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HOW PHINEAS LOST IT

ALAN ALDA This is the skull of Phineas Gage, who over 150 years ago became one of the most celebrated cases in the history of medicine -- which is why he's still here in the Warren Museum at Harvard Medical School. A smart and likable young man, according to his friends, Phineas was working as the foreman at a railroad construction gang in Vermont when a blasting accident blew this three-foot long iron rod through his left cheek and clear through the top of his head. The rod landed about 25 yards behind him. And Phineas got to his feet and walked away. As a local newspaper put it the next day, "The most singular circumstance connected with this melancholy affair is that he is alive and in full possession of his senses and free of pain." But while he lived another twelve years with part of his brain destroyed, he was, as his friends said, "no longer Gage." He was described as "fitful" and "grossly profane." On the one hand "impatient and obstinent" and on other, unable to make plans for the future: unable, in fact, to make up his mind. Phineas Gage's fame stems not only from him simply surviving such a ghastly accident, but he was the first patient to suggest a link between personality and the functions of the front part of the brain, the frontal lobes. In this show, we're going to explore how our frontal lobes shape who we are and how we go about our lives. But first we're going to find out exactly what happened to Phineas' brain when that iron bar blew clean through it on September 14, 1848.

ALAN ALDA (NARRATION) The Gage skull is easily the most prized possession of the Warren Museum. Only members of the Museum staff are allowed to lay hands on it. Recently a specialist in trauma medicine at Harvard Medical School began wondering how Phineas could possibly have survived the accident. The researcher asked for permission to examine the skull with the latest diagnostic technology -- fortunately available right next door to the Warren Museum at Brigham and Women's Hospital. Phineas' day trip has brought him to one of the hospital's state-of-the-art CT scanners, more usually employed checking for disease in living patients. The puzzle he's here to resolve is one that has

tantalized Dr Peter Ratiu from the moment he first saw the skull in the museum. How could the rod pass clean through the skull and cause so little damage?

PETER RATIU We know where the rod went. But the problem is the rod is twice as big as the opening. So it was a miracle enough that he survived. That would have been a direct godly intervention to stick a one-in-a-half inch rod through a half-inch hole.

ALAN ALDA How has that been accounted for up until now?

PETER RATIU Nobody bothered to measure.

ALAN ALDA (NARRATION) What Peter Ratiu suspects is that to let the rod through the skull must have cracked and opened like a door on its hinge.

ALAN ALDA So the rod went in through here? PETER RATIU The rod went through here and entered the skull. This is the most obvious crack ….

ALAN ALDA (NARRATION) Today Peter his hoping the CT scan will reveal a pattern of cracks in the skull consistent with his explanation for Gage's survival… That the rod actually opened the skull as it passed through, the skin and tissue of Gage's face and skull stretching for an instant then snapping the skull closed again.

ALAN ALDA Is this something you've experienced before? PETER RATIU Absolutely not. This guy dodged five ways to die. Each one is a sure shot. So never try this.

ALAN ALDA It's amazing.

ALAN ALDA (NARRATION) While Peter Ratiu is interested in how Phineas survived, what's made Gage famous is how he later behaved.

ALAN ALDA What's the area of the brain that was affected during this accident?

JORDAN GRAFMAN I think the area that everybody focuses on are the frontal lobes. Now they're might have been some damages to areas a little bit outside the frontal lobes but what makes this person and their case interesting to scientists is the fact that their injury was in the frontal lobes and a result of the injury, Gage's personality changed.

ALAN ALDA Can we tell what kind of personality change? I mean, was it an inability to make decisions, or…it's hard to tell.

JORDAN GRAFMAN It's hard to tell. Other than the fact we know is it changed. He couldn't resume his former position . Although he did work afterwards…

ALAN ALDA He wasn't good as a foreman.

JORDAN GRAFMAN …he wasn't good as a foreman. Which requires executive skills.

ALAN ALDA I brought a brain in a box here and I wonder if you can show me where on the brain the accident affected him?

JORDAN GRAFMAN Sure. So these are the frontal lobes of the brain. This is the right side, and the left side. And the rod probably entered somewhere from the bottom of the frontal lobes on the left side and came out somewhere on the top of the frontal lobes. So all the tissue in between here to here no doubt was damaged, as well as some of the surrounding tissue.

ALAN ALDA What was the thinking in those days about the relationship of the brain to the personality? How did they organize their thoughts about that?

JORDAN GRAFMAN Well, there wasn't a lot of sophisticated thinking. Here's an example of such thinking. This is a phrenology skull. And you can see etched into the skull in different places are what might be called faculties.

ALAN ALDA (NARRATION) Phrenology was invented by a very bright fellow called Franz Joseph Gall, who thought that different parts of the brain did different things. His mistake was in believing bumps in the skull reveals what lies beneath.

ALAN ALDA Has any one of these areas shown to conform--? You don't even have categories like this?

JORDAN GRAFMAN Alan, It was a crap shoot, you know?

ALAN ALDA I know…benevolence? Nobody's looking for benevolence in the brain, are they?

JORDAN GRAFMAN We're all looking for benevolence. But not right now in the brain.

ALAN ALDA Reasoning faculties he's got over here.

JORDAN GRAFMAN So that's not a bad place to have it. There's probably some relationship between the functions of the frontal lobe and your ability to do some certain of reasoning.

ALAN ALDA He's got language under the left eye. Is that possible? I mean-why would he say that? Is there brain under the left eye?

JORDAN GRAFMAN I don't know what kind of plaster cast he was studying to in order to do that. Under your left eye is your left cheek.

