ABBY NOYCE: So yesterday, we talked about theories and models of attention. Today, we're going to get down into the nitty gritty a little bit more and actually talk about some of the neuroscience that underlies it. So what were some of the attention models we talked about yesterday?

AUDIENCE: Spotlight.

ABBY NOYCE: The spotlight one is one of the older models, that attention focuses on a particular location. We talked about some of the evidence showing that attention seems to be more object-focused than space-focused, which is one of the big flaws in that theory. What's another one?

AUDIENCE: The feature integration?

ABBY NOYCE: Yeah. What's the feature integration one?

AUDIENCE: Wasn't it like each feature in the brain has a certain map? And when you're searching for that feature, that map is pulled up when you're looking for it. And then when there's two new features, you line the maps next to each other?

ABBY NOYCE: Yeah. Good. The feature integration theory is trying to explain the difference between those disjunctive single-feature different searches, where you're looking for the black circle among white circles and the conjunctive, multiple-feature black circle among white circles and black squares and the difference between those tasks. What's another one?

AUDIENCE: Did someone mention spotlight?

ABBY NOYCE: Spotlight we got.

AUDIENCE: Thank you. Early selection.

ABBY NOYCE: So early selection, which is kind of from way back in the day when people first started thinking about this. It says that attention happens really early in the processing stream. And the counterexample to that is the cocktail party effect, where someone says your name from across the room and you go, "Huh? What? They're talking about me," even if you hadn't been paying any attention to the conversation previously. So you're switching your attention based on the semantic content of that, not just from a low level feature. Good. OK.

So today, we're going to start with looking at what do we know. Well, we know that attention has to do with an awful lot of the brain. Somewhere or other, when you are paying attention to a task or stimulus, lots of different regions get involved. There's two big cortical areas. There's this posterior attention network, which is kind of like the dorsal parietal lobe here. Remember dorsal is towards the top of the head? And there's the anterior attention network, which is way down here in the prefrontal area.

Prefrontal is, of course, kind of a silly name-- in front of the frontal-- but it means the very forward-most part of the frontal lobe, where it kind of ducks underneath there.

So these are areas that have been shown to be involved in both PET and fMRI imaging, which we know are imaging techniques that are good for finding areas that are involved in stuff. They're not so good at figuring out exactly what those areas are doing. We'll talk today about evidence from a couple of different methodologies. We talked yesterday also about evidence from patients with lesions-- patients who have holes in their brain in certain areas.

So these two. The posterior attention network. Remember this is the dorsal parietal area. It seems to be really involved in spatial attention. When you shift your attention to a particular region, like on a display, the posterior attention network seems to be the part that's involved in this. This is involved in like visual search tasks.

Again, think of looking for that black circle among the black boxes and the white circles. Then your posterior attention network is the part of your cortex that's directing your attention to each of the shapes there one at a time, checking to see if they're going to be the correct target and shifting it back and forth between these. And this is our hemispatial neglect drawing from yesterday. So remember that patients with hemispatial neglect can't or are biased against, at the very least, directing their attention to usually the left-hand side of their visual field. Usually you see this with damage to the right parietal lobe. And so this posterior attention network seems to be what's damaged in these patients who are biased against shifting their attention to certain regions.

This posterior attention network-- which I wrote "parietal," but I'm wrong-- also seems to be linked to the specific processing modules of color and feature and shape in the visual system. We talked last week about how the visual system has areas that work on processing color, areas that work on processing shape, areas that work on processing direction of movement. When you're doing a visual search task that looks for one of those things, the posterior

attention network seems to be influencing the responsiveness of neurons in those individual modules.

AUDIENCE: Is that supposed to be "posterior" and not--

ABBY NOYCE: Yeah.

AUDIENCE: OK.

ABBY NOYCE: Too many P words. And so what it will do is, if you're looking for a target that's a black circle, it'll mean that the neurons that respond to things that are black are going to be more responsive. The posterior attention network connects to those neurons and makes them a little bit more excitable than neurons that are tuned to less relevant features, like blueness or redness or whiteness. So attention is one of these functions that seems to really take advantage of the interconnectedness of all our different cortical abilities.

We're going to do this, but it's not going to link for me because it's not a pretty link. Copy. Firefox. Nope. This is a kind of classic attentional task, the Stroop test. Just be quiet. Go on. This is not my Firefox. Are you going to be trouble?

AUDIENCE: Safari runs faster.

