[SQUEAKING]

[RUSTLING]

[CLICKING]

PROFESSOR: Yeah, we just did the quiz. And that's for people who are watching this later. That's not on the video. We're going to do some introduction to music cognition. I don't think we're going to have time, but we can also unlock voice leading if we do. Now I'm going to put this down. Great. And I'm going to turn off these-- no. That one's OK. Turn off that. Is that OK? Yeah, that's better.

Great. So music cognition is one of these things that intersects with huge numbers of parts of music in general, with music theory, with music history, with performance, with performance anxiety-- all these things. But it also has a big impact on computational music, especially computational music theory. It sort of formed this field, and it continues to be part of it.

I just want to give a little introduction from a professor of music cognition at Northeastern down the street and also Wesleyan Psyche Loui. Just a couple of minutes while I also checked to make sure I have the-- well, we'll see if the sound's still working.

[VIDEO PLAYBACK]

- Consider, for instance, this musical example.

[PIANO CHORDS PLAYING]

All right. You might say that sounds nice and normal, kind of like saying, I took the tea here today. What about this?

[PIANO CHORDS PLAYING]

[DISCORDANT CHORD]

Right. If you think that sounded normal, you can come talk to me afterwards, and we might sign you up for that tone deafness study we're doing.

[LAUGHTER]

So when you heard that last chord, your brain does a double take, right? There's something about it. That's like saying, I took the tea here, octopus. Nothing wrong with octopus, but it just doesn't fit the context of what happened before it. It doesn't fit the grammar. Now, this double take that your brain does can be measured using electrical potentials on the surface of the scalp. This is a picture of my mom getting her brain potentials recorded. And she's got 64 electrodes on her cap there. And what those do is make recordings like this.

And so on the left, I'm showing you brain responses to expected and unexpected musical chords. And on the right, I'm showing you the difference between expected and unexpected on the surface of the scalp. So there's a bird's-eye view of the scalp. So right away, you can see that 200 milliseconds after the onset of the unexpected chord, your brain is doing its double take, or saying, oh, that was unexpected. And 500 milliseconds, you get the brain saying, oh, how do I integrate that into what happened before?

So this is telling us with millisecond accuracy that we know about music. There is something about our brains that is very sensitive to what's grammatical in Western music. So the question is, where does this knowledge come from? How do we come to know what we know? So to answer that question, we again have to go all the way back to the ancient greeks. Pythagoras found that if two strings are being played together, where one string is twice the length of the other, those two sound good together. They sound consonant.

So this 2-to-1 frequency ratio is what supposedly brought us closer to the Greek gods. In fact, the word symphony originally means vibrating in perfect harmony using these mathematical integer ratios. So this 2-to-1 frequency ratio is true of music all around the world. Now, different cultures divide that 2-to-1 frequency ratio in different ways. In our culture, the equal-tempered Western chromatic scale divides them in 12 steps. So this is how it sounds.

[ASCENDING SCALE PLAYING]

OK. Then these two guys came along and said, does it have to be this way? Why 2 to 1? Why not 3 to 1? So the Bohlen-Pierce scale is based on a 3-to-1 frequency ratio. And within that, we've got 13 logarithmic divisions of that scale. So you still get some mathematical integer ratio. So the Greek gods are not offended here. But what this sounds like is completely different from Western or other types of music.

[ASCENDING SCALE PLAYING]

So this is a really powerful approach to find out what people know about music in the laboratory. So we can be pretty sure that people have never heard this music before. But when they come in, then they can listen to this music for a while, and then we can measure how they come to know what they know. So I'm going to play you for about a minute a snippet of a piece by It's called "Reminiscences." And it's written in the Bohlen-Pierce scale, just so you get an idea.

[STEPHEN YI, "REMINISCENCES"]

So this really is kind of an otherworldly new musical experience that we're entering here and in our lab. What we wanted to do was figure out how people learn this new musical system. So we have these well-controlled melodies that people listen to for about half an hour.

[ELECTRONIC TONES PLAYING]

So you listen to these things for half an hour. And they're they're defined using rules and principles or grammatical structures that we've defined ourselves. And then the question is, what can people learn from this new musical experience? The first thing we found was that memory increases with repetition. Turns out also that preference increases with repetition. So what we're seeing here is the beginning of musical taste. The more you listen to something, