JEREMY WOLFE: Good afternoon.

AUDIENCE: Good afternoon

JEREMY WOLFE: If-- so there I was in my car this morning, as the pouring rain started, thinking, if I make a dash for it, I got to take the computer. I need the coffee, because otherwise, I'm going to fall asleep. I don't need anything in that bag, do I?

So I took off without the bag, which-- and it was true that I didn't need most of what was in the bag, but the lecture notes for today's lecture would have been a useful thing to take with me. On the other hand, if there was ever going to be a day where I forgot the lecture notes, this is probably the one to do it, because I'm going to talk about attention today.

And attention research is what I do for a living. If there's anything that I should be able to just stand up and lecture about, this is it. Now, of course, that means that you should find this to be the most gripping topic in the entire course and that you should decide that what you want to do-- you want to do this for a living.

Well, when you decide you want to do it for a sort of living, like a $10-an-hour living, you can come and be a subject in attention research in my lab. I would, again, advocate that you sign up. This is still-- I saw there's still these notes around about signing up to be a subject, generally, in BCS. My lab is separate from the BCS business, because I'm technically Brigham and Women's Hospital.

But you can sign up with us, too, and we'll pay you $10 an hour to do visual attention research. What could be better than that? Is Kristen here? I don't see Kristen. Kristen, one of the TAs, is also in my lab, and I was going to point her out. You could-- anyway.

You know, send me an email. We'll sign you up. Talk to me. You know, we'd love to have you. And you can do Where's Waldo experiments for $10 an hour.

[STUDENTS CHUCKLING]

You think I'm joking.

[STUDENTS CHUCKLING]

Let me-- let me try to explain why it is that I'm putting an attention lecture in between a sensation lecture and a perception lecture. It's not terribly typical. More typically, if people talk about attention, they go off and do it later, after doing sensation and perception. But why am I putting it in there?

The core reason is that you simply cannot process all of the information that you take in from the world. You're taking in a vast amount of sensory information. Your perceptual capabilities-- for instance, those that allow you to recognize specific objects-- are limited. You cannot recognize all of the objects in the world that you are looking at all at the same time. It simply doesn't work.

And so roughly speaking, things are-- here's the situation. You've got a lot of stuff coming in from the outside. And you've got a box here that does-- let's say, let's call this one a recognition-- whoops-- recognition box. And only one thing at a time gets to go in and come out of that box, basically.

So from this, this is like the basic MIT metaphor about drinking from the fire hose. Well, if you're really going to drink from a fire hose, it's a very useful idea to restrict the flow in some fashion and let some of that water just go-- [BLOWS RASPBERRIES] and get you wet or whatever. And so there's a severe constriction, sometimes called a bottleneck-- I think I've got some slides that call it a bottleneck later-- that takes all of this and only lets some of it through.

And that bottleneck is governed-- it's not just random what gets through. It's governed by mechanisms of selective attention that allows some things to get through and leave other things on the floor. And so if you think of this as sensation and perception, which is a little bald, but then that's why you put attention in the middle there.

Now, to motivate this a bit further, let me do a demonstration. Actually, this is the demonstration of why reading the tech while listening to my lecture may not be a brilliant idea. Well, it may be a brilliant idea. It just depends on your particular goals in life.

I need a couple of volunteer-type people who wish to read here. All right, there's a volunteer person, and there's a pink volunteer person. Yes, you MIT person-- you have to come up here. So kick a few people on the way by and stuff like that. You have to come up here and do a dramatic reading.

What I'm going to do is have these people both read to you at the same time. You're going to read from here, from where it says, Katherine. And you're going to read from here, and you're both going to read nice and loudly and steadily-- at the same time, yes. That's the interesting part.

And what you're going to do is, you're going to listen to her for-- actually, to her, specifically. Listen for the third instance of the word, her. When you hear, "her," say, "her," for the third time. Raise your hand, OK? OK, we got this? Yeah, yeah, all right. This her, not that her.

AUDIENCE: I could tell you my name.

JEREMY WOLFE: Oh, that would help. You are?

AUDIENCE: Nina.

JEREMY WOLFE: That's Nina. This is?

AUDIENCE: Zena.

[STUDENTS LAUGHING]

JEREMY WOLFE: Right. OK. "Zayna" or "Zeena"?

AUDIENCE: Zena.

JEREMY WOLFE: Zena. OK. At least it's not just--

AUDIENCE: [INAUDIBLE], if that helps.

JEREMY WOLFE: No, this is not going to help at all. [LAUGHS] Her-- when Nina says "her" for the third time, raise your hand. OK? You got it?

AUDIENCE: Yep.

JEREMY WOLFE: You got it? On your mark, get set, read.

[BOTH READING SIMULTANEOUSLY]

Oh, OK, thank you. All right, that was good. That was excellent. All right, so what was she talking about?

[STUDENTS TALKING]

Something. Yeah, no, no, no, somebody raise their hand. Raise hand, hand. What was-- a letter. Thank you, that sounds good. She was-- she'd gotten a letter. Was it a nice letter?

AUDIENCE: I don't know.

JEREMY WOLFE: Who knows? It didn't sound too good. Her countenance wasn't doing good things. What was she talking about? Zena. What?

[STUDENTS LAUGHING]

Uh, she was talking about, "uh." OK. Was she talking?

AUDIENCE: Yeah.

JEREMY WOLFE: So what's your problem? What you were doing was-- so how many people-- well, obviously, the hand suggested that everybody could manage to do the task. What could you pick up from-- Zena?

AUDIENCE: Zena.

JEREMY WOLFE: Zena. I'm not going to-- otherwise, it's going to turn into warrior queen and stuff like that.

[STUDENTS LAUGHING]

Zena-- what could you pick up about Zena's speech? Anything? No content. How many people knew she was talking? All right, so you can pick up something. What else did you know about her?

AUDIENCE: The tone she was speaking in.

JEREMY WOLFE: The tone she was speaking in. If it had been a male voice, if she'd switched to a male voice, you would have noticed. Anything else, you think?

AUDIENCE: Was she reading from *Heart of Darkness?*

JEREMY WOLFE: Was she reading from *Heart of Darkness?* [CHUCKLES] No, actually, what she was reading from was Lucretius,*On the Nature of the Universe,* a wonderful book. *De rerum natura,* in Latin-- he's a Roman author. This is the first intro psych book.

It's also the first intro physics book, intro everything. But in those days, you could write a book called, "On the nature of the universe," in verse, and this is a prose translation. But she was actually reading Lucretius's *Theory of Vision.* And even she may not have noticed that, because it's all about thin films and cool stuff like that.

AUDIENCE: --think about a video.

JEREMY WOLFE: A video? Yeah, well, it's an ancient Roman video. But only a very limited amount of stuff got in. And so there was a certain amount of stuff that was getting in, but at some point, your auditory system gave up on processing that stream.