ABBY NOYCE: Yeah, OK. It works. Safari does not run faster. So this is a task where it's going to show you a set of words printed in different colors and the goal is to say the color that the word is printed in, not the word itself. Some of you may have seen this demo before. It's kind of a classic. So what we're going to do is we're going to have somebody read the list aloud as fast as they can. We're going to do two rounds of it, a congruent and an incongruent round. Anyone want to volunteer to go first? All right. Jen, ready? Read the color the word is printed in.

AUDIENCE: OK. [INAUDIBLE] Up? Down?

ABBY NOYCE: Across.

AUDIENCE: OK. Red. Green. Blue. Yellow. Pink. Salmon? Blue. Green. Blue. Is it orange?

ABBY NOYCE: It's probably orange.

AUDIENCE: Orange. Blue. Green. Blue. White. Green. Yellow. Orange. Blue. White. Brown. Red. Blue. Yellow. Green. Pink. Yellow. Green. Blue. Red.

ABBY NOYCE: All right. 23.241 seconds, but there was a lot of hemming and hawing about what we're doing in there. Yeah, I think that color is meant to be orange.

AUDIENCE: Or salmon?

AUDIENCE: You talking about the orange one?

ABBY NOYCE: Yeah. All right. Anyone want to volunteer to do the next round?

AUDIENCE: All of those ones are the same.

ABBY NOYCE: Yeah. So this is the congruent case. Anyone want to volunteer to read for the next round? Sarah? Ready? Go.

AUDIENCE: Green. Yellow. White. Pink. Orange. Blue. Red. Yellow. Green. Blue. Green. Green. Red. Blue. Green. Blue. Pink.

ABBY NOYCE: That's not blue.

AUDIENCE: Ah! Red. Pink. Ah, I keep reading. Blue. Yellow. Pink. Green. Orange.

AUDIENCE: That wasn't--

ABBY NOYCE: That was totally orange. She's right.

AUDIENCE: Is that orange?

ABBY NOYCE: Yeah.

AUDIENCE: Red. Blue. Pink. No, that's orange. Red. Green.

ABBY NOYCE: Very nice. Is there a difference?

AUDIENCE: Yeah. It made quite a difference.

ABBY NOYCE: Which one's harder?

AUDIENCE: The discongruent one.

ABBY NOYCE: Yeah. The incongruent task is a lot harder. So what you're doing here is your brain-- reading for most literate adults is a really automatic task. You see text. You have to read it. And what you're trying to do in this task is inhibit that reading response and do this other, less familiar

thing. We don't spend a lot of time trying to read off colors of ink.

AUDIENCE: If you squint your eyes enough so that you can't read the text anymore, you can actually do it with [INAUDIBLE].

ABBY NOYCE: It's easier. You get better at it with practice, too. This is definitely something in which there's a practice effect. It's also something on which women are dramatically better than men. And this goes all the way back to when Stroop first demonstrated this in the '30s. And his theory was that, well, because women are the domestic members of the household, they spend time thinking about colors of fabric and furniture and clothing and has so much more practice thinking about colors and naming colors than men do. Who knows? I think that's a bit of a stretch.

AUDIENCE: It has some merit.

AUDIENCE: Ha, ha.

ABBY NOYCE: But there's definitely a significant difference. Anyway, this is a task that requires a lot of attention, but it's not attention that's in the sense of focusing on a specific spatial location in the way a visual search task is. This is a task that requires the other cortical attention network. This is the anterior attention network that isn't so spatially-oriented, but on tasks like this, where you're really working on a response and inhibiting something and really having to focus on what you're doing, the anterior attention network, which is right up there in that prefrontal area, is really involved. Anyone want to read this one? Who hasn't done one yet? Naman, go for it.

AUDIENCE: Red, bue, yellow, purple, yellow, blue, green, red, green, red, purple, blue, blue, red, green, yellow, red, green, yellow, purple, yellow, blue, white, purple. green. purple. [INAUDIBLE]. So green, purple, green, yellow, red, purple, red, blue, green.

ABBY NOYCE: This is also one of those tasks where you can start out just fine and get about halfway through it and then you stumble, and it throws you all off. I don't know. But it's definitely easier to do for a shorter list of words than for a longer one. It gets harder the more you continue doing it, again, fitting into this idea that attention is limited and you're kind of using it up on a task like this.

