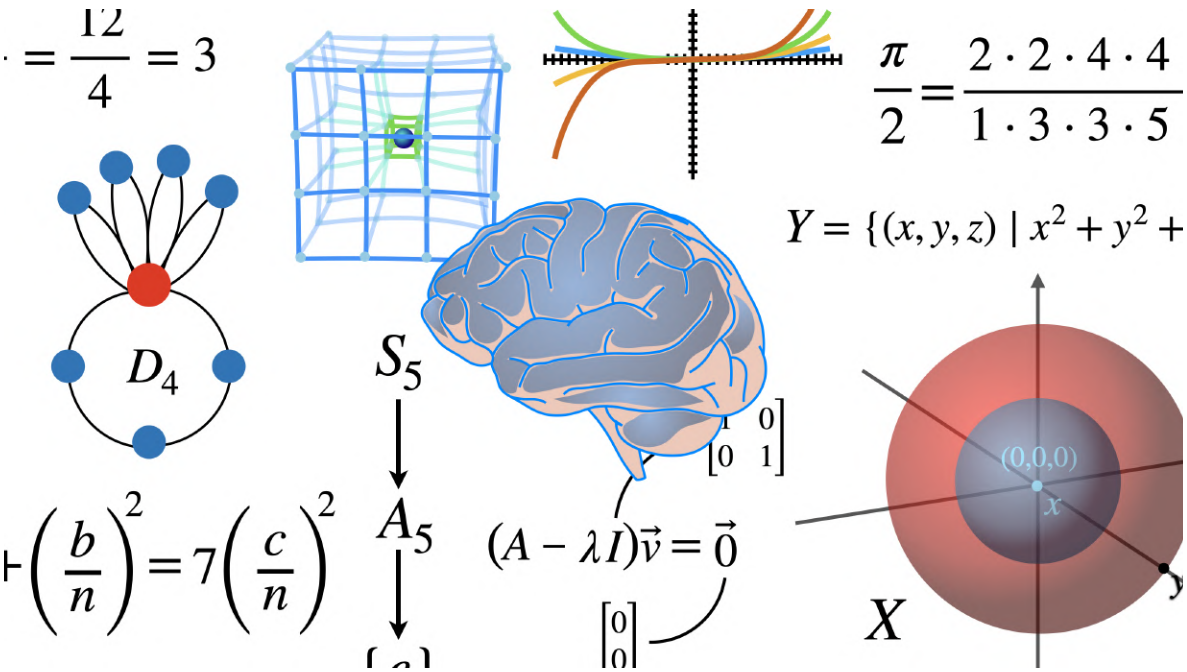
What Happens to Your Brain When You Study Advanced Math

by DiBeos

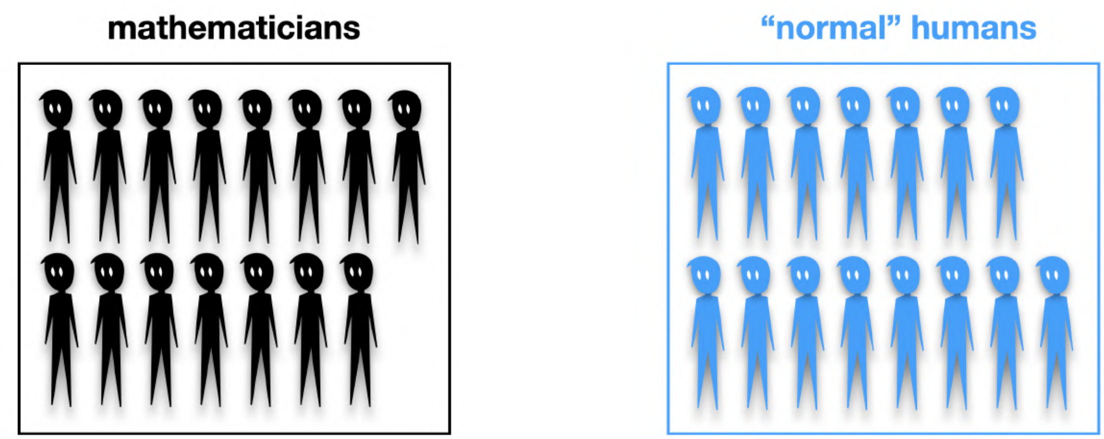


"Math is like going to the gym for your brain. It shapes your mind."
– Danica Mckellar

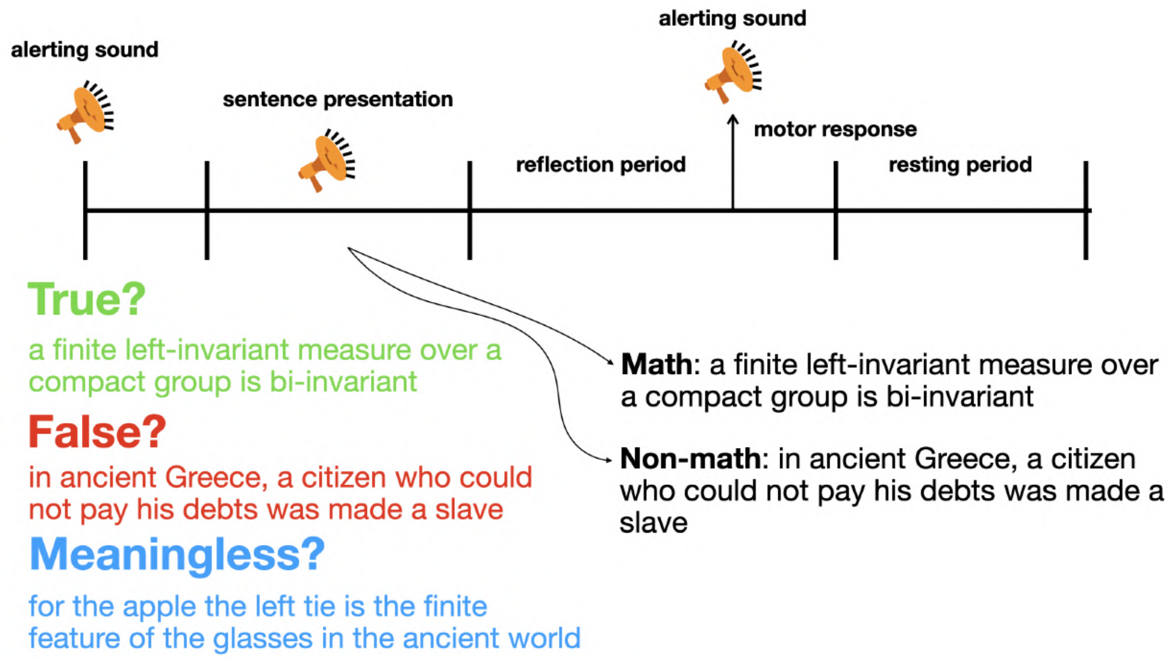
Introduction

Ever thought about what happens to your brain when you study mathematics?

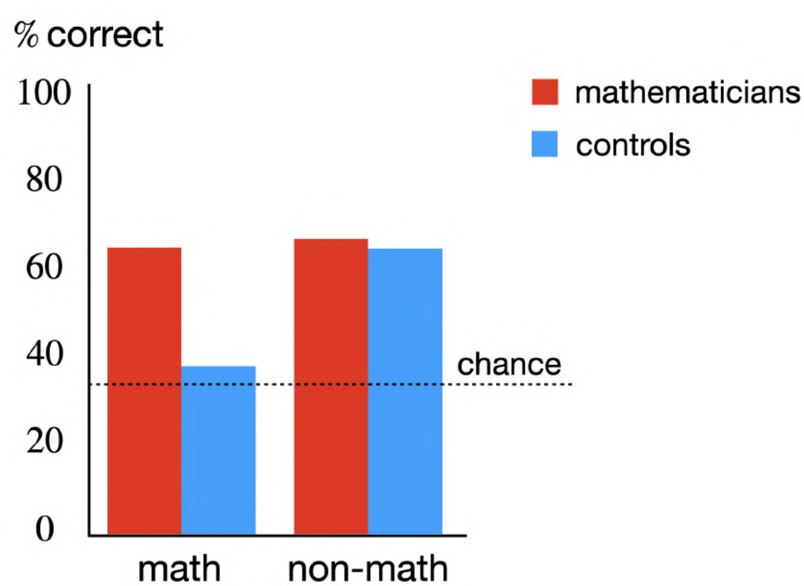
In a study in 2016, researchers studied the brains of 30 well educated adults, by putting them in an MRI machine. 15 of them were advanced mathematicians, while the other 15 were professionals in fields of humanities, like history, linguistics and philosophy, but without any professional mathematical training.



