Supplementary Results - On the Side Effects of Methylphenidate on Dishonesty

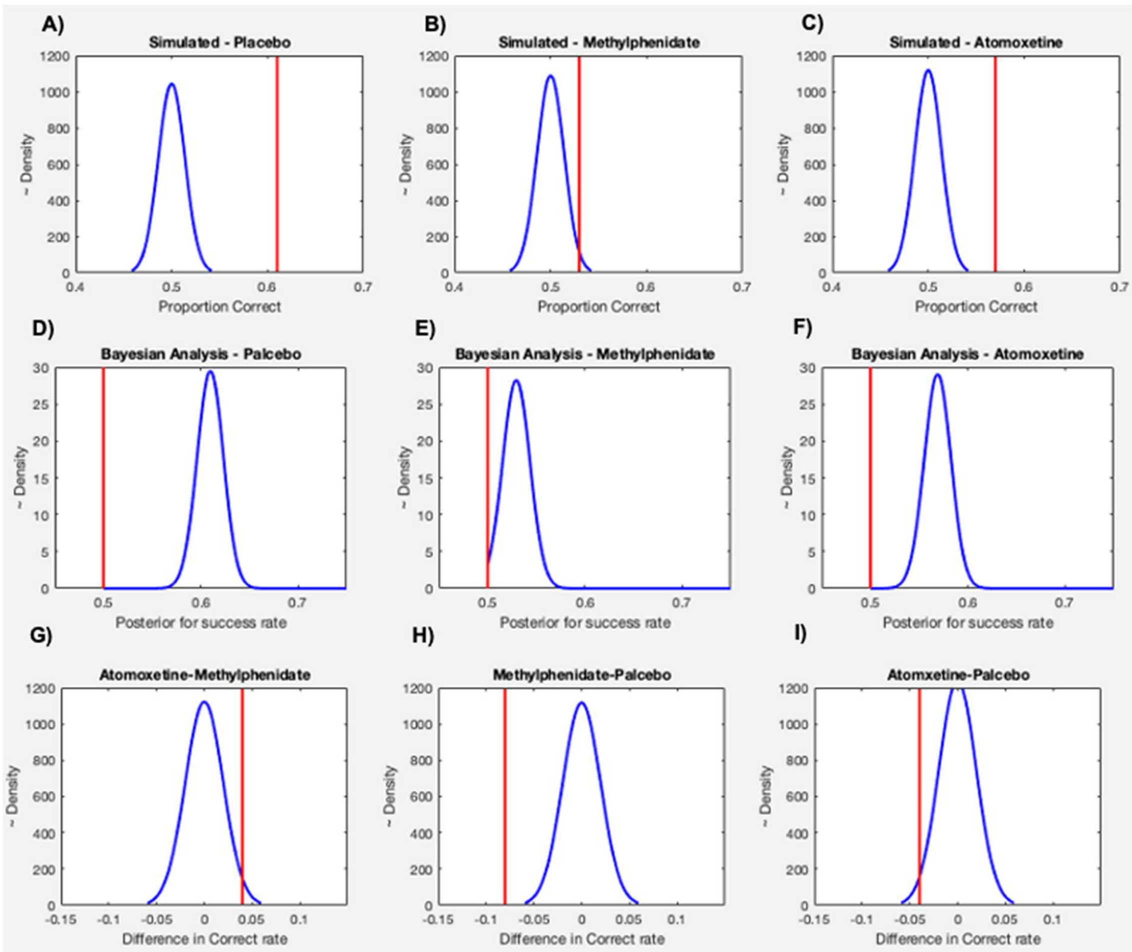

Figure S1: Simulations and Bayesian analyses demonstrate that the observed findings are unlikely to be attributed to random fluctuations in the outcomes of die rolls. The plots in panels A, B, and C show the density distributions of successful die rolls as a percentage based on 100,000 simulated samples, assuming truthful reporting of n*25 die rolls with a 50% success rate. Here, n represents the sample size for each drug condition: Placebo (n=52) in panel A, Methylphenidate (n=50) in panel B, and Atomoxetine (n=52) in panel C. The red lines represent the average percentage of successful die rolls observed in the actual data. Note that the lines in the placebo condition (panel A) and the atomoxetine condition (panel C) lie clearly outside the simulated distributions, suggesting that participants in both groups lied to some degree. In the methylphenidate condition, the line is at the edge of the simulated data, suggesting a minimal level of dishonesty ($P = 0.017$). Additionally, Bayesian analysis was employed to compute the 95% highest density intervals (HDIs) in panels D-F. These intervals do not encompass the 50% mark for honesty in the placebo condition (0.58-0.63) or the atomoxetine condition (0.54-0.59). Similarly, the HDI for the methylphenidate condition (0.50-0.55) barely includes the mark. Panel H illustrate that the probability of participants behaving honestly and generating the observed difference in die rolling success rates between the methylphenidate condition and the placebo condition is $p = 0.00002$. Hence, in only 2 out of 100,000 experiments with a similar sample size of honest participants would a methylphenidate effect of a similar or larger magnitude be observed. In contrast, as shown in panels G and I, 2,170 out of 100,000 experiments would exhibit a similar difference between the atomoxetine condition and the placebo condition ($P = 0.0217$), and 2,100 experiments would demonstrate a similar difference between the methylphenidate condition and the atomoxetine condition ($P = 0.0210$).

