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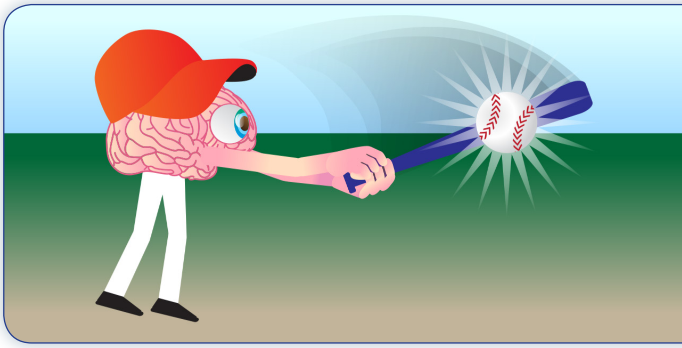

Hitting a baseball needs the brain

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Krishna
8 years old

We tend to think about sports and games as if they were physical activities that depend on strength and speed, and reading and math problems as if they were mental activities that depend on being brainy and smart. It is true that hitting a baseball requires a lot of strength and speed – you need to be able to lift and swing the bat (and if you are good, you can hit home runs!). But it is also a problem that depends heavily on the brain!

This may seem strange, but it is true: almost everything you do is controlled by your brain, even things you might not "think" about. For example, if you sit down to do some particularly difficult math homework, the parts of your brain that allow you to manipulate numbers and solve problems, like the prefrontal cortex, will be working in overdrive. But even for relatively "simple" things, like looking around the room and recognizing a table or a chair, is controlled by the activity of the brain, even if it is not something you have to think hard to do (Figure 1).

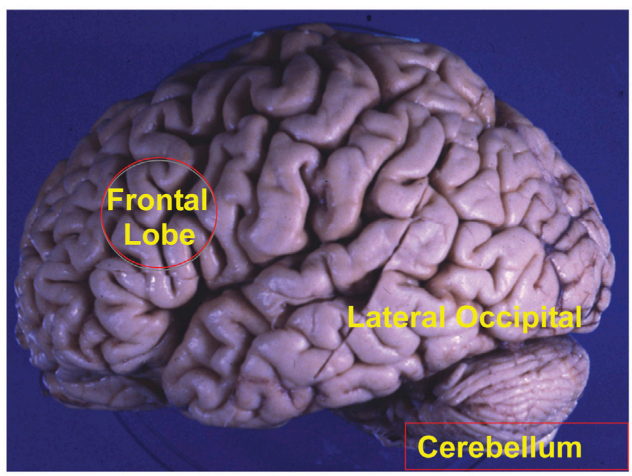

FIGURE 1 - Areas of the brain.
Visual information starts at the back of the brain, a part called the "Occipital Lobe." The "Frontal Lobe" is important for thinking and planning. The Cerebellum is important for balance and actions. One reason it is so hard to hit a major league fastball is because it takes time for information to get to your frontal lobe (about 80 ms), and the ball very quickly reaches the point where you have got to start swinging (at 250 ms) since the ball reaches the plate by 400 ms. So, you have got very little time to think about what you are doing!

The same is true for groups of actions, like running, throwing, and hitting. Even though it does not seem to be a brainy activity, making sure that you do not fall over when you run down the first base line requires the precise coordination of dozens of muscles. Similarly, hitting a baseball requires the parts of the brain that coordinate a series of actions. This motor coordination is performed by both the motor cortex and the cerebellum, two areas of the brain. One interesting idea that has recently been discussed by Nicolas Schweighofer and colleagues is that the batting practice, which many players take before a game helps to fine tune these cerebellar circuits, so that the actions during the game are more repeatable [3].

But there are other reasons why hitting a baseball depends so heavily on the brain. These reasons have to do with the fact that the baseball is moving very fast and, at the major league level, is being thrown by a pitcher who does not want it to get hit. During the same time a major league hitter (like David Ortiz of the Boston Red Sox) is preparing to swing, he has to decide: "Is this a pitch I want to swing at?" And he also has to determine: "Where is the ball going to be?" and "When is it going to be there?" and "Hey, do I need to get out of the way before this hits me?!"