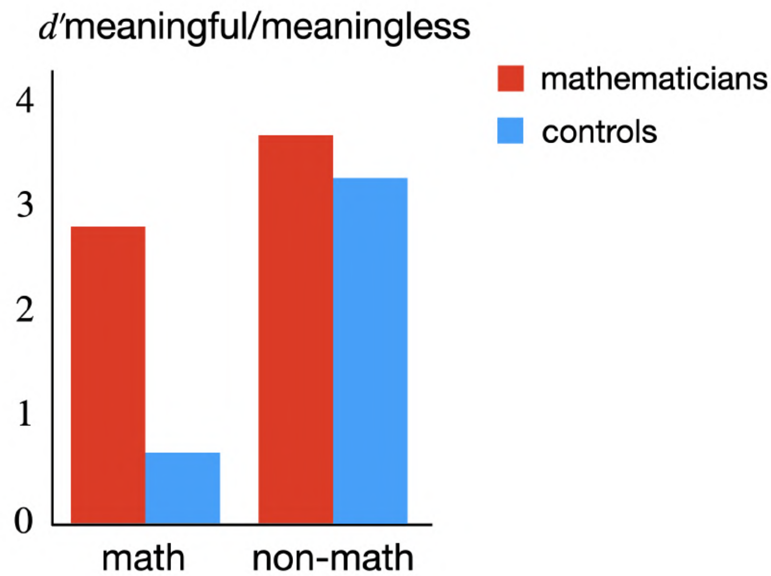
The main thing participants had to do was listen to statements that were read out loud, which could be either about general knowledge, like nature or history, or about mathematics. The math statements came from various fields, like **Analysis**, **Algebra**, **Topology**, and **Geometry**. All the statements, whether general or mathematical, matched each other in length and complexity. The participants had to determine whether each statement was true, false, or meaningless. Meaningless meaning that they were grammatically correct, but made no sense.



As might be expected, mathematicians scored high on the correctness of mathematical statements, while the *controls* (i.e. the non-mathematicians; that's what we will call them here: controls) were close to chance in guessing whether a mathematical statement was correct or not. In non-math questions, the two groups scored pretty much the same.

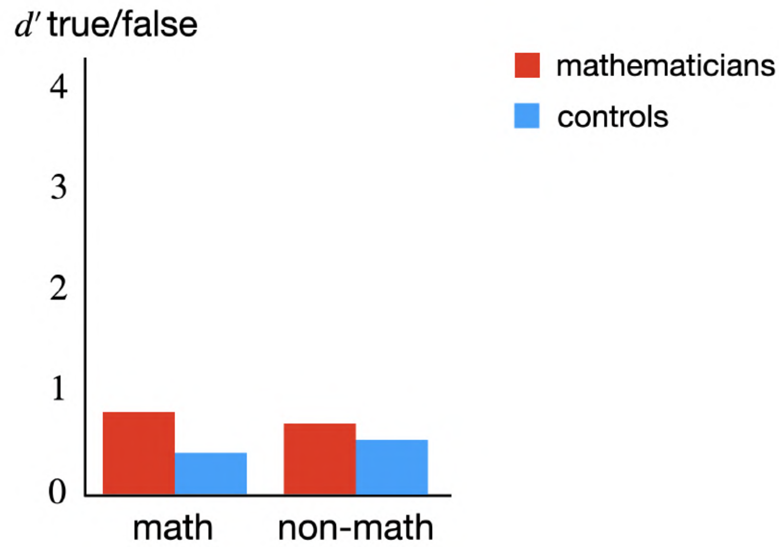


Mathematicians of course also scored higher in being able to quickly tell whether a statement in mathematics made sense, no matter whether it's true or false. And both groups had similar scores for non-math questions.



Again, this is totally expected, but the point here is not to compare the knowledge of math or of general subjects, but to show how the brain responded when it came to the other types of questions.

And finally, once a participant has recognized that a statement is meaningful, this **d'** tells us how well they could decide if it was actually true or false.

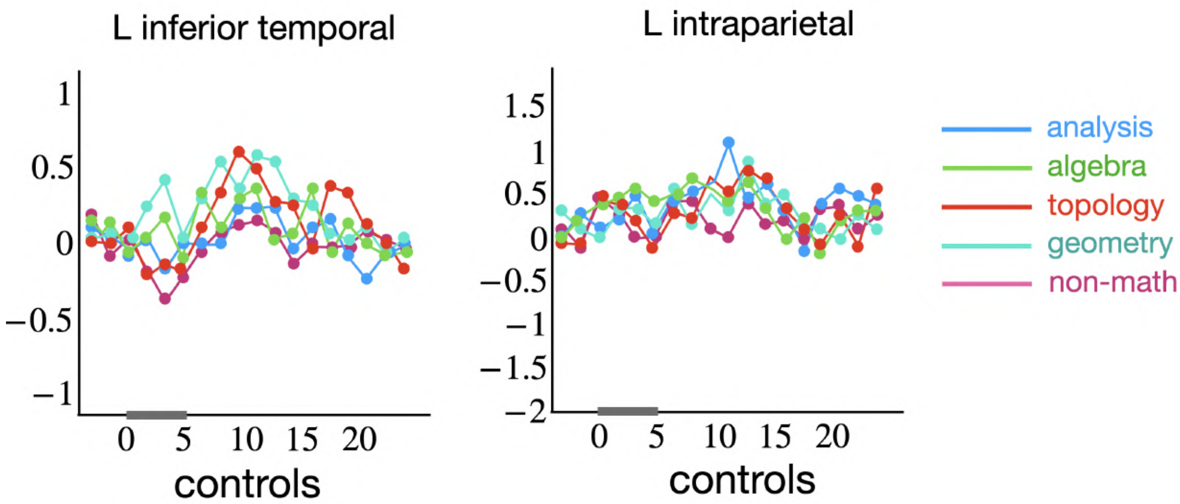


Mathematicians scored above chance for both, though clearly not as high as the meaningful and meaningless discrimination. This makes sense, since judging truth requires deeper reasoning than just spotting meaning. And as expected, controls basically scored at chance level on the math part, and well on the non-math part.

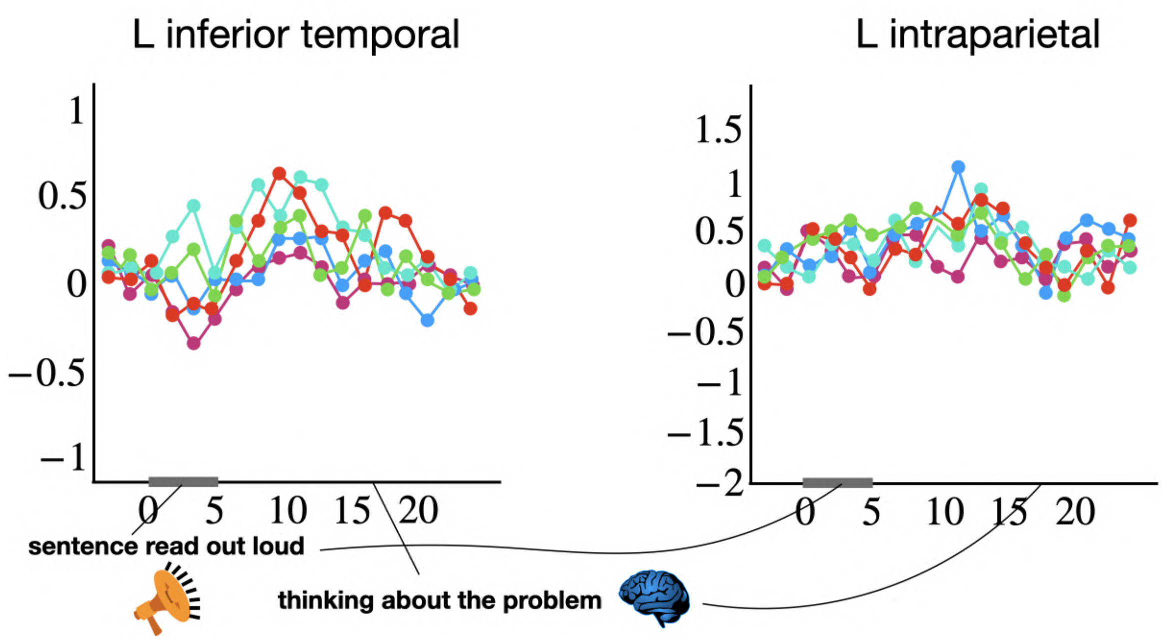
The answers were what we would expect: mathematicians were pretty good at answering everything, and the controls, or the non-mathematicians couldn't make much sense of the math statements but scored well on the general statements. So what? What's so special about that? Well let's see how their brains responded.

