PLOS Science Wednesday: Hi reddit, my name is Hector and my research shows computation is a sophisticated method for studying human cognition and behavior, also that behavioral complexity peaks at age 25 – Ask Me Anything!

PLOSScienceWednesday [1] and r/Science AMAs[1]

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REDDIT

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If human behavioural complexity peaks at 25 does it decline immediately or does it remain at peak for several years?

If it declines immediately how quick is it? For example at what age is behavioral complexity roughly equivalent to a 16 year old again?

davios

There are 2 important factors here to take into consideration:

1. The variation between ages is very small, it may look large in the paper plot, but this is an artifact for visualization purposes (our aim was to illustrate the differences and not the similarities).
2. We show in the paper that 'behavioural complexity', as measured by the human ability to produce algorithmic randomness, peaks at 25 but remains quite high until 60 years old (relative to 25 years old and relative to the absolute maximum randomness for the fixed size of the objects evaluated). Then at 60 years old there is a much stronger decline, but we have to still consider, again, that the variation is small. So it only means that the effect is noticeable but not dramatic. When you are 16 years old, you reach the same 'behavioural complexity', according to the plots in our paper, at about age 65. That is an interesting question and you would need to draw an horizontal line over our random task plots and place it at 16 to see to what older age it corresponds! =)

What is meant specifically by 'behavioral complexity'?

ironywasamistake

Hi! I am Hector Zenil and I am very excited to be here at a Science AMA. Thanks for the invitation to PLOS Science and reddit Science, and to all of you for coming.

It is great to see this question on top as it is at the heart of our paper and research. Behavioural complexity was measured, in this paper, by algorithmic complexity. Algorithmic complexity is the

accepted mathematical definition of randomness, and unlike statistical randomness, it can quantify more than simple statistical patterns. Indeed, what measures such as Shannon Entropy or Entropy rate do is to look for repetitions in data, but humans (and possibly animals to some extent) do not only care about repetitions. Take the sequence 1234567... We know it is not random, yet any statistical tool will find no pattern (the sequence has actually been proven to never repeat in a fundamental mathematical way), yet this sequence is highly algorithmic in the sense that it can be described by a short mathematical formula or computer program (x=1, f(x) = x+1). This kind of complexity is very difficult to measure and most people have used lossless compression algorithms in the past without realizing that lossless compression algorithms are Entropy rate estimators, and thus are not truly capturing algorithmic complexity beyond the scope and power of traditional tools such as Shannon Entropy. This is what my group and I have contributed with: A set of methods and tools to approximate this kind of complexity that we know the mind cares about and that had not been quantified before. Previous attempts to measure 'behavioural randomness' using statistical tools mostly failed showing no differences (we present 2 cases in the Supplement of our paper, where those other measures fail to find any trend). The surprising finding was that the trend confirms what it is known in literature about cognitive abilities that I will discuss in the answers to other questions. Thanks!

Hi! Fascinating work. Do you think when the age 25 and over participants in your study were completing the task, they were basing their choices mostly on what they'd learned constitutes randomness, or is there an element of neurological development here that isn't complete until 25?

justsudoit_

That is a very interesting and good question! I think people tried hard to behave random, although we told them not to overthink it. All people were given exactly the same instructions (you can still visit the online experiment and do it yourself: http://complexitycalculator.com/hrng/) and yet, we found that clear trend over all tasks, also telling us that people at the age of 25 years old also spent less time than others to produce better algorithmically-random quality. But something I definitely think, is that one of the reasons contributing to behaving slightly less random after 25, is that we become more experienced in our world, and we tend to find and become more biased towards the algorithmic-patterned world around us, so to speak.

As a 26 year old I agree, I peaked last year.

What can individuals do to retain behavioral complexity, and is that even worth an individual worrying about?

ameliabedelia7

There is an active area of research on how to slow ageing and how to stay mentally sharp. There have been suggestions in related literature that if you keep your mind busy it will remain sharper for longer. One recent paper even seems to suggest that social interaction is a key helping factor, but our research is not going in that direction even if we hope to contribute with the measures to better quantify those results.

Define "random". Philosophically speaking, as it pertains to your experiment, are you a determinist or do you believe that true randomness can exist in the world?

