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Objective: This study was designed to find out whether Adderall impairs creativity in healthy young adults.

Material and methods: In a double-blind placebo-controlled study, the effects of Adderall on the performance of 16 healthy young adults were measured on four tests of creativity from the psychological literature: two tasks requiring divergent thought and two requiring convergent thought.

Results: Adderall affected performance on the convergent tasks only, in one case enhancing it, particularly for lower performing individuals, and in the other case enhancing it for the lower-performing and impairing it for higher-performing individuals.

Conclusion: The preliminary evidence is inconsistent with the hypothesis that Adderall has an overall negative effect on creativity. Its effects on divergent creative thought cannot be inferred with confidence from this study because of the ambiguity of null results. Its effects on convergent creative thought appear to be dependent on the baseline creativity of the individual. Those in the higher range of the normal distribution may be unaffected or impaired, whereas those in the lower range of the normal distribution experience enhancement.

Keywords

cognition, creativity, adderall, amphetamine, neuroethics, enhancement

Comments

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Martha J. Farah · Caroline Haimm · Geena Sankoorikal · Anjan Chatterjee

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Keywords Cognition · Creativity · Adderall · Amphetamine · Neuroethics · Enhancement

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The past decade has seen a rise in the use of prescription stimulants by normal healthy individuals for cognitive enhancement. McCabe et al. (2005) estimated that 4% of American college students had used a stimulant for nonmedical purposes in the past year and found that on some campuses, the past year prevalence was a high as 25%. Hundreds of adult respondents to a Nature Magazine poll on cognitive enhancement reported using prescription stimulant medication for this purpose (Maher 2008).

The most commonly used stimulants for cognitive enhancement are Adderall (mixed amphetamine salts) and Ritalin (methylphenidate), both of which are typically prescribed for the treatment of attention deficit hyperactivity disorder. Their ability to enhance the cognition of normal healthy people has been demonstrated by a number of laboratory studies with tests of problem solving and executive function (e.g., Elliott et al. 1997).

The use of stimulant medication for cognitive enhancement by healthy individuals raises a number of ethical issues, which have become a focus of discussion and analysis in the neuroethics literature (e.g., Farah et al. 2004; Hyman 2006; Sahakian and Morein-Zamir 2007). These issues include safety, especially how a medication's risk-benefit ratio is changed when the benefit is enhancement rather than therapy. They also include the individual's freedom to enhance or not to enhance. The latter may be difficult to maintain when and if cognitive enhancement becomes so widespread that it is preferred or even expected

by schools and employers. Fairness is another issue raised any cognitive enhancement, as its advantages will undoubtedly be enjoyed disproportionately by the wealthy and well connected. Indeed, unequal access to cognitive enhancements may, over time, have a deleterious effect on society as a whole by further reducing mobility between socioeconomic classes and increasing stratification.

An issue that has yet to be addressed in the neuroethics literature is the effect of cognitive enhancement on what could be called "cognitive style". Do the prescription stimulants currently being used for enhancement influence the *way* people think? More specifically, do they enhance certain forms of thought at the expense of creativity? The impact of cognitive enhancement on the individual and on society more generally depends on the answer to this question. The societal effects could be particularly consequential. If cognitive enhancement continues to be more widely practiced and does decrease creativity, the effect on society as a whole could be grave. It would mean less creativity in our workforce and in our leaders.

Psychologists define creativity as the process of accessing seemingly irrelevant or unrelated information in ways that serve a purpose or solve a problem (Runco 2004). This suggests that a certain degree of distractability may be a requirement for creative thought, and the reports of some creative individuals are consistent with this. The mathematician Poincare, who is often quoted for his observations on mathematical creativity, emphasized the value of not focusing one's mind but letting it range widely. He described creativity as the discovery of "unsuspected kinship… between facts long known but wrongly believed to be strangers to one another", and he recounted his failure to solve a problem when he focused on it, only to have the solution come to mind later (Ackerman 2004). Charles Darwin attributed his insights in part to his tendency to notice irrelevant stimuli, which he was so unable to screen out that he required absolute silence to work (Kasof 1997). Research with ordinary people lends further support to the association of creativity with distractability (e.g., Ansburg and Hill 2003; Dykes and McGhie 1976; Finke et al. 1992; Kasof 1997; Martindale 1995; Rawlings 1985; Wallach 1970). For example, normal adults who scored highly on a battery of creativity tests showed more intrusion errors in a dichotic listening task (Dykes and McGhie 1976). Similarly, individuals with attention deficit hyperactivity disorder (ADHD) are often described as unfocused but creative (Palladino 1999), and a recent study of highly creative children found that 40% met criteria for ADHD (Healy and Rucklidge 2006).