How all of this happens is actually a very tricky question. The problem comes from the fact that there is almost no time to make these decisions. How little time is "almost no time"? The average major league fastball gets to the plate in less than half a second. To describe how fast that really is for the brain, we can make use of the fact that scientists often ask people silly questions to see how quickly they are able to respond. One of those silly questions is to show them a colored square and ask "Is this square 'Red' or is it 'Green'?" Try it with Figure 2. It turns out that most people – even very smart kids and adults – take longer to answer the question "What color is this square?" than it takes for a major league fastball to get from the pitcher's hand to home plate!

In order to measure things that happen this fast, we actually need an even smaller unit of time than the second: the millisecond. Milliseconds are tiny one-thousandths of a second – so tiny, in fact, that 500 of them is "half a second" and 250 of them is a "quarter of a second."

So, in the blink of an eye – and faster than most people can identify colors – David Ortiz's brain

FIGURE 2 - What color are these squares?
Even if you know the answer – because you have known colors for a long time – your brain still probably takes longer to decide on "Red" vs. "Green" than the amount of time a batter has to look at a major league fastball.

needs to make a complex set of decisions. Luckily, David Ortiz can use some prior information to help him arrive at an answer – that is, he can "guess" a little bit. For example, if David Ortiz is facing Adam Wainwright, who was a pitcher for the St. Louis Cardinals in last year's playoffs, he might have had some information before the at-bat about how likely Wainwright was to throw his sinking fastball. Knowing that the pitch is a sinker (or not) will help him determine if, when, and where to swing. By studying his previous game action, we know that on the first pitch of an at-bat to a left handed hitter (Ortiz is a lefty) with no runners on base, Wainwright will start with a sinker more often than any other pitch, and only rarely start with a curveball. But if there are runners on base, Wainwright will start with a sinker much less often, and start with a curve much more often – in fact, more often than any other pitch he might throw! So, if there are no runners on base, Ortiz might simply "guess" that the first pitch is a sinker and be right more often than not; if there are runners on base, Ortiz should anticipate that Wainwright is more likely to throw the curve.

One reason this is so important is because, if you look at the path the ball takes to the plate, there is almost no difference even between very different pitches. Michael Richmond, a physicist, has charted the trajectory (or "path") of the ball from the pitcher's hand to the catcher's mitt in Figure 3 [2]. Even 200 ms after the release of the pitch – which is about halfway through the fastball's trajectory to the plate – it is very tough to tell which pitch will end up in which place. The fastball (black line), changeup (green line), and curveball (blue line) are almost entirely on top of each other through that first few hundred milliseconds – it is only later, after the batter should have decided when to swing, that the pitches become visually distinct. So, having information before seeing the pitch is critical to being able to hit the ball.

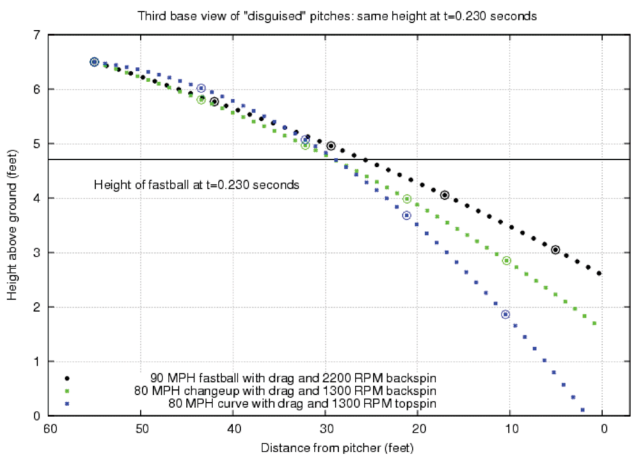

FIGURE 3 - Chart showing how much the trajectories of curveballs, fast-balls, and changeups overlap in the first few hundred milliseconds of their flight to the plate.
Note that the plate is 60 feet and 6′ from the pitcher's mound.

Even while using that prior information, how does David Ortiz's brain actually decide which pitch he is seeing? This is a tough question for scientists to answer, because it is difficult to get David Ortiz into the lab to test him (or other baseball players), and it is important to be able to run tests on baseball players in order to be able to definitively answer the question.