1 The Brain Builds a Unique Network for Math

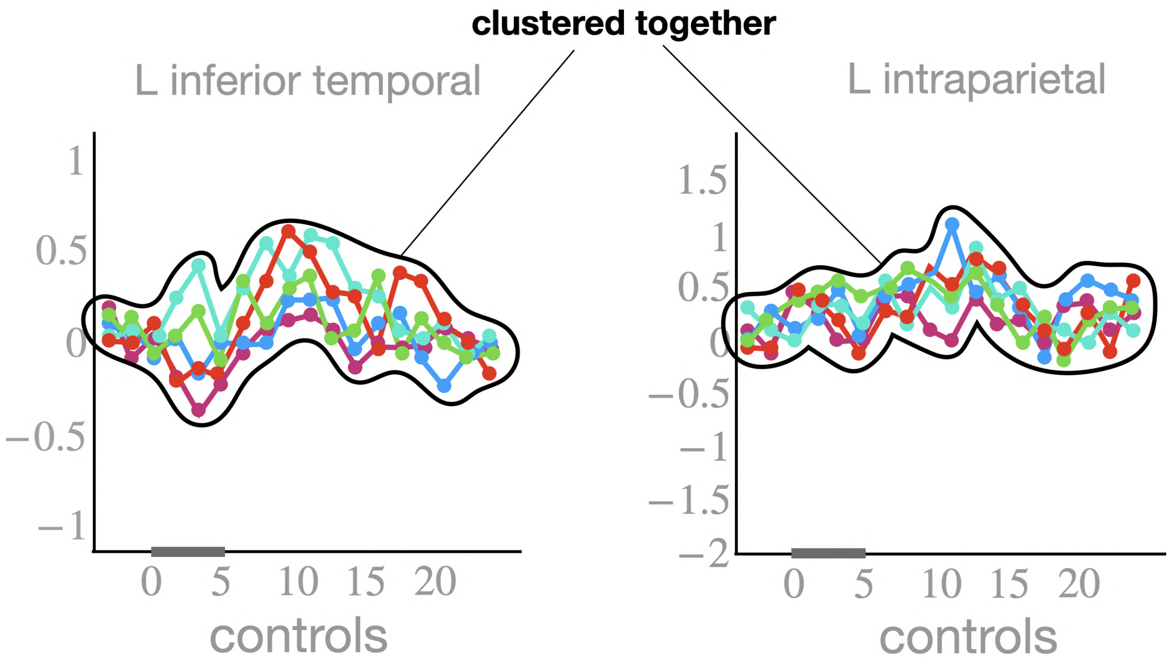
Look at these graphs measuring the brain regions called *left inferior temporal* and *left intraparietal*:



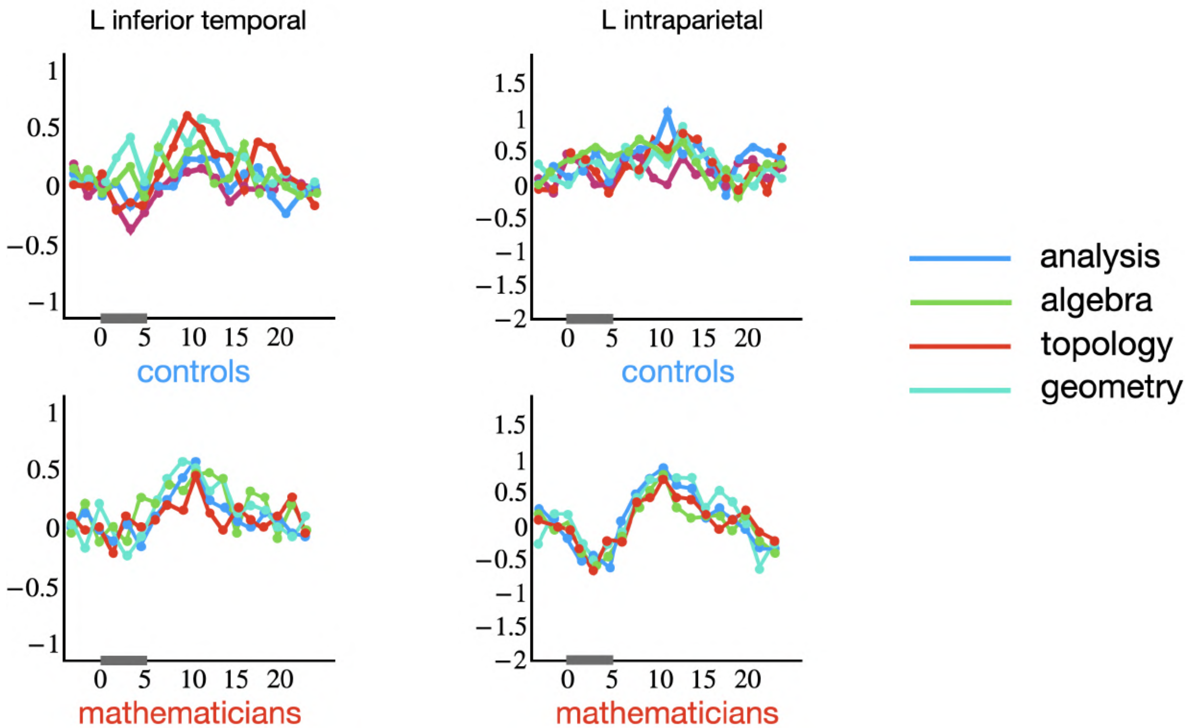
The thick grey line on the x-axis marks when a sentence was being read to the control group, while the rest of the x-axis shows how activity in these regions changed while they thought about the problem.



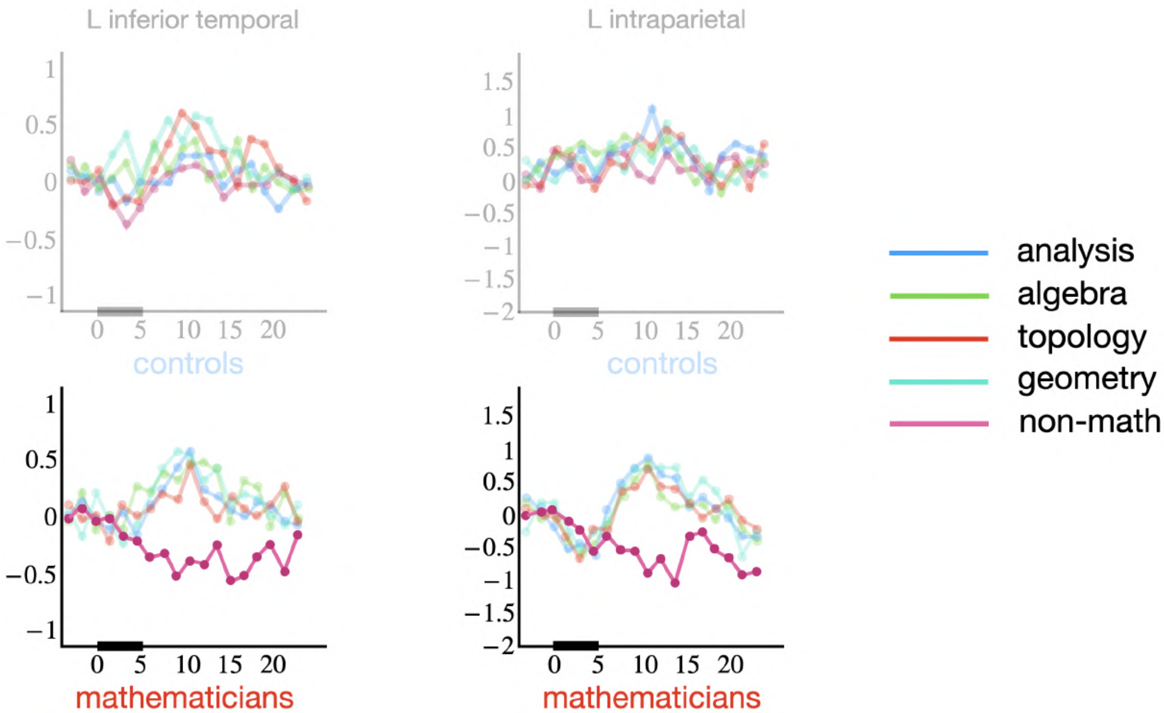
The lines on the graph itself represent activation in these areas when the control group was thinking about meaningful sentences in each topic. The topics being: Analysis, Algebra, Topology, Geometry and non-math. As you can see, the responses to all topics (math and non-math) were mild and similar, showing that these regions weren't strongly specialized for mathematics in their brains.



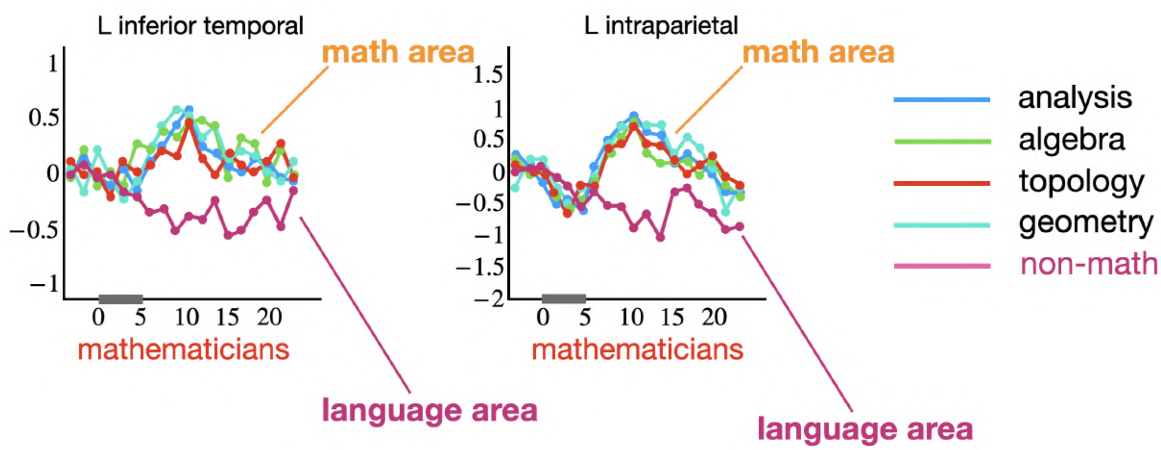
Now look at the **mathematicians**.



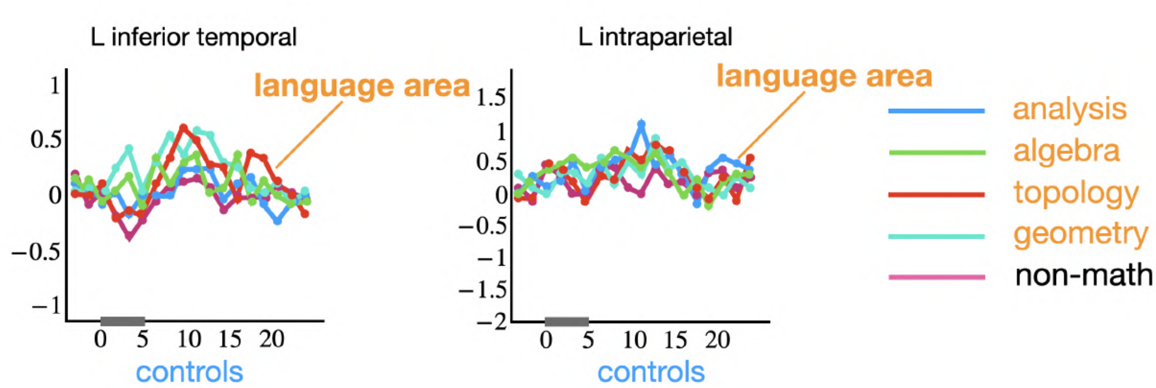
Hearing math statements in any field, whether Analysis, Algebra, Topology, or Geometry, caused a clear and sustained rise in activation in these brain regions. But non-math statements kept the activity near baseline, because processing shifted to other brain regions specialized for general knowledge.



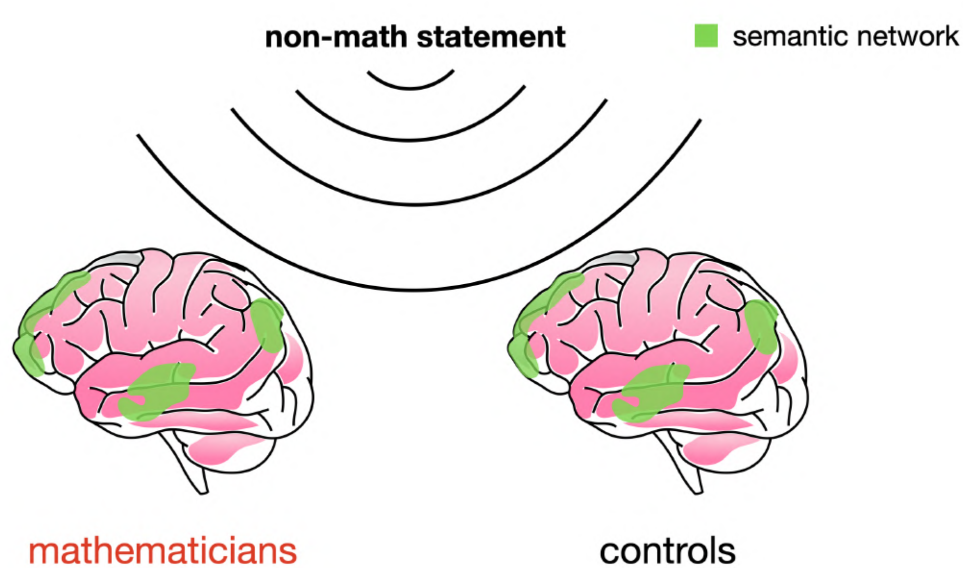
When they heard math statements, these areas showed a large increase in activity. But for non-math statements, activity in these same regions decreased or stayed near zero.



