A Critique of "Persistent Cannabis Users Show Neuropsychological Decline from Childhood to Midlife" (Meier Et. Al.)

by

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The most often repeated sound byte from this 2012 publication is that if you smoke marijuana as an adolescent, then your IQ will drop 8 points by the time you are 38. Before I respond to this, let me say two things. First, even if smoking marijuana as a teenager doesn't permanently impair your IQ, there are still many, many reasons not to be imbibing at that time except for those with a medical condition that requires cannabis. In general, our brains are undergoing rapid development during our teenage years, and this is a time for developing mental discipline, mathematical skills, writing skills, and a variety of other skills that will serve us for the rest of our life. This is not a good time to be frequently intoxicated on anything. And second, I don't necessarily completely discount the findings of this article. I do, however, have problems with some of the analysis, and that is what I want to talk about.

Meier et. al. used data from the Dunedin Study, a prospective study of 1,037 individuals in New Zealand that were followed from birth to age 38, in order to study the effect of cannabis on IQ. Below is Table 1 from that study.

Table 1. IQ before and after cannabis use

	N	% male	Age 7–13 full-scale IQ	Age 38 full-scale IQ	Δ IQ effect size*
Persistence of cannabis dependence					
Never used, never diagnosed	242	38.84	99.84 (14.39)	100.64 (15.25)	0.05
Used, never diagnosed	479	49.48	102.32 (13.34)	101.25 (14.70)	−0.07
1 diagnosis	80	70.00	96.40 (14.31)	94.78 (14.54)	−0.11
2 diagnoses	35	62.86	102.14 (17.08)	99.67 (16.11)	−0.17
3+ diagnoses	38	81.58	99.68 (13.53)	93.93 (13.32)	−0.38
Persistence of regular cannabis use					
Never used	242	38.84	99.84 (14.39)	100.64 (15.25)	0.05
Used, never regularly	508	50.59	102.27 (13.59)	101.24 (14.81)	−0.07
Used regularly at 1 wave	47	72.34	101.42 (14.41)	98.45 (14.89)	−0.20
Used regularly at 2 waves	36	63.89	95.28 (10.74)	93.26 (11.44)	−0.13
Used regularly at 3+ waves	41	78.05	96.00 (16.06)	90.77 (13.88)	−0.35

Means (SDs) are presented for child and adult full-scale IQ as a function of the number of study waves between ages 18 y and 38 y for which study members met criteria for cannabis dependence or reported using cannabis on a regular basis (at least 4 d/wk). The last column shows that study members with more persistent cannabis use showed greater IQ decline from childhood to adulthood.
*This coefficient indicates change in IQ from childhood to adulthood, with negative values indicating decreases in IQ. These change scores are in SD units, with values of 0.20, 0.50, and 0.80 reflecting small, medium, and large changes, respectively.

This table is meant to illustrate the magnitude of the effect of smoking marijuana on IQ as one progresses from adolescence to age 38. In the top half of the table, we see the results for people who were diagnosed as cannabis dependent 1, 2, or 3 or more times, and in the bottom half we see the results for those who were identified as regular users 1, 2, or 3 or more times. A regular user, in this study, is defined as someone who uses cannabis at least 4 days per week.

The one obvious thing that is missing from this table, however, is any sort of statistical analysis to determine if the differences between the before and after means are statistically significant. The usual test that would be done in this situation is a dependent t-test or repeated measures ANOVA that would examine the average difference between before and after IQs and then test to see if that difference is significantly different from zero. However, since that test is not done in this paper, we can only assume that the researchers tried it and found no significant differences. Unfortunately, while it is often important to know that something doesn't result in a significant difference, when it comes to publishing, results like that just aren't as sexy. Nonetheless, we can take the data that is given in the table and do independent t-tests to see if anything significant pops up. In an independent t-test we look at the means of the two groups and try to determine if the differences between the two group means are significant or not, and while it would

certainly be better to do the dependent t-test, that doesn't mean that the results of an independent t-test are in any way invalid. Below is a table showing the results.

