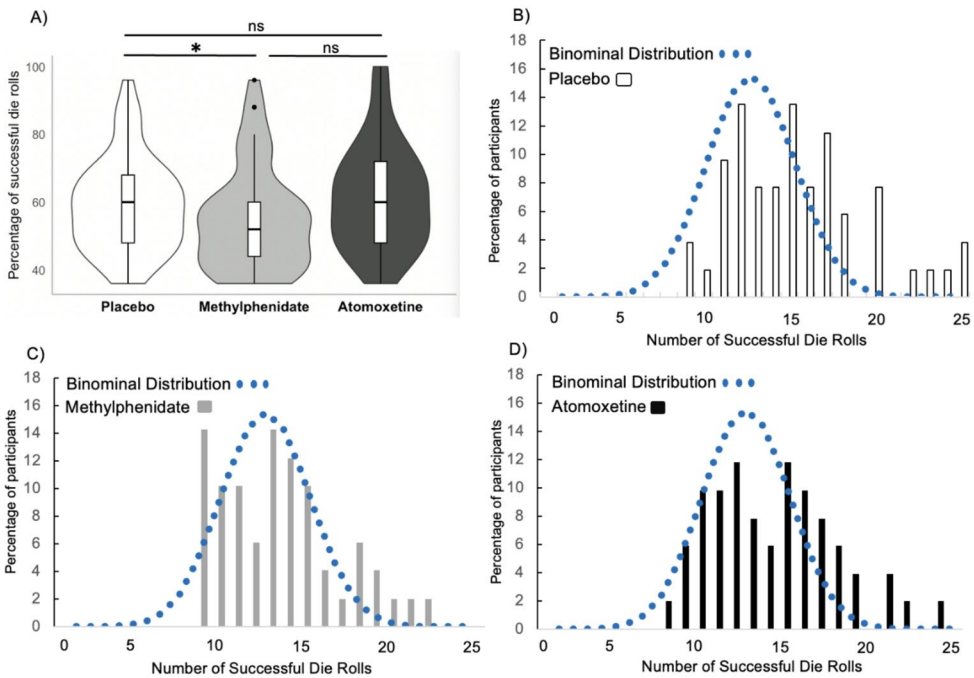

Fig. 2 **A** Participants in the methylphenidate condition cheated less than those in the placebo condition $P=0.039$, Bonferroni adjusted). Boxplot - The lower and upper hinges of the box represent the first quartile and third quartile, the line inside the box represents the median. **B**–**D** Empirical distributions in the different conditions compared to the binomial distribution representing honest behavior. *$P<0.05$, Bonferroni corrected. ns = not significant. Error bars indicate +/- 1 SEM."Did random variations account for the effects of methylphenidate on dishonesty?

In contrast to methylphenidate, atomoxetine did not have a significant impact on dishonesty relative to placebo. Participants in the atomoxetine condition (Fig. 2D) reported successful die rolls in 56.7% of the trials (equivalent to cheating in 14% of the trials). Although this success rate is significantly higher than the 50% honesty benchmark ($t(49)=3.76$, $P<0.001$; 95% confidence interval: 53%–62%), it does not differ significantly from the placebo condition ($z=1.483$, $P=0.414$, Bonferroni adjusted). Moreover, there was no significant difference in reported success rates between the methylphenidate condition and the atomoxetine condition ($z=0.988$, $P=0.969$, Bonferroni adjusted).

Were the observed differences in reported die rolls across conditions a result of random variations due to the probabilistic nature of the die-rolling task, or did they reflect a genuine effect of methylphenidate on dishonesty? To investigate this, we conducted simulations and employed Bayesian analysis. In these simulations, we generated 100,000 experiments mirroring our study in terms of participant numbers and die rolls. The simulations assumed that all participants consistently reported the truth, with an underlying 50% success rate.