And in terms of extracting meaning, understanding the words, it went with Nina, because that was the job. You can't do both of them at the same. We'd better let them go sit down. Thank you for being--

[APPLAUSE]

What would have made the task easier? What would make it easier to pay attention to one and not the other, do you think?

[STUDENTS TALKING]

Amplifying one of them, yes. If the warrior queen would have just been quiet, it would have been no problem at all.

AUDIENCE: If they read the same thing.

JEREMY WOLFE: If they read the same thing-- no, that's probably true, but not a deeply interesting true. What could-- no, well, for instance, if she was male, it would be easier to segregate the two voices. If we moved them apart further, it would be easier to segregate the two voices.

If one of them was singing, it would have actually probably been easier to segregate them. So if you change the low-level sensory information, it would be easier for you to decide which one to pay attention to. This is something that happens-- oh, and so if you're sitting there reading the newspaper, while you're trying to listen to this lecture, odds are, you are missing one of the two messages. It's dealer's choice there.

But it's also not desperately polite, in case anybody was wondering. If you want to read the paper, you might as well go somewhere else. But this happens in the real world all the time.

You go to-- there's a version of it, known as the cocktail party effect. You go to a party, and you're talking to someone, and you hear, typically, what? Like, your name over there. So you do this selective attention thing, and you listen to that conversation.

You seem to be paying attention to this guy who's talking to you. But you're actually listening over there. The problem is, eventually, this guy stops talking. And you realize, oh, yeah, like, I'm supposed to say something now, right? I wonder what we're talking about.

It can lead to a certain amount of embarrassment. Now, this happens ubiquitously in sensory systems and across sensory systems. So for example, right now, until I mention it, you are not particularly aware of the pressure of your posterior on the seat.

If I direct your attention to that, you say, oh, yeah, there it is. It was presumably there all along. I wasn't floating a moment ago. But until I direct your attention to it, it doesn't rise to the level of conscious-- current conscious awareness.

And it shows up in vision, because the visual world is far too rich for you to process everywhere at once. And that's what makes these Where's Waldo problems interesting and fun. Look, if there was not a bottleneck like this, Waldo man would not have gotten rich, right?

Yeah. Where's Waldo? Oh, there he is. [BLOWS RASPBERRIES] Big deal. And have you found him?

[STUDENTS TALKING]

Yeah. Oh, look, I have a little laser today. Isn't that nice? So that-- does it work? Oh. I mean, even when you-- that's Waldo up there.

So well, you say, oh, that's really stupid, because I can't even see him now that-- oh, and we decided to exploit the technology by having it on three screens. There's no added information there. It's just, it was too cute not to do it.

But if I say, where is the elephant spraying a car, you can find it. You might have noticed it before if you'd been scrutinizing it. It was certainly visible all along, right? It wasn't that there was a black hole here before.

It's just that only when you had the desire to go and search for it, did you manage to direct your attention to it in a way that allowed you to recognize these couple of objects. And it's that ability to constrict your processing that's really the focus, at least of the first part of today's lecture. Let me show you the equivalent of the reading example, but now-- of the talking example, but now switch to reading.

What you want to do here is to look at the little asterisks. And I'll put up two streams of text, one on the left-- columns-- one on the left, one on the right, nice and big, so that you can read them. But what you should notice is-- and keep your eyes moving down from asterisk to asterisk. What you should notice is you can read one or the other. You just can't read both at the same time, even though they're nice and big.

Right? It just doesn't work. It's not a visual restriction. It's a central-- it's a capacity limitation later on in the system. So this is by way of an answer to question 1 on the handout. What's the problem that attention is solving?

Attention is solving this problem of having too much-- too much going on. And oh, attention is a grab-bag term. I'm going to be talking about visual selective attention. Attention isn't one thing, like my laser pointer here.

There are attentional mechanisms, selective mechanisms, all over the place in the nervous system. So when you are attending to the pressure of your posterior on the seat, you are selecting-- probably using a different set of neural circuitry than when you're selecting one of these words. It's the same basic idea, but not jusy-- it's not like there's a single attention box in your brain somewhere.

OK. Some things, as we saw in that auditory demo, the reading demo, some things escape the bottleneck. Some things can be appreciated everywhere all at the same time. Well, question 2 is, what is that set of things?

And the answer is-- the answer is not babies.

[STUDENTS LAUGHING]

The answer is that there's a limited set of basic features that can be processed across the entire visual field at one time. Or, if you could do it in auditory space, there'd be a set of basic features in auditory space, too, that could be processed at the same time. But I'm going to stick with vision.

So all these babies look alike. It doesn't take much to figure out that now, there is-- where did Mara go? Oh, there's Mara. If the baby turns green, you do something about it, right? It's highly salient stimulus.

Or, if the baby's head gets squashed, you know. So there are a collection of simple basic features, like color, size, orientation, that are not bottleneck-limited in the same kind of way. You can find that if there's a single red thing in the field, you can find it anywhere without having to go hunting around.

Other things that you might think would be pretty obvious are not anywhere near so obvious. So as you look around here, you may notice that most of these baby heads are upside-down, and two of them are right-way-up. But it's not like the green baby head. Right?

You had you have to go hunting for upright versus upside-down, even though that's a very salient thing in the real world, whether or not you're upright or upside-- or whether your baby is upright or upside-down. So there are about, by last count-- last count was done by me, as it turns out-- 12 to 18 of these things that seem to escape the bottleneck. And that's probably about it.

And they are a bunch of simple things-- well, seemingly simple things-- like color, orientation, and size-- things that you could imagine, for instance, the earliest stages of visual cortical processing doing. And then, there are some rather more elaborate things that also escape this bottleneck. And they're things like, well, if you believe my friend Chen from China, this would be an example of the importance of topology.

He thinks that the distinction here is that this has a hole and this doesn't have a hole. The other possibility is that this has line terminations and that this doesn't. These are the things you can fight about in this field.

But anyway, it's easy to find that among that. Curvy things among straight things are easy. Orientation in the third dimension works. So that cube is pointing up this direction. These cubes are pointing down over here. That turns out to be easy.

Other examples would include motion. So actually, motion makes an interesting point. It's easy to detect the presence of something, but not so easy to detect its absence.

So imagine the following. I didn't make a demo of this. I could have. Imagine you're looking at the ground, and there's one little ant moving around. He's pretty easy to find, right? That's because motion is one of these features that you don't have to go hunting for. It's just there.

On the other hand, imagine you're looking at an ants nest, and there's one dead ant. How easy is it to find the one ant who's not moving? It's not easy. So the absence of a feature can be hard to detect. The presence of a feature, one of these 12 to 18 basic features, can be easy to detect.

Now, how do you actually go about establishing that something is easy to find or hard to find? I've been doing this in very qualitative terms, but now, let me explain how you actually go about studying this-- what we would pay you $10 an hour for if you show up in the lab.

What we would do is show you a computer screen full of stuff and ask you a question, a simple-minded question, like on the next one-- is there a tilted line? And what you would be doing is sitting there with a couple of computer keys. Bang one key if the answer is no, bang another key if the answer is yes. Do it as fast and accurately as you can.

