frontiers FOR YOUNG MINDS

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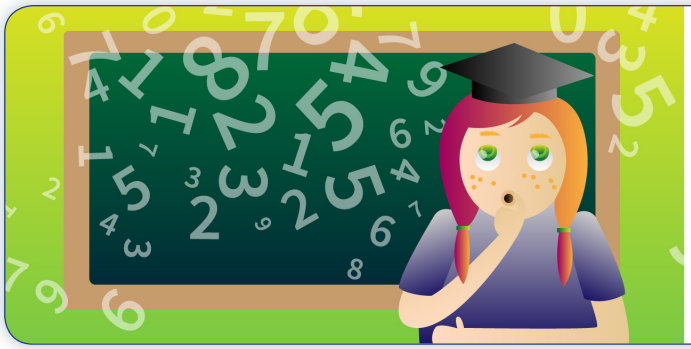


White matter counts: brain connections help us do 2 + 2

Anna Matejko

Numerical Cognition Laboratory, Department of Psychology & Brain and Mind Institute, University of Western Ontario, London, ON, Canada

Reviewed by:

Nikola
15 years old

The brain is made of many millions of cells, and different kinds of cells have different functions. The part of the brain that looks darker in pictures is called gray matter (Figure 1). The cells in this part of the brain help us do things like think and process information. White matter looks lighter and has different kinds of cells that have a fatty layer of insulation around them called myelin. This layer helps signals go through the cells, and makes information transfer faster. It is also what makes white matter look white! Gray matter and white matter work together to help us do all sorts of things like think, sing, and do school work.

HIGHWAYS OF THE BRAIN

White matter is a lot like the highways of the brain. These highways connect different parts of the brain and pass information from one part of the brain to others. The better built the highways are, the easier it is to do things like read and do math. These connections or highways are called tracts, and each tract will connect different parts of the brain. There is a special kind of brain imaging called diffusion tensor imaging (DTI) that helps us study white matter and how strong the connections are. In recent years, a lot of studies have used DTI to look at how the connections in our brain might help us think. You can also make really cool colored pictures from DTI scans that show you in which direction the tract is going (Blue = Top of the head to the bottom of the head, Red/Pink = Left to right, Green = Front of the head to the back of the head). For every part of the brain, you can calculate a number between 0 and 1 that tells you the strength of the connections in that region. These numbers are called fractional anisotropy (FA) values. When FA is close to 1, it means that the connections are stronger, and when it is closer to 0, then it means that the connections

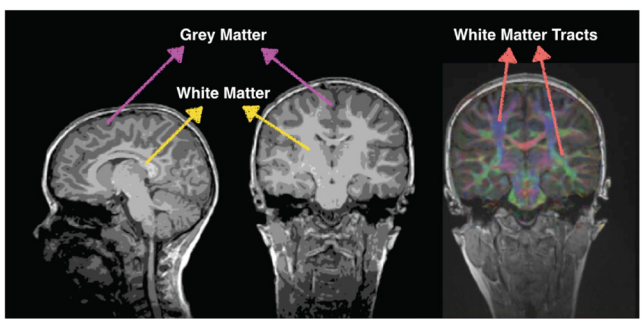
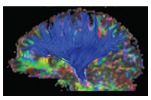
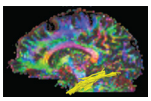
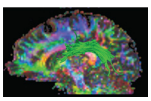
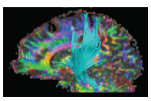


FIGURE 1 - These are pictures of a child's brain.
Gray and white matter are shown on the left and middle pictures. The picture on the right is a diffusion tensor imaging color map that shows white matter tracts (highways) in the brain.

TABLE 1 - This table shows some of the white matter tracts in the brain. It shows their full name, their short name, and what they look like in the brain!

White matter tract name	Short name	What it look like
Superior Corona Radiata	SCR	
Inferior Longitudinal Fasciculus	ILF	
Superior Longitudinal Fasciculus	SLF	
Corticospinal Tract	CST	

are weaker. There are a lot of different tracts in the brain. You can see some of the tracts we will be talking about in Table 1.

HOW DO BRAIN CONNECTIONS HELP US WITH MATH?

You use many parts of your brain when doing addition or subtraction problems like 2 + 2 = 4 or 3 − 1 = 2 [1, 2] (Figure 2). In order for these brain regions to communicate with each other, the information from one region needs to be transferred to another region through white matter tracts, the highways of the brain. Remember, FA is a number that tells us how strong the connections are in the brain. If you find that FA is 0.9 in a tract, it means the connections are very strong, and if FA is 0.1, it means the tract is weak. We can use FA values to see whether stronger connections are related to stronger math skills in both children and adults.

In order to look at this question of whether differences in white matter are related to differences in math abilities, some researchers in our laboratory measured white matter in children aged 7–9 [3]. The children also completed two math tests. The first test involved solving simple arithmetic problems like adding, subtracting, multiplying, and dividing. The second test included more complex math questions such as identifying patterns and interpreting graphs. The researchers were then able to take the FA values from different white matter tracts in each child's brain, to see if the strength of those tracts were related to performance on the math tests. Two white matter tracts seemed to be important in predicting how well the children performed on these math tests: a tract called the SCR and another tract called the ILF. The SCR is a tract that goes from the bottom of your brain to the top, and the ILF is a tract that goes from the front to the back of your brain (Table 1). In other words, children who had stronger connections in these tracts (had FA values closer to 1) also did better on the math tests!