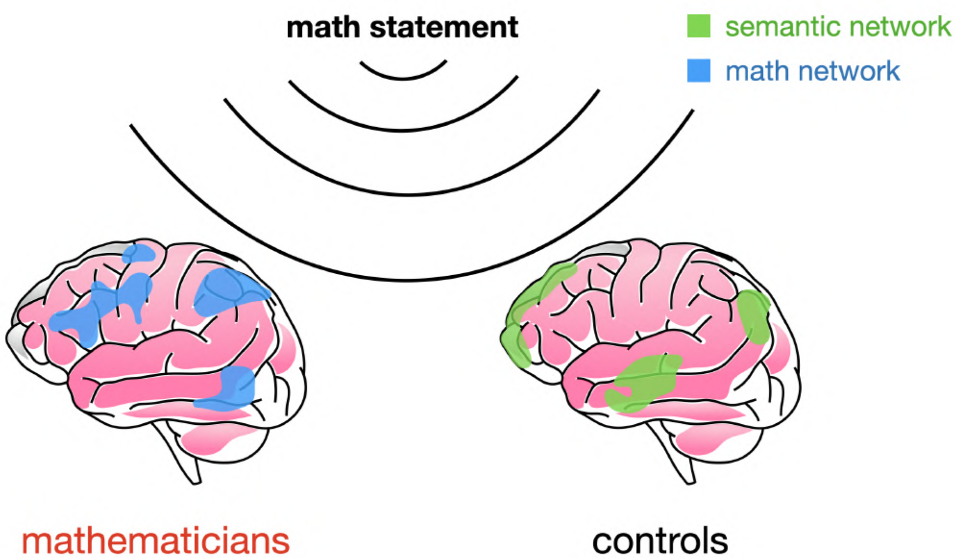
In controls, these same regions showed only mild and similar responses to all statements, whether math or non-math, indicating no math-specific specialization.



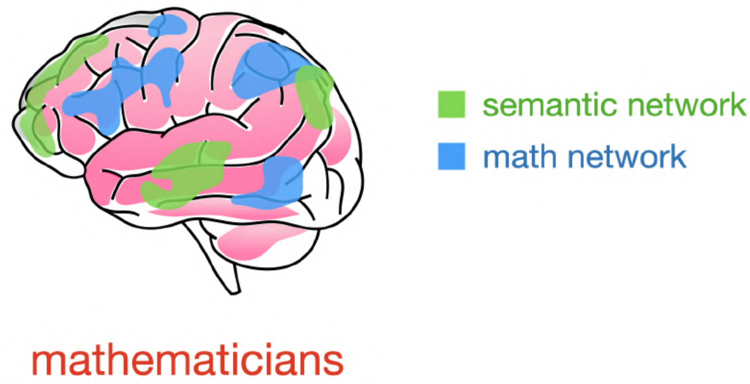
So, basically, for both math and non-math, the controls lean on the same *general-purpose*, *language-heavy* areas. That's why the activation looks similar across all topics – they're processing all of it with the same "general reasoning" network.



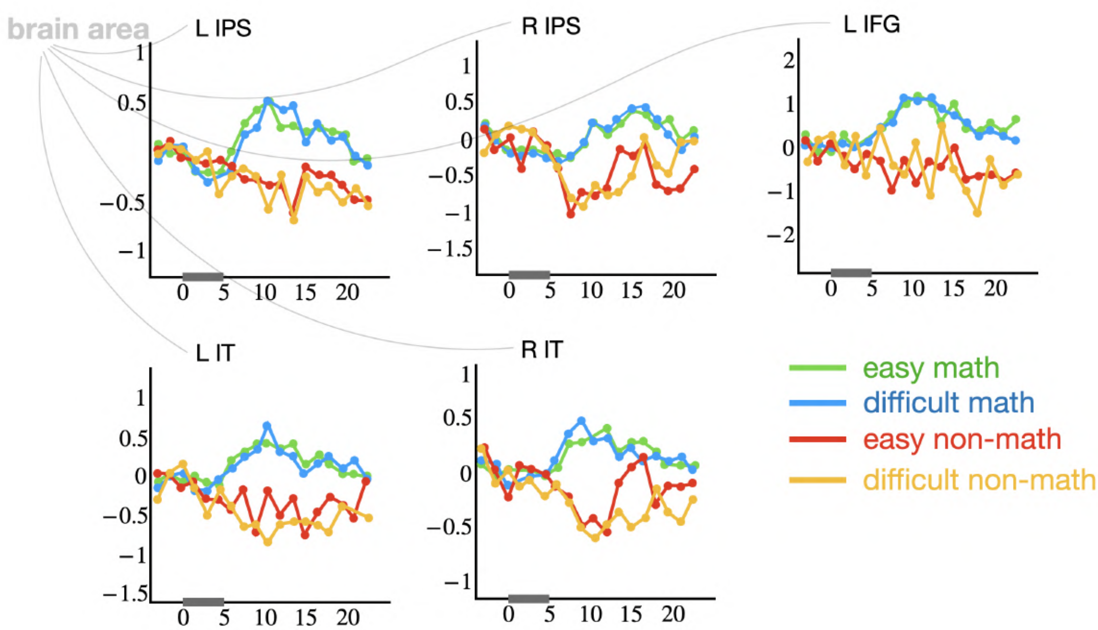
Mathematicians though, when it comes to math, strongly recruit the math-specific *parietal–frontal network*. For non-math, they don't use that network, they shift over to language and general semantic regions.



Basically, even though there is more nuance to this explanation, the scans show that the green areas, which are part of the brain's general semantic network (i.e. responsible for language and communication), lit up in both groups when they thought about general knowledge questions. When the control group was thinking about the math statements, the same green areas lit up. When mathematicians thought about math statements, a different set of regions, which are shown in blue, the math-specialized network, became active instead.



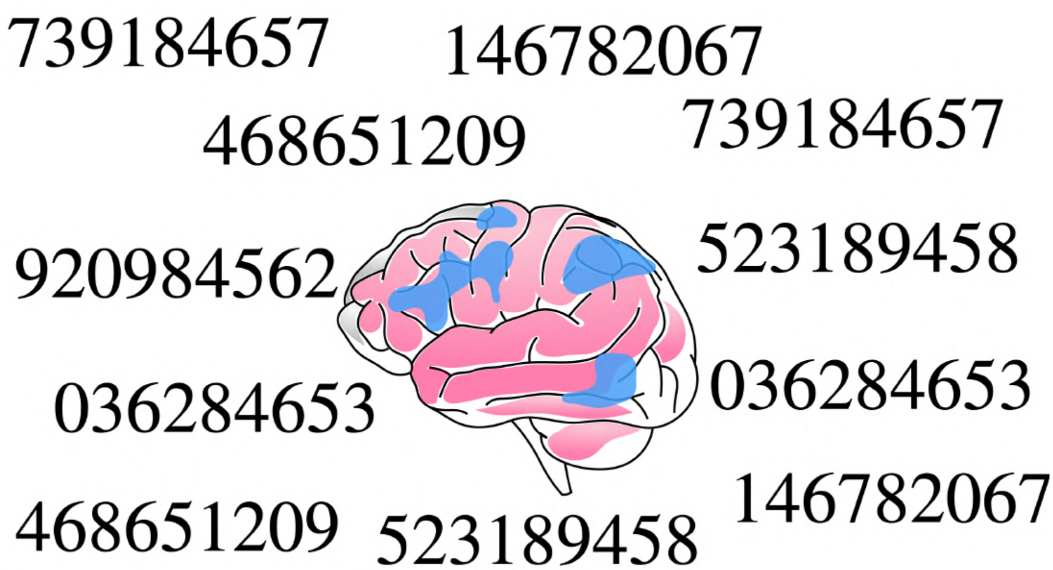
The takeaway, then, is that **mathematicians have a math-specialized network that is distinct from general semantic processing**.



You may say that "maybe mathematicians' brains looked different just because the math questions were harder for the controls, or for the non-mathematicians. Not because of any special network".

It was found that the difficulty of the math problem has nothing to do with the activation of the region. As you can see on these graphs, the math-specific network was always activated for both easy and difficult math problems. While a completely different general semantic network was activated for non-math questions, whether easy or hard.

This rules out the "maybe they were just thinking harder" explanation and confirms that these brain areas are content-specific.