Nearly 100 years ago, scientists were able to get Babe Ruth into a lab at Columbia University and found that all of his reaction times were much faster than those of ordinary people, which may explain some of his home run hitting prowess. The best recent information on the neural correlates of pitch recognition comes from several years ago, when Jason Sherwin, Jordan Muraskin, and Paul Sajda, from Colombia University, brought regular, non-baseball playing people into the lab, hooked them up to a machine that measures brain activity, called an electroencephalography (EEG), while they were in an MRI (magnetic resonance imaging) scanner, and recorded their brain activity while they tried to identify pitches from video. What they found was that brain activity in areas such as the Lateral Occipital Complex, an area involved in object recognition, and area MT (Medial Temporal), an area involved in motion perception, were critical for pitch recognition.

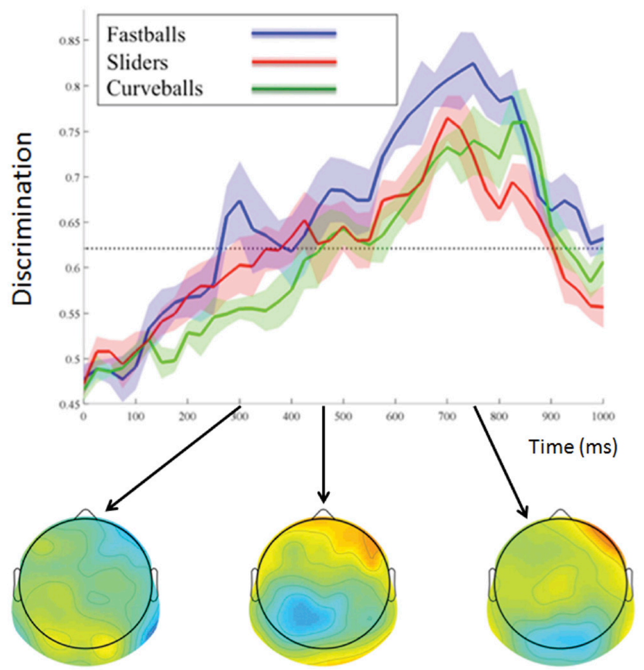

FIGURE 4 - Timecourse (top) and spatial map (bottom) of neural discrimination from Sherwin et al. [1].
The different colored lines in the top part of the figure show different pitch types. "Discrimination" refers to the ability of the neural data to correctly identify each pitch. On the bottom, orange and blue areas show areas of strong and weak neural signal. The yellow and green areas show less important areas of the brain for understanding pitch recognition, but demonstrate that the signal was being measured from the entire brain.

The timecourse (and spatial maps) of pitch recognition from this study are shown in Figure 4. Interestingly, fastballs (shown in blue) reach the dotted line that indicates recognition faster than the other pitch types. You can also see that, in people's brains, the signal for pitch recognition starts in the back, where visual areas are located.

There is something funny about this graph, when you consider how fast people's brains seem to recognize pitches. Even though the data show that the brain of non-baseball players (like the ones in this study) recognize pitches in less than a second, they are still really slow compared to major league hitters. In fact, if this were how fast major league hitters recognize pitches, they would not even start their swing until close to half a second after the ball hit the catcher's glove! Of course, these people were not baseball players facing live pitching and did not have to program the complex ballet of muscle movements required to hit the ball with the barrel of the bat. These people also did not have to worry: "Hey, do I need to get out of the way?!"

One interesting, open question is how being a major league batter changes your brain. For example, you might be an "expert" in recognizing particular kinds of music, and your parents or teacher might be experts in recognizing other kinds of music: this allows you to quickly and easily identify and tell the difference between kinds of music you like, but makes all of their music sound less distinct. When people are experts at things, especially at recognizing particular types of objects, their brain changes to reflect that expertise. So, it is still an open question as to how a major league hitter's brain has changed to reflect the thousands of hours of practice he is spent trying to hit the best pitchers in the world! Maybe you will figure it out someday.

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I love science and sports. I play baseball and learn kung-fu. I love to do experiments to understand how science works. In the science – I enjoy space/astronomy and physics. I enjoy reading a lot – and hope to write lot of kids' books. (I have started on three already). In my life, I want to invent something new and bring back to life something that is extinct – using DNA research.

AUTHOR

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I am a scientist who studies animal learning and visual perception. Understanding how animals learn about the world and form things like categories and concepts without the use of language is interesting! I also love baseball, the best sport on earth, and run the baseball analysis website BrooksBaseball.net. When not looking at data, I like spending time with my wife and my dog Teddy.