	N	Mean(SD) Age 7-13	Mean(SD) Age 38	p-value
Cannabis Dependence				
never used	242	99.84(14.39)	100.64(15.25)	p=0.5531
used, never diagnosed	479	102.32(13.34)	101.25(14.70)	p=0.2384
1 diagnosis	80	96.40(14.31)	94.78(14.54)	p=0.4786
2diagnoses	35	102.14(17.08)	99.67(16.11)	p=0.5358
3+ diagnoses	38	99.68(13.53)	93.93(13.32)	p=0.0659
Regular Cannabis Use				
never used	242	99.84(14.39)	100.64(15.25)	p=0.5531
used, never regularly	508	102.27(13.59)	101.24(14.81)	p=0.2484
regulary use at 1 check	47	101.42(14.41)	98.45(14.89)	p=0.3284
regular use at 2 checks	36	95.28(10.74)	93.26(11.44)	p=0.4425
regular use at 3+ checks	41	96.00(16.06)	90.77(13.88)	p=0.1187

For each separate row, I have sought to determine if the mean of the first group is significantly different from the mean of the second group, and you can see that at the 0.05 level of significance nothing unusual is going on. In other words, all the differences observed between mean IQs at age 7-13 and again at age 38, could be due to mere chance!

The next item I examine from this published research is Table 2 where the authors argue that the level of observed decline in IQ is dependent upon the amount of cannabis consumed.

Table 2. IQ subtest changes

IQ test/subtest	Never used, never diagnosed, *n* = 242	Used, never diagnosed, *n* = 479	1 diagnosis, *n* = 80	2 diagnoses, *n* = 35	3+ diagnoses, *n* = 38	Linear trend *t* test*	*P*
Full-scale IQ	0.05	−0.07	−0.11	−0.17	−0.38	−4.45	<0.0001
Verbal IQ	0.02	−0.05	−0.13	−0.19	−0.31	−4.15	<0.0001
Information subtest	0.05	−0.08	0.02	−0.25	−0.15	−2.40	0.0168
Similarities subtest	0.03	−0.05	−0.03	−0.19	−0.44	−2.78	0.0056
Vocabulary subtest	0.07	−0.05	−0.16	−0.16	−0.45	−3.67	0.0003
Arithmetic subtest	−0.05	−0.07	−0.05	0.00	0.06	−0.73	0.47
Performance IQ	0.08	−0.08	−0.09	−0.08	−0.42	−2.84	0.0046
Digit symbol coding subtest	0.15	−0.09	−0.17	−0.23	−0.62	−5.60	<0.0001
Block design subtest	−0.03	−0.07	−0.01	−0.11	0.02	−0.55	0.58
Picture completion subtest	−0.01	−0.08	0.08	0.05	0.15	1.18	0.24

Mean change in IQ subtest scores from childhood to adulthood is presented in SD units as a function of the number of study waves between ages 18 y and 38 y for which a study member met criteria for cannabis dependence. These change scores can be interpreted as effect sizes, with values of 0.20, 0.50, and 0.80 reflecting small, medium, and large effects, respectively. Persistent cannabis dependence was associated with IQ decline for the majority of IQ subtests administered in both childhood and adulthood, i.e., when each study member served as his or her own control.

*To test for a dose–response effect, we conducted an ordinary least-squares regression, estimating the linear trend controlling for sex.

The authors have used a linear trend t-test to show that, in many instances, the linear correlation coefficients are significantly different from zero, and, unfortunately, this is probably the most abused test in all of statistics! To illustrate, recall that the linear coefficient of correlation simply measures the strength of a linear relationship and also whether the output variable tends to increase or decrease with respect to the input variable. However, if we have determined that a correlation coefficient is significantly different from zero, that still doesn't mean that it is strong enough to be meaningful. For example, suppose at the end of the semester that a student has a test average of 1 out of 100. That average is still different from zero, but that's not saying very much! Unfortunately, our authors left out both the linear correlation coefficients from this table and the corresponding regression equations. That is unfortunate as that is information that people with a serious interest in this subject would like to know. However, it is possible to either recapture the correlation coefficients from the data given by using the formula for computing *r* or to simply contact the authors. I did both, and both methods led to the same result. Below is the revised Table 2 showing the correlation coefficients *r*.