ALAN ALDA (NARRATION) Gall may have been wrong in the details, but his concept of the brain as an organ with specialized regions has been vindicated. And of all the specialized regions, none is more important in distinguishing us from the rest of the animal kingdom - and from our pre-human ancestors -- than the enormously enlarged front part of our thinking brain, the frontal lobes, or pre-frontal cortex.

JORDAN GRAFMAN It serves as sort of the central executive, the chairman of the board of the brain. And it helps guide our behaviors, it helps us plan, it helps us carry out plans, it helps us reason about difficult topics, it helps us make certain kinds of decisions, it helps us inhibit behaviors that are not really appropriate, more primitive behaviors. For example, say you want to be on a diet and you love chocolate and in front of you, you see this wonderful, delicious chocolate cake in front of you but you know you shouldn't have it. So the front--.

ALAN ALDA So the back of my brain…

JORDAN GRAFMAN Wants it.

ALAN ALDA …and the front of my brain....

JORDAN GRAFMAN Is saying, "not good for me."And so you're able to put it off because you have another goal. Maybe the goal is to lose weight. Maybe the goal is to live longer. So these goals are gonna to be much more important than sort of the short term goal based on just seeing the chocolate cake in front of you.

ALAN ALDA (NARRATION) For much of this show we'll be peering into our pre-frontal cortex to discover how it works - and how it allows us to be ourselves - in ways that Phineas irrevocably lost that day he became "no longer Gage.".

JORDAN GRAFMAN If you were to look at any part of the cortex and say what makes us human, well, we always look to language-related cortexes. But I

happen to think it's the pre-frontal cortex and the anterior part that makes us most human.

ALAN ALDA Did you ever notice that I have a tremendous shelf right there?

JORDAN GRAFMAN And I'm impressed by that.

ALAN ALDA I know it's back to phrenology, but--.

JORDAN GRAFMAN Whatever works.

WHY KIDS DON'T GET IT

ALAN ALDA (NARRATION) The first stop for my brain and me is at the Shriver Center in Waltham, Massachusetts, which houses one of the leading laboratories investigating the minds of children. In the cheerful basement is a large room where kids of all ages hang out with their parents. We all know that kids brains work differently from grow-ups'. And it turns out from work here and at other labs that while much of a child's brain is up and running from the start, the slowest to come on line is the pre-frontal cortex -- which, as we're about to find out, accounts for a lot.

ALAN ALDA These kids look very comfortable in here. What are they here for?

ADELE DIAMOND We give them games to play, problems to solve, which teaches us how they're understanding the world and how their mind is working. Every time they do something and they do it differently than us, they did it that way because it made sense to them. So we're trying to figure out how they're understanding the world and how their mind is changing as they get older and the relationship of that to how their brain is changing. Now this is supposed to be boring…

ALAN ALDA (NARRATION) Adele Diamond frequently plays a game with babies like 10-month old Alexandra which are spellbinding in what they reveal about the infant mind.

ADELE DIAMOND OK, Alexandra, watch. Alexandra. OK. Where'd it go? Where'd it go? Where'd the toy go? Good job! Yeah, good job.

ALAN ALDA (NARRATION) Like most babies her age, Alexandra finds this part of the game child's play.

ADELE DIAMOND OK, hold her hands again.

ALAN ALDA (NARRATION) But now Adele hides the toy a second time.

ADELE DIAMOND Watch where it's going. Watch Alexandra, look, hello, watch where it's going. OK Alexandra, go ahead, where'd it go? Where'd it go? Where did the toy go, Alexandra? Where'd the toy go?

ALAN ALDA (NARRATION) Alexandra seems a little bemused - but not half as much as I am.

ADELE DIAMOND Look, look, it's over here. Yeah. OK, let's try again. OK, hold her hands. Yeah. Are you watching? Are you watching?

ALAN ALDA (NARRATION) Despite watching intently as the toy goes into the left hand well for a second time…

ADELE DIAMOND She's so sure of herself.

ALAN ALDA It's amazing. Now what's happening there? Why is that happening?

ADELE DIAMOND Well, what I think is happening is she's got only a very fragmentary memory of it being there. And she got rewarded for going here. So I think you have a battle going on, between the fragile memory of where the toy went and this very strong impulse to go to what was rewarded before. So they go back. They go back.

ALAN ALDA (NARRATION) Monkeys with damaged frontal lobes make the same, suggesting it's Alexandra's immature frontal lobes that cause her to keep going back to the same old well. By the time she's Graylen's age, Alexandra will be having no problem with the well task. But she'll still be doing things that to an adult brain seem baffling.

RESEARCHER And in the color game all the red ones go here and all the blue ones go here, right?

ALAN ALDA (NARRATION) Graylen is three.

RESEARCHER Can you point and show me where the blue ones go? Yeah, perfect. Where do the red ones go? Perfect.

ALAN ALDA (NARRATION) The cards can be sorted either by shape or by color. Graylen's first learning the color game.

ALAN ALDA She has to match up the cards with the colors of the objects…

ADELE DIAMOND And now she's going to do the shape game, when she has to match the shapes.

RESEARCHER Can you show me where the stars go? Yeah. Where do the trucks go? Oh, excellent.

ADELE DIAMOND Now they won't be red or blue, so she can only match them by shape, see, it's a yellow star. This is training.

RESEARCHER Now remember. Stars go here, and trucks go here. Here's a truck. Where are you going to put that?

ADELE DIAMOND OK, so now she's done color, and she's done shapes. No problem with either.

RESEARCHER Can you point and show me where the trucks go? Where do the stars go? Good job. Here's a truck. Where are you going to put that?

ALAN ALDA That was a blue truck.

ADELE DIAMOND Yes.

ALAN ALDA So…

ADELE DIAMOND Now it's the testing. Now she's got the conflict.

ALAN ALDA (NARRATION) In the shape game, the color doesn't count - and Graylen has learned the game well.