And we're going to measure your reaction time, the amount of time from the onset of the stimulus to the onset of your response. How fast can you do it? Well, I don't have keys for everybody here. So let's just do it verbally. Say yes or no, as fast as you can, in response to these guys.

Tell me if-- is there a tilted line present? You ready?

AUDIENCE: Yes.

JEREMY WOLFE: Ready?

AUDIENCE: No.

JEREMY WOLFE: Ready?

AUDIENCE: Yes.

JEREMY WOLFE: Ready?

AUDIENCE: No.

JEREMY WOLFE: OK. That's pretty straightforward. What's the next thing? OK. What you should have heard is that your answers were given crisply in unison, and it didn't make any real difference whether there were lots of vertical lines on the screen or a few vertical lines on the screen.

So if we were to collect real data and to plot the reaction time in milliseconds, thousandths of a second, as a function of the set size, the number of items on the screen, what you would get for any of these 12 to 18 items, if you did the experiment right, is an essentially flat line here. This would be the line for saying, yes, it always turns out to take a little longer-- or typically, it turns out to take a little longer to say no, but it's not dependent on the number of items on the screen.

So you know, is there an L? Is there a green thing? Is there an X among these pluses? All of those things would produce similar-looking results, where the slope of this reaction time by set size function would be, essentially, zero. Not all tasks behave that way. So let's do a different one.

In this case, you're looking for the letter T. It can be rotated, by 90 degrees, left or right. Or I think-- well, maybe it can also be upside-down. I don't remember what I put in. But it may not be an upright T.

But it will be a T. The distractor items are all Ls. And I just want you to say, as fast as you can, is there a T present. Ready?

AUDIENCE: No.

JEREMY WOLFE: Ready?

AUDIENCE: Yes.

[SCATTERED RESPONSES]

JEREMY WOLFE: Yeah. Yeah, OK. Ready?

AUDIENCE: Yes.

JEREMY WOLFE: Ready?

[SCATTERED "YES" AND "NO" RESPONSES]

You also heard the speed accuracy tradeoff there-- what's known-- this is a known phenomenon in reaction time studies, which is, one can respond very quickly if you don't sweat the accuracy thing. And people do that routinely. Well, people do that a lot in our studies. We call them "bad subjects." And we don't invite them back.

But what you should have heard there is that-- and should have felt yourself-- is that the responses were faster when there were fewer items present and that the responses of the group, particularly for large-- these larger set sizes-- were spread out. Why were they spread out?

Well, some people got lucky, you know, that this thing came up, and their attention happened to be around here. Oh, look, there's a T. Some people were unlucky. [SINGING] Oh, yeah, there's a T.

And some people were trying to psych out the professor and said, there was a yes, there was a no, there was another yes. I know about this. There's going to be a no. And they said, no, without doing anything so boring as to actually look at the display.

So what you get for data in an experiment like this would look much more like this. As you increase the set size, now, the reaction time increases in a fairly linear kind of a way. The slope on these is quite fast.

I mean, this is 20 to 30 milliseconds, thousandths of a second, for each additional item to say yes, and about twice that amount to say no. Depending on how one exactly models, this suggests that you're running through 20 to 40 of these letters a second. So you're going through it quickly.

But you're having to search now. It's not simply obvious that there's a T there. You've got to go and hunt for it-- or over here, you can look for the 5-- is another typical task that would produce-- that would produce results like that.

I wanted to say one other thing about that, but now, I don't remember what it was. Oh, yes, what I wanted to say was that the speed of this tells you that you're not looking at the rate with which-- not looking at the rate of fixation on each letter. If you're doing this in the lab, you make sure that your stimuli are big enough, that you don't have to move your eyes to look at each one.

If you have to move your eyes, your eyes only move at a rate of about four per second. And so if you have to fixate each one of the items before you can tell if it's a T or an L-- so if you use little T letters, this slope would be more like 250 milliseconds per item, not 40 or 50 or something like that.

The eyes-- attention can move much more quickly than the eyes. One of the things that tells you is that you can attend where you're not looking-- something that basketball players know very well. When you hear that a basketball player has great peripheral vision, what that really means is that he can be looking here and see-- he can be paying attention to his teammate over there and throw the ball and fake out the opposition.

Because the usual assumption is that you're attending where you're looking. Most of the time, that's true. But OK, so now, I'm looking at this guy wearing red up there, and he thinks that I'm actually paying attention to him, but I'm not actually. Because of acuity limitations, I have no idea what I'm paying attention to here, but I think it's a woman person, and I think she just moved.

Yeah, look, it is a woman person. I can move my attention away from the point of fixation. And I can move my attention much more rapidly than I can move my eyes.

Now, these are just-- so the "find the red thing among green things" is a case where the property of the target is one of these basic features and immediately gets your attention. The "find the 2 among 5s or the T among Ls" is a case where everything in the relevant display is, essentially, the same, as far as the early visual system is concerned.

Ts among Ls-- a vertical and a horizontal line among other vertical and horizontal lines-- there's nothing in this early processing that tells those apart, it turns out. Most real-world searches are not like that. In most real-world searches, oh, let's see. What do I feel like looking for?

I'll look for glasses. If I'm looking for eye glasses, there's some right there, and there's some more. I don't just search. There's no process early in my visual system, some huge chunk of cortex devoted to eyeglass detection. Just doesn't happen.

At the same time, I don't search around randomly, you know. No glasses there, no glasses there, no glasses there, no glasses there. I'm searching in an intelligent fashion. Here's how you do that.

Let's do one more basic search. What you're looking for here is a red horizontal line. Tell me as fast as you can, whether it's present.

AUDIENCE: Yes.

JEREMY WOLFE: Now, how you do that is not by having a chunk of your brain devoted specifically to red horizontals. Oh, remind me later, I got to check whether you still have a McCollough effect, speaking of red horizontals. We'll check that out later.

The way you do that is you use those 12 to 18 basic features to guide your attention around in an intelligent fashion. So if you're looking for red horizontals, you've got something that can do red. Give me all the red things. You've got something that can do vertical. Was I looking for red horizontals or red verticals?

Well, anyway, this is a red vertical. You've got something that can do vertical. So I've got the red things. I've got the vertical things. I can do that early on in the system.

All I need is something that will do something like an intersection operation. And if I were to guide my attention to the intersection of the set of all red things and the set of all vertical things, that would be a really good place to look for red vertical things. Oh, look, there it is.

So what you do-- what you've got is a front end that collects information that can be used to control this bottleneck to guide your attention around to feed sensible things to the back end of the system. I think that's pictured there.

And the result is that a search for something like a red vertical line-- it's not as easy as finding a red thing among green things, but it's pretty easy. It's easier than finding a 2 among 5s or a T among Ls or anything like that.