There is a small literature on stimulant effects on creativity in ADHD, but the outcomes of the different studies are difficult to reconcile. Solanto and Wender (1989) found that methylphenidate enhanced the performance of children with ADHD on tests of creativity, although only with repeated testing, relative to the untreated children who apparently lost interest in the task. Funk et al. (1993) found no effect. Douglas et al. (1995) found that high doses of methylphenidate improved the performance of ADHD subjects on a test of creativity. Finally, Smartwood et al.(2003) found that methyphenidate impaired creativity in children with ADHD by one of their measures. In sum, there is no clear pattern in the literature on ADHD and stimulants regarding stimulant effects on creativity.

The goal of our study was to examine the effects of a widely used stimulant, Adderall (mixed amphetamine salts), on creativity in healthy young adults. In overview, we conducted a double-blind placebo-controlled study of the effects of Adderall on the performance of healthy young adults on four tests of creativity from the psychological literature. These tests were given as part of a larger battery of cognitive tests. In order to capture as broad a sample of creative thinking as possible, we administered two tasks requiring divergent thought and two requiring convergent thought, and within each of these pairs, one emphasizing verbal processes and responses and one emphasizing nonverbal processes and responses.

Material and methods

Participants Sixteen healthy adult subjects (four men, 12 women) between the ages of 21 and 30 (mean=21.25, SD=0.45) participated. Exclusion criteria included the following: history of neurological or psychiatric illness, history of epilepsy or seizure disorder, history of glaucoma, history of gastrointestinal blockage, history of heart disease, history of thyroid problems, or history of a diagnosed learning disability. Subjects were excluded if they were regular users of nicotine, cocaine, opiates, narcotic pain killers, tranquilizers, methamphetamine, or ecstasy (MDMA). Subjects who consumed more than 700 mg of caffeine per day were excluded from participation in the study. Furthermore, subjects who used warfarin, phenytoin, phenobarbitol, primidone, nortiptyline, amytryptyline, doxepin, desipramine, clomipramine, imipramine, fluoxetine, fluvoxamine, paroxetine, sertaline, clonidine, guanethidine, D-amphetamine, methylphenidate, and Wellbutrinin the past 14 days were not allowed to participate. We excluded women who were pregnant or likely to become pregnant and subjects who regularly used over-the-counter antihistamines like Claritin D-24 or Benadryl. Eligibility was determined based on a phone screening session. The small size of our sample precludes the investigation of gender effects in this study.

Procedure The data reported here were collected in two sessions of about 2.5 h, approximately 1 week apart,

scheduled to begin at the same time of day and beginning no later than 3:30 PM so that participants would be finished by no later than 6 PM. A separate 1-h session was scheduled on a different day prior to these sessions for the purpose of familiarizing participants with the tasks. Familiarization involved receiving the instructions and performing practice trials. Participants were instructed to avoid eating a heavy meal in the 3 h prior to testing. Visually indistinguishable pills containing 10 mg mixed amphetamine salts or inert ingredients were administered to the participants 30 min before the beginning of testing by a research assistant who was blind to pill identity. Half of the subjects received placebo first and half received amphetamine first. Two versions of each task, with different items, were used on the first and second day of testing, resulting in each task version being performed equally often by participants on amphetamine and placebo. Four tasks to assess creativity were administered in the same order for each subject: the Alternative Uses Task, the Remote Association Task, Group Embedded Figures Task, and the drawing task from the Abbreviated Torrance Test for Adults. The testing session also included other tasks unrelated to creativity, which are not described further here, and task order was rotated over participants. Two of the tasks (Remote Association and Alternative Uses) were performed at varying points in the session, between a 0.5 and 3 h after pill administration, with order matched between the placebo and drug sessions for a given participant. The other two tasks (Embedded Figures and Torrence) were performed at the end of the session by all participants, which is about 3 h after pill administration.

Remote Association Task This provides a measure of convergent creative thinking and insightful problem solving in the verbal domain (Mednick 1962). Participants were presented with three words at a time and asked to supply the one word that was associated with the other three words. Subjects had 1 min to complete each triad. Fifteen triads were presented in each session, counterbalanced with drug condition. An example of a triad is "manners", "round", and "tennis" (answer: "table").

Group Embedded Figures Task This nonverbal task requires participants to regroup the elements of a geometric design in ways that reveal the figures embedded in it and has been used as a test of convergent creative thinking (Noppe 1996; Witkin et al. 2002). An example is shown in Fig. 1. The original test of 18 items was divided into two sets of nine administered in sessions 1 and 2, and in the present study, participants outlined as many embedded figures as they could from one section in 3.5 m; set was counterbalanced with drug condition.

Alternative Uses Task This is a standard measure of divergent thinking, whose stimuli and responses are verbal. Following Guilford (1957), participants are given the name of an object and asked to come up with as many alternative uses as they can for the object within a specified time period; for this study, the period was 80 s. Participants were instructing with the help of an example: If given "tissue" as the object, an example of an appropriate alternative use would be a "blanket for a doll". They were told that the alternative use must make sense, so a response such as "eat as food" would not count. Three objects were named per session: shoe, button, and key in one session and brick, paperclip, and newspaper in the other. Session was counterbalanced with drug condition. The responses of the participants were recorded and scored by three independent judges, blind to condition, for originality, fluency, flexibility, and detail of the response according to the criteria of Guilford (1957).

Drawing task from the Abbreviated Torrance Test for Adults The Abbreviated Torrance Test for Adults is a standardized, abbreviated form of the Torrance Test of Creative Thinking (Goff 2002) used to assess divergent thinking. It includes two picture-drawing tasks and a single verbal task. In order to make within-subject comparisons, only the picture items were used, one in each testing session. Participants were given one of the pictures in Fig. 1 (counterbalanced with drug condition) and told "Use the incomplete figure below to make a picture. Try to make your picture unusual. Your picture should communicate as interesting and as complete a story as possible. Be sure to give your picture a title." They were given 90 s to carry this out. Scoring was done by three independent judges, blind to condition, according to the criteria of Torrance, with the exception that scores for the verbal section and for the relations between the two figures were omitted. Thus,

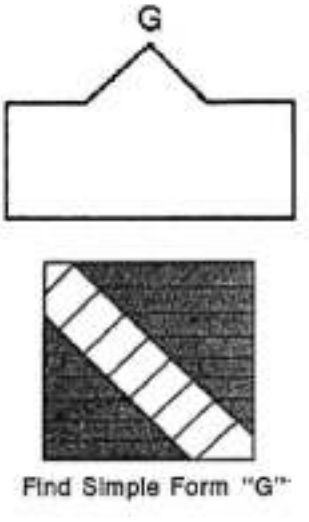

Fig. 1 Example of an item from the Embedded Figures Test

performance was scored according to norm-referenced measures (fluency, originality, elaboration, and flexibility) and criterion-referenced creativity indicators (openness, unusual visualization, movement, and/or sound, richness, and/or colorfulness of imagery, abstractness of title, context, synthesis of two or more figures, internal visual perspective, expressions of feelings and emotions, and fantasy; Goff 2002; Fig. 2).

In contrast to the convergent thinking tasks, which have objectively right and wrong answers, participants' responses to the two divergent thinking tasks must be evaluated by blind raters. Three undergraduate students, blind to condition, rated participants' productions in the Alternate Uses task and the drawing task from the Abbreviated Torrance Test according to the criteria described above. Their ratings have an intraclass correlation of 0.817 overall and were averaged for purposes of the analyses reported next.

Results

In overview, our data analysis consisted of outlier removal followed by matched pairs *t* tests and analyses of variance for the effect of Adderall on creativity in each of the four tasks and regression analyses to assess the effect of Adderall as a function of individual differences in creativity in the four tasks.

Outlier removal For each task, any participant whose performance fell more than 2.5 SD from the mean in the placebo or drug condition was eliminated from the analyses. Because the comparisons were within-subject, elimination of a participant's data from one session of a task, placebo, or drug resulted in the elimination of both sessions' data for that task from the analysis. There were just four outliers identified among the 128 subject-by-task-by-drug data points using these criteria; in other words, about 3% of the data were classified as outliers by our method. These occurred once for each task, equally often in Adderall and placebo sessions, and involved three different participants (i.e., one participant was an outlier in two tasks).