RESEARCHER Can you point and show me where the stars go? Excellent. Where do the trucks go? Yeah. Here is a star. Where're you going to put that? Now remember, all the stars go in this box and all the trucks go…

ADELE DIAMOND Notice that every trial either the experimenter restates the rules or the child answers, restating the rules. RESEARCHER Where'd the stars go? Good girl. What about the trucks? Where do they go?

ALAN ALDA She's learning in a way to ignore the color during this part.

ADELE DIAMOND Yes. And then she's got to undo that.

RESEARCHER You know what we're going to do now, Graylen, now we're going to play the color game again, all right? Now remember, in the color game, blue

ones go here and red one go here? Can you show me where the red ones go? Where do the blue ones go? Excellent. Here's a blue one.

ALAN ALDA Hmmm…

ADELE DIAMOND Yeah.

RESEARCHER Have a look and tell me where the blue ones go. Excellent. Where do the red ones go? Yes. Here's a red one. Where does that go?

ALAN ALDA Wow, where do the blue ones go, where do the red ones go. Here's a red one. Star.

ADELE DIAMOND Right.

ALAN ALDA It's really remarkable.

ADELE DIAMOND What I think is happening is before the child sees the card, the child has clearly in mind what the rules are and what she's supposed to do. She knows that red ones go here and blue go there. She's got it. Then she sees this card that is relevant to both dimensions in incompatible ways. And that creates a problem for her. What we call this is attentional inertia. They can't get their attention off of what had been relevant before.

ALAN ALDA So what you start with seems to get dominance in some way. Why is that? Because it's been reinforced many times?

ADELE DIAMOND I think so, yes. You've got used to doing those rules that way.

ALAN ALDA (NARRATION) The part of the brain that's good at sticking to the tried and true is down in the more primitive regions. In the adult brain, it's the pre-frontal cortex that jumps in and over-rules the ingrained response.

RESEARCHER What is that?

JULIANNA A star.

ALAN ALDA (NARRATION) But in a three-year-old brain like Julianna's, the pre-frontal cortex still isn't up to the job of switching her mind to the new set of rules. Adele Diamond has an idea she's testing here that if a child herself names the color or shape it will help her get out of her rut.

RESEARCHER And what is this called?

JULIANNA Truck.

RESEARCHER Where do trucks go?

ADELE DIAMOND Before the experimenter said, this is a truck. Now she's saying what is it and having the child say this is a truck. That's the only difference.

RESEARCHER What color's that?

JULIANNA Red.

ADELE DIAMOND I think that it provides a verbal scaffold to help her move her attention. When she's named it as something else, I think that helps her get over the hump of moving her attention to what's newly relevant now. That's what I think is happening.

RESEARCHER What color is this?

JULIANNA Red.

RESEARCHER Where do red ones go?

ALAN ALDA (NARRATION) For a moment it looks as is Julianna's got it…

ALAN ALDA Oh, oh, oh a little indecision there.

ALAN ALDA (NARRATION) But even with a verbal cue helping out…

RESEARCHER Can you tell me what color this one is?

JULIANNA Blue

ALAN ALDA (NARRATION) Julianna's frontal lobes aren't quite up to the task.

ADELE DIAMOND OK, so she made a liar out of me.

RESEARCHER So this is the adult version of the child card sort that you just saw, and it's computerized…

ALAN ALDA (NARRATION) Well, here's the inevitable moment when my pre-frontal cortex is going to be on public display. The word tells me whether to respond to the shape or the color. So far so good - when they're all shapes, my frontal lobes have it easy. When the rule changes, things get trickier. Now the

heat's really on - sometimes the rule is color, sometimes it's shape. The computer's been measuring my reaction time - which in the mixed trial slowed drastically.

ALAN ALDA I am all washed up.

ADELE DIAMOND The children make the mistake at the level of accuracy. They actually get it wrong. Adults make the same kinds of mistakes but now at the level of reaction time. We're slower to do the things that the children do wrong.

ALAN ALDA Now what's this telling us about what's happening in the brain? In an adult brain, that's supposed to be totally developed. Well, maybe I'm on the downside…

ADELE DIAMOND The older part of the brain- the part that's involved with habit and doing what comes naturally - has had a lot more time to develop than pre-frontal. So fragile pre-frontal cortex can't always solve everything. It's hard to switch, it's hard to change what your system has gotten used to doing.

ALAN ALDA (NARRATION) This time my system is getting used to pressing the button on the same side as the gray dot - which isn't too hard. But now of course the rule changes. When the dot's striped I have to press the button on the opposite side - and I'm slower. Then when the dots are mixed…

ALAN ALDA Ah! Ah!

ADELE DIAMOND Everybody make mistakes.

ALAN ALDA I'm pressing everything. If it was a pinball machine I'd have done fine.

ALAN ALDA (NARRATION) At least I got to do my test sitting comfortably at a computer. Ten-year-old Kevin is going to do the same test while lying in an MRI machine - actually a mock MRI machine, or his braces - and maybe his teeth -- would be yanked right out of his mouth.

ALAN ALDA Are my credit cards OK doing this?

ADELE DIAMOND It wouldn't be if it was a real scanner because of the magnetic field. But this is just like the real thing except that there's no magnet here so your credit cards are safe. This is what we use to get people acclimated to the scanner.

ALAN ALDA Oh, I see.

TECHNICIAN OK Kevin. Here we go. Here's your box. Put you hands on this, hold your thumbs just like that. OK, I'll slide you in a little bit.

ALAN ALDA (NARRATION) Kevin's prefrontal cortex - as his parents will no doubt discover in the next few years - still has quite a bit of maturing to do.

TECHNICIAN There you go. How's that?