Now, this guidance comes in two different forms. Or you can think of it as coming in two different forms. There's a bottom-up form that's stimulus-driven, and then there's a top-down form that's user-driven by your desires. Let me illustrate that with a couple more searches for a T.

Tell me, as fast as you can, whether or not there's a T in the next display. Ready?

AUDIENCE: Yes.

JEREMY WOLFE: Well, that was pretty crisp. How'd you do it?

[SCATTERED RESPONSES]

[MUMBLING] Yeah. That's what I thought. Most people probably found their attention automatically grabbed by this one oddball, which, conveniently enough, turned out to be the T. And so rather than having to search around, your attention was grabbed, bottom-up, to this item.

Top-down is based on what you know, or what you've been told, or what-- or instructions that you've somehow given to yourself. So I'm going to tell you. If there's a T in the next display, it's red.

What happened out there? Oh, that was another-- that was also grabbing attention. It works in the auditory domain, too, if you-- if we set off an explosion, unsurprisingly, you would notice. All right, you ready? Is there a T in this next display?

AUDIENCE: Yes.

JEREMY WOLFE: Whoever said, no, was another speed accuracy tradeoff. Try to smoke out the professor who had a yes on the last one, and therefore must have a no on this one. Look at the display! Anyway, that's not as easy as the previous one.

But if you searched around, you probably noticed-- or you may have noticed-- that you were searching through the red items. You're not going to bother searching through the black items if you know the T is going to be red. So let us suppose-- suppose we did an experiment where the T could be either black or red.

And I show you a bunch of displays like this. I vary the set size, the number of items on the screen. Measure your reaction time. Let's suppose that the slope of that function was 30 milliseconds an item.

If that's the case, and half the items are red in this display, or on average, half the items are red, what's the slope going to look like if I tell you that the T is always red if it's present?

AUDIENCE: [INAUDIBLE]

JEREMY WOLFE: Less steep, yeah. Specifically, how less steep?

AUDIENCE: Very.

JEREMY WOLFE: Very less steep. That's not specific. I want a number.

AUDIENCE: Half.

AUDIENCE: 15.

JEREMY WOLFE: 15. Good number. Right? If you can eliminate half the items, the effective rate of search is going to be twice as great. So the slope will drop in half. And that's exactly what you get in experiments like this.

They work very nicely. if you have only half the items on the screen relevant, subjects behave as though they are only looking through half of the items. So by now, I have answered the question 2-- what escapes the bottleneck of attention? Well, there are these basic-- 12 to 18 basic properties or features of the world that seem to escape the bottleneck.

We can study this by measuring reaction time. There are other methods, too, of course, but I was telling you about the reaction time methods. Oh, I see, I put Anne Treisman and feature integration theory on there.

That's-- don't worry about the feature integration part. That's simply to allow me to give honor to Anne Treisman, who really bounded the modern study of visual attention after having pioneered an awful lot of the auditory things of-- the auditory demo at the beginning was a classroom version of what's called dichotic listening.

Typically, what you do is put on a pair of headphones, and you'd have one stream of speech in one ear and one stream of speech in the other ear. And you ask questions about, if you're attending to this ear, what can you pick up through-- what can you still pick up through this year. Anne was doing those things in the late '50s, early '60s, went on in the '70s and '80s to really invent this field of-- the study of visual search and is still doing great stuff now at Princeton.

She was not at Princeton when I was an undergraduate there. But she's there now. All right, so I answered the question 3. And question 4, I answered by saying, oh, a conjunction search.

That search for a red vertical thing is a conjunction of two basic features. It's not adequate to know that it's red. It's not adequate to know that it's vertical. The conjunction of those two sources of information is adequate-- is what defines the target.

And you can use this basic feature information, the basic attributes of the stimulus, to guide your attention around in an intelligent fashion. So that guidance comes in two forms. It can be bottom-up stimulus-driven or top-down user-driven.

All right, so what is that attention actually doing? Why is it that you need to have this-- what is attention making possible here that wasn't possible before? Oh, look, it says that right there.

Or what were those features doing before attention shows up? Well, here is-- here's an answer to that. The answer is that you've got all those features. And in fact, early processes in the visual system seem to cut the scene up into what you might consider to be proto objects.

But those features are just bundled together with an object. So before your attention arrives, something like this would be red and green and vertical and horizontal, and it's got points on it or something. What attention does is to bind those features together in a way that makes it possible for you to know that the greenness goes with the verticalness here, and the redness goes with the horizontalness, and those points are arranged-- the whole thing is arranged into a plus.

The argument is that, OK, I have to-- I need attention in order to recognize any given individual. Before attention arrives on that individual, that person isn't a black hole in space. That person is a loose bundle of features, that attention allows me to bind those features together in a way that allows me to understand how they interact and what that recognizable feature might be.

So oh, there's Kristen. Hey, Kristen, stand up and wave. No, really, I was plugging you before. So if you want to be-- if you want to do this for $10 an hour, go find Kristen. So all right, the good example-- now, we can make fun of Kristen.

So before Kristen arrived-- no, before Kristen arrived, she was not visible. Before I attended to Kristen, there was presumably a proto-Kristen object out there that was a bundle of Kristen bits. Only when I got my attention to her-- even though she'd been visible all along, and I'd looked over there a bunch of times-- even though she'd been visible all along, only when I got my attention to her could I bind those features together and make her into a recognizable Kristen.

Let me see if I can illustrate that to you with another demo here. And the way that's going to work is-- OK, so what you want to do in the next slide is to look for red verticals again. You ready? So tell me if you find a red vertical.

AUDIENCE: Yes.

JEREMY WOLFE: Yeah. In fact, you might have noticed there are two of them. Very easy. What's the point? Well, this is a standard guided search kind of thing. Give me all the red things. Give me all the vertical things. Look at the intersection of those two sets, and oh, looky, there's two red verticals up there.

Now, what I'm going to do is to simply take the vertical-- the horizontal bit here and jump it up to the middle of the vertical bit. That's why this is a sort of odd arrangement. I'm going to jump it up here, so I'm going to make a plus, like those pluses that we just saw.

The reason for doing this is, I'm going to keep all the same pixels on the screen. Right? I'm just going to rearrange where the reds and greens are. And of course, I'm going to change the location of the red vertical, because it's really boring if I keep it in the same place. But you're looking for red vertical again. Ready?

AUDIENCE: Yes.

JEREMY WOLFE: Who said no?

AUDIENCE: I said whoa.

JEREMY WOLFE: Oh, whoa, OK. [CHUCKLES] Whoa's good. Whoa's good. Particularly by the time it says, find the two red vertical lines. Anyway, so if you didn't find-- you should have found both of them.

Let's check intuition here. Is your intuition-- how many people vote that it was easier to find the red verticals when they were in pluses? How many vote that it was easier when they were ripped apart? That is the correct intuition.

Actually, I think I put the data-- I think I realized earlier that I put half the data on a slide. This is the data for looking for the pluses. Quite steep slopes, of about 50 milliseconds an item here, and about 140 here.