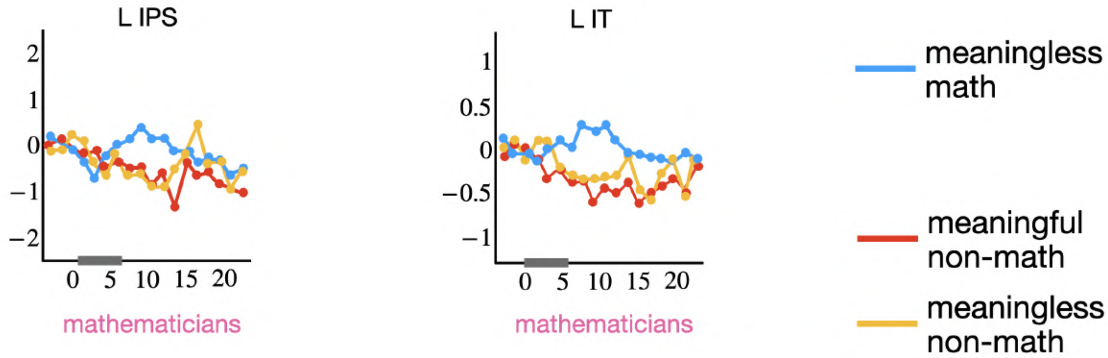
Now, we saw earlier that mathematicians have certain brain areas (blue) that activate more for math than for non-math.

That's a domain distinction – it shows that there's a separation between a "*math network*" and a "*general semantic network*".

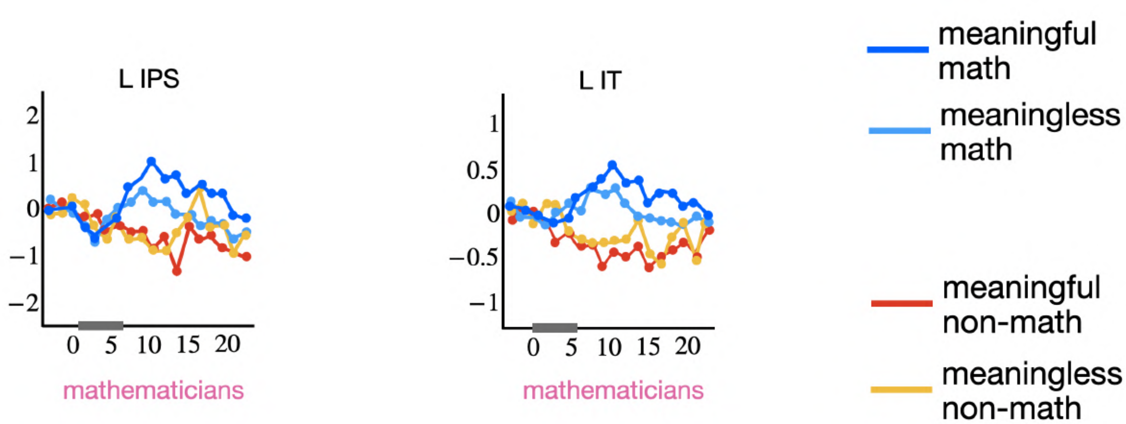
But this by itself doesn't prove that the math network is actually processing meaning. Hypothetically, those math-specific areas could light up for any string of symbols or jargon that looks like mathematics, even if it's nonsense, simply because it's in a math-like form.

So that's why the researchers compared meaningful math statements with non-meaningful math statements and found interesting results.

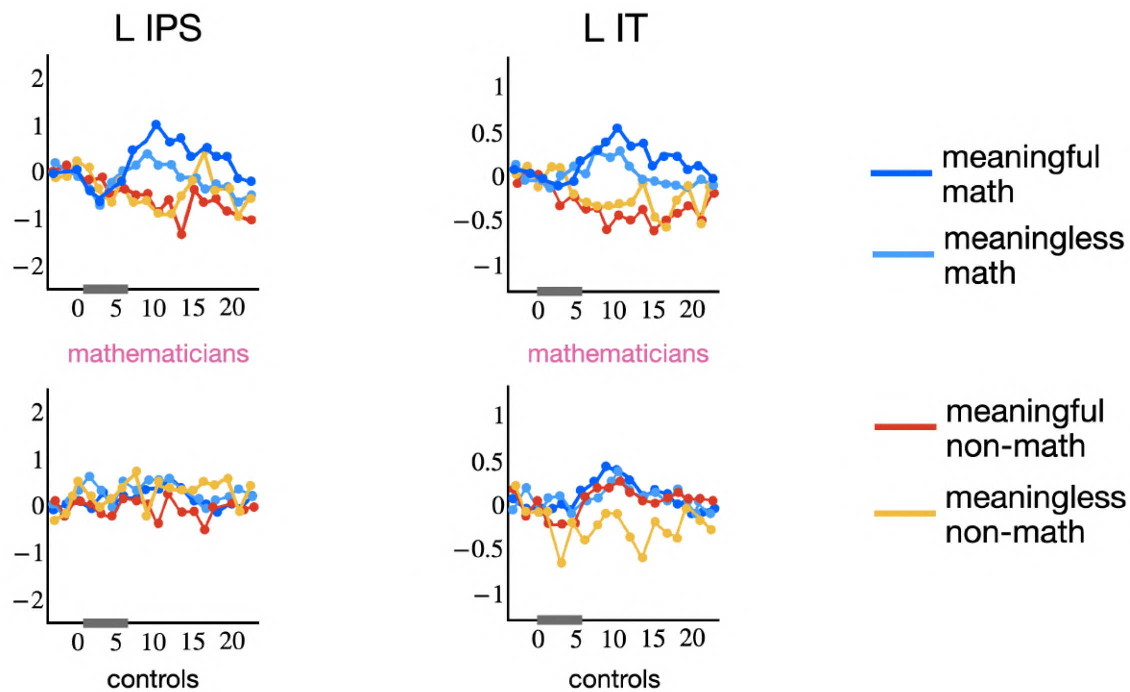
2 Your Brain Knows Math Before You Do



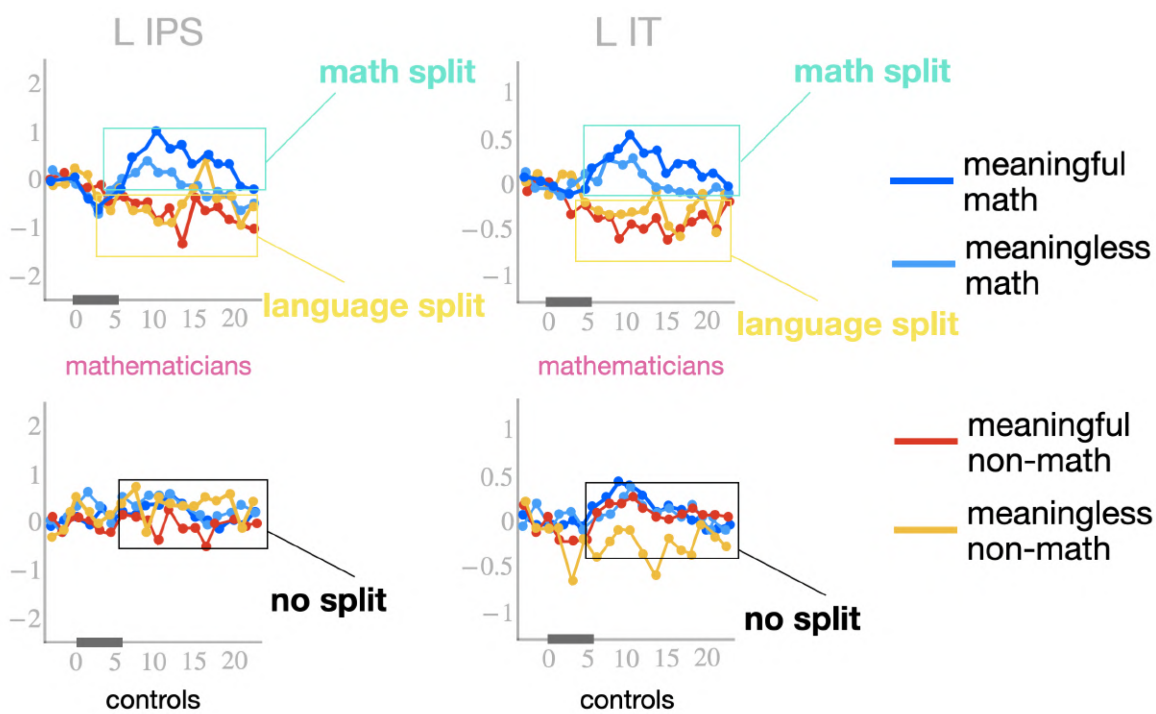
In the graphs, when we look at mathematicians, we see that simply recognizing a sentence as mathematical, even if it's nonsensical, does send the signal to specialized math-processing areas in the brain. But when the math statement actually makes sense, those same regions activate even more strongly – those areas work even more.