Table S1. Demographic variables across conditions

	Placebo	Methylphenidate	Atomoxetine	Condition Effect
Gender				
Male	26 (50.0%)	24 (49.0%)	22 (44.0%)	*p* = .751
Female	26 (50.0%)	23 (46.9%)	28 (56.0%)	
Education	2.87 (1.05)	2.91 (1.10)	2.58 (1.18)	*p* = .309
Income	3.23 (2.01)	2.49 (1.56)	2.94 (2.36)	*p* = .218
Age	24.35 (4.12)	23.68 (3.88)	23.08 (3.69)	*p* = .265

The Effect of Methylphenidate on Dishonesty was not Mediated by Mood, Attention, Impulsivity, Risk, or Self-interest

Methylphenidate administration resulted in a reduction of misreporting compared to the placebo condition. This effect might be attributable to a modulation of domain-general processes or specific processes related to dishonesty. Below, we examined each potential mechanism in detail.

Attention. Attention may play a crucial role in understanding the relationship between methylphenidate's effects on cognitive performance and dishonest behavior. Improved performance on the attention task indicates enhanced cognitive control, potentially attributed to the drug's neuromodulation effects on prefrontal control regions (Dockree et al., 2017; Pauls et al., 2012). Moreover, previous research has linked higher levels of cognitive control to reduced levels of dishonesty (Piquero et al., 2007). To explore these relationships, we conducted a regression analysis to predict dishonest behavior using response times in the attention task and drug condition as predictors. Consistent with prior studies, we found a relationship between response times in the attention task and dishonest behavior ($F(2,138) = 3.21$, $P = 0.040$). 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 ($F(1,95) = 4.63$, $P = 0.030$). These findings suggest that the effects of methylphenidate on attention and dishonesty operate independently of each other.

Mood. Mood is a relevant aspect to consider since methylphenidate have been associated with increased positive mood (Smith & Davis, 1977), which is a risk factor for potential drug abuse (Kollins et al., 2001). Moreover, positive mood has been linked to dishonest behavior (Siniver & Yaniv, 2019; Vincent et al., 2013). We assessed mood using a 16-item scale that measured participants' levels of energy (e.g., energetic, alert, clear-headed) and contentment (e.g., content, happy, relaxed). We found a significant main effect of drug condition on feelings of energy ($F1,138) = 4.53$, $P = 0.012$). Specifically, methylphenidate increased feelings of energy ($F(1,46) = 15.96$, $P < 0.001$), while neither the placebo condition ($F(1,48) = 0.23$, $P = 0.630$), nor the atomoxetine condition had an impact ($F(1,44) = 0.06$, $P = 0.860$). However, the drugs did not affect feelings of contentment ($F(1,138) = 0.0308$, $P = 0.735$). 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 ($F(1,97) = 5.708$, $P = 0.019$). These findings suggest that while methylphenidate may influence feelings of energy, which could be related to mood, its impact on dishonest behavior remains significant even after accounting for these mood-related effects. Thus, the reduction in misreporting observed with methylphenidate administration cannot be solely attributed to mood alterations.

Impulsivity. Impulsivity is closely associated with dishonest behavior, as individuals with a stronger preference for immediate rewards over delayed rewards tend to engage in more dishonest acts (e.g., criminal behavior (Åkerlund et al., 2016) or infidelity (Reimers et al., 2009)). Methylphenidate has been shown to reduce impulsive choices for small, immediate rewards in individuals with ADHD (Shiels et al., 2009) and those with a history of criminal behavior (Pietras et al., 2003). Hence, it is possible that methylphenidate reduces dishonesty by mitigating impulsivity.

To measure impulsivity, participants made a series of binary choices between receiving a larger reward at a later date or obtaining 120 tokens (£12) at an earlier date. We implemented three conditions: “today vs. in 3 months”, “today vs. in 6 months”, and “in 3 months vs. in 6 months.” For each condition, participants were given a list with 25 choices between the delayed payment and an earlier payment. Impulsivity was conceptualized as participants’ unwillingness to wait for a delayed (yet larger) reward. The responses in all three conditions correlated highly with each other (rs between 0.78 and 0.86) and were combined to create an overall impulsivity score. However, we did not observe a correlation between dishonest behavior and impulsivity score ($r(151) = r = -0.07$, $p = 0.410$). Furthermore, we did not find an main effect of drug conditions on impulsivity score ($H(2) = 0.008$, $P = 0.996$), or on time inconsistent behavior (difference between today/3months and 3months/6months scenarios) ($H(2) = 1.17$, $P = 0.557$). Importantly, when controlling for impulsivity, we still observed the effect of methylphenidate relative to placebo on dishonesty (controlling for impulsivity score: $F(1,92) = 5.016$, $P = 0.028$; “today vs. in 3 months”: $F(1,90) = 5.63$, $P = 0.020$; “today vs. in 6 months”: $F(1,90) = 4.59$, $P = 0.035$, “today vs. in 6 months”: $F(1,90) = 3.88$, $P = 0.050$; time-inconsistent behavior, $F(1,90) = 5.28$, $P = 0.024$). These results suggest that the effect of methylphenidate on dishonesty is not explained by changes in impulsivity.