Just looking for the red verticals when they were in the dissociated pluses would have been down here, with a slope of about 10. But I somehow left it off the-- left it off the slide. Why is this-- why are the pluses so much more difficult?

The answer is that before attention arrives on the object, these two pluses are, essentially, the same thing. They are red and green and vertical and horizontal. And without attention, you just don't know the difference between them.

This thing-- this square has red and green and vertical and horizontal in it, but it's in two objects. And so since you direct your attention to objects, to things that are objects-- I got too many to's in there-- this is not a problem in the way that these guys are a problem. In fact, anything that you do to-- I don't think I brought the demo.

But anything that you do to make this less like a single object makes the task easier. So if I was to put a little shadow on here, so that it would look like this thing was-- the vertical piece was sticking out in front of the horizontal piece, it would get easier. Because now, you could direct your attention separately to different planes in depth.

So attention is directed to objects, and objects are available ahead of time as just these loose constellations of features. Once attention gets there, they get glued together into recognizable objects. All right. So what happens when you move away from an attended object?

That's not an unreasonable question in this framework. So let's see, I need Rachel. There's Rachel. I thought I recognized her. All right, I have now recognized Rachel. Limited number of people who I actually recognize by name in here, and they come to regret it.

But anyway, all right. So she was here all along. I happened to have attended to her and bound Rachel into a recognizable Rachel object I now, without moving my eyes, in fact, am attending elsewhere, and somebody's up there. Again, my peripheral vision is lousy, but I can see that somebody was moving up there. They waved a piece of white paper a moment ago.

The question is, when I moved my attention elsewhere, what happened to Rachel? Did she remain bound or did she collapse into Rachel bits again?

AUDIENCE: [INAUDIBLE]

JEREMY WOLFE: What? Is that? She collapsed into Rachel bits. How could you tell?

AUDIENCE: [INAUDIBLE]

JEREMY WOLFE: Well, that's why I was deliberately still looking at her, to avoid the issues of blur. But let me-- the way to do this is not to continue picking on Rachel, but to switch to dancing chickens here. So there, we have-- you can tell we're back in the realm of my artwork.

[STUDENTS LAUGHING]

Oh, I like this, with the chickens on three screens. This is so good.

[STUDENTS LAUGHING]

Anyway, I like those a lot. Now, so you know what you're looking at here. You're looking at a bunch of chickens, right? And they're doing this little leggy thing.

You would think that, having recognized that there's a bunch of chickens there who are doing this little dance, that if one of those chickens fell apart into chicken bits, that you would notice, right? Seems reasonable. How many of you noticed?

Ooh, ooh, very slow group here. It should be-- how many chickens are there here? About 20? It should be about 1 in 20 of you happen to be-- you have all seen that already.

[STUDENTS TALKING]

So one of these chickens fell apart. Well, if you think-- I mean, quite apart from the fact that the artwork is a little lame, the implications are non-lame. The implication is, all right, I'm looking at you guys. I think I'm looking at a bunch of humanoid life forms that-- they're moving a little bit and stuff like that.

And you would think that if one of you just went to pieces here, that I would notice. The data strongly suggest that that's not the case, that I would eventually notice as my attention roves around the room. If it turned out that, oh, my god, not only has that person not dozed off, but her head fell off, I would notice that and react with according shock and amusement.

The way this experiment is actually done is something like-- is not with a-- it's not with the cute little dancing bits. You'd be looking at a screen like this, and you'd hear, beep, and the question would be, is there a destroyed chicken? Yeah, it's there, right? Beep. Whoops. Beep.

AUDIENCE: Yes.

JEREMY WOLFE: Beep.

AUDIENCE: No.

JEREMY WOLFE: Beep.

AUDIENCE: Yes.

JEREMY WOLFE: And so on. You can do it. It's not a difficult task at all, particularly with a few big chickens. But you have to search. You have to search through the chickens each time. And you're no better with a display that's got the same fixed number of chickens up there all the time, compared to a display which has de novo chickens popping up out of nothingness each time.

That's-- oh, the feet are moving around-- for the demo, right? Why are the feet doing this little chicken dance? Remember, I said that motion is one of these things that you can pick up automatically.

If you don't pick up-- if you don't have something like the little moving feet, then when you have a chicken fall apart-- boink-- the movement of the contour, compared to all the ones that aren't moving at all, tips you off that there's something there. And that tells you that motion is important, but it doesn't tell you the interesting fact that you're not aware when an otherwise coherent object falls to bits.

By the way, it turns out you're also not aware when previously incoherent material coheres into a chicken. We did the classic Chicken Soup experiment. We had a screen full of chicken bits like this, and you heard a beep, and you had to figure out whether or not there was now a chicken present, and you had to search for that, too. So chickens emerging from the Chicken Soup, which you might think would be striking, don't turn out to be striking either.

All right. Well, you know, the chickens are kind of ugly and complicated. Let's-- how bad is this problem? So let's get basic here. No more-- no more trying to fool you.

Well, of course I'm trying to fool you. No more dancing around chickens, and then, oh, did you see? After the fact, I asked you whether you saw something that fell apart. These are what?

AUDIENCE: [INAUDIBLE]

JEREMY WOLFE: Red and green dots. You can-- if you weren't sure about that, it says so at the top. Right? All I'm going to do is, I'm going to queue one dot. I don't care about any of the other dots.

All I want to know is, did that one dot change color? Say yes or no. Whoops, where did it go?

[SCATTERED RESPONSES]

[CHUCKLES] Well, the answer turns out to be no.

[SCATTERED RESPONSES]

[LAUGHTER]

This is such a-- this is such a great exercise in applied statistics, right? You know, how many-- he can't really be-- he said no to last time, so no. Right.

AUDIENCE: Yes.

JEREMY WOLFE: Oh, yeah, but he can't possibly be doing three in a row, right?

[STUDENTS LAUGHING]

AUDIENCE: No.

JEREMY WOLFE: That does turn out to be a no. Look, you could hear people going both ways. People are terrible at this. They're just barely above chance. And the "barely above chance" is consistent with them sitting on two or three dots and keeping-- because you're not just doing a couple of these. You're doing hundreds of these for $10 an hour.

Yeah, so you're sitting-- you can sit on a couple of them and say, if I get really lucky and he queues the one I'm looking at, I'm going to get this right. And if he doesn't, I'm clueless. I mean, it's red and green. It doesn't get more basic than that. Yep.

AUDIENCE: I have a question. Do people's reaction times-- do they change? Because red and green are like-- they have the same after-color or after-image. I mean, like--

JEREMY WOLFE: They'd better not have the same-- they have the opposite, yes.

AUDIENCE: But the opposite of red is green, and opposite of green is red. So like, if you do, like, yellow and blue or something else, like--

JEREMY WOLFE: Well, yellow and blue are also opposite in the same sense, but it doesn't matter. The color does not matter. In fact, we can do another one with different colors. Look at this. OK.