The results of these simulations align with our empirical analyses, providing further evidence for a robust effect of methylphenidate compared to placebo on dishonesty (Fig. S1). In particular, the simulations indicate that participants in the placebo condition ($p<0.0001$) and the atomoxetine condition ($P<0.0001$) were dishonest. A similar trend was observed in the methylphenidate condition, albeit with a lower probability estimation ($P=0.017$). When computing the Bayesian 95% highest density intervals (HDIs), it is evident that the intervals for the placebo condition (0.58–0.63) and the atomoxetine condition (0.54–0.59) do not include the 50% honesty mark. Similarly, the HDI for the methylphenidate condition also falls outside the range of honesty (0.50–0.55). Importantly, the probability of participants behaving honestly and still generating the observed difference in die success rates between the methylphenidate condition and the placebo condition is extremely low ($P=0.00002$, Panel H in Fig. S1). This implies that only 2 out of 100,000 experiments with a similar sample size of honest participants would yield a methylphenidate effect of similar or larger magnitude than what we observed. In contrast, 2,170 out of 100,000 experiments would have found a similar difference between the atomoxetine condition and the placebo condition ($P=0.0217$), and 2,100 experiments would have found a similar difference between the methylphenidate condition and the atomoxetine condition ($P=0.0210$).

Can demand effects explain the effects of methylphenidate on dishonesty?

An alternative explanation for our findings is that participants who received methylphenidate may have experienced a demand effect, where their beliefs about being under the influence affected their behavior rather than the actual neuromodulatory effects of the drug. We asked participants at the end of the experiment to identify which drug they believed they received: placebo, methylphenidate, or atomoxetine. The majority of participants thought they received a placebo ($n=73$, 46.8%), followed by methylphenidate ($n=54$, 34.6%), and atomoxetine ($n=24$, 15.4%). Interestingly, most participants (61.9%) provided incorrect guesses, indicating that their beliefs about the received drug were not accurate, with their guesses being no better than chance ($t(154)=1.039$, $P=0.301$).

Importantly, participants' beliefs about the received drug did not have an impact on their level of dishonesty ($H(2)=2.228$, $P=0.328$). Participants who believed they received a placebo cheated as much (mean percentage of successful die rolls = 58.2%) as those who believed they were in the methylphenidate condition (mean percentage of successful die rolls = 59.2%). Similarly, when dividing the sample into participants who believed they were in the placebo condition and those participants who believed they were in a drug condition (either methylphenidate or atomoxetine), we do not find a difference in dishonesty between these groups ($H(2)=0.044$, $P=0.834$). Furthermore, when controlling participants' beliefs about drug administration, we still find a significant effect of methylphenidate on dishonesty ($F(1,96)=4.86$, $P=0.030$), with no interaction between the effect and drug administration beliefs ($F(1,96)=0.27$, $P=0.600$). These analyses suggest that the effect of methylphenidate on dishonesty is likely attributable to its neuromodulation effects rather than participants' beliefs about the drug[2].

Beyond demand effects, methylphenidate may have influenced dishonesty through various underlying mechanisms,

[2] Note that we also asked participants if they felt that taking methylphenidate or taking atomoxetine makes a person feel less responsible for their actions. For each drug, the majority indicated that the drug does not influence how responsible one is for one's actions. And the condition participants were in did not influence their beliefs about the responsibility of their actions, ps > 0.05. Finally, we also asked if participants thought that the drug influenced their behaviour during the experiment, and if so, how. Most participants indicated that the drug they received did not alter their decision making (60.3%), while some indicated that it made them more focused (13.9%), faster (4.6%), more analytical (3.3%), and take more risks (2.6%). None of the answers indicated that participants suspected that the drug made them more honest or influenced their honesty.

including mood, attention, impulsivity, risk, and self-interest. Previous research has established connections between these mechanisms and dishonest behavior (see SI Results for detailed discussion about how each of these processes is related to honesty). First, we tested if enhanced attention is responsible for the effects of methylphenidate on honesty – was participants' enhanced focus in the methylphenidate condition the reason for their relative honesty? However, changes in response times induced by the drug were not significantly related to dishonest behavior (beta = 0.003, $P = 0.969$). Furthermore, controlling for drug-induced changes in response times did not alter the effect of methylphenidate relative to placebo on dishonesty ($F(1,95) = 4.63$, $P = 0.030$). In addition to its impact on attention, we found that methylphenidate had a significant impact on mood, specifically enhancing self-reported feelings of energy compared to both the placebo and the atomoxetine condition. Importantly, even when controlling for the effect on energy levels, we still found a significant effect of methylphenidate on dishonest behavior ($F(1,97) = 5.57$, $P = 0.020$). Similarly, controlling for feelings of contentment did not alter the methylphenidate effect on dishonesty ($F(1,97) = 5.708$, $P = 0.019$). No significant effects of methylphenidate were observed in relation to impulsivity, risk, or self-interest. Importantly, even after controlling for these variables, a significant effect of methylphenidate on dishonesty persisted in comparison to the placebo condition. This finding suggests that the influence of methylphenidate on dishonest behavior cannot be attributed to changes in mood, attention, impulsivity, risk, or self-interest induced by the drug. Put differently, one might argue that the effects of methylphenidate on dishonest behavior are not simply a downstream consequence of its effect on primary processes; at least the ones tested in this study.