Risk Preferences. Dishonest behavior carries inherent risks as the possibility of being caught and facing punishment exists. One potential mechanism through which methylphenidate may have reduced dishonest behavior is by decreasing participants’ risk tolerance. However, previous work mainly suggests that if anything, methylphenidate actually increases risk tolerance (Campbell-Meiklejohn et al., 2012)), while more recent work did not find an effect, albeit in regular methylphenidate users (Yechiam & Zeif, 2022). Moreover, in the current experiment, we did not expect a correlation between risk preferences and dishonest behavior because our die-rolling task was designed to eliminate the risk of detection. Nonetheless, we measured participants’ risk preferences by allowing them to chose between a risky payment and a certain payment (Falk, et al., 2016). The risky payment option was always the same, with a 50% chance of participants gaining 200 tokens (£20) and a 50% chance of gaining nothing, while the certain payment increased by 10 tokens on each trial.

We did not find a correlation between risk-taking behavior and dishonesty ($r(152) = 0.06$, $P = 0.410$). Additionally, we found no influence of the drug condition on risk-taking behavior ($H(2) = 2.63$, $P = 0.267$). Importantly, even after controlling for risk preferences, we still observed the effect of methylphenidate relative to placebo on dishonesty ($F(1,100) = 6.75$, $P = 0.010$). These findings indicate that the impact of methylphenidate on dishonesty cannot be attributed to changes in risk tolerance.

Material Self-Interest. Material self-interest is another factor that may have been influenced by methylphenidate, leading to a reduction in dishonesty. Dopaminergic activity has been associated with self-interest (Crockett et al., 2015; Pedroni et al., 2014), and previous research suggests a link between behavior in dictator games and increased cheating in other tasks (Maggian & Villeval, 2016; but see Kerschbamer et al., 2019). We measured participants’ self-interest using a dictator game. Participants were endowed with 200 tokens (£20) and had to decide how much money they wanted to donate to different charities (Red Cross, UNICEF, and Doctors Without Borders), presented in randomized order.

Consistent with previous findings, we found a positive correlation between selfish behavior in the dictator game (i.e., the amount of money kept) and participants’ earnings from the die-rolling task ($r = 0.218$, $P = 0.007$). However, we did not find any significant effect of drug condition on donation amounts ($F(1,144) = 0.16$, $P = 0.850$). Importantly, even after controlling for self-interest, we still observed the effect of methylphenidate relative to placebo on dishonesty ($F(1,100) = 6.60$, $P = 0.012$). These results suggest that the impact of methylphenidate on dishonesty cannot be attributed to changes in material self-interest.

In summary, the effects of methylphenidate on dishonesty cannot be accounted for by drug-induced alterations in attention, impulsivity, risk preference, or self-interest.

The effects methylphenidate on dishonesty cannot be explained by changes in participants' mood, heart rate, or blood pressure

We further investigated whether the effects of methylphenidate on dishonest behavior could be attributed to changes in heart rate or blood pressure (systolic and diastolic). However, none of these factors accounted for the drug's effect on dishonesty.

Heart rate and blood pressure. Regarding heart rate, we found a significant difference in measurements before and after the drug manipulation across conditions ($F(1,149) = 11.73$, $P < 0.001$). Specifically, methylphenidate increased participants' heart rate, while the other two conditions showed a decrease. Nevertheless, even after controlling for the effect on heart rate, we still found a significant effect of condition on dishonest behavior ($F(2,145) = 3.97$, $P = 0.021$). Similarly, condition had a significant impact on systolic ($F(2,149) = 7.198$, $P = 0.001$) and diastolic blood pressure ($F(2,149) = 4.318$, $P = 0.015$). However, even after controlling for these effects, we observed the effect of condition on dishonest behavior (systolic: $F(2,145) = 2.915$, $P = 0.057$, diastolic: $F(2,145) = 3.475$, $P = 0.030$).

Attitudes towards Dishonesty

At the end of the experiment, we measured participants' attitudes using five items adapted from the World Values Survey. These items gauged participants' views on various scenarios, including the justification of claiming government benefits to which one is not entitled. Attitudes were rated on a 10-point scale, ranging from 1 (never justifiable) to 10 (always justifiable). Overall, most participants expressed a negative attitude towards dishonesty, with a median score of 2.6, a mean score of 2.81, and a standard deviation of 1.38. Furthermore, we found a positive correlation between participants' dishonesty attitudes and their earnings from the die-rolling task ($r = .299$, $P < 0.001$). In other words, participants who believed that dishonesty is sometimes justifiable were more likely to engage in misreporting during the die-rolling task. However, we did not observe an effect of drug condition on dishonesty attitudes ($H(2) = 0.191$, $P = 0.909$). Neither methylphenidate nor atomoxetine influenced participants' attitudes, suggesting that these measures reflected participants' pre-existing and stable attitudes towards dishonesty.

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