KEVIN Great.

TECHNICIAN OK, so we'll get started here…

ALAN ALDA (NARRATION) But when he performed this task in a real scanner, the images revealed a critical part of his pre-frontal cortex already hard at work.

ALAN ALDA This is your brain here?

KEVIN Yeah.

ALAN ALDA Do you recognize it?

KEVIN Yeah.

ADELE DIAMOND So first what I thought I'd do is show you some of the anatomy of his brain. You're going to see us go from the front of his brain to the back, and as we're doing that you'll see what it looks like at each of those levels. Pretty neat, huh? So these are the slices, Kevin, that we took through your brain when we were looking at the functioning of your brain when you were doing the task.

ALAN ALDA (NARRATION) The area that lit up brightest was up over his forehead and near the surface of his brain, called the dorsolateral pre-frontal cortex.

ADELE DIAMOND So this is how much harder his dorsolateral pre-frontal cortex had to work when he had gray dots and striped dots.

ALAN ALDA Were you aware that it was harder? Did you see yourself, like, trying to concentrate on it?

KEVIN Yeah.

ADELE DIAMOND Yeah, it's harder when they're mixed together than when you just have one.

ALAN ALDA Would you get them wrong and then realize it a second later?

KEVIN Yeah.

ALAN ALDA Yeah, that happened to me all the time. And then I'd go "oh, oh," and get real excited.

ADELE DIAMOND And you tend to see almost across whatever task that the more difficult condition you get activation of dorsolateral pre-frontal cortex. When you have to concentrate, when it's hard, when you need executive control, you need dorsolateral pre-frontal. The more you can go on automatic, the more you don't have to concentrate as much, the less you need dorsolateral pre-frontal.

ALAN ALDA (NARRATION) So your dorsolateral pre-frontal cortex is critical to helping you make up your mind. But as we'll see in our next segment, it doesn't work alone…

TOUGH CHOICES

ALAN ALDA (NARRATION) Our next stop as my brain and I try to make up our mind is the campus of Princeton University, where inside the Department of Psychology another test of my pre-frontal cortex awaits.

JONATHAN COHEN All right, so name the color and ignore the word.

ALAN ALDA Okay, name the color and ignore the word. Name the color. Yellow. Red. Yellow. Green. I did it. I'm so ashamed.

ALAN ALDA (NARRATION) A classic in psychology, this is called the Stroop test.

ALAN ALDA Name the color, ignore the word. Green. Yellow. Red. Green-Blue. Yellow. Yellow. Blue. Red.

JONATHAN COHEN OK.

ALAN ALDA Boy.

JONATHAN COHEN You did it.

ALAN ALDA But I probably took three times longer.

JONATHAN COHEN Well describe to me what you felt when you were doing it.

ALAN ALDA I just tried to look at it as some symbols that had a color and I was trying to read the color. And then, at one point, all I saw, I mean, I heard myself speaking what was written there. Even though I had decided to just think of it as a meaningless.

JONATHAN COHEN You scratched the itch.

ALAN ALDA Well, yeah, it just produced the word in me. I want to look at this on my brain, okay?

ALAN ALDA (NARRATION) If I'd been in an MRI machine at the time, no doubt my dorsolateral pre-frontal cortex would have been glowing like mad. But Jonathan Cohen is more interested in another part of the pre-frontal cortex, deeper down in the brain, which also seems to get involved when we're faced with inner conflict.

JONATHAN COHEN It's this strip of cortex right over here lying right over the corpus callosum which is this white area right over there.

ALAN ALDA (NARRATION) This brain region is called the anterior cingulate, which Cohen believes is watching out for those times when it's hard to make up your mind - when you're struggling to say red when you're seeing the word green. The anterior cingulate then signals the pre-frontal cortex to focus, focus, focus…

ALAN ALDA There's an organization to this tissue that's built in, that works that way, that helps you do that, that takes a recognized mistake and on the next trial, sends stuff in that make it a little better. I mean, this is built that way, from what you're saying?

JONATHAN COHEN That's the hypothesis. I mean, in some sense it has to be, right? The question is, how? And what we're trying to understand is, how that happens. Just as an aside, one of my favorite book as a kid was "How Things Work". I don't know if you ever saw that.

ALAN ALDA Yeah.

JONATHAN COHEN But it was a book that basically showed the mechanisms underlying all these things that we interact with on a daily life. You have a ballpoint pen…You press the clicker once and the stylus comes out. You press it again…

ALAN ALDA And it goes back. Same click.

JONATHAN COHEN Yeah. That's magic, right? What was great about that book was that it demystified that magic. It said how that happened. There's not a little guy in there keeping track, "oh, we pressed it last time, it went out, I better pull it back in." It's not some homunculus. There's some mechanism that explains it. And the joy of science is discovering that mechanism.

ALAN ALDA (NARRATION) It's not just when the brain's having trouble saying red instead of green that the anterior cingulate yells to the prefrontal cortex for help. Consider this classic problem in philosophy, involving a train, or in some versions, a trolley. You're standing next to a railroad switch as a train approaches. If you do nothing, the train will surely kill five foolish but innocent people standing on the track. You could save them by hitting the switch, diverting the train. The problem is that there's another foolish innocent standing on the second track.

JOSHUA GREENE So the moral question is, is it possible to hit the switch so you only run over one person instead of five? What do you think? Off the top of your head?

ALAN ALDA Off the top of my head it seems it would be regrettable to kill anybody, but if you could save the five people, then you would throw the switch.

JOSHUA GREENE Well, that's what pretty much everybody we ask says. Okay, now here's a slightly different case. Trolley headed towards five people, this time, there's no other track. You're on a footbridge standing over the track. And you're standing next to this big person. And this time, the only way you can save those five people is to push the big guy off of bridge. He'll land on the tracks. He'll get squashed by the train. He'll die, but the five people will live.