Discussion

Taken together, our results reveal a diminished tendency toward dishonest misreporting among individuals administered with methylphenidate in comparison to those receiving a placebo. This effect was consistently observed across both our empirical analysis and simulations, and it is not attributable to demand effects or changes in mood, impulsivity, self-interest, or risk preferences. In contrast, the administration of atomoxetine did not yield any discernible impact on dishonest behavior relative to either methylphenidate or placebo conditions. These findings raise an interesting question: While many people perceive taking drugs in the hope to improve performance as dishonest (Schermer 2008; Goodman 2010; Bell et al. 2013), do they also anticipate that the use of such drugs itself might have side-effects on honest behavior? To investigate this, we explored the intuitions of previous drugs users and non-users regarding the impact of methylphenidate on dishonest behavior. We recruited a nationally representative sample of US participants ($N = 574$), ensuring representation across gender, age, and race. Participants were provided with a description of the pharmacological study procedures, including the observed level of dishonest misreporting in the placebo condition. Subsequently, they were asked to make predictions about the extent of dishonest misreporting in the methylphenidate condition, with incentives provided for accurate predictions.

Methods

Participants

We contracted the services of Prolific to recruit a national representative sample in terms of age, gender, income, and education. Initially, a total of 611 participants were recruited, but 36 individuals failed to pass a basic attention check administered at the beginning of the study and were subsequently excluded from the analysis. The final sample consists of 575 American participants, with 50.4 identifying as female, 49% as male, and a negligible percentage (0.3%) falling under the categories of "other" or "prefer not to say." The average age of the participants was 46.94 years (with a median age of 47). Regarding educational attainment, the majority of participants reported having completed some college education (22.1%), followed by those with a 4-year college degree (38.8%), a postgraduate or professional degree (20.5%), a high school degree (9.2%), and a 2-year college degree (9.2%). In terms of household income, about one-third of participants indicated an income at the average level (29.7%), while another third reported a below-average income (35.3%), and the remaining third indicated an above-average income (32.9%). In our sample, 7.3% of participants reported previous use of methylphenidate. Among the methylphenidate users, the primary reasons for usage were to enhance work or studying performance (59.5%), while a smaller proportion mentioned socializing or seeking intoxication effects (23.8%), and a subset selected "other" as their reason. An additional 17.4% of participants reported using prescription drugs other than methylphenidate. Similar to methylphenidate users, the main motivation for using prescription drugs among participants was to enhance performance (60%), followed by socializing or seeking intoxication effects (27%), with a subset indicating "other" as their reason (13%).

Measures

The instructions for every task can be found here: https://osf.io/uv5ke/?view_only=ce44a28f86d543e3a5839b7fda79acb8.

At the beginning of the study, participants were informed about the purpose of the prediction study, which aimed to investigate their estimation of the impact of a drug on the level of dishonesty exhibited by study participants. They were further informed that accurate predictions would result in a bonus payment of $2, and that their comprehension of the study would be assessed with an opportunity to earn $0.50 for correct answers.

Subsequently, participants were provided with information regarding drugs which are known to enhance cognitive performance and attention. Although typically prescribed for individuals with attention-related difficulties, the use of these drugs has become prevalent among individuals without medical diagnoses. Specifically, participants were informed that the drug used in our study was Ritalin (methylphenidate). To facilitate understanding, we employed simplified language and utilized infographics to explain the randomization process of the drug study, the task employed to measure dishonesty (a coin toss task was used as a substitute for the die-rolling task), and the placebo condition results, which served as a reference value for participants' predictions.

Finally, participants were presented with the following question: "Now, we want to know what you think: How did Ritalin affect cheating? Did participants in the Ritalin condition report less, equal, or more HEADS compared to those in the placebo condition? Try your best to get it right. If your prediction is correct, you will get a $2 bonus payment." The response scale comprised five options, ranging from "Ritalin decreased cheating significantly compared to the Placebo condition (more than a 5% point decrease in reported Heads)" to "Ritalin increased cheating significantly compared to the Placebo condition (more than a 5% point increase in reported Heads)." Following their estimation of methylphenidate's effect on dishonesty, participants were assessed on their comprehension of the study procedures through a quiz.