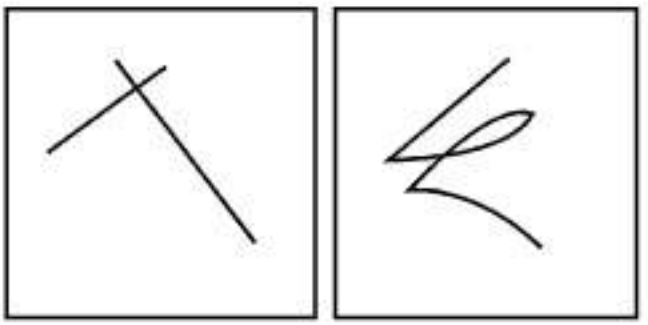

Fig. 2 Figures to be completed in the Abbreviated Torrance Test for Adults

Comparison of performance on Adderall and placebo Matched pairs *t* tests were carried out to assess the effects of Adderall on performance in the four creativity tasks. The hypotheses under consideration include facilitation of performance by Adderall, impairment of performance by Adderall, and no effect of Adderall. Because we do not have a directional prediction, reported *p* values are two-tailed.

We begin with the convergent thinking tasks. In the Remote Association Test, participants obtained on average 5.07 out of 15 correct in the placebo condition and 5.00 in the Adderall condition, $t(14)=0.120$, ns. In the Group Embedded Figures Task, participants identified 6.07 of nine shapes in the placebo condition and 7.13 in the Adderall condition, $t(14)=-2.477$, $p=0.027$. Turning to the divergent thinking tasks, in the Alternative Uses Task, participants' responses were scored 33.92 on average scored in the placebo condition and 33.45 in the Adderall condition, $t(14)=0.300$, ns. Finally, in the drawing task of the Abbreviated Torrance Test for Adults, participants' responses were rated 12.51 on average in the placebo condition and 13.44 in the Adderall condition, $t(14)=-1.019$, ns.

In sum, Adderall reliably affected performance on the Embedded Figures Task. On this measure, Adderall enhanced creativity; participants were reliably more able to discover embedded shapes that require distancing oneself from the most natural parse of a large pattern and recombining the elements of that pattern in a less obvious way. For the other three tests, average performance was similar between the placebo and Adderall conditions. The null results with these three tasks could indicate a true lack of effect of the drug on the creative thought processes tapped by these tasks or a lack of power in our experimental design. Power analysis suggests that with the sample size we used and power of 0.80, we would be able to detect only a relatively substantial effect of size 0.75, which is medium–large by Cohen's classification of effect sizes. The lack of drug effect on creativity in these three tasks should therefore be interpreted with caution. In contrast, the finding of statistically significant enhancement of creativity in one task can be interpreted with confidence as contradicting the hypothesis that Adderall diminishes creativity.

To examine the effects of drug along with those of session order, we carried out analyses of variance with drug (Adderall or placebo) as a within-subjects factor and order (Adderall first or placebo first) as a between-subjects factor. Recall that order was confounded with the specific items presented in each task: The first session test items were the same for all participants, regardless of whether they had taken Adderall or placebo, and the same was true for the

second session test items. Also relevant to the interpretation of order effects, on a different day prior to the first session, participants received task instructions and performed practice trials. Finally, order was a between-subjects factor, so incidental differences in the two groups of participants could manifest themselves as an "order" effect in this study. As with the t test, the ANOVA showed that the effect of drug was significant for only one task, Embedded Figures, $F(1, 13)=5.83$, $p=0.031$, all other tasks ns. There were no main effects of order and no interactions between drug and order with the exception of an interaction for the Remote Associates Test, $F(1, 13)=23.22$, $p<0.001$. Examination of the means indicates that the drug enhanced performance for those who took it second (from 4.00 to 5.70 correct on average), whereas it impaired performance for those who took it first (from 6.00 to 4.38 on average).