So how do we measure what the brain is doing if we don't want to use PET or fMRI? Because

PET and fMRI have lousy temporal resolution. They can tell you what portions of the brain are active, but it takes them a few seconds to get that response and neurons work a whole lot faster than a few seconds. You'll see neural responses on the order of tens of milliseconds. So this is a picture of the lab I'm going to be working in when I start school in the fall of an EEG, electroencephalogram, setup. So this is a net of electrodes that covers the scalp.

And an EEG can measure the electrical activity of the brain. All the electrical stuff that your neurons are doing actually emits a very subtle electrical field around your head, and the electrodes in this can pick it up. And usually, EEGs are used in particular for what's called an ERP study, where they're measuring the event-related potential, so changes in the electrical field that the brain generates in response to a particular stimulus. EEGs are not good for high spatial detail the way fMRI is, but they're really good for time detail. You can present a stimulus and see these very quick changes in how the brain responds to them. And you get to look like a space alien.

AUDIENCE: Can you get money for participating?

ABBY NOYCE: Usually you can get money for participating in studies like this, yeah, if only because they take a couple of hours because getting one of these things set up is annoying and fiddly. You've got to check each individual electrode and make sure it's getting adequate signal, and there's a little gel you have to squirt into it to make sure it's getting good contact with the scalp. And then you've got gel in your hair. It's not harmful in any way or risky in any way to the participants, but it's kind of a pain.

AUDIENCE: What was it-- oh, never mind.

ABBY NOYCE: Electroencephalograph or electroencephalogram, depending on who you ask. It's like an electrocardiogram is an EKG. It measures how your heart is doing. This measures what your brain is doing.

AUDIENCE: [INAUDIBLE]

ABBY NOYCE: So the way they're working is because they can only pick up the electrical field on the surface of the scalp. It's really hard to tell from an EEG where exactly in the brain that signal is coming from. You can certainly do broad signal. So the signal is strongest in the back of the head, and it's weaker in the anterior areas. Some people will tell you that with lots of electrodes capped like that-- I think that's the 256-electrode cap they have-- that's a lot. And you can get better

spatial information with more electrodes, but it's still not as accurate as fMRI because you're not getting it in those three-dimensional slices that fMRI gets.

AUDIENCE: [INAUDIBLE] the chart will sort of even out when it gets [INAUDIBLE]?

ABBY NOYCE: Right. Well, kind of. That's why you want to make sure your electrodes have good contact with the skull and stuff. Mostly it's this kind of triangulation problem. If that signal's coming from deep inside your brain, then it's going to activate a wide range of electrodes on the surface. So this is the kind of data you get out of these things, where you've got a track for each electrode showing how the charge in its spot is going up and down.

And then people analyze these and come out with meaningful changes. What they're usually looking at is-- this red vertical line is a point in time. Time's going along this axis, and then each of these is an individual electrode. And they're looking at some of these characteristic changes in the spiking that happened after a stimulus is presented. And negative is up, and positive is down is the other thing you need to know about these.

So there's this positive spike, which is P1, a big negative spike, which you can see is labeled here N1, P2, N2, and so on. P3, this big positive drop, you can see there. And you can see that across different electrodes, they're pretty much the same. You can pull out these big patterns. And so what people are doing when they're doing ERP measurements is they're looking mostly for changes in the sizes of these particular potential changes you see after the stimulus happens. And I don't know a whole lot about ERP. I just know the basics. It's one of the things I want to learn to do.

So ERP and attention. Here's a couple of classic ERP tasks. This is an old study, a 1985 study. So when ERP had really terrible spatial detail because you were using like 60 electrodes nets or something. Sams et al had their subjects listen to a set of headphones. And the headphones would go (LOW-PITCHED) beep beep, beep, and occasionally they'd go (HIGH-PITCHED) beep, (LOW-PITCHED) beep. And they'd have them listen for that higher pitch tone and press a button. And then the control case was subjects who had the exact same set of cones, but they were just told to ignore the high-pitched tone and just listen to it.

So this is a task of central control of attention. You're deciding whether or not your goals in the task are controlling whether or not the higher-pitched tone is salient, whether it's important. And they're measuring what happens what those ERPs-- Event-Related Potentials-- look like when subjects heard that higher tone. And what they found is that, when subjects were

attending to that particular tone, the stimulus-- the high-pitched tone-- caused a bigger change in the electrical fields in their brains than when they were instructed to ignore it. And that's a whole brain kind of measure.