Table 2. IQ subtest changes. This table presents mean change in IQ subtest scores from childhood to adulthood in standard deviation units as a function of the number of study waves between ages 18-38 years for which a study member met criteria for cannabis dependence. This table shows that persistent cannabis dependence was associated with IQ decline for the majority of IQ subtests administered in both childhood and adulthood, i.e., when each study member served as his/her own control.

IQ Test/Subtest	Never Used, Never Diagnosed (N=242)	Used, Never Diagnosed (N=479)	1 Diagnosis (N=80)	2 Diagnoses (N=35)	3+ Diagnoses (N=38)	Linear trend r	Linear trend t-test[a]	Linear trend p
Full Scale IQ	0.05	-0.07	-0.11	-0.17	-0.38	-0.15	-4.45	<.0001
Verbal IQ	0.02	-0.05	-0.13	-0.19	-0.31	-0.14	-4.15	<.0001
Information Subtest	0.05	-0.08	0.02	-0.25	-0.15	-0.08	-2.40	.0168
Similarities Subtest	0.03	-0.05	-0.03	-0.19	-0.44	-0.10	-2.78	.0056
Vocabulary Subtest	0.07	-0.05	-0.16	-0.16	-0.45	-0.12	-3.67	.0003
Arithmetic Subtest	-0.05	-0.07	-0.05	0.00	0.06	-0.02	-0.73	.47
Performance IQ	0.08	-0.08	-0.09	-0.08	-0.42	-0.10	-2.84	.0046
Digit Symbol Coding Subtest	0.15	-0.09	-0.17	-0.23	-0.62	-0.19	-5.60	<.0001
Block Design Subtest	-0.03	-0.07	-0.01	-0.11	0.02	-0.02	-0.55	.58

What we see in this table is that in each instance where we have a result that is significant at the 0.05 level of significance, the linear correlation coefficient is very weak. For

instance, for the full scale IQ test the correlation coefficient is r = -0.15. This means that the coefficient of determination is the square of -0.15 or 0.0225 = 2.25%. What this means, in turn, is that only 2.25% of the variability in IQ is determined by the amount of marijuana used, and that is not very much at all. A full 97.75% of the variability is due to other factors, and, thus, the situation is not as simple as this research paper would lead us to believe. While there may be a slight downward trend in IQ over time as cannabis use increases, it is not at all a certainty that if someone consumes large amounts of cannabis that their IQ will decrease over time. Because the correlation coefficient is so weak, many people with heavier cannabis use may actually see their IQ increase over time while others will, indeed, experience a decline. But the point is that it's a weak correlation, and our predictive power of IQ as a function of dose is very poor. Furthermore, the result that, in most instances, our correlation coefficient is significantly different from zero is also questionable. This is because, for this test, sample size is a confounding variable and the sample size in this study is quite large (N = 874). To summarize, (1) having a correlation coefficient significantly different from zero doesn't mean that you have a correlation that is very meaningful, (2) our correlations are, in fact, very weak, and (3) in those cases where we do have a correlation significantly different from zero, that may actually be just a consequence of our sample size and nothing more. Cannabis may, indeed, play a role in these declines, but based upon the coefficient of determination, only a small role.

Related to the above discussion is Table 4 where a similar regression analysis is shown for the decline in IQ for those with a high school education or less.

Table 4. IQ decline after holding education constant

Sample	Never used, never diagnosed	Used, never diagnosed	1 diagnosis	2 diagnoses	3+ diagnoses	Linear trend *t* test*	*P*
Full sample	0.05 (n = 242)	−0.07 (n = 479)	−0.11 (n = 80)	−0.17 (n = 35)	−0.38 (n = 38)	−4.45	<0.0001
High-school education or less	−0.03 (n = 59)	−0.14 (n = 130)	−0.16 (n = 43)	−0.25 (n = 20)	−0.48 (n = 26)	−3.36	0.0009

Mean change in full-scale IQ from childhood to adulthood is presented in SD units as a function of the number of study waves between ages 18 y and 38 y for which a study member met criteria for cannabis dependence. These change scores can be interpreted as effect sizes, with values of 0.20, 0.50, and 0.80 reflecting small, medium, and large effects, respectively. Change scores are presented for the full sample and for the sample of study members with a high-school education or less. Persistent cannabis dependence was associated with IQ decline in the full sample and the sample of study members with a high-school education or less.