ALAN ALDA Okay, so, will I push him off the bridge?

JOSHUA GREENE Yeah.

ALAN ALDA Well, it's so hypothetical. I mean, I don't even understand…First of all, I don't understand how he could … I'd have to be really convinced that he could stop the train. But I'd be, as I'm sure most people would be, less inclined to push the guy. But, um…I don't know….It depends. It kind of depends, I mean, do I have anything against this guy?

JOSHUA GREENE No.

ALAN ALDA Would it matter to me if I lost him?

JONATHAN COHEN Yeah. Is that what you really want to do?

JOSHUA GREENE The fact that you're looking for all these sort of angles and ways out and things to question is very telling. Because most people are made rather uncomfortable by that one.

ALAN ALDA Right. I'm taking a very active role--.

JOSHUA GREENE Structurally, these are very similar cases. I mean, it's death by trolley to one person in order to save five people. Perhaps you can try and find a reason why it's OK. And this is what philosophers have been busy doing…Well we put the philosophical question about what is right and wrong aside for a second, and we asked, what's going on in the brain?

ALAN ALDA (NARRATION) What they found when people struggled with these problems in a scanner is that regions of the brain thought to be involved in emotion lit up when people thought about pushing the guy off the bridge. And just as I did, it took them longer to make that decision than the less personal one of throwing the switch. The Princeton researchers also borrowed a story line from the last episode of MASH in their exploration of how the brain wrestles with moral dilemmas. A bus full of people has to hide from enemy soldiers…

SOLDIER Quiet, nobody make a sound until they've passed.

ALAN ALDA (NARRATION) But a crying baby endangers everyone's life. In the MASH story Hawkeye urges the mother to keep the baby quiet - and she ends up smothering it. In the Princeton study, subjects were asked to decide if its OK to smother the baby in a case like this. They were also asked about a second moral choice.

JOSHUA GREENE A teenage mother, gives birth in the locker room at school and she just doesn't want to deal with it. Is it okay for her to just throw the baby in the dumpster? Almost everybody says no, that's not okay and they say no very quickly. That's a personal case, in the sense of having that up close and personal interaction. It's the same kind of action, killing your own child, as in the MASH sort of case. But, very different in terms of what's going on in people's heads. In both cases, according to our view, there's a proponent emotional response, saying "no, no, don't do it." In the case with the teenage mother, because, at least, according to our moral views, there's really is no …There are no strong countervailing rational considerations that would make that OK. You could probably come up with some if you modify the case a bit, but there the thought is that the emotion occurs and it just wins because there's nothing to oppose it. Where as in the MASH kind of case, you have that proponent emotional response, but then your reason kicks in says, well, wait a second, if you don't do this, everyone could die, including the baby. So there's this drawn-out conflict and

instead of people answering in two seconds or three seconds, they take closer to ten seconds to give their answer.

ALAN ALDA (NARRATION) Josh Greene is now looking at the brain scans of people wrestling with the MASH kind of case to see if the anterior cingulate - which the Princeton group believes is monitoring conflict- is working overtime listening to all the different parts of the brain - both rational and emotional -- clamoring for input before someone finally makes up their mind. How emotion and rationality compete in decision making is also the subject of an experiment that I'm about to be suckered into - along, apparently, with some dozen Princeton students.

ALAN SANFEY Our subject today is going to Alan Alda, whom I'm sure you all recognize, and slightly different from out run of the mill Princeton undergraduate. And so, the way it'll work is that each of you, in turn, will play one round of the game. You'll be brought into a room and sat in front of a computer terminal. You'll play the game with Alan who's gonna be downstairs in the scanner. Just Alan, if you just kinda shake people's hands. Maybe you can just briefly introduce yourself and give your name.

PETER VINCENTERS I'm Peter Vincenters. I'm a junior in mechanical engineering.

ALAN ALDA How do you do?

KATHLEEN I'm Kathleen Brand, I'm a chemical engineer.

ALAN ALDA (NARRATION) Now all I know about the game so far is that I'll be asked to accept or reject various financial offers each of these fellow players will be making.

ROB Hi, I'm Rob Wurtz, senior economics major.

FINN Finn Colabra, I'm a senior electrical engineer.

ALAN ALDA How do you do? I gotta watch out for the economics guy.

ALAN ALDA (NARRATION) I'll be having my brain scanned while each of the other players offers to split ten dollars with me. I can either accept or reject the offer - but if I turn it down, we both get nothing.

ALAN ALDA Well, if they give me a ridiculous offer, then I lose money because I don't accept their ridiculous offer?

JIM RILLING That's correct. If you reject the offer, neither of you get anything.

ALAN ALDA This game is like life.

ALAN ALDA (NARRATION) So it's into the MRI machine I go - a real one this time. I get given a button box to respond to the offers, which I can see projected on to a mirror above my face.

TECHNICIAN Alan, are you able to read the words "Welcome to the Experiment" written on the screen there?

ALAN ALDA Yes.

ALAN ALDA (NARRATION) I hadn't expected a computer as a partner - but it's offer seems what a reasonable machine would make - so OK, I'll take it. Kelly seemed a nice person… and she is, fine. Kathleen, let's see… What? That's ridiculous. No way. I'm beginning to wonder if this is a set-up and the people aren't actually playing, just lending their faces. Ah, another selfish oaf… Take that. Clare… surely…Oh, dud, dum, dum…yes, no… No. To heck with it. I'm now pretty sure I'm being manipulated by the experimenters, not those nice polite Princeton students…Oh, here's the computer again - maybe I can teach it a lesson in manners too. Zap. OK, after some thirty minutes in the scanner wrestling with my outrage - freedom.