In the final part of the prediction study, participants were asked about their prior use of potentially performance-enhancing drugs in general, as well as methylphenidate specifically. They were asked about their primary motivations for using potentially performance-enhancing drugs, perceived effects, and frequency of usage, following established protocols (Maier et al. 2018).

Data analysis

The primary dependent variable was the distribution of predictions across these five response categories. Descriptive statistics were used to summarize the proportions of participants selecting each prediction option. To explore whether previous experience with cognitive enhancers influenced these intuitions, we compared the prediction distributions of self-reported users and non-users of such drugs. This comparison was conducted using a chi-square test of independence.

Results

Intuitions about the effects of methylphenidate on dishonest behavior

The results show that the participants had limited intuitions about the effects of methylphenidate on dishonesty. The majority of participants (27.9%) did not expect any impact of methylphenidate on dishonest behavior (Fig. 3). Conversely, a comparable number of participants expected a small increase (21.3%) or decrease (24%) in dishonesty resulting from methylphenidate administration, whereas fewer participants predicted substantial decreases (11.7%) or increases (15.2%) in dishonesty. Thus, only a small fraction of participants accurately predicted the large decrease in dishonesty observed in the methylphenidate condition compared to the placebo condition. Additionally, when participants were asked about their prior usage of prescription drugs used to enhance cognitive performance, 17.4% of respondents reported having used them. Notably, upon comparing the intuitive beliefs of users and non-users, we found no statistically significant differences in the distribution of their predictions ($\chi 2 = 3.16$, $P = 0.551$). In summary, our findings indicate that a representative sample of Americans lacks reliable and shared intuitions regarding the side effects of methylphenidate on dishonest behavior.

General Discussion

In a double-blind, placebo-controlled experiment, we examined the impact of two popular cognitive performance enhancing drugs, methylphenidate and atomoxetine, on participants' dishonesty. We measured dishonesty using a die-rolling task where participants could misreport their outcomes to increase their earnings without risk of detection. Our findings reveal that, compared to the placebo condition, methylphenidate increased attention, improved mood, and reduced dishonesty. These effects are not attributable to statistical fluctuations, demand effects, or domain-general mechanisms such as mood or attention. In addition, both individuals who use drugs to enhance performance and those who do not have limited intuitions about the impact of methylphenidate on

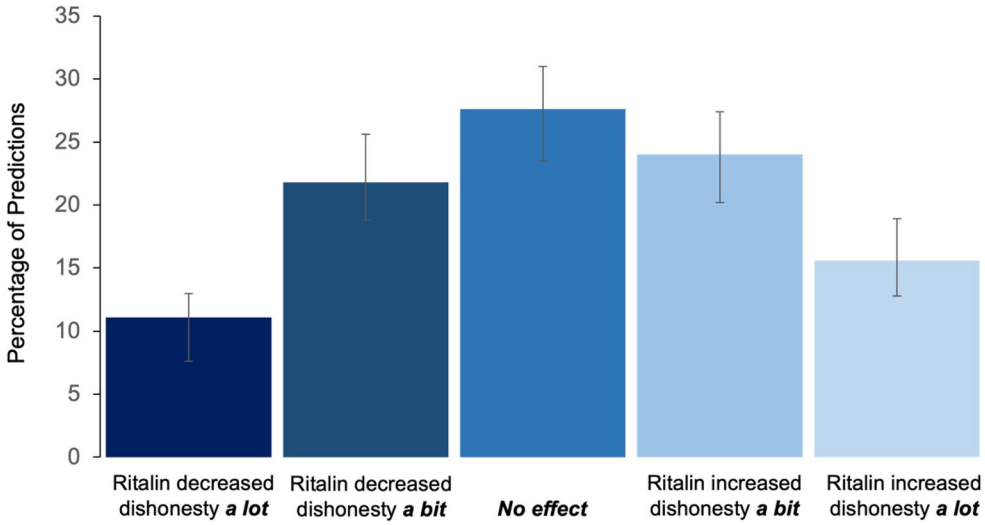

Fig. 3 The majority of participants did not expect methylphenidate to have an impact on dishonest behavior (27.9%). However, almost as many participants suspected a small increase (21.3%) or decrease (24%) in dishonesty resulting from methylphenidate administration, while fewer expected a substantial increase (15.2%) or decrease (11.7%) in dishonesty. * Error bars indicate 95% confidence interval

dishonest behavior. Conversely, the effects of atomoxetine on dishonest behavior were inconclusive, despite its ability to enhance attention. Therefore, our results suggest that not all potentially performance-enhancing drugs are likely to exert similar effects on dishonest behavior.