AUDIENCE: Were those significantly higher? Like, you'd be able to tell [INAUDIBLE]?

ABBY NOYCE: Yeah.

AUDIENCE: [INAUDIBLE]

ABBY NOYCE: I don't know. It was different enough that-- no subjects said they had any difficulty distinguishing the tones. This is one of the things you check for in a debrief. If you've got a subject who's so tone-deaf they can't hear the difference in the two tones you're having them listen to, you want to catch that data and get it out of the pile. It's not useful.

There's lots of studies like this showing this. Here's another one that was using exogenously cued attention-- attention that is being driven by something [INAUDIBLE]. They'd have subjects look at a display, fixate on the X at the bottom, and they would briefly flash a Q, which in this case is just going to be the little X in one box. You're going to keep your eyes fixated on the plots, but you're going to direct your attention to whichever box is cued, and then they'd flash you a stimulus in the same place usually, and ask you to determine is this a green star or a red star?

And this is kind of my mocked-up model of the type of tasks that they were doing. And sometimes people will do this and they'll cue you to one box and then they'll flash the stimulus in the other box. Sneaky. And what they're comparing is these correctly cued responses to the stimulus when your attention's already there versus the opposite. And again, just like the endogenously cued tone task, you get ERPs that are bigger for the cued than the un-cued location. But it's a short effect. You've got to have the cue and then the target. They've got to be 300 milliseconds or less apart. If it's longer than that, then the effect dies off. So exogenous cuing of location is a short-term effect. It doesn't last for a long time. People's attention leaves that in shifts again.

And somebody ran this more recently in a better EEG setup, a better one that gives you some spatial detail and shows that where you're actually seeing the increased ERP is in the early processing areas. So the one kind of primary visual processing jumps is more responsive to stimuli that are in the attended space than if it was in the unattended space. So this is one of

the pieces of information showing that those two attention networks, the posterior and the anterior attention networks, actually have effects on a lot of other parts of your brain.

Brains. OK. As for some of the fMRI data, again, fMRI, good spatial resolution, lousy temporal resolution. And they found that these endogenous and exogenous attentional shifts again are coming from very different areas. Endogenous are coming from way down here in the frontal lobe and in the dorsal parietal lobe, so towards the top of the parietal lobe. And endogenous attentional shifts are happening down here in the temporal parietal junction right down into the ventral part of the frontal lobe. So there's these two distinct attention networks, and they seem to be independent of one another, but you can activate one more strongly than the other or vise versa. Activating one doesn't necessarily activate the other, but they interact. They share a lot of connections.

One more new methodology thing we haven't talked about, which is this stuff called TMS-- Transcranial Magnetic Stimulation. This is a methodology that's really freaky and really cool. What they do is they've got this little wand. It looks like it's got a figure 8 on it. It's got an electromagnetic coil inside there, so it can create this localized, pretty strong-- it doesn't have to be super strong-- magnetic field, a fairly small one, about a cubic centimeter. And you hold this thing up against somebody's head, and you send a pulse through it. And the magnetic field it generates stops the neurons in that particular region of cortex from firing. They just get all thrown out of whack by the magnetic field messing up their electrical stuff, and they just don't go.

People have done a lot of really cool work with this because it lets you take healthy patients, patients who don't have real lesions or brain injuries or any kind of neurological complications, and you can disrupt very particular portions of their brain, very particular cognitive abilities, and you can do it quickly or you can give kind of a sustained series of pulses and knock the neurons in that particular region out for a longer time. And as far as anyone can tell, it doesn't have any lasting side effects. You can knock your neurons out for 15 minutes and then they come back and they're just fine.

AUDIENCE: Wait. Does it hurt?

ABBY NOYCE: It doesn't hurt. I haven't gotten to play with this. I'm a little bit freaked out by it. But it's very cool. I've heard people say that if you are doing it kind of along the sides of the forehead, it can make the muscles there twitch, which is uncomfortable. And again, it's the magnetic

pulses interfering with the electrical parts of your body.

AUDIENCE: Can it damage things?

ABBY NOYCE: Can damage things? If it's used incorrectly, like very incorrectly, it can cause seizures, and seizures can cause you to damage yourself. But if it's done right, it doesn't seem to have any kind of long-term side effects.

AUDIENCE: Is it like an X-ray? Like, you can't have too many X-rays. Can you not have too many [INAUDIBLE]?