ALAN ALDA Was there somebody live on the other end?

ALAN SANFEY Well, um, no. Not exactly, no.

ALAN ALDA At one point they were alive. When you took their picture.

ALAN SANFEY Exactly.

ALAN ALDA I think it occurred to me somewhere in the middle of the first run, I think.

ALAN SANFEY Did that affect how you played the game?

ALAN ALDA No, I played it as if they were real people.

JONATHAN COHEN You actually rejected a couple of offers from the computer where it made avowedly unfair offers but nevertheless there's presumably there's no personal...

ALAN ALDA Well, the chances were better for me if I could move the computer around than if I just had an emotional reaction to it.

JONATHAN COHEN Or if it was just a dry response. Which is, "Hey, it's just a computer, what do I care? I'll take the two bucks and run. There's no consequences down the road for what I get.

ALAN ALDA And it's just a couple of bucks, I could--.

JONATHAN COHEN We discussed that too. And at first we thought, maybe this is an inconsequential part of your salary, but then we realized, this is PBS…maybe this is more than your getting.

ALAN ALDA No. I did very well today.

JONATHAN COHEN We haven't paid you yet. This is part of the experiment. IRISH

JONATHAN COHEN You want this right now?

ALAN ALDA You think I'll be giving this back to Princeton. Forget it. What did I make? IRISH

JONATHAN COHEN Forty eight dollars.

ALAN ALDA Forty eight dollars.

JONATHAN COHEN Not bad, huh?

ALAN ALDA Now, of course, you know, this has nothing to do with the science, but how did I do compared to other people?

JONATHAN COHEN I'll let these guys answer, because they're the ones…

ALAN ALDA Is that about average?

ALAN SANFEY That's actually low. Because most people would be…would reject less offers.

ALAN ALDA They would. Because--. What do they report when they talk to you? Why would reject?

ALAN SANFEY Typically around the 7 and 3 mark, people have typically told us, "It's a little bit unfair but it's not too bad." So they tend to accept that. They also

tend to accept everything a computer offers them. They don't really draw distinction between fairness and unfairness of a computer. Most of them will reject a 9 and 1 offer, and about half will reject the 8 and 2, and most will accept the 7 and 3.

ALAN ALDA Yeah. I must say, it would be interesting to know what you recorded when I was offered the 7 and 3. Because I thought, well, gee, that's being awfully particular. Why don't you take the three? But I thought, no, no.

ALAN ALDA (NARRATION) Decisions that mix emotion with reason are awfully hard to make - and the longer it takes, if the Princeton team is on the right track, the more that little strip of brain called the anterior cingulate is calling on your frontal lobes to resolve the conflict, and make up your mind.

INTO THE DARK

COURTNEY Hi Michelle, I'm Courtney, one of the dieticians.

ALAN ALDA (NARRATION) So far we've focused on how the brain uses specialized regions to make up its mind. But now we're going to see how the brain can sometimes change its mind about what region does what. Michelle Geronimo has volunteered to be the subject of an extraordinary experiment. I'm here to lend a little moral support. In a few moments, Michelle is going to lose her sight.

ALAN ALDA Is this real food?

COURTNEY These are food models that we use for teaching purposes.

ALAN ALDA That's a great relief.

MICHELLE GERONIMO For me too.

ALAN ALDA Because if that was the real food I wouldn't wear that blindfold if I were you.

ALAN ALDA (NARRATION) Neuropsychologist Alvaro Pascual-Leone makes sure Michelle won't peek by tucking a tell-tale snippet of photographic film into the blindfold.

ALAN ALDA Your last look, huh?

MICHELLE GERONIMO Yeah, into the darkness.

ALVARO PASCUAL-LEONE Here we go.

MICHELLE GERONIMO Here we go.

ALAN ALDA (NARRATION) It's now 9 am Monday morning.

ALVARO PASCUAL-LEONE We're going to start bandaging, OK?

ALAN ALDA (NARRATION) Michelle will be totally blind until 3 pm Friday. Aisling Ward There are eye pockets, so you can blink.

ALAN ALDA (NARRATION) Here's the moral support I mentioned.

ALAN ALDA Michelle, can you hear me?

MICHELLE GERONIMO Yes I can.

ALAN ALDA Hi!

ALAN ALDA (NARRATION) To get a sense of Michelle's next few days, I'm being blindfolded for the morning. CAROL Are you both ready to start walking with the cane?

ALAN ALDA Yeah, who's this, here? Who's that, the cameraman? PETER Yes sir.

ALAN ALDA Well get out of the way!

ALAN ALDA (NARRATION) We're headed for the hospital's Clinical Research Center -- and at once my awareness of the surroundings shifts from sight to my other senses. CAROL The differences in sound quality…

ALAN ALDA Sound and temperature.

ALAN ALDA (NARRATION) In fact the whole point of the experiment Michelle's about to go through is to see if this shift in sensory input has an impact on her brain -- in particular, on her sense of touch while she learns to read Braille.

ALAN ALDA D. It feels a little thicker on the top. LAURIE It's like a C with another dot.

ALAN ALDA (NARRATION) I'm having trouble even feeling the dots, let alone interpreting them as letters.

ALAN ALDA Eventually you get the shape of it and they just go automatically into your brain as a letter, I guess. LAURIE Right. GIL "As things turned out, my mother and I were able to leave Cuba together in 1962…"

ALAN ALDA (NARRATION) But we now need to back up a little in our story, and meet Gil Bush, who's been blind from birth. He earns his living as a proof-reader for Braille publications. Information pours into his brain -- principally through the tip of his right index finger -- at an astonishing rate. For years, brain scientists have been fascinated by this skill and have wondered if it involves a change in the way the brain is organized. This little device presents Braille letters to a fingertip for just a few milliseconds. GIL E. I. L.O.