BlizzGrimmly

I personally believe that there are many more suggestions from science itself to think that the universe

is deterministic than not deterministic. I also think that some people find a deterministic world troubling, and who wouldn't? It would mean that we are meant to do what we do without making any true decision in life. To say that the universe is deterministic is, however, and to the surprise of many, not a controversial statement. Classical mechanics does imply a deterministic universe and quantum mechanics does not yet necessarily imply a non-deterministic universe. There seems to be more believers in interpretations that favour true randomness in quantum mechanics, but an apparent increasing number of physicists (at least until recently) seems to have switched to more exotic (and previously discarded) interpretations, such as the many worlds or multiverse, that make quantum mechanics deterministic for any specific universe and thus would make our universe deterministic (yet they do not solve indeterminism at the level of the multiverse because you are still in any specific universe 'by chance'). But regardless of the true answer, what I truly believe is in an 'algorithmic universe' and this, again, is not that controversial. The fact that science has been so successful is because the universe turns out to be highly predictable to a great extent, and we have been able to make increasingly more accurate and more encompassing physical theories over time, thus pointing towards the direction that the universe is ultimately ruled by a few equations, or computer programs (physical models are computable, even if often intractable, and also deterministic, so they are also algorithmic).

Did you find substantial differences between the age of peak behavorial complexity between men and women? Is there any research out there that studies the effect of teenage drug use (or any drug use) on computational ability?

EugeneAzeff

We could not find any difference other than age. That we could not find any difference between groups with different educational backgrounds, education levels, gender, language, etc., strongly suggests that the signal we picked up is truly related to cognition (and thus ultimately biology and evolution), so it is good that we could not find any other parameter explaining the data.

One obvious research direction is to see if we can profile cases of mental diseases or conditions, such as drug addiction. If it is not us, we hope that other research groups tackle it using our measures now that we have shown their versatility and power.

When you were conducting this study, did you find groups with behavioral or mental disorders i.e. ADD, autism, etc were better or worse than the rest of the sample size?

At risk of sounding condescending, what are the future applications of the study? I apologize if my question has already been answered and I didn't see it.

futureGAcandidate

Future applications are precisely the ones you suggest! We would like to see these measures contribute to disease/condition profiling.

How different is personal decision making from group decision making?

(had bean jar experiment in mind)

Pandektes

Good question. It is something we should test for in the future!

Is there a a way to keep or maintain our complexity as we age?

Ehcadroj

The difference is very small, I do not think it should be something to worry about. However, the more likely situation is that this (dis)ability to produce algorithmic randomness is connected to the decline of other cognitive abilities, and for sure we should worry about them, such as forms of dementia. We think our measures will help to measure and quantify all these processes in a much more objective way than what was possible before.

What are your thoughts on research into psychedelics for treatment of depression/anxiety and PTSD?

mantagal

Another profiling experiment for our measures. It would be interesting!

Brilliant stuff! I was curious as to how much individual variability is hidden in this measurement? Also, are there any indicators suggesting that this ability can be trained, or is it just an innate property of the development of the brain?

BoringUsernameHere

Those are wonderful questions (and future directions). Individual variability is high, but the trend is strong enough that we were able to find these curves at every task (there were 5 tasks reported in the paper, related to people producing randomness). This is to see if training actually makes you better or worse. If you think life is an educational experience it looks like the more you live after 25 the worse you become. Before 25, however, it is when you get most of you formal education, and then it may suggest that it made you better. However, we had people tested over a large range of educational backgrounds and levels, and we could not find any difference between people that were highly educated (e.g. holding a PhD) and other people, so this suggests this is an ability that cannot be trained. However, it could be, and I would expect, that training specifically for randomness may change your individual results, but I do not yet decide in which direction, if for better or worse, and it would be very interesting to find out!

Hello Hector thank you for answering questions! I have two questions for you:

1) I've read that since the invention of computers, they have been used as a metaphor for understanding the way the brain works and are even reminiscent to our cognitive processing. Given your current research, would you agree with this statement?

2) I'm in college studying biology and psychology, but I also have a strong background in computer sciences. It sounds like what you do is a good way to combine all three of these interests of mine. Do you have any advice for someone heading into a career field similar to yours?

Thanks!

navyblue161

Hi! Thanks for coming.

1) I agree. However, notice that analogies about the human mind with computers in the past were

oversimplifications, and today nobody believes or even dares to think of the human mind as a traditional digital computer such as a Turing machine (and I think nobody really thought so before, other than to perform thought experiments ad absurdum). However, this paper and our approach that we are calling 'algorithmic cognition', does reintroduce the concept of the human mind as a sophisticated algorithmic recognizer/producer heavily based on traditional computation, but instead of equaling the mind to a particular digital computer we see the mind as a generator of algorithmic models about the world, and that is the way in which we performed this test and the main motivation behind our research programme. 2) I definitely sympathize with your multidisciplinary approach to science. I am myself trained as a mathematician and theoretical computer scientist but I also formally studied philosophy and epistemology, and I am applying my knowledge to topics of computational biology and cognition. I think this is the best way to do science: To build bridges across disciplines. I think you are doing the right thing but I would also suggest that you focus on a method or approach and then enrich your portfolio by trying to see how such methods and tools can be translated into other areas.

Dr. Zenil. Thank you for this AMA. This research sounds like it could go a long way in helping us understand ourselves!

Besides the peak at 25 have you found any other clusters forming that correlate with personality traits as we understand them now? For instance people who tend to be more organized vs. disorganized internally (me!) Or, creativity for instance.

-ellipse

I think there should be a strong connection with creativity, but that of course depends on how to define creativity. I think we should test in the future ways to relate complexity and creativity and I am aware some people have made suggestions before but has not yet been measured as we did in this study. So it is definitely an interesting direction to pursue.

Does your research tell us anything about the ability of people of different ages to do mathematics or computer science? As in, once you are older than 25, does your ability slowly decline?

tmsidkmf

Not at this moment, but I think it is an interesting question.

Why we tend to make seemingly more mistakes in tests when we 'correct' our answers?

Pandektes

Great observation. I think for some tests overthinking leads to a lower quality answer and this is what we also wanted to measure partially in this study.

1 - How can you distinguish between (a) the peak behavioral complexity being at 25 years old for humans versus (b) the current generation around age 25 just having more behavioral complexity than the other generations (younger are probably not as developed, older probably had proportionately less technological stimuli growing up)?

2 - Furthermore, you account for mother language and field, which I agree are important, but what about fundamental cultural differences? African, South American, European, etc., and incredible

diversity within these groups as well. How can you be confident that this "25" reflects all humans?

3 - Lastly, I have a stats question because I just had to do something similar for my current masters project - how did you account for such imbalanced design in your model? Males outnumber females 2 to 1, and the other 3 categories show quite a wide range in sample size as well. (This question is more just a genuine curiosity for anyone to answer, but I'd also like to see how a successful publication has done it).

Melkovar

1. We probably can't test over generations at this stage, we would probably need to perform an experiment over various generations, which is in general extremely difficult. But you are right, it could well be that millennials just happen to outsmart us in behaving randomly =) But if the trend is generational (which implies cultural as opposed to biological as we suggest) maybe we should see more plateaux. It is interesting to think about it.
2. Sure! That is something we would like to test, there are so many factors that it would be hard to perform tests for all them, but we should definitely look at the potentially most interesting.
3. I think the key is to normalize by groups before comparison, perhaps I or one of my colleagues will be able to further elaborate later.

Hey Hector, First of all congrats in for getting in your position at your age, I hear a lot of people say that for one to get into research like that they need to go though at least a masters.

My question is related to that topic. How was the process for you to get into research? (Im a Computer Engineering and Neuroscience student and want to get into research, and I'll take a look in your paper since its really pertinent to my area)

SuperTeddyGuy

Thanks! Your words are very kind. I hope not to discourage you, but indeed it is hard to do research with a PhD (or even 2!). I think it would be even harder to do with a Masters. A PhD gives you the experience to undertake a long-term project focused on a single topic making you the world expert in such a topic. That does not mean that you cannot get that experience by other means, you actually can. On the other hand, I think people can do much more for science than they think, with a Masters or a Bachelor degree (or any degree) in different forms, for example, by always checking sources and favouring good science versus bold science and volunteering in tests like ours. And this is a good opportunity to thank each one of the more than 3400 participants in our experiment!

Is free will real or is it illusion?

Specifically I am curious if our brain generates impulse to do something before we can review it?

And alternatively if we can only 'adjust our brain' to choose better for us in future by forming new neural pathways and 'forgetting' old ones?

Pandektes

Yes, I think there is literature showing that you have already made a decision before you become aware of it, making even harder to answer the question of free will.