ABBY NOYCE: Well, it's not giving you radiation. X-rays are exposed to radiation, right? It's harmful.

AUDIENCE: [INAUDIBLE] too many of them?

ABBY NOYCE: It's been around for only a very little while. Like five to 10 years this technology has been around, so nobody's managed to find any long-term side effects. It may turn out that if you do this to yourself once a week for 10 years, bad stuff happens, but nobody's been exposed to that level yet. It's kind of scary. There was a point where people thought that X-rays were harmless, too. Definitely something to think about.

AUDIENCE: [INAUDIBLE]?

ABBY NOYCE: Yeah. In like the '40s, you could go into the shoe store and try on your shoes and they'd put your feet into the little X-ray and they checked to make sure your shoes were fitting with an X-ray. Nobody knew that it was bad for you.

AUDIENCE: [INAUDIBLE]

AUDIENCE: [INAUDIBLE]

ABBY NOYCE: Like an upscale shoe store, a classy shoe store.

AUDIENCE: [INAUDIBLE]

ABBY NOYCE: Now it would be. And it would be dumb because we know that cumulative exposure to X-rays is bad. But nobody knew it then. Try them on. You could see if your toes were scooched up together badly.

AUDIENCE: Can't you just [INAUDIBLE], though?

ABBY NOYCE: But it was scientific.

AUDIENCE: Oh.

AUDIENCE: A-ha.

AUDIENCE: Technological, it's more attractive.

ABBY NOYCE: There's a lot of good data showing that people are more responsive to information that seems to be presented in a scientific manner. Somebody did a study about like, science has shown that something or other, and there was some vaguely neurosciency babble that didn't really mean anything in with it, and had people read this little paragraph with or without a picture of your classic fMRI brain with the pretty colors lighting up in a certain area-- that had nothing to do with the study-- information that didn't even really make sense, then had them rate how believable and convincing this article was. Adding the picture of the brain brought it up significantly.

AUDIENCE: Is it like them feeling like [INAUDIBLE]

ABBY NOYCE: Or it just seems like there's "more data supporting it" even if you're not qualified to assess the data. It's interesting. It's definitely a matter of if you frame this data like it is being presented by somebody who knows what they're talking about, then people are more likely to buy into it. Things to think about when you write your research articles.

So transcranial magnetic simulation lets you knock out neurons in a particular region of cortex. It only works for stuff that's right on the surface of the brain. It won't work for any sort of subcortical areas or cortex that's down in the gap between the hemispheres. But people have used this to look at, OK, we know that patients with parietal lesions have difficulty in especially visual attention tasks.

What happens if we do the same thing with normal patients and try and knock out that portion of the parietal lobe? And you get very similar to patients with parietal lesions so that they take more time on conjunctive tasks, where they've got to match more than one feature, which, remember, takes visual attention to check each individual member of the set. But on disjunctive tasks, which are pre-attentive-- they don't require visual attention to jump between things. You can just see which one is different. So TMS meshes up the attention requiring task but not the pre-attentive task when it's applied to the parietal lobe, particularly to the dorsal

parietal lobe, that parietal attention network region.

We've been talking about the brain, the whole brain, bits of the brain. Let's talk for a minute about what happens at the cellular level. We've been talking about neurons. So one of the things that's really true is that cells early in the visual processing stream-- ganglion cells, cells in primary visual cortex-- have these very small receptive fields. They're focusing on a particular region of your visual input.

But as you move up into higher processing areas, each of those higher cells is taking input from several or even many lower-level cells, and their receptive fields get bigger as you go up. So by the time you're looking at cells in, say, the fusiform face area or in the parietal place, whatever it's called, the place-monitoring cells-- cells that respond to pictures of houses and landscapes, these cells have very large receptive fields. They'll respond to their preferred stimulus over a wide range of locations.

And somebody said, well, what happens if we take that range of locations that the cell will respond to-- maybe the cell responds to the entire left-hand side of your visual field-- and we have you attend to a particular, smaller location within that big receptive field? Does the cell notice? Do you see the effects of attention on the cellular level here? And the answer is yes. Yes, you do.

So people doing single-cell recordings-- so that's with an electrode dropped straight into the neuron. You can't do this in people. You do it in monkeys-- shows that the cells are way more responsive to stimuli in the attended area. They respond more strongly to stimuli in the attended location than they do normally. And if you're attending to one location within the receptive fields, they are less responsive than the baseline to stimuli elsewhere in the receptive field. The cell kind of actively throws that information away and doesn't respond to it. So attention is modulating how responsive these cells are to stimuli in different locations in their respective fields.

[CELL PHONE RINGING]

Tsk, tsk, tsk. [INAUDIBLE].

So remember yesterday, I said we'd come back to talking about this competition model of attention, which is what especially most people with a neuro perspective on attention think is really what's going on here. So attention is basically a competition between all of the different

inputs coming into your brain at any given time. You can get low-level competition very early in processing. You can get high-level competition. At any of these points in times, one input can kind of elbow another out of the way and say, hey, no, I'm getting major processing resources right now. So these guys say that inputs that are the most salient-- and saliency--

AUDIENCE: Can you go back to [INAUDIBLE]?

ABBY NOYCE: I can go back one. So we were talking yesterday about like bottleneck models that think of attention as being limited, and different tasks call on different amounts of attention, and they're using up your attentional resources. Competition model people say, it's not so much that you have attentional resources. You've got honest to goodness processing resources, and attention is a means of directing processing resources to different tasks or different inputs.

So inputs with the most saliency can claim the most resources. They can push other inputs out of the way. If you know you're looking for something red, then informational about red things that's coming in kind of trumps information about other things, and you assign more resources to things that are red. And so the red ones get processed the most deeply. Think about the basketball passing video that we looked at yesterday. You're busy watching the white team pass the ball, so all of the information about the people wearing white got assigned more saliency endogenously by your central control system.

And so they're shoving aside the information about the people wearing black so completely that you don't even notice this guy in a gorilla suit walking into the middle of the screen and being like, rahh. You watch it again when you're not focusing so explicitly on the white ones, then the saliency of, hey, wait. Something weird just walked into the frame. Now stimulus that's interesting in some way can grab your attention and direct it to it.

So in early stages of processing, saliency depends on things like color. In a scene of mostly dark things with one bright thing, or vise versa, your attention is going to be drawn to the one that's different in some way. We've said the brain likes things that are different. It likes changes. Your attention is drawn to these places where things are different, especially in low-level processing. So areas that have edges get processed more heavily in early vision. We know that.

In later processing, this competition is affected by things like what do I want to do? What's around it? It's affected by all of this more semantic, higher-level input that's coming in from

you, from what you want to get out of the information that you're looking at. And so the thing is that all through the stages of processing, the different things that are being thought about are competing. So if you're looking at, say, the red chair, people who are really into competition models will say, OK, we're already thinking about your perception of color as depending on how activated different color representations are.

You can say that even just seeing the color red is a result of having the redness model be more strongly activated than the greenness or the blueness or the brownness representation. And this is a similar kind of processing as it goes up the chain. And because there's so much connection between different regions of the brain, connections up and down between different levels of processing, then each kind of local competition for attention for processing manages to influence-- when one piece of information wins a local competition, then it can influence other competitions.

So if you're trying to split your attention between the water bottle and the red chair, if you're paying more attention to the water bottle, that's going to actually go back down the chain and affect how your color processing is working. At a lower level, you're going to put more effort into the blue processing than the red processing. But you'll also see, for example, there's connections between sensory modes. So if you hear a loud noise behind you, you're going to turn around and look at it. That's, again, dependent on connections between the parts of your brain that analyze auditory information and try and figure out where it is in the parts of your brain that direct your visual gaze. So the brain is very interconnected. The competition model here really takes advantage of that.

Another good piece of evidence for this model is what's called competition effects. This is an fMRI study. It had subjects look at individual, moderately complex shapes on a screen. It measured how strongly their primary visual cortex responded to these shapes and found that, compared to how much it responded for shapes one at a time, if they showed four shapes at once, response actually went down, which at first seems like an odd effect. You're looking at more things. You'd think you'd be getting more processing going on.

And the theory is that when you've got multiple things competing for attention and competing for resources, each of them kind of inhibits the processing of the other things that are in the competition. So when there are four objects and not one of them has any kind of edge up in this competition, then they all inhibit each other and none of them gets processed as fully as one object at a time would. And if the experimenter says, OK, I want you to attend to the object

in the upper left-hand corner, all of the sudden you see the V1 activity go right back up to what it was when you were just looking at one object. The suppression object wins the competition between the four objects and gets to be fully processed. So your option of attending to a particular location-- the upper left-hand corner-- then makes the items in that location more salient, and they get more processing.