For the control group though, the pattern is completely different. Whether the statement is math, non-math, meaningful, or meaningless, the same general semantic areas are used, and there's no sign of switching to a math-specific network.



This tells us that mathematicians have a distinct neural *routing system* for mathematical content that non-mathematicians simply don't turn on, even when they do recognize that it is math that is being talked about.



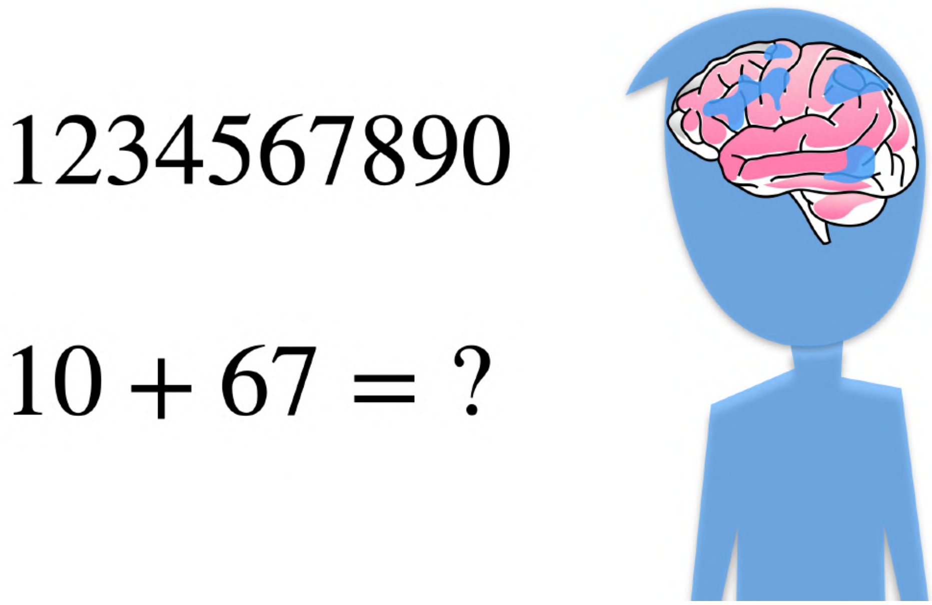
So, to summarize everything, we've talked about so far:

While listening to the statement, everyone's language system of the brain is engaged, that's expected. But when it's time to reason about the mathematical statements, mathematicians switch into a dedicated neural math network; controls on the other hand don't. The language network doesn't take over for math either. In controls, the math scans look like gibberish material rather than understood content.

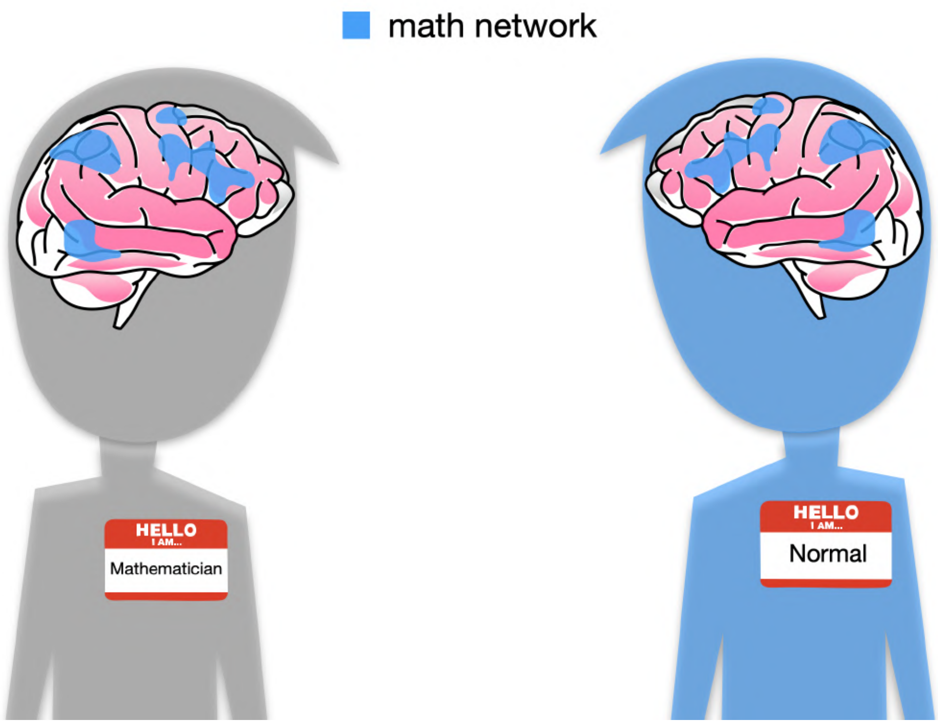
3 A Math Brain is Ready for Anything

An important thing to say is that, when the controls were shown *arabic numerals*, or were asked to perform simple calculations, their math network also lit up. This means that everyone, not only mathematicians, have these neural networks. But there's a catch.

Even for the same simple arithmetic, mathematicians lit up those calculation-related regions more strongly than controls did.

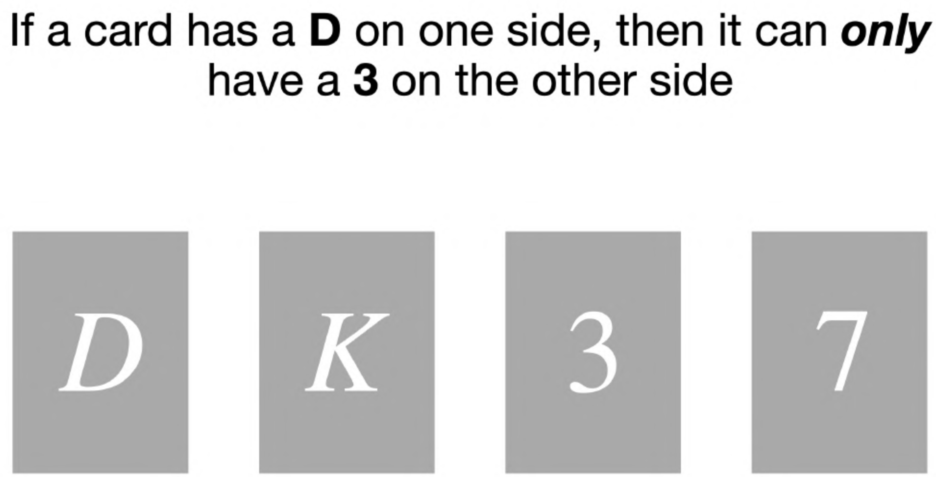


So what? You may say. It's not like there has been strong proof that this somehow benefits their reasoning outside of mathematics. Well, the scope of this study was to observe exactly how mathematical reasoning works. But there are studies that are precisely focused on this very question. And guess what they found?