It is important to note some limitations of our research. First, this is the first research showing that methylphenidate decreases dishonesty. While our study has been adequately powered and our computational simulation suggests that the result is not due to random variation, it would be important to replicate this finding. Second, our study primarily aimed to investigate the potential unintended side effects of methylphenidate on dishonesty, rather than unravelling the specific neural mechanisms underlying these effects. Nevertheless, our findings offer speculative insights into the underlying neural processes of dishonesty and how methylphenidate might influence them. During the decision-making process of whether to report dishonestly or not in the die-rolling task, participants had to weigh the costs and benefits associated with each option. Honesty entailed financial sacrifices, while dishonesty involved violating a social norm and incurring affective costs (Garrett et al. 2016). Methylphenidate might have modulated this deliberation process. Previous research by Westbrook and colleagues shows that methylphenidate enhances dopamine signals, directing attention toward the benefits of cognitive effort and priming individuals to invest effort accordingly (Westbrook et al. 2020). Without this signal, desired outcomes might not have enough motivational force to mobilize cognitive effort. Considering that our participants displayed negatives attitudes toward dishonesty (see SI Results), it is plausible to hypothesize that methylphenidate enhanced the readiness to invest effort in aligning their actions with their values and resisting financial temptations. Interestingly, the effects of methylphenidate on effort investment are most likely due to its effects on striatal dopaminergic activity which would also explain the lack of atomoxetine on dishonesty; methylphenidate increases striatal dopamine, atomoxetine not. However, drugs like methylphenidate have far-reaching effects on the brain and hence are less than ideal for testing mechanistic hypothesis about the brain.

The findings of our study may have policy implications, particularly regarding the use of drugs such as methylphenidate and the potential paradox that arises. On one hand, individuals who do not have a relevant diagnosis may turn to drugs to enhance their cognitive performance, with the intention of gaining an advantage on academic tests or other tasks. This raises concerns about academic integrity and the maintenance of a level playing field in educational and professional settings (Singh and Kelleher 2010; Ragan et al. 2013; Bard et al. 2018). Individuals with an ADHD diagnosis might feel that drugs such as methylphenidate level the playing field, an effect that is reversed when people without a diagnosis also take these drugs. However, our results suggest a contrasting effect of methylphenidate, as it was found to reduce subsequent dishonesty. This paradoxical relationship between the use of drugs for performance enhancement and their potential impact on honesty warrants careful consideration. Ultimately, the paradoxical relationship between drug use, enhanced performance, and increased honesty underscores the complexity of the issue.

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Study Implementation: AK, AN, MB, PC.
Analysis: AK, AC, MAM, MC.
Writing—original draft: AK, MC.
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Data availability All data will be made available upon publication at: https://osf.io/uv5ke/.

Declarations

Ethical approval This study has been reviewed by, and received ethics clearance through, the University of Oxford Central University Research Ethics Committee, reference R43997/RE001.

Consent to participate All participants were provided with the participant information sheet to ensure their understanding of the study's procedures and risks before they signed the consent form to participate. All participants signed the informed consent form before participating in the study.

Consent to publish Not applicable.

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

References

Abeler J, Nosenzo D, Raymond C (2019) Preferences for truth-telling. Econometrica 87(4):1115–1153

Artigas SO et al (2019) Enhancement in dopamine reduces generous behaviour in women. PLoS One 14(12):e0226893. https://doi.org/10.1371/journal.pone.0226893

Ballentine B et al (2019) 'Academic Integrity Task Force Report'.