Individual differences in drug effect Given the finding that Adderall enhanced performance in one creativity task, the next set of statistical analyses tested the possibility that Adderall may affect performance differently in different subjects, depending on their baseline or placebo level of performance. The dependence of a drug effect on participant level of ability can entirely mask the effect of the drug when the whole sample of participants is considered together. This was first observed by Kimberg et al. (1997) with the dopamine agonist bromocriptine. Their sample's mean performance on an executive function battery was numerically almost identical on drug and placebo, similar to the findings with three of the tasks in this study. However, after a median split on working memory span, it was found that the lower half of the participants improved significantly on the drug and the upper half declined by the same amount. A similar, though less extreme, pattern has been found in studies of the effects of methylphenidate and amphetamine on executive functions, including working memory (Mattay et al. 2000, 2003; Mehta et al. 2000) and inhibitory control (DeWit et al. 2002). In these studies, participants who performed worst on placebo tended to improve the most with stimulant medication, whereas those who performed best tended to show less improvement or even show worse performance with the stimulant.

To determine whether Adderall has an enhancing effect on creativity for the less creative participants that declines or even reverses for the more creative participants, we performed a regression analysis. The dependent measure was drug effect, that is, the difference in performance between placebo and Adderall. The independent or predictor variables were the participants' performance on placebo and the order in which they performed two conditions (placebo first or Adderall first). The former is a measure of the participant's baseline ability level. Given the findings just cited of greater enhancement for lower-performing individuals, the prediction tested by the regression is that lower placebo performance will be associated with larger drug effects, and the p values are accordingly one-tailed.

Placebo performance predicted the size of the drug effect in both of the convergent thinking tests, $p<0.001$ for the Remote Associates Test and $p=0.003$ for the Embedded Figures Test. In each case, the direction of the relationship was as predicted: larger enhancement effects for lower-performing individuals. The two divergent thinking tests did not show this pattern. For the Alternative Uses Task, the drug effect was not significantly predicted by placebo performance, $p=0.142$, and the drawing task showed a borderline trend, $p=0.082$, but in the other direction (more enhancement for better performing participants). Consistent with the results of the earlier ANOVA, the Remote Associates Test also showed a significant order effect, with larger drug effects for participants who received Adderall in the first session, $p=0.002$.

A problem with these analyses is that the dependence of drug effect on placebo performance could reflect regression toward the mean. That is, to the extent that there is measurement error in the data, participants who scored well in the placebo condition would be expected to score less well on average in a different session, and participants who scored poorly in the placebo condition would be expected to score somewhat better on average in a different session. The ideal way to assess the effect of a participant's baseline ability on the drug effect would be to have a second measure of placebo performance so that the measure used as the predictor variable is not the one used to calculate the drug effect. Unfortunately, we did not collect second placebo measures with our participants. A second-best solution is to replace placebo performance as a predictor variable with the average of placebo and Adderall performance. To the extent that the drug effect is indeed larger for participants with lower placebo performance, the use of a placebo–Adderall average will bias the results against finding the hypothesized effect. However, at least this method of testing is at least not biased in favor of finding the effect.

We reanalyzed the data from the two convergent thinking tests using the average of placebo and Adderall performance as the estimate of participants' baseline level of creativity, along with session order as before. Despite the bias in this analysis against finding an effect of baseline on drug effect, the relationship remained significant for the Remote Associates Test, $p=0.027$. For the Embedded Figures Test, which showed an overall significant enhancement with Adderall, the trend for greater enhancement for lower-performing subjects was borderline significant, $p=0.086$. Figure 3 shows the performance of participants whose average placebo–Adderall performance level fell above the median (left) and below the median (right) in the