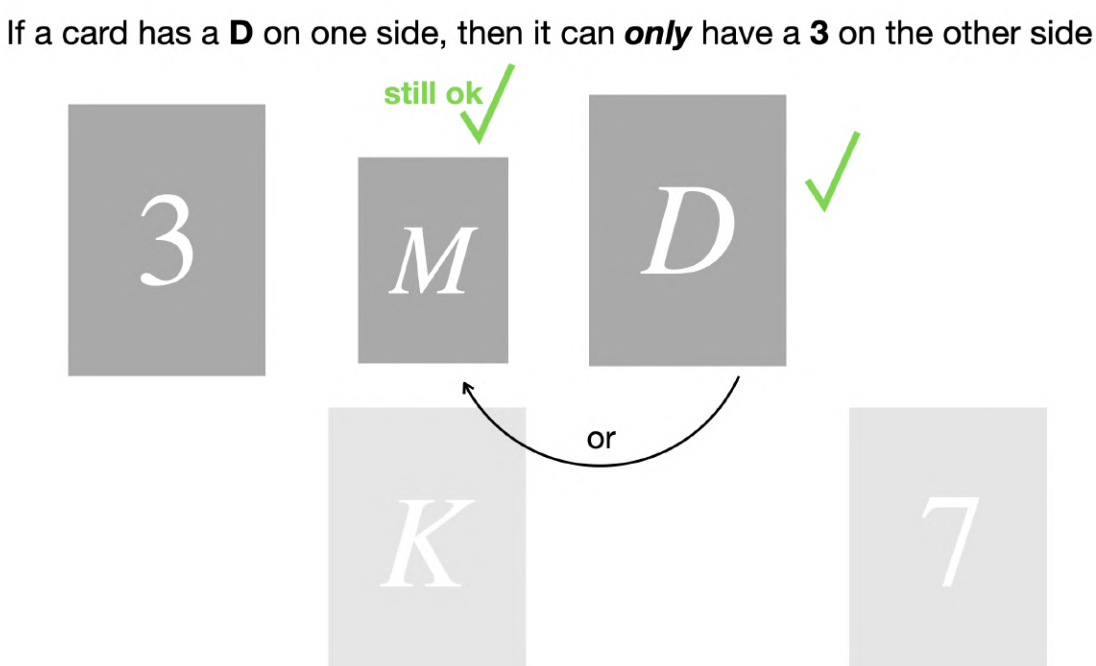


A study from 2020 from the **University of Sydney** gathered people from low mathematical knowledge, to advanced mathematical knowledge. They were given logical reasoning problems, often ones that have to do with everyday life.

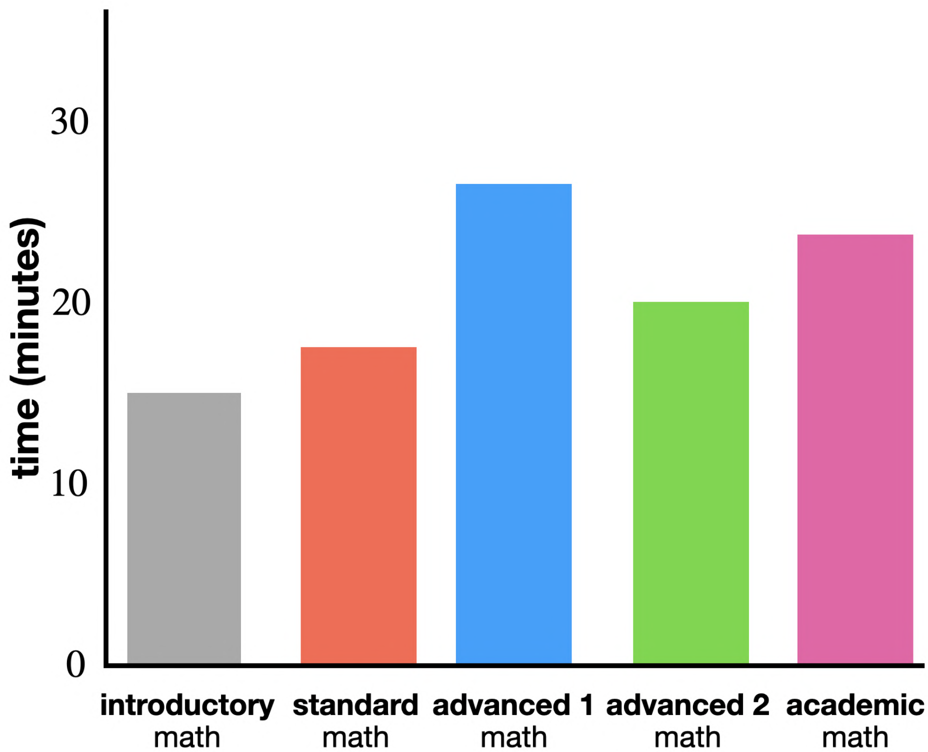
One of the reasoning tests was the classic *Wason selection task*, which has cards that have a letter on one side and a number on the other. Participants saw four cards: **D**, **K**, **3**, and **7**. The rule was simple: “If a card has a **D** on one side, then it can only have a **3** on the other side”. Your job is to flip the smallest number of cards needed to check if the rule is true or false.



The logically correct choice is **D** and **7** – the **D** checks for the expected **3**, and the **7** checks that there isn't a **D** hiding on the back. The twist is that people often make the classic error of turning over **D** and **3**, looking for confirmation instead of trying to falsify the rule – which is usually more powerful and conclusive in mathematical proofs.

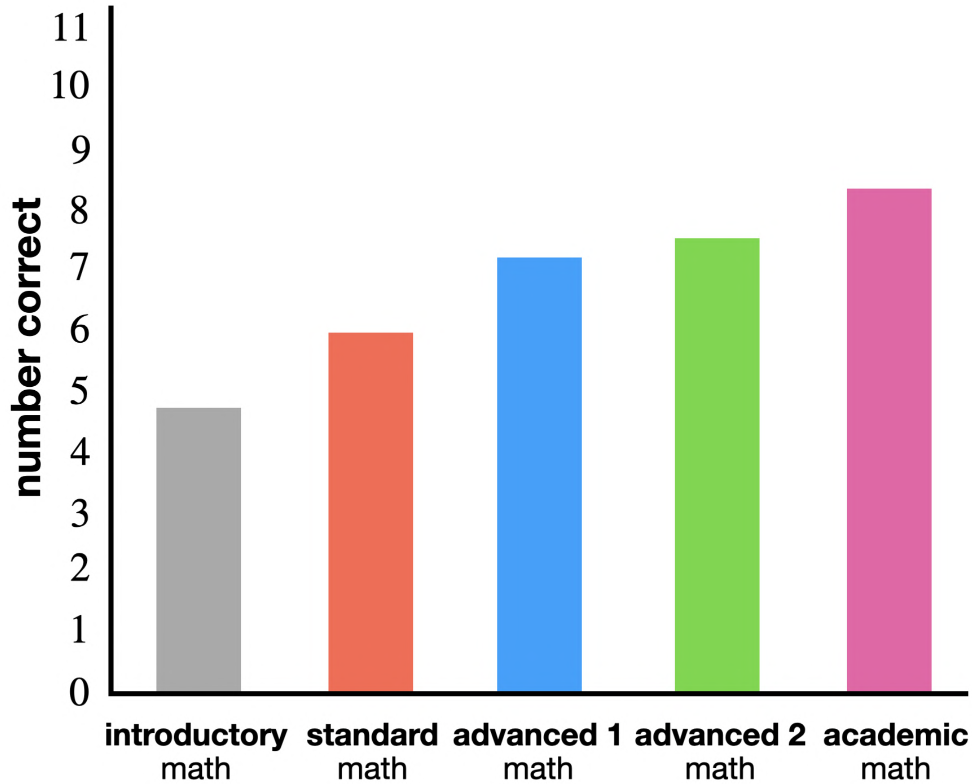


In any case, after all the tests, the results showed that the greater the mathematical training a person has, the more they answered correctly. Interestingly, their response time (so, the amount of time they took to think about the problem) also increased, suggesting that they had a "pause and consider" approach.



So overall, **the more mathematics a person knows, the more logically they make their decisions, and the more they think them through**.

These two studies show something important: learning mathematics changes how your brain processes information. And research on logical reasoning shows that the more math you know, the more likely you are to reason correctly. There are countless other benefits of mathematics, from understanding the way the universe is built, to making better decisions, the list of benefits is infinite.



A math-trained brain doesn't just know numbers, it actually thinks differently. It routes problems through specialized networks that most people barely activate. A mathematician is able to resist the urge to guess, and instead pauses to consider every angle. This way of thinking isn't confined to just equations or mathematical statements. It is a mindset that spills into everyday life, sharpening logic, focus, and decision-making. In a way, it's like a mental **superpower** that rewires your brain to solve problems more clearly, reason more deeply, and see the world with a sharper lens.

If you want to see the research papers that this PDF is based on, check them out below:

Origins of the brain networks for advanced mathematics in expert mathematicians.

Does mathematics training lead to better logical thinking and reasoning? A cross-sectional assessment from students to professors.

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