Bard I et al (2018) Bottom Up Ethics - Neuroenhancement in Education and Employment. Neuroethics 11(3):309–322. https://doi.org/10.1007/s12152-018-9366-7

Beck AT, Steer RA, Brown GK (1996) Beck depression inventory-II. San Antonio 78(2):490–498

Bell S et al (2013) Australian university students' attitudes towards the acceptability and regulation of pharmaceuticals to improve academic performance. Neuroethics 6(1):197–205

Blake KR, Gangestad S (2020) On attenuated interactions, measurement error, and statistical power: guidelines for social and personality psychologists. Pers Soc Psychol Bull 46(12):1702–1711. https://doi.org/10.1177/0146167220913363

Board AR et al (2020) Trends in stimulant dispensing by age, sex, state of residence, and prescriber specialty — United States, 2014–2019. Drug Alcohol Depend 217:108297. https://doi.org/10.1016/j.drugalcdep.2020.108297

Bowman E et al (2020) 'Surveying the Use of Pharmaceutical Cognitive Enhancers in the Australian Financial Services Industry', *Available at SSRN 3661966* [Preprint]. Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3661966 (Accessed: 3 June 2024)

Bowman E et al (2023) Not so smart? "Smart" drugs increase the level but decrease the quality of cognitive effort. Sci Adv 9(24):eadd4165. https://doi.org/10.1126/sciadv.add4165

Buckholtz JW et al (2015) From blame to punishment: disrupting prefrontal cortex activity reveals norm enforcement mechanisms. Neuron 87(6):1369–1380

Busardò F, Kyriakou C, Cipolloni L, Zaami S, Frati P (2016) From clinical application to cognitive enhancement: the example of methylphenidate. Curr Neuropharmacol 14:17–27

Carlson RW, Crockett MJ (2018) The lateral prefrontal cortex and moral goal pursuit. Curr Opin Psychol 24:77–82

Chamberlain SR et al (2006) Neurochemical modulation of response inhibition and probabilistic learning in humans. Science 311(5762):861–863. https://doi.org/10.1126/science.1121218

Chamberlain SR et al (2007) 'Atomoxetine increases salivary cortisol in healthy volunteers', *Journal of Psychopharmacology* [Preprint]. Available at: https://doi.org/10.1177/0269881106075274

Cohn A, Maréchal MA (2018) Laboratory measure of cheating predicts school misconduct. Econ J 128(615):2743–2754

Cohn A, Maréchal MA, Noll T (2015) Bad boys: how criminal identity salience affects rule violation. Rev Econ Stud 82(4):1289–1308. https://doi.org/10.1093/restud/rdv025

Crockett MJ et al (2015) Dissociable effects of serotonin and dopamine on the valuation of harm in moral decision making. Curr Biol 25(14):1852–1859. https://doi.org/10.1016/j.cub.2015.05.021

Crockett MJ et al (2017) Moral transgressions corrupt neural representations of value. Nat Neurosci 20(6):879–885. https://doi.org/10.1038/nn.4557

Dai Z, Galeotti F, Villeval MC (2017) Cheating in the lab predicts fraud in the field: an experiment in public transportation. Manage Sci 64(3):1081–1100. https://doi.org/10.1287/mnsc.2016.2616

Daubner J et al (2021) Pharmacological neuroenhancement: current aspects of categorization, epidemiology, pharmacology, drug development, ethics, and future perspectives. Neural Plast 2021:e8823383. https://doi.org/10.1155/2021/8823383

DeSantis A, Noar SM, Webb EM (2009) Nonmedical ADHD stimulant use in fraternities. J Stud Alcohol Drugs 70(6):952–954

Dietz P et al (2013) Randomized response estimates for the 12-month prevalence of cognitive-enhancing drug use in university students. Pharmacotherapy: J Hum Pharmacol Drug Therapy 33(1):44–50

Dietz P, Soyka M, Franke AG (2016) 'Pharmacological Neuroenhancement in the Field of Economics—Poll Results from an Online Survey'. Front Psychol 7. Available at: https://doi.org/10.3389/fpsyg.2016.00520

Dockree PM et al (2017) The effects of methylphenidate on the neural signatures of sustained attention. Biol Psychiatry 82(9):687–694. https://doi.org/10.1016/j.biopsych.2017.04.016

Ehlert AM, Wilson PB (2021) A systematic review of stimulant use in civilian and military aviation. The International Journal of Aerospace Psychology 31(3):198–218. https://doi.org/10.1080/24721840.2020.1869553

Falk A et al (2016) *The Preference Survey Module: A Validated Instrument for Measuring Risk, Time, and Social Preferences*. SSRN Scholarly Paper ID 2725874. Rochester, NY: Social Science Research Network. Available at: http://papers.ssrn.com/abstract=2725874 (Accessed: 24 August 2016)