*To test for a dose–response effect, we conducted an ordinary least-squares regression, estimating the linear trend controlling for sex.

In this case we can begin with the formula $t = \frac{r}{\sqrt{\frac{1-r^2}{n-2}}}$, solve it for r^2 to obtain $r^2 = \frac{t^2}{n-2+t^2}$, and then conclude that for those with a high school education or less we have $r = -.198$. This is still a fairly weak correlation, and my remarks on Table 2 apply to this situation as well. The predictive relationship between marijuana use and IQ is still low even if it is significantly different from zero.

Figure 1 in this study illustrates some other problems with the analysis.

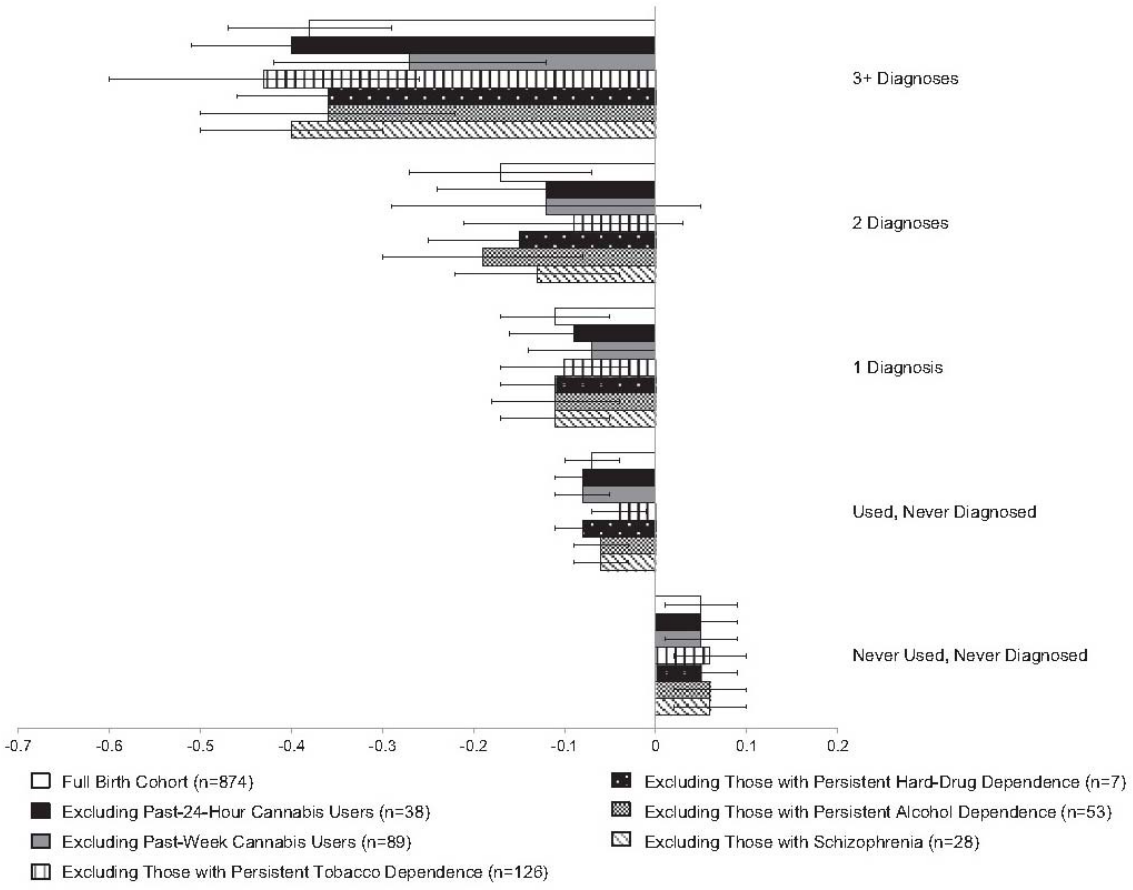

Fig. 1. Ruling out alternative explanations. Shown is change in full-scale IQ (in SD units) from childhood to adulthood as a function of the number of study waves between ages 18 y and 38 y for which a study member met criteria for cannabis dependence. Change scores are presented for the full birth cohort and the cohort excluding (*i*) past 24-h cannabis users, (*ii*) past-week cannabis users, (*iii*) those with persistent tobacco dependence, (*iv*) those with persistent hard-drug dependence, (*v*) those with persistent alcohol dependence, and (*vi*) those with lifetime schizophrenia. Persistent tobacco, hard-drug, and alcohol dependence were each defined as dependence at three or more study waves. IQ decline could not be explained by other factors. Error bars = SEs.

In this chart, the authors wish to show that the effects on IQ persist even after removing one potential confounding variable at a time. However, here is the problem. Suppose we consider both alcohol and tobacco to be poisons (and indeed they are!). Then if we remove those who use alcohol from our sample, but leave those who use tobacco in the sample, then the people in the sample are still poisoned! The same problem occurs if we remove those who use tobacco, but leave in those using alcohol. In other words, as long as at least one poisonous substance is left in the sample, we can't conclude that the poisoning is due to cannabis. Similarly, by removing only one potentially confounding variable at a time from our sample, we can't conclude with certainty that marijuana use is the cause of the decline in IQ. Nonetheless, I can understand why the authors