So what's our general consensus? Does the competition model explain decreased performance on divided attention tasks?

AUDIENCE: Yes.

ABBY NOYCE: Why? In terms of the competition model. Sorry, Sarah. I missed you entirely. In terms of the competition model, what's going on when you are trying to do two things at once?

AUDIENCE: The object is like competing for your attention [INAUDIBLE]. And therefore, if there's two things that-- equal things are going to have 50% of your attention, I guess? And they won't be done so efficiently as if it was just one thing.

ABBY NOYCE: Yeah, although remember that this model talks about attention kind of is that competition, and what they're competing for is kind of processing power. But yeah. So you've got two things going on, and they're both kind of trying to get processing power. So does either one of them get all of it? Probably not.

AUDIENCE: I think the other thing's that [INAUDIBLE] differentiate between stimuli versus actually a [INAUDIBLE] perception of or processing of [INAUDIBLE]-- say driving and talking on the phone. There's stimuli by light and color of what you see on the road, because a bit from your ears [INAUDIBLE].

You also have stimuli in what you're hearing, and you have to process what the person's saying on the phone. And then you also have to form words in your mind and, I guess, make sure your grammar's correct or something, pronunciation. And that's not even two stimuli. That's a whole bunch.

ABBY NOYCE: Yeah. These two tasks are both ones that need a lot of resources. You can't half-ass either one of them. You've got to put a lot of processing into both of them. So it's probably a more demanding divided attention task than some others. And this is true. I actually have a friend who works on attention. And one of the things she does is, when she designs a task, she's got to run them through a pilot group, like two or three people, just to make sure they're not too

easy because they've got to be a challenging task or you're not going to get any interesting results across different experimental groups. Everyone's just going to get 100%. And they can't be-- well, they can be pretty hard. I've been a subject for her from time to time, and it's usually really frustrating because you're like, this is an easy task and I am failing! OK. Thank you very much.

Moving along, the other thing I wanted to talk about today was ADHD really briefly, in part because it's a really common diagnosis, especially among kids. So what is ADHD? This is the DSM IV text revision criteria for diagnosis of ADHD. The DSM is the *Diagnostic and Statistic Manual,* and it is the book that psychologists use to make diagnoses. So for everything that is an "official" disorder of one sort or another, there's a page of information roughly like this that says, in order to be diagnosed with this thing, you've got to have these criteria.

So for ADHD, to be diagnosed with it, you've got to have six or more symptoms of inattention. So this would include things like spacing out in school. It would include things like being needed to be given directions more than once, difficulty staying on task, distractibility. Six or more symptoms of hyperactivity. Again, most of these are over an extended period of time. This can't be just like you have one bad day. Inattention, hyperactivity, and impulsivity are maladaptive. They're causing you problems. And they are inconsistent with developmental level. Clearly, your attention span expectations for a three-year-old are going to be different than your attention span expectations for a seven-year-old.

Saying a three-year-old is being inattentive because they can't sit still as long as a seven-year-old can is not productive. So it's got to be based around how old the kid is. Some symptoms present pretty young. Impairment from symptoms present in at least two settings, so at school or at home. And to be diagnosed, it's got to be impairing functioning. And this is pretty typical for DSM diagnoses is that, if you meet all the other symptoms but you are functioning just fine in your life and it's not causing you any problems, then you do not have a disorder. It's got to be causing you trouble for you to get a diagnosis of a disorder.

ADHD is pretty common. It's estimated to occur in about one in every 16 or 17 grade-school-age kids. And we don't know a whole lot about what causes it. There's been a little bit of stuff. There's some subtle differences. Kids with ADHD tend to have slightly smaller overall brains than kids without. Particularly frontal cortex and basal ganglia are areas that tend to be smaller.

Mothers who smoke during pregnancy are three times less likely to have a kid with ADHD. But it hasn't been shown that that's a causal link, that smoking causes ADHD. There could be other factors involved in both of those things. Remember that one of the things that happens in people with ADHD is they're more impulsive, and smoking links pretty well to impulsivity. Doing things that you know are bad for you often link to impulsivity. What else can we say?

Kids in a family where there is one child with ADHD are more likely to have other kids with ADHD. Kids in families with more than one kid with ADHD also tend to be, on the whole, again, less functional than families with kids without. It's a complicated disorder. Nobody really knows what causes it for sure.