[STUDENTS TALKING]

More cool colors. But, but, but, but maybe the problem-- maybe I was just being nasty to you, because there were a lot of dots up there for you to choose among. So I'll tell you that the relevant dots-- what I'm going to do here is I'll ask you about the color of specific dots.

I won't change 'em. I'll just put them up there and ask you about particular dots. And what I want you to do is tell me the color. So you know, so if I say, what color is that dot, the answer is--

AUDIENCE: Purple.

JEREMY WOLFE: Good. That's-- if I happen to cover it up with a black blob, tell me what color it was before I covered it up. OK?

[STUDENTS TALKING]

Ready? All right, here we go. You'll see how this works. Well, where'd it go? Oh, there we go.

AUDIENCE: Red. Yellow. Blue. Green. Green.

JEREMY WOLFE: Good.

[STUDENTS LAUGHING]

See? You're not-- I put this in, because at this point, you might be sitting there saying, oh, I'm so hopeless! And I wanted to prove to you that you're not-- well, you are, but not that hopeless. All right. Ready?

AUDIENCE: Purple, red, blue, yellow, red, green, yellow-- [LAUGHTER]

JEREMY WOLFE: Ooh, a few people actually got it. A bunch of people did the-- [GASPS] But yes, indeed, that was yellow. It was queued before, so we know you paid attention to it. But it was queued about five items back.

And already-- so you'd paid attention to it. It didn't take much binding to say, oh, that's yellow. You'd already done all the work on it.

You know, that's a yellow-- five blobs later, by the time your attention is somewhere else, it didn't-- it wasn't invisible during that time, right? You don't really know what it is. All right. Try this.

AUDIENCE: Red. Green. Red.

JEREMY WOLFE: Whoa, whoa, whoa. Couple of people caught on. Ooh, he changed it. This is what happened here. Whoops, not that way. Nyeh, nyeh, nyeh, go back. OK, so this makes a useful and important point. So red-- while your attention was diverted, I changed the color.

[STUDENTS TALKING]

Why is that important? What that tells you, with a very basic stimulus, is that the following ought to be true. I attend to Rachel. I attend away. While I've attended away, Rachel is replaced by a kangaroo.

[STUDENTS LAUGHING]

I am now asked, what was there? I say, it was Rachel. The fact that-- even though still visible in the visual field and everything, until I attend back, I would simply not know that something had changed there.

So in fact, if you're worried that-- the trick here, obviously, since there are 300 of you or so, is you want to convince me that you're paying attention in this class. You draw my attention early in the class. And then, you suddenly sneak out, and presumably, I think you're here attending the whole time, because how often do I get back to each individual person?

Well, actually, it's not that good, because at 30 to 40 people per second, I can get back to you pretty quickly. So forget it. But don't forget the basic point here, which is that you're only aware, you're only updating your knowledge about the world through this narrow bottleneck of attention at-- for the current object of attention.

Everything else-- you're basically working on your hypothesis based on the last time you checked up on it. So here's actually what the data for an experiment like this look like. So if you didn't pay attention to the colored dot, right? If I never asked about it at all, here's chance-- 50% in this particular experiment, because this is a two-color version of it.

Is it red or is it green? You've got about a 50/50 chance of getting it. You'd do a little bit better than that. If it was recently queued, if I just asked you whether it was red or green, youd' do pretty well.

But as soon as it's four items ago or 8 or 12 ago, you're back to being pretty pathetic. So you don't keep a good record of this. You're only updating in the current object of attention. This suggests that your memory is pretty small here.

We'll talk about memory more extensively later, but let me illustrate that your memory is actually fairly small. Here, what we're going to do is, I want you to remember these guys. And got 'em? OK, take 'em away. Are these the same?

AUDIENCE: No.

JEREMY WOLFE: OK. Well, your memory isn't that small. That's good. How about these guys?

AUDIENCE: No.

JEREMY WOLFE: No, no, no, no, this is a new set.

[STUDENTS LAUGHING]

Ready? Boink.

AUDIENCE: Yes. [SCATTERED SPEECH]

JEREMY WOLFE: Whoops. Sadly, I can't remember. Remember these.

[SCATTERED RESPONSES]

They look the same, don't they?

AUDIENCE: Yes.

JEREMY WOLFE: OK. So-- oh, well, hmm. Or how about these? No, no, this is a new set.

[STUDENTS LAUGHING]

AUDIENCE: Yes. Yes.

JEREMY WOLFE: Yes, something changed. Yes, so this time, I transposed the red and the yellow. That's a little more difficult, because I didn't introduce a new color. How about this?

AUDIENCE: Yes. [SCATTERED RESPONSES]

JEREMY WOLFE: People aren't quite sure. You're not going to-- the answer is-- the capacity of this memory is about four-- is about four. And so some of you will have gotten the fact that there was another transposition, right? Like, the yellow and the-- whoops-- the yellows and the greens. Yeah, the yellow and green guys are-- whoops-- switching there.

Some of you will have gotten it, and some of you will have not gotten it, because some of you were sitting on the right four, and some of you were sitting on the wrong four. But it's only about four.

Four what? It turns out to be four objects. Look at this. Tell me if anything changes. So here, we have at least color, shape, and orientation going on.

AUDIENCE: Yes.

JEREMY WOLFE: Yeah, most people will know here that the red thing flipped from pointing up to pointing down. That would seem to suggest that you can keep track of 12 things, because there are four colors, four shapes, and four orientations. But if I spread those out across 12 objects, you'd be very bad.

It's that you can keep track of about four objects. You can keep track of multiple features of each of those objects, but it's only about four objects that you can keep track of. Now, let's see, how are we doing in question land?

OK, so the answer to question six, at least to the first part about it, is that the objects don't seem to stay bound, that you need to continuously update the visual world in order to have some idea of what its current state is, and that you're only updating the current object of attention. After a brief break, we will establish what the Sistine Chapel has to tell us about that fact.

But those of you who wish may study this image for the next second or that next couple of minutes or so. And then, everybody else can just stretch, and we'll come back. And-- while I apologize to Rachel for picking on her. You're not traumatized for life or anything?

AUDIENCE: No.

JEREMY WOLFE: OK, good.

[SIDE CONVERSATIONS]

AUDIENCE: Have you seen this video they have where it's like a bunch of people bouncing balls to each other?

JEREMY WOLFE: Yes, sir. That's now gotten to be so common, that I'm not using it.

AUDIENCE: Right.

JEREMY WOLFE: Yeah.

AUDIENCE: Is Amy here?

JEREMY WOLFE: Is Amy here?

AUDIENCE: The TA.

JEREMY WOLFE: I know. Amy, are you-- Amy, are you here still? Yeah, Amy's here. Here's Amy.

AUDIENCE: Do you know who did that?

JEREMY WOLFE: Yes, Dan Simons, then at Harvard, now at-- OK, thank you-- now at University of Illinois. I'll tell-- I will describe a different Dan Simons experiment in a minute. OK, let's get back together here.