might be removing only one variable at a time. Recall that there are only 38 people in this study who were diagnosed as dependent on cannabis 3 or more times. This cannabis dependent group is already pretty small in size, and if we simultaneously exclude those who are schizophrenic, use alcohol or tobacco or hard drugs, and those who have used cannabis in either the past 24 hours or the past week, then there might be so few left that we would be looking only at the results of a few individuals rather than something that could be reliably extrapolated to larger groups. Hence, it is not surprising that they removed only one variable at a time, but a consequence of that decision is that the results still aren't very meaningful. We still don't know if the decline in IQ is due to cannabis or to one of the other variables left in the study.

There are two other problems that I see with the analysis in Figure 1. The first involves the variables "excluding past-24 hour cannabis users" and "excluding past-week cannabis users." The problem with these is that THC from cannabis is fat soluble and can stay within one's system up to 30 days, and past studies by Harvard Professor Harrison Pope[1] have indicated that IQ doesn't return to its peak until after a full month of cannabis abstinence has passed. The other problem I have with Figure 1 has to do with what is not reported. In particular, the horizontal axis indicates change in terms of standard deviations, but not actual IQ points gained or lost. Now I fully understand the use of standard deviations as a measure of effect size, but at the same time the reality is that our

[1] "Neuropsychological Performance in Long-term Cannabis Users" (*Pope et. al.*)

brains are able to more readily grasp information on a simple numerical change in IQ points, and that is also the information that we are most interested in seeing! The other item of information that is unfortunately not reported is the sample size associated with each particular bar in the graph in Figure 1. This is important to know because if a bar in this graph, for instance, represents only two people, then we know that we are looking only at the results of individuals and not those of a group that is large enough to provide meaningful extrapolation to a larger population.

Next, let's take a look at Figure 2.