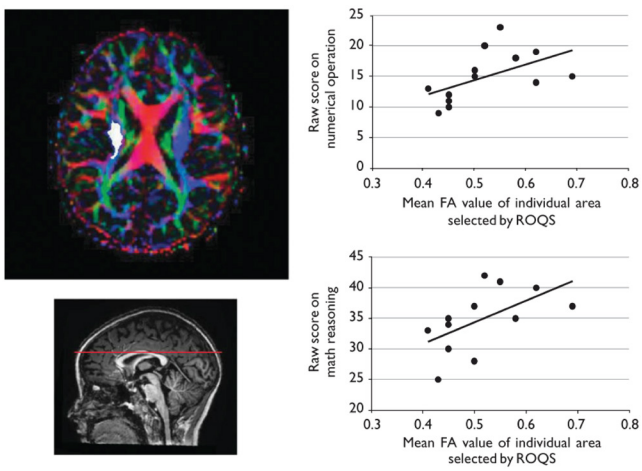


FIGURE 2 - The colored brain shows where you can find the superior corona radiata in the brain.
The graphs show that better math performances are linked to stronger white matter tracts in this region! This figure was adapted from Ref. [3].

We also wanted to see if similar white matter tracts might be related to high-school level math skills as well [4]. We had Grade 12 students come to the lab and have pictures of their brain taken with DTI. We also knew how well they performed on a national high-school level math test (The Preliminary Scholastic Aptitude Test). We found that three tracts were related to these math skills, namely the SCR (the same tract as in the last study!), another tract called SLF, and a tract called the CST. The SLF is

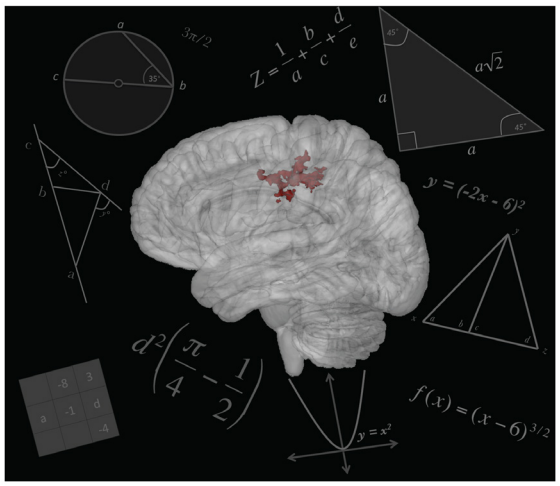


FIGURE 3 - This picture shows the white matter areas that were related to a high-school level math test (Preliminary Scholastic Aptitude Test).

a tract that connects many different regions of the brain and generally goes from the front of the brain to the back (Table 1). The CST is a tract that goes from the bottom of the brain all the way to the very top (Table 1). High-school students with stronger connections in these three tracts were also better at solving high-school math problems. This might mean that similar tracts are related to both more complex and basic math skills (Figure 3).

These studies have shown that at least a few highways in the brain are related to math skills, but how might these tracts be related to activity in the brain when you are solving math problems? A few researchers from our laboratory asked themselves the same question and decided to see whether there was a link between white matter tracts and how adults use their brain when solving math problems [5]. The researchers had some adults solve math problems like 8 + 2 = 10 in the MRI and took pictures of their brain while they were solving these problems. This showed which regions of the brain were working when the adults were trying to solve the math problems. They also took some DTI pictures of the brain, to see whether white matter tracts were related to brain activity. Remember the tract from the last two studies called the SCR? Well, the researchers found that the strength of the exact same tract was related to activity in the brain when solving math problems! They found that the relationship between this tract and brain activity was especially strong when the math problems were basic and the participants were more likely to remember the answers. This means that both gray and white matter work together to help us remember math facts like 2 + 2 = 4!

CAN I CHANGE MY BRAIN CONNECTIONS?

You may be thinking, if white matter is related to math skills, can I improve my brain connections and get better at math? Or am I just born with good or bad connections? The studies that we just talked about all looked at the relationship (correlation) between white matter and math, but they cannot tell us whether good brain connections cause us to be good at math or whether being good at math makes our brain connections stronger. One way to look at this is to see whether learning improves white matter connections. You might be happy to hear that white matter can actually become stronger with practice. For example, some researchers found that learning to juggle strengthened certain white matter tracts [6]! Practicing reading can also help improve your white matter connections [7]. We think that the same thing probably happens when we practice math. In a word, the more you use these tracts more, the stronger they become. So remember, when you are doing your math homework, you are making your brain connections stronger!

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REVIEWED BY:

Nikola, 15 years old

I live in Serbia. Not much to tell actually, since I am only 15 years old. I take an interest in science, because I love mystery and to me science is all about asking questions you do not have answers to. The most fascinating scientific discipline for me is astronomy. There are just so many different theories and speculations that it is really breathtaking.

AUTHOR

Anna Matejko

I am a Ph.D. student in the University of Western Ontario in Canada. I study how children use their brain when they think about numbers and do problems like 2 + 2. I want to help figure out why some children do well in math while others find it really hard. In my free time I like to play cello, ride my bike, and watch movies.