All right, let me-- to briefly review, the story I have been developing thus far is that even though you're looking at this scene from the Sistine Chapel-- and this is "The Expulsion" from Eden. There's Adam and Eve and this very cool snake.

And there's Adam and Eve getting chucked out, with the angel poking him in the head and stuff like that. Even though you are looking at this, you know what you're looking at, that at any given moment, you are only-- the only thing that's really coming through from the world to recognition is whatever is currently being fed through the bottleneck, the current object of attention, and that may be three or four objects-- the recent status of the three or four objects is currently held in this visual short-term memory.

The implication here is that I could change this scene, and you wouldn't notice. So let's find out. What did I change?

[STUDENTS LAUGHING]

I need a hand or two here. Uh, oh, yeah, sure, right.

AUDIENCE: [INAUDIBLE] the fig leaf.

JEREMY WOLFE: The fig leaf, the fig leaf. Yes, this is-- the originator of change blindness, which is what this phenomenon is known as, is Ron Rensink, now at the University of British Columbia. And he refers to what he calls areas of interest.

[STUDENTS LAUGHING]

If you change something that people are paying attention to, they notice that. But of course, I knew that. And so how many people picked up the other three changes?

[SCATTERED RESPONSES]

Whoop, we have a few people who picked the-- what'd you get? I can't hear you.

AUDIENCE: The stick moved.

JEREMY WOLFE: The stick thing. And what-- sorry?

AUDIENCE: Something showed up at the top.

JEREMY WOLFE: Something showed up at the top that's funny. The stick thing moved, and something showed up at the top that's funny. So now, with that information, we can go-- whoops. Whoops.

AUDIENCE: Right there.

JEREMY WOLFE: You got the stick. See, the reason for the blank is the same as the moving chicken legs, which is that you don't want to have motion transience giving stuff away. But if you have motion transience--

[STUDENTS TALKING]

[SINGING] You would think that if you were in the Garden of Eden, and the branches were moving from tree to tree, or-- whoops-- or, for that matter, you know, Eve's foot was moving to Adam's body, you would notice. But if you're not attending to it, you don't notice.

This leads-- so this is part of a large set of phenomena that come under the general heading of change blindness. At the break, somebody was reminding me of one that you may have seen, because it's made it onto, you know, Nova and things like that, done by Dan Simons, where you're watching people play-- apparently, play a weird game of basketball in front of the elevators, it turns out, in the psych department at Harvard.

And while you're doing that, a guy in a gorilla suit actually-- Dan reminded me-- a woman in a gorilla suit-- it's hard to tell-- she's in a gorilla suit-- walks in, walks into the middle of the game, waves, walks out, and then afterwards, you ask-- these guys-- and you're doing a demanding task. You're supposed to count how many passes there are or something like that.

And you're asked, did you notice the person in the gorilla suit? But first, you're asked, do you notice anything weird? Ah, very boring. Notice the person in the gorilla suit? Yeah, right, what person in a gorilla suit?

Show 'em the video again. Oh, my--

[STUDENTS LAUGHING]

Like-- another great Dan Simons experiment was done when he was at Cornell, actually. You're on the street in Ithaca, New York. And some guy walks up to you and asks you for directions.

Actually, it's Dan Simons-- walks up to you and asks you for directions. And so since you are a nice person, you start giving Dan directions. Now, you're standing there on the street, and who knows why, but these two guys with a door are carrying a door down the street, and they, like, walk between you and Dan, which is kind of rude.

And when-- then, they're off down the street somewhere. And the question is, do you continue to give directions once you see Dan again? Well, of course, the real question is, did you notice that when the door went by, Dan Simons ducked down and left with the door?

[STUDENTS LAUGHING]

And his then-student Dan Levin popped up in his place, and it's a different guy.

[STUDENTS LAUGHING]

50% of the subjects in this study kept on talking.

[STUDENTS LAUGHING]

A surprisingly large number of these, on being debriefed later, claimed to have noticed a change, which is a little strange, right? I'm talking to this guy, and the door-- and now, I'm talking-- there's another guy here, but what the heck, he probably wants the answer to the same question?

[STUDENTS LAUGHING]

I don't know what that's about. But the important finding there is that 50% of the people behaved as though they hadn't noticed the change from one person to another who they were talking to. What's going on here?

Now, people aren't completely stupid. The experiment has not been done, but we kind of absolutely know that if, you know, I'm talking to Dan Simons-- short, white guy-- and now, the door goes through, and a tall Black woman is standing there, hmm, you know?

Probably, that's, again, this front-end stuff that people tend to pick up on. But if what you're doing is-- I don't know this guy, but I've got a model of this guy, I'm talking to a short, white guy person-- I'm still talking to a short white guy person. It's not the same one, apparently. But it doesn't-- that turns out not to be a problem.

This has given rise-- this has given rise to a notion that vision, that perception is what Kevin O'Regan has called a grand illusion, that the only thing that you actually see is the current object of attention-- that I think I'm seeing all of you, but all I'm really doing at the moment is paying attention to the guy with the gray stripe on up there. And yeah, there he is.

And now that he's riveted my attention by waving at me, the rest of you are just not there. You are just some grand illusion floating around in my head. Now, in some sense, that's correct, that what you are seeing is a crea-- the burden of the lecture next time will be to say that you're always seeing a theory about the world. You're not seeing the world directly.

You're always making an interpretation, your best guess, about what the stimulus means. And all the evidence I've been showing you for the past hour or so suggests that you're only updating that theory through this very narrow bottleneck. So in some sense, you are only seeing this-- you're seeing this creation of your mind, and the only object that you are currently updating is the one that you are currently attending to.

But to call the whole thing an illusion, it seems to me, misses an important aspect of the experience. Look, when you look, you don't have the feeling-- well, let's take-- actually, let's take a very old example. The French philosopher of the-- I'm thinking early 18th century, whose name I will now proceed to misspell.

That look-- any good philosopher source? Is that about right? Condillac, I believe, is how you pronounce it properly. But anyway, Condillac wrote a number of very interesting things about sensation and perception.

He's most famous for his statue, his statue that he proposed with-- as an entity with no senses at all. And he asked, what would the mental life of this statue be? And argued that in the absence of any sensory input, there would be no mental life.

And now, he said, let's imagine opening up-- I think he opens up the statue's nostrils and argues that the entire mental life of this statue is now the smell. Whatever-- I think he waves a rose under it or something like that. But the example-- a little further on, he has a different example, where he says, imagine you're in a dark-- a dark chateau, I believe.

And it's completely pitch black, because it is heavy curtains, and it's morning. And you throw open the curtains. If it were the case-- this is not what he's saying, but if it were the case that all the vision was nothing but a grand illusion, you only saw the spotlight of attention, this one thing that you're attending to at any one moment, your experience of this brand new scene ought to be like a weird paintbrush.

Initially, I don't see nothing, because I don't know-- I haven't attended to anything. Now, I attend to an object. And now, this person-object is the only thing in the scene. And boom, boom, boom, boom, and I slowly fill you in. That's not the impression you get, ever, when you see a new scene.