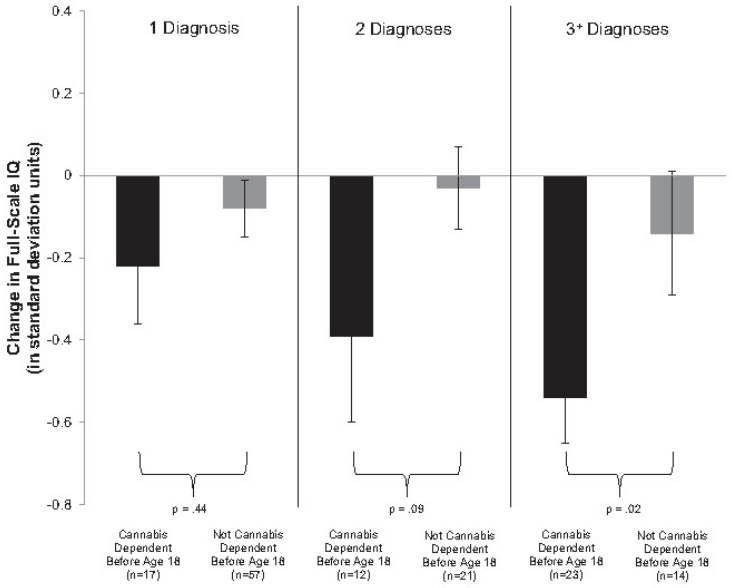

Fig. 2. Adolescent vulnerability. Shown is change in full-scale IQ (in SD units) from childhood to adulthood among study members with 1, 2, or 3+ diagnoses of cannabis dependence as a function of age of onset of cannabis dependence. Individuals with adolescent-onset cannabis dependence (black bars) experienced greater IQ decline than individuals with adult-onset cannabis dependence (gray bars). IQ decline of approximately –0.55 SD units among individuals with adolescent-onset cannabis dependence in the 3+ group represents a decline of 8 IQ points. Error bars = SEs.

This is the table that has led to the often repeated statement that using cannabis as an adolescent will result in your IQ decreasing by 8 points by the time you are 38. However, let's look at what the data actually says and what the limitations of that data are. Thus, if we look above at the results for those participants who received 3 or more diagnoses of cannabis dependence, we see that those who were diagnosed as cannabis dependent before the age of 18 lost approximately 8 IQ points by the time they were 38, and those that were not cannabis dependent before the age of 18 appear to have lost considerably fewer IQ points. The differences between the two groups are stated to be significant at

the 0.05 level with $p = 0.02$. Unfortunately, once again information has been left out that would have been nice to know. For example, it would have been nice if the authors had reported, for greater clarity, actual IQ changes along with the standard deviation units, and it would have been good to include the linear coefficient of correlation and, particular, the linear regression equation. I'm curious to know if the regression equation predicts a loss of 8 IQ points. However, what is given is the sample size, and that, in itself, is very telling. For example, for the group that lost approximately 8 IQ points, the sample size is 23, and that is not very large at all. In other words, it's as if I had a statistics class of size 23 and then declared that whatever grade distribution was observed at the end of the semester is going to be approximately the same for all statistics students around the world! Common sense tells us that it is not a good idea to extrapolate from a grade distribution for only 23 students and expect that all students around the world will perform the same, and, likewise, common sense should tell us that the sample size in this IQ study is also too small to allow any meaningful extrapolation to larger groups. In other words, because of the smallness of the sample, we may be looking more at the results of particular individuals than we are at meaningful aggregate behavior.

And finally, let's look at Figure 3. The authors of this study make the claim that the effects of this decline in IQ do not reverse themselves once the participants quit using cannabis, but that doesn't seem to be what their data actually shows. In the left-side of Figure 3 we are shown bar graphs of child and adult IQs for both those who used cannabis frequently at age 38 and those who used cannabis infrequently at age 38. Notice that we are not looking at a group that has definitely quit using cannabis by age 38. Instead, infrequent use is defined as once weekly or less, and that is the problem. Other studies have shown that in order to achieve maximum results on an IQ test, one should abstain from cannabis for at least a month (see my previous footnote). Consequently, the differences in IQ noted in this figure may not be permanent reductions in IQ after all.