Faraone SV et al (2020) Systematic review: nonmedical use of prescription stimulants: risk factors, outcomes, and risk reduction strategies. Journal of the American Academy of Child & Adolescent Psychiatry 59(1):100–112. https://doi.org/10.1016/j.jaac.2019.06.012

FeldmanHall O et al (2015) Empathic concern drives costly altruism. Neuroimage 105:347–356

Franke AG et al (2011) Non-medical use of prescription stimulants and illicit use of stimulants for cognitive enhancement in pupils and students in Germany. Pharmacopsychiatry 44(2):60–66. https://doi.org/10.1055/s-0030-1268417

Franke AG et al (2013) Use of illicit and prescription drugs for cognitive or mood enhancement among surgeons. BMC Med 11:102. https://doi.org/10.1186/1741-7015-11-102

Franke AG et al (2014) Substances used and prevalence rates of pharmacological cognitive enhancement among healthy subjects. Eur Arch Psychiatry Clin Neurosci 264(1):83–90. https://doi.org/10.1007/s00406-014-0537-1

Garrett N et al (2016) The brain adapts to dishonesty. Nat Neurosci 19(12):1727–1732. https://doi.org/10.1038/nn.4426

Gesundheitsreport (2015). Available at: (no date). Available at: https://www.dak.de/dak/bundesthemen/gesundheitsreport-2015-2109048.html (Accessed: 11 January 2023)

Gilbert DL et al (2005) Comparison of the inhibitory and excitatory effects of ADHD medications methylphenidate and atomoxetine on motor cortex. Neuropsychopharmacology 31(2):442–449. https://doi.org/10.1038/sj.npp.1300806

Goodman R (2010) Cognitive enhancement, cheating, and accomplishment. Kennedy Inst Ethics J 20(2):145–160

Hanna R, Wang S-Y (2017) Dishonesty and selection into public service: evidence from India. Am Econ J Econ Policy 9(3):262–290

Hernaus D et al (2017) Noradrenaline transporter blockade increases fronto-parietal functional connectivity relevant for working memory. Eur Neuropsychopharmacol 27(4):399–410. https://doi.org/10.1016/j.euroneuro.2017.02.004

Hester R et al (2012) Neurochemical enhancement of conscious error awareness. J Neurosci 32(8):2619–2627. https://doi.org/10.1523/JNEUROSCI.4052-11.2012

Ilieva IP, Hook CJ, Farah MJ (2015) Prescription stimulants' effects on healthy inhibitory control, working memory, and episodic memory: a meta-analysis. J Cogn Neurosci 27:1069–1089. https://doi.org/10.1162/jocn_a_00776

Linssen AM et al (2014) Cognitive effects of methylphenidate in healthy volunteers: a review of single dose studies. Int J Neuropsychopharmacol 17(6):961–977

Maier LJ, Ferris JA, Winstock AR (2018) Pharmacological cognitive enhancement among non-ADHD individuals—a cross-sectional study in 15 countries. Int J Drug Policy 58:104–112

Marquand AF et al (2011) 'Pattern Classification of Working Memory Networks Reveals Differential Effects of Methylphenidate, Atomoxetine, and Placebo in Healthy Volunteers', Neuropsychopharmacology, 36(6), pp. 1237–1247. Available at: https://doi.org/10.1038/npp.2011.9

Müller U et al (2005) 'Plasma level-dependent effects of methylphenidate on task-related functional magnetic resonance imaging signal changes', *Psychopharmacology*, 180(4), pp. 624–633. Available at: https://doi.org/10.1007/s00213-005-2264-9

Nandam LS et al (2011) 'Methylphenidate But Not Atomoxetine or Citalopram Modulates Inhibitory Control and Response Time Variability', *Biological Psychiatry*, 69(9), pp. 902–904. Available at: https://doi.org/10.1016/j.biopsych.2010.11.014

Nandam LS, Hester R, Bellgrove MA (2014) Dissociable and common effects of methylphenidate, atomoxetine and citalopram on response inhibition neural networks. Neuropsychologia 56:263–270. https://doi.org/10.1016/j.neuropsychologia.2014.01.023

Pedroni A et al (2014) Dopaminergic stimulation increases selfish behavior in the absence of punishment threat. Psychopharmacology 231(1):135–141

Qu C et al (2019) 'Neurocomputational mechanisms at play when weighing concerns for extrinsic rewards, moral values, and social image', PLoS Biology 17(6)