You may not know what you're looking at, but you see something everywhere instantly. And the grand illusion thing misses the fact that you're somehow sensing something about the entire visual field all at once. Let me offer a way understanding that, that will then tie back to the visual physiology that I was talking about in the last lecture.

Here's the idea. Early in your visual system, you've got processes that-- sort of a big river of information that tells you about those 12 to 18 features or attributes that you can get out. These are eyes. This is my drawing again, right?

So from your eyes, you got this big flow of information up into your brain. And at some point, it hits this bottleneck that's taken care of by attention. Object recognition, the ability to tell that that's a branch, that that's a snake and so on-- only one object at a time can go in and come out and rise to the level of some perpetual-- perceptual awareness, populating your visual experience.

And that bottleneck is guided by these collection of basic features that you've got, that-- if you know you're looking for red stuff, you set these settings for red, and maybe vertical and big and moving and so on. And so you can regulate what gets through here. And only the one thing at any one time is getting up into there.

And so the object, the current object of attention, gets to rise to awareness, and you know what you're looking at. That's the story that I've told you to this point. That's the story that gives rise to the notion that everything else in the visual field is an illusion.

But look, when I was doing that red and green dot thing, it wasn't that you didn't see the other red and green dots. They were there. You just somehow had a very impoverished ability to tell me anything about them.

And a way to think about that is to propose that there's another pathway, another big fat river of information about, say, these 12 to 18 attributes, that isn't limited by the bottleneck, but that it doesn't let you-- it's not a cheat. This doesn't now let you go and recognize objects everywhere all at once. It can only do a few things.

It can give you the statistics of the world. You know, I'm looking out at you guys, and I'm seeing a texture of people amongst purple. And that sort of impression of purpleness, of a tilted plane, is the sort of thing that you might get out of there, out of this big, broad, unrestricted, non-selective, as it's labeled on there, pathway.

There's evidence that you can get a little bit of semantic information. Semantic means the meaning of-- when you're talking about language, it's the meaning of the utterance, let's say. When you're talking about vision, it's the meaning of the stimulus.

So I might get the notion that I'm in an enclosed space. This pathway by itself is not going to tell me what enclosed space I'm in, but I'm in a space. There's a tilted surface there, and so on.

But this is going to give me-- that broad pathway is going to give me this feeling that there's something happening everywhere. And this pathway is going to tell me what's happening specifically here, now. And between the two of them, I can build up an idea in my head of, oh, I'm in 10 to 50. I'm talking to this bunch of people, some of whom I know by name, some of whom I recognize, because they've been here before, and so on.

And I can keep updating that 20, 30 times a second through this pathway. And I can keep experiencing something, "a wallpaper of the world" effect, through this other pathway. Now that ties back-- it might tie back to things that we talked about before, if you remember the idea that you can broadly cut visual processing-- visual cortical processing into two big pathways, a what and a where pathway-- a what pathway going down into the temporal lobe and a where pathway going up into the parietal lobe.

This selective pathway, this thing that only does one object at a time, would then be mapped onto the what pathway. What am I looking at? What am I attending to right now?

If you were to lesion that, if you were to lesion it, or you were to have a damage to the temporal lobe of your brain, you might well end up with an agnosia. That's not a term that ended up on the handout, so you want to write that one down.

An agnosia is a failure to know, if you like-- to know what something is. So an agnosic, if you have a person with a fairly global agnosia, visual agnosia-- they would be able to say, yeah, I'm looking at a bunch of objects here, but I don't know what they are. Here's this-- here's this object.

It's orange. It's got orange and brown and white blobs on it, and it's got this very long part, and there are these four pointy things coming off the bottom of it. I got no idea what that-- maybe it's furniture of some or-- anyway, you'd look at it and say, that's a giraffe.

An agnosic would be able to tell you about it but not know that it was a giraffe. There are very specific-- smaller lesions produce rather specific agnosias. There are reports in the literature of agnosias specific to say fruits and vegetables. There are-- more common is a form of agnosia called prosopagnosia, which is a specific inability to recognize faces.

You know that it's a face. It's got two eyes. It's got a nose and a mouth. You don't know who it is. Small lesions down in that pathway will produce-- can produce that sort of damage.

That would suggest, then, that the other pathway ought to be mapped on to where pathway. And if you get damage to-- bilateral damage, for instance, to the parietal lobe, you can end up with a disorder known as Balint's syndrome-- might as well write the word on here, named after Balint-- that has, as one of its properties, what's called a simultanagnosia.

This is a situation where you can recognize an object if you can get your attention on it. But you can only recognize-- that's the only thing you can respond to, in some sense. It is as if you can only see-- it is as if the grand illusion theory was really right, that you could only see the current object of attention.

So you do something like this with a simultagnosic-- say, what's that? Draws attention to it. That's a book. OK. What else have we got here?

OK, what's that? That's a cell phone. What's that? That's a cell phone. Anything else? No. What's that? That's a book. What's that? It is a book. Anything else? No.

So one object at a time, as if where of the world had disappeared. If you get damaged-- we'll talk about this more later in the term. But if you get damage to just one-- the parietal lobe on one side, particularly on the right side, what you can end up with is a disorder known as neglect.

Comes in a variety of flavors, again, depending on the particular lesion. But the characteristic is, you ignore the contralateral, the other side. Now, that can be the other side of space, so that if I'm a patient with a right hemisphere parietal lesion, and I'm looking at MIT volleyball here, everything in the left visual field, I would simply ignore. I would behave as though it did not exist.

If I took away everything else and put a stimulus in my left visual field, I could show that the patient could still see it. But with a full visual field, he behaves as though there's nothing there, nothing there at all. Patients with neglect will do weird things, like-- they're in the hospital, typically, because they've had a stroke.

You give them their dinner. They eat everything on the right side of the plate and leave everything on the left side of the plate. Why? Because they didn't like the mashed potatoes? No, if you rotate the plate, they'll eat the stuff on the other side of the plate.

It's as if they didn't-- as if it just didn't exist, in some fashion. Now, you'll remember that parietal lobe is also where you get the representation of the body surface and stuff like that. So neglect patients can also be patients who neglect one half of their body and deny that part of their body is theirs.

This is a little easier to understand if you figure that the stroke might well have also knocked out the ability to control that side of your body. So a stroke on the right might leave you paralyzed on the left, but you can end up with situations like one described, I think, by Oliver Sacks in one of his books, where a patient is saying, this is a cheap hospital. This is a really cheap, lousy hospital.

How do you know it's a cheap lousy hospital? Because they're doubling up on beds. What do you mean they're doubling up on beds? He says. Look at that leg. Who is-- that's not my leg.

So you can get-- so this is somebody looking at their own leg and denying that that leg belongs to them. That's another aspect of neglect. OK, what I'm going to do next time is to talk about the way in which you make hypotheses about the world.