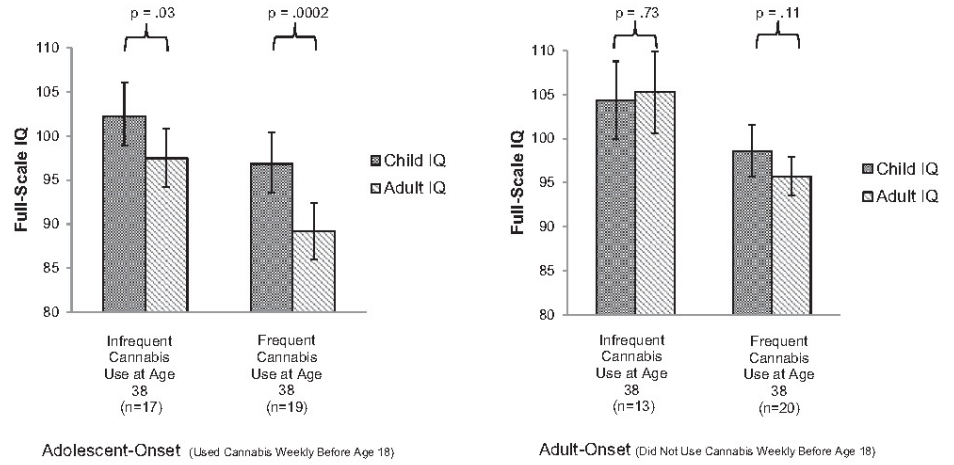

Fig. 3. Postcessation IQ among former persistent cannabis users. This figure is restricted to persistent cannabis users, defined as study members with two or more diagnoses of cannabis dependence. Shown is full-scale IQ in childhood and adulthood. IQ is plotted as a function of (*i*) age of onset of at least weekly cannabis use and (*ii*) the frequency of cannabis use at age 38 y. Infrequent use was defined as weekly or less frequent use in the year preceding testing at age 38 y. Median use among infrequent and frequent adolescent-onset cannabis users was 14 (range: 0–52) and 365 (range: 100–365) d, respectively. Median use among infrequent and frequent adult-onset cannabis users was 6 (range: 0–52) and 365 (range: 100–365) d, respectively. IQ decline was apparent even after cessation of cannabis use for adolescent-onset former persistent cannabis users. Error bars = SEs.

Personally, it wouldn't surprise me if heavy use of cannabis beginning before age 18 does impact IQ either directly or indirectly. However, I seriously doubt the neurotoxicity hypothesis that the authors suggest at the beginning of their paper because when something is quite toxic, it generally affects everyone pretty much the same way. However, the weakness of the linear correlation coefficient that we saw earlier tells us that the level of cannabis use is definitely not affecting everyone's IQ the same way. Thus, while I would say that this 2012 study does present some interesting smoke, I still haven't seen any fire.

And finally, one must also look at the results of other research that has been done on marijuana and IQ, even though comparisons are sometimes difficult because the studies are rarely designed in exactly the same way. However, with that caveat in mind, here are some of those results. Fried et. al. ("Current and former marijuana use: preliminary findings of a longitudinal study of effects on IQ in young adults") reported a decrease in IQ of 4.1 IQ points among heavy users (5 or more joints per week), but also an increase of 5.8 IQ points among light users (less than five joints per week). This is interesting to me in light of a study by Filbey et. al. ("Long-term effects of marijuana use on the brain") that showed that marijuana users had "higher functional connectivity in the orbitofrontal cortex (OFC) network, and higher structural connectivity in tracts that innervate the OFC

(forceps minor) as measured by fractional anisotropy (FA)." This makes me wonder if light/moderate cannabis use might cause some brain rewiring that results in a greater creativity that also ultimately translates into a higher IQ. In another study, Harvard Professor Harrison Pope (again, see my previous footnote) examined "180 people, 63 of them heavy users who currently smoked pot daily, 45 former heavy users, and 72 who had used the drug no more than 50 times in their lives. Heavy use was defined as smoking pot at least 5,000 times." Each group took a battery of tests 0, 1, 7, and 28 days after quitting cannabis, and by the 28th day "there were no significant differences among the groups on any of 10 different tests, and no significant association between cumulative lifetime marijuana use and test scores." The resulting conclusion was that heavy marijuana use produced no irreversible damage to the brain. Similarly, a 2014 study in the United Kingdom using data on 2,612 children from the Avon Longitudinal Study of Parents and Children found no association between marijuana use and IQ, though it did note that heavy use resulted in lower academic achievement. Additionally, that study found that when an association between marijuana and IQ was present, it could be accounted for by other behaviors such as alcohol or tobacco use. The bottom line, though, is that there are variety of studies that have been done on marijuana and IQ, and they sometimes give conflicting results. This illustrates both that the relationship between our variables is not as simple as one would wish and that there is a need for greater study. In the meantime, while most people agree that it is not a good idea for teenagers to be using recreational marijuana (or alcohol or tobacco), it is not a forgone conclusion that early use will automatically subtract 8 points from your IQ, and those who have been repeating for political purposes this distortion of the data should stop doing so immediately.