Ragan CI, Bard I, Singh I (2013) What should we do about student use of cognitive enhancers? An analysis of current evidence. Neuropharmacology 64:588–595. https://doi.org/10.1016/j.neuropharm.2012.06.016

Reinert DF, Allen JP (2007) The alcohol use disorders identification test: an update of research findings. Alcohol Clin Exp Res 31(2):185–199

Roberts CA et al (2020) 'How effective are pharmaceuticals for cognitive enhancement in healthy adults? A series of meta-analyses of cognitive performance during acute administration of modafinil, methylphenidate and D-amphetamine', European Neuropsychopharmacology 38:40–62. Available at: https://doi.org/10.1016/j.euroneuro.2020.07.002

Sáez I et al (2015) 'Dopamine Modulates Egalitarian Behavior in Humans', Curr Biol 25(7):912–919. Available at: https://doi.org/10.1016/j.cub.2015.01.071

Saniotis A, Kumaratilake J (2020) Amphetamines, cognitive enhancement and their implications for medical military ethics. J Mil Ethics 19(1):69–75. https://doi.org/10.1080/15027570.2020.1776479

Sarter M, Givens B, Bruno JP (2001) The cognitive neuroscience of sustained attention: where top-down meets bottom-up. Brain Res Brain Res Rev 35(2):146–160

Sauer J-M, Ring BJ, Witcher JW (2005) Clinical pharmacokinetics of atomoxetine. Clin Pharmacokinet 44(6):571–590. https://doi.org/10.2165/00003088-200544060-00002

Schermer M (2008) On the argument that enhancement is cheating. J Med Ethics 34(2):85–88

Shang CY et al (2016) Differential effects of methylphenidate and atomoxetine on intrinsic brain activity in children with attention deficit hyperactivity disorder. Psychol Med 46(15):3173–3185. https://doi.org/10.1017/S0033291716001938

Sharif S et al (2021) The use and impact of cognitive enhancers among university students: a systematic review. Brain Sci 11(3):355. https://doi.org/10.3390/brainsci11030355

Simpson D, Perry CM (2003) Atomoxetine. Paediatr Drugs 5(6):407–415. https://doi.org/10.2165/00128072-200305060-00005

Singh I, Kelleher KJ (2010) Neuroenhancement in young people: proposal for research, policy, and clinical management. AJOB Neurosci 1(1):3–16. https://doi.org/10.1080/21507740903508591

Soutschek A et al (2017) The dopaminergic reward system underpins gender differences in social preferences. Nat Hum Behav 1(11):819. https://doi.org/10.1038/s41562-017-0226-y

van Baar JM, Chang LJ, Sanfey AG (2019) The computational and neural substrates of moral strategies in social decision-making. Nat Commun 10(1):1–14

van den Bosch R et al (2022) Striatal dopamine dissociates methylphenidate effects on value-based versus surprise-based reversal learning. Nat Commun 13(1):4962. https://doi.org/10.1038/s41467-022-32679-1

Van Puyvelde M et al (2022) A state-of-the-art review on the use of modafinil as a performance-enhancing drug in the context of military operationality. Mil Med 187(11–12):1286–1298. https://doi.org/10.1093/milmed/usab398

Volkow ND et al (2001) Therapeutic doses of oral methylphenidate significantly increase extracellular dopamine in the human brain. J Neurosci 21(2):RC121–RC121

Volkow ND et al (2005) Imaging the effects of methylphenidate on brain dopamine: new model on its therapeutic actions for attention-deficit/hyperactivity disorder. Biol Psychiatry 57(11):1410–1415

Westbrook A et al (2020) Dopamine promotes cognitive effort by biasing the benefits versus costs of cognitive work. Science 367(6484):1362–1366

Wingelaar-Jagt YQ et al (2021) Fatigue in aviation: safety risks, preventive strategies and pharmacological interventions. Front Physiol 12:712628. https://doi.org/10.3389/fphys.2021.712628

Wolraich ML et al (2019) ADHD diagnosis and treatment guidelines: a historical perspective. Pediatrics 144(4):e20191682. https://doi.org/10.1542/peds.2019-1682

Zoh Y, Chang SWC, Crockett MJ (2022) The prefrontal cortex and (uniquely) human cooperation: a comparative perspective. Neuropsychopharmacology 47(1):119–133. https://doi.org/10.1038/s41386-021-01092-5