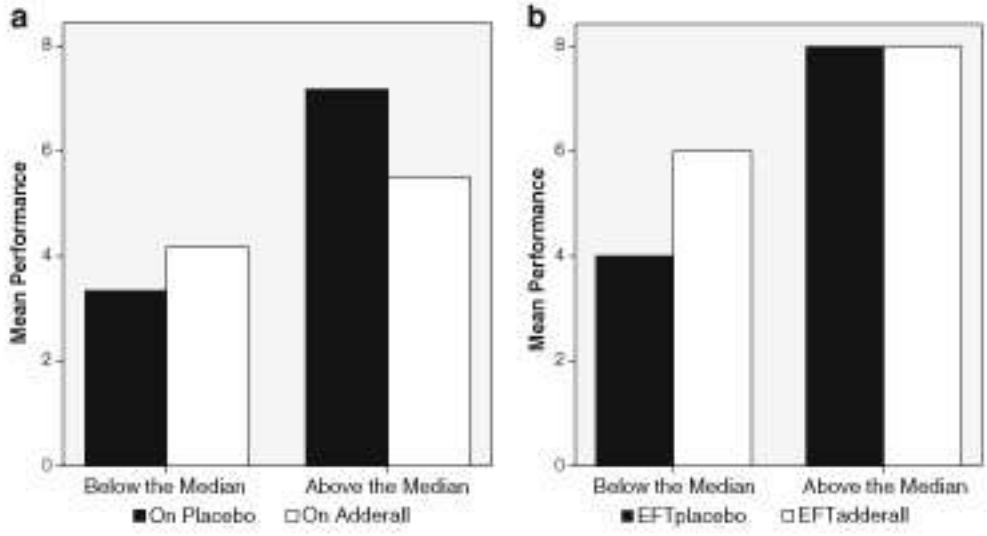

Fig. 3 Mean performance of participants whose overall performance was below or above the median (of the mean of placebo and Adderall conditions) on placebo (*black*) and on Adderall (*white*) in the **a** Remote Associates Test and the **b** Embedded Figures Test. Conventional error bars are not shown because placebo–Adderall comparisons are within-subject

placebo and Adderall conditions of the Remote Associates and Embedded Figures Tasks.

Discussion

Does cognitive enhancement with Adderall impair creativity? In this preliminary exploration of the issue, using four different tests of creative ability in healthy young adults, we found no evidence of a general impairment. On the contrary, Adderall enhanced performance on one test of convergent creative thought. For this test, the Embedded Figures Test, there was also a trend toward disproportionate enhancement of the lower-performing participants. For another test of convergent creative thought, the Remote Associates Test, Adderall also affected performance, although the direction of the effect depended on the creativity of the participant; the drug enhanced creativity for the lower-performing participants and impaired it for the higher-performing participants. This pattern has been noted in other studies of stimulants and cognition and is not unique to creative thought (DeWit et al. 2002; Mattay et al. 2000, 2003; Mehta et al. 2000).

These results are reassuring in view of the increasing number of healthy people using stimulant medications to enhance cognition. They suggest that healthy individuals seeking to enhance their cognitive abilities with Adderall are not necessarily impairing their creativity. However, just as stimulants may impede high ability individuals in other cognitive tasks, Adderall may impair rather than enhance the creativity of highly creative individuals, judging from the results of the Remote Association Task.

The present study assessed creativity using four different tasks, including verbal and nonverbal tests of convergent and divergent creative thought. Adderall was found to affect performance on the convergent tasks only. Although this may reflect a fundamental difference between the effects of Adderall on convergent and divergent thought, it may also reflect differences in the sensitivity of the tasks. By their nature, convergent thinking tasks have objective right answers, whereas the success of divergent thinking is a more subjective matter and must be measured by the ratings of others. Although our inter-rater reliability was good, it was not perfect, and this would make the divergent tasks weaker instruments for measuring drug effects on creativity than the convergent tasks.

Other aspects of the design that would be expected to influence the sensitivity of the experiment include sample size, test length, dosage, and dose timing. Although a sample of 16 participants is comparable in size to some samples used to demonstrate effects of stimulant medications on healthy participants (e.g., Mehta et al. 2000), there is no doubt that a larger sample would confer more power on the study. Tests with more items for each task would also have a beneficial effect on the sensitivity of the research. Although the dose we used, 10 mg, is a commonly used dose for therapeutic and research purposes (e.g., de Wit et al. 2002), many studies have used higher doses, and a higher dose in the present study might have led to different results. Finally, although two of the tasks were administered approximately 3 h after pill administration when plasma levels of the drug would be high (the Torrance test and the Embedded Figures test), the timing of two others varied over participants, with some performing them as early as 0.5 h after pill administration when the drug effects would have been just onsetting (the Alternative Uses Task and the Remote Association task). Taken together, these considerations suggest that the effects of Adderall on creativity may well have been underestimated by the present study. Nevertheless, the findings of reliable enhancement effects of Adderall in one task and ability-dependent effects in another task tell us that the answer to the title question is not a simple "yes". The neuroethical worry that widespread

stimulant use could create a general downward shift in the creativity of the population is assuaged by the present results.

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