Can people block their peak through alcohol or drug use and then reach it later?

jewelsinme

I am pretty sure. We should test it! Maybe I will volunteer =)

Not necessarily specific to your field but where do you recommend reading science research and articles that are as close to the source as possible?

roidedgoose

This is very difficult to answer! Many years ago I would have recommended magazines such as Scientific American and the New Scientist, but I am now convinced that they are mostly after what I call 'bold science'. 'Bold science' is not always good science (nor necessarily bad science either) but it can damage a lot of 'good science' that does not make bold statements (e.g. negative results that disprove a previously bold claim published by a blue-ribbon journal). Unfortunately, this is not only a problem of popular magazines such as Scientific American or New Scientist, but of blue-ribbon journals such as Science, Nature, PNAS and Cell, to mention a few. The problem is that often only papers that are worded in a striking fashion make it to some of these journals, and so you only get a very tiny fraction of a type of sensationalist science that is sometimes not even reproducible. So my best advice, if any, is to try to form your own view of a subject by reading as many sources as possible both in favour and against. If you can, try directly the primary papers (sometimes abstracts and conclusions are written for a broader audience). Discussions with authors like these AMA sessions organized by reddit and PLOS are great opportunities where authors can be more open and honest about their work.

Not only for science but in general, try to avoid any of these logical fallacies when you judge science or any other subject (such as politics): https://en.wikipedia.org/wiki/List_of_fallacies In particular, for example, cognitive bias.

how do your findings relate to other fields in cognitive science or even psychology? Do you think cognitive complexity informs personalit type, for example? It seems that 25 is an age with so much going on psychologically, there would have to be a connection.

freebiscuits

It could, but we haven't tested for this. It is something we should explore.

Hi! I recently graduated with degrees in philosophy and psychology (within psychology, I'm particularly interested in evolutionary and cognitive studies), and I'd love to conduct my own research someday.

Anyway, I suppose this is a very general and possibly 'out there' question, and you can answer however you want, but I've been intrigued by the hologram or holographic theory of the model of the brain, and I was wondering if you had any opinions about it?

Also, do you enjoy research and is the world of academia ever frustrating?

rageflows

I do enjoy following developments in Cosmology and Physics in general. I do have an opinion about the holographic principle and I have had the chance to discuss the topic and even its possible connection to algorithmic complexity with pioneers in the subject of the holographic principle such as Raphael Bousso. I think the holographic principle is incredibly interesting but I get very frustrated when statements such as 'all the information about the universe is contained in the surface' are made. In Physics, information means Entropy, which means Shannon Entropy (and somehow equal to Boltzmann's Entropy) in the context of the holographic principle. To make the story short, what the previous statement that makes me unhappy should look like (as an expert in algorithmic information

theory) is 'the statistical distribution of the universe is contained in the surface', which is a whole different story, it only means (sill surprising but not as incredibly old as the original statement) that you can reconstruct all the universes that have the same statistical distribution to the one on the boundary, which in fact can be almost any universe! For example, if the universe were highly random (it is not), the number of universes compatible with a high Entropy universe is not informative at all as basically most possible random universes would have the same distribution! Now, if you make the Entropy lower, as it actually is in our universe, things are different but still you can construct a really large number of possible universes with the same statistical distribution. For me, that does not mean that the information of our universe is contained in the surface of the universe itself, it only means that the statistics of the universe are contained in the surface, a world of difference! This kind of use of 'information' in Physics is very common at all levels, and they have not been able to move on from Shannon Entropy that was developed in the 40s to the most mature theories of information such as algorithmic information. It is a pity and maybe only explainable by how difficult it is to move on to measures that are more difficult to use and apply, but circumventing it is probably not the way forward, especially if they want to continue using the word 'information' as they seem to imply (e.g. that our universe can be reconstructed from information in a surface, which is not true). Mathematics and theoretical computer science have much better definitions of information as opposed to randomness, and related to causality and lossless reconstruction. A close (physicist) friend of mine and I often make the joke that most physics, even the most modern, is not that different from steam-engine physics, but it is only a joke =)

Hi Hector,

Thanks for taking the time to answer our questions. After watching this, I wonder if your group (or others you know of) know how this sort of behavioral complexity relates to how the individual processes their subjective experience and objective reality. For example, have you observed correlations between this complexity and how people approach problem-solving, creativity, self-care, or other common life experiences?

Hari___Seldon

It is definitely a subject to think a lot about and I am sure we will in the future, so I hope you stay tuned or even help us to find the answer.

My research focuses on connecting the world to computation in a fundamental way.

Isn't this the original meaning of cybernetics?

NilesCaulder

Somehow, but I think cybernetics tried to do so at a different level of abstraction, between macroscopic machines and natural phenomena. The difference is mostly our algorithmic approach, we think natural phenomena is algorithmic in a fundamental way, something I do not think cybernetics was claiming other than for more pragmatic purposes. In any case, I would be more than happy if you think that our aim or our research can be framed in the context of cybernetics, as I love the work of Norbert Wiener and the Radio Club in general (von Neumann, Bigelow, Shannon, Pitts, and so on)