But one of the things we've found is there's this set of drugs that treat it really, really-- well, moderately, anyway-- well. And these drugs are a group of drugs called psychostimulants. They're closely related to cocaine. They're closely related to amphetamines. And the way they work is, so if you're at your dopamine synapse here. There's our synapse, right? Cell 1, cell 2. So at the dopamine synapse, the presynaptic cell, remember, has these transporter channels that are going to vacuum up extra dopamine from the synapse.

And these psychostimulants get picked up by the channel, brought into this cell, and they bind with the vesicles that contain the dopamine neurotransmitter. And these drugs actually cause those vesicles to go ahead and release dopamine into the synapse. So the effect of the drug is that more dopamine gets released into the synapse at a dopaminergic cell. Now, we'll remember that most of the dopamine in your brain is coming from right here in the midbrain, in the very upper portion of the brain stem. And there's two main pathways. There's this one that goes to the nucleus accumbens and up into cortex, and there's this other one that goes to like motor control.

So dopamine has effects on lots of portions of your brain. Changing how dopamine is behaving at the synapse has effects on large portions of the brain. There's some evidence that ADHD patients start out with a different form of the dopamine transmitter, kind of a more efficient transporter, a more efficient form of this, so that it kind of vacuums dopamine out of the synapse more enthusiastically than the normal form so that you start out with a shortage of dopamine in the synapse. And one of the things the psychostimulants are doing is causing there to be enough stimulants. Stimulants usually cause increased motor activity. It's one of the things they do. They stimulate all this motor cortex. They get you up and going. So having Ritalin or Adderall or one of these drugs actually work to calm patients with ADHD was

originally called a "paradoxical" response, and people thought it was something different about how ADHD brains work.

More recently, people have tried it, because one of things that happens is the dose of an amphetamine you take if you're trying to get high off of it is a lot higher than the dose that is prescribed for a kid with ADHD. And it's actually turned out that both in animal models and in humans, if you give one of these stimulants in that really low dose, it actually does decrease locomotor activity in the animal models. It's calming on both kids and adults, again, in the low doses-- not just ADHD kids and adults, but even people who are not diagnosed with the disorder.

One of the big problems with most of these stimulants, on the other hand, is that things like methylphenidate, they're upping the amount of dopamine in your brain. Dopamine is the reward pathway. Drugs that up the amount of dopamine in your brain are prone to addiction and abuse. Methylphenidate is Ritalin. It's the actual drug name for it. Rates of abuse of Ritalin and other drugs are on the rise. They've been going kind of steadily up since this drug hit the market, jeez, like 15 years ago now. You'll see like college students use them as like study drugs. There's a black market for these. But don't do that. Taking things that are not prescribed to you is dumb.

AUDIENCE: [INAUDIBLE] the entire dorm at school was like kicked out because of this one kid. He had ADHD and gave the drugs to his friend, who sold it to like the rest of their dorm. And it's like a high-pressure environment [INAUDIBLE]. They all got kicked out.

ABBY NOYCE: Yeah. Yeah, it's prone to abuse, partly because it's so widely prescribed now that there's a lot of kids who can get their hands on it, and kids are lax about prescription drugs in a way that adults or people-- and I think this may be a generational thing more than an age thing-- aren't and are much more likely to be like, "Oh yeah, a doctor prescribed it to me. It must be safe. Here, have some," and have that kind of train of thought that says that if it came from a doctor, it must be safe. Street drugs are bad, but prescription drugs are OK. This is dumb. The reason they're prescription is because they can mess you up. If they were harmless, you could get them over the counter. More harmless.

Anyway, because these are psychostimulants, because they trigger that reward pathway, that dopamine pathway that goes up into the nucleus accumbens-- that's this pathway that goes right in here-- they are prone to abuse. And there is a second, newish ADHD drug called

Strattera is the market name for it, and it actually doesn't work on dopamine. It works on norepinephrine. So dopamine goes up into the nucleus accumbens here.

Cells in the nucleus accumbens, then, are mostly norepinephrine cells. And they also go up and have wide links to cortical areas. And so often, you see a chain where you've got groups of one neurotransmitter that affect then a group of cells of another. And you can affect the broad outcome by intervening at different places along the chain. So there's some people looking to see if the seemingly dopaminergic portions of ADHD are actually because of how dopamine then adequately or inadequately activates the norepinephrine at the next stage.