ALAN ALDA (NARRATION) With Gil's baseline skill established, now comes the dramatic part of the experiment.

ALVARO PASCUAL-LEONE I'm just taking the magnetic stimulation coil…

ALAN ALDA (NARRATION) This coil will deliver a powerful magnetic jolt to Gil's brain, temporarily disabling the region immediately beneath it.

ALVARO PASCUAL-LEONE We're targeting the back of your brain and in fact the back part we call the visual cortex.

ALAN ALDA (NARRATION) The visual cortex handles information from the eyes -- at least in those of us with sight.

ALVARO PASCUAL-LEONE Does it feel OK? GIL It feels fine.

ALAN ALDA (NARRATION) Which makes this experiment seem rather odd. Why zap the visual cortex, when what's being tested is a skill involving touch, which is processed in another part of the brain entirely? In fact, this is a recreation of an experiment first done by Alvaro and his colleagues several years ago. Gil's experience today perfectly replicates that experiment. GIL They felt very dim, like the dots weren't coming up as well as before.

ALAN ALDA (NARRATION) Gil's accuracy declined too. The extraordinary implication is that Gil's visual cortex is involved in reading Braille -- as if his brain has somehow rewired itself to recruit for touch, brain cells most of us use for seeing. And this is the reason for Michelle's abrupt encounter with blindness. The question is: Can her brain also rewire itself to help read Braille -- in her case after just a few days as compared with Gil's lifetime without sight?

MICHELLE GERONIMO Or king, king, G -- six dots.

ALAN ALDA (NARRATION) But for me, three hours of total blindness is enough.

ALAN ALDA That is bright. Michelle, I can't see!

MICHELLE GERONIMO That's comforting!

ALAN ALDA (NARRATION) Later on that first day of Michelle's blindness, she goes to have her head examined -- in an MRI machine that will take pictures of her brain while different senses are stimulated. To understand the results we need a brief lesson in brain anatomy.

ALAN ALDA Can you show me the parts of the brain that I use when I'm looking at stuff?

ALVARO PASCUAL-LEONE Yeah. Let me open up your head.

ALAN ALDA OK.

ALVARO PASCUAL-LEONE So basically of course the light would be coming in through here, and it actually travels all the way to the very back of the brain, the occipital cortex, that is the visual cortex.

ALAN ALDA Back over here.

ALVARO PASCUAL-LEONE Back over there.

ALAN ALDA So if that's where I see, where do I feel?

ALVARO PASCUAL-LEONE Right, so the information from your hand, from your right hand, will come to the left side of your brain, specifically here, to the posterior part of the central sulcus. Information from your left hand will come to the other side, on the right side of the brain.

ALAN ALDA (NARRATION) In this day one testing of Michelle's brain, the results were no surprise. When the index finger of her left hand was stimulated, the touch-sensing region on the right side of her brain lit up, just as it would in you or me. But now Michelle settles down for her 100 hours of blindness. A favorite movie doesn't need the picture. There are walks around the hospital corridor. Activities to exercise her sense of touch.

MICHELLE GERONIMO Happy Valentine's Day.

ALAN ALDA (NARRATION) And practice reading Braille -- hours and hours of practice reading Braille. Until finally it's Friday. CLOCK 12:39 pm

MICHELLE GERONIMO 12:39 pm, which means I have 2 hours and 21 minutes left.

ALAN ALDA (NARRATION) Michelle's week of total darkness was relieved by one vivid visual hallucination.

MICHELLE GERONIMO I had an image on my blindfold, on the left side, black and white still shot of a face, looking to the left, really clear, really distinct really odd -- because it was Elvis Presley. And it was Elvis the later years, Elvis with a little more hair and the rhinestone outfit with the white collar.

ALAN ALDA (NARRATION) In these last few hours of blindness, Michelle returns to the MRI scanner. This time her brain looks very different. Instead of her touch-sensing region lighting up, now her visual cortex is activated. It's as if, finding itself with nothing better to do, the visual cortex has stepped in to help with a task it's more skilled at than is the touch region -- making sense of symbols. This possibility is strengthened when Michelle is tested as Gil was -- to see if disrupting her visual cortex impairs her ability to read Braille. Her Braille test is a little easier than Gil's -- to identify whether pairs of letters are the same or different. Now Michelle's visual cortex gets 10 minutes under the magnetic coil.

ALVARO PASCUAL-LEONE OK, we're all done.

RESEARCH ASSISTANT Michelle, we're going to test your right index finger again.

MICHELLE GERONIMO OK.

RESEARCH ASSISTANT Ready?

MICHELLE GERONIMO Yes. Different. Different.

ALAN ALDA (NARRATION) Sure enough, just like Gil, her accuracy drops markedly. For Alvaro, already happy as the results emerge, there's a bonus.

MICHELLE GERONIMO I found that my fingers have been a little less sensitive, since the TMS testing, the stimulation, to the feel of the characters from the Braille task.

ALVARO PASCUAL-LEONE That's fabulous. We'll pay you another $500!

MICHELLE GERONIMO Thank you.

ALVARO PASCUAL-LEONE That is exactly what we're looking for. We were wondering whether there would be some function related to touch that would be taken over by the visual cortex over the time that you've been blindfolded. And the fact that your fingers feel less sensitive now would suggest that that actually has been the case. Wow! This is good.

ALAN ALDA (NARRATION) Alvaro has reason to be excited. Michelle's experience is dramatic confirmation of his hypothesis that the brain can reorganize itself in just a few days, let alone a lifetime.

ALVARO PASCUAL-LEONE I would say that the brain is like, you know, market economy. There is demand for a certain thing, we activate what it needs to cover that demand. There is no demand for it, we use it for something else. It is just like any good shopkeeper would do: you adjust whatever you offer to people passing by by virtue of what they are going to need.

MICHELLE GERONIMO I feel this blindfold has become part of my face.

ALVARO PASCUAL-LEONE You ready? You want to keep your eyes closed to begin with.

MICHELLE GERONIMO Oh, geez. Hi. When the blindfold came off I was a bit disoriented and a bit unbalanced. I'd been dependent on hearing to orient myself, and then when the vision came back I found myself off guard and had to take things in a new way now. But now I'm alright.

ALVARO PASCUAL-LEONE So, we'll ask you to put on a blindfold again -- just for the test -- and do the Braille discrimination.

ALAN ALDA (NARRATION) Having her vision restored has in fact had an even more profound effect than Michelle realizes. When her visual cortex is zapped the next morning, her ability to read Braille is unaffected. After just a few hours of working at its usual job, her vision center has apparently found it's much too busy to any longer help out with touch. Michelle's five days of blindness has provided astonishing confirmation of the malleability of the human brain.

THE POWER OF HALF

ALAN ALDA (NARRATION) We're began our show with the story of Phineas Gage, who lived without a chunk of his brain. We're ending with the story of an equally remarkable young woman.

JORDAN GRAFMAN This is the right side of her brain; this is the left side of her brain. And what happened was, in utero, she had a stroke. And the stroke, not entirely, damaged a large proportion of her left hemisphere.

ALAN ALDA So that never developed?

JORDAN GRAFMAN Never developed.

ALAN ALDA What is the left hemisphere usually there for?

JORDAN GRAFMAN Verbal processing. Language processing. Not all aspects of language by the way, but enough that we consider it the hemisphere that really dominates our language abilities. It also plays a fairly large role in recognizing objects. Our ability to look at objects to know what they are and even how to use them.

ALAN ALDA So if those functions of the brain were only to be found in that area, then you'd expect that a person without that part of the brain would have difficulty saying words or recognizing objects. But this is not the case with Michelle?

JORDAN GRAFMAN This is not the case with Michelle, and that's why I'd like you to come and meet her.

ALAN ALDA (NARRATION) Missing almost the entire left side of her brain,

MICHELLE MACK has an obvious problem controlling the right side of her body. But at the Catholic Church where her mother's a pastor, it's equally obvious that Michelle has few problems either with language or recognizing objects. She regularly helps out with the church records.

MICHELLE MACK I take them home and I update them on my computer at home and I bring them back to my mother and I file them.

ALAN ALDA (NARRATION) Recently Michelle's mother Carol contacted

JORDAN GRAFMAN at the nearby National Institutes of Health outside Washington DC.

CAROL MACK I wonder what testing Dr Grafman will be doing.

ALAN ALDA (NARRATION) Every month or so now, mother and daughter drive to the NIH to join Grafman and his team in a study of how Michelle's right brain copes with a workload most brains share with the left. Today, Carol told the film crew of a skill even Grafman doesn't know about.

ALAN ALDA If I say a date, you can come up with what day of the week it is?

MICHELLE MACK Yeah, I think so, yes.

ALAN ALDA Well, let me not go too far out. Let's say this year, the year 2000, October 19th.

MICHELLE MACK OK. October 19th is going to be on a… Thursday.

ALAN ALDA OK, I don't have a calendar so I can't check that. So far you're doing great. OK. So let me go a year later. The year 2001, August 12th.

MICHELLE MACK OK… Sunday.

CAROL MACK They're all checking! (Off camera) They're both right.

ALAN ALDA They're both right?

CAROL MACK They're both right.

ALAN ALDA Maybe we should stop at 100% correct, right? That's amazing.

MICHELLE MACK That's great. I hope this is on tape.

ALAN ALDA Did you know she had this ability?

JORDAN GRAFMAN Not until right now. And that's why it's fun to work with Michelle because she's always surprising us.

ALAN ALDA (NARRATION) Jordan's work with Michelle is only beginning. But already it's apparent not only that her right brain has taken on tasks usually done by the left, but that it's had to make some changes of its own. For instance, Michelle has problems with tests of her visual-spatial skills, even though her right brain -- where these are normally tackled -- is intact.

ALAN ALDA It's almost a question of geography. Like there's a whole bunch of word people who have no place to live on the left side, and they're crowding on to the right piece of geography and there's only a certain amount of land there…

JORDAN GRAFMAN They're not asking permission.

ALAN ALDA That's right. They're coming in, they're barging in and the folks who are living there who handle spatial stuff are getting crowded out. Not as many of them can do the spatial stuff. That's what it sounds like is happening.

JORDAN GRAFMAN Couldn't have said it better!

ALAN ALDA But that's fascinating isn't it. I mean there's this old saying that you hear all the time, you know, we only use 10% of our brain. It sounds to me we're all using every bit we've got…

JORDAN GRAFMAN Every bit we've got, and we'd try to stake out more if we could.

ALAN ALDA Right. And it's almost as if there are parts of our brain competing…

JORDAN GRAFMAN Exactly.

ALAN ALDA …for a place to work.

JORDAN GRAFMAN Exactly. As you learn new things, there's always somewhat of a cost. There's a finite amount of space and a finite amount of tissue, and you can enrich that tissue but you're also going to compete with adjacent territory as you learn new skills and have new abilities. And you use the whole brain, and the whole brain is a competitive organ. Each piece of the brain is competing with its neighbors to get more territory, to have more action. And it's happening now in you and it's happening in Michelle as she takes the tests and develops throughout her life.

ALAN ALDA (NARRATION) That's it for our show on how our brains make up our minds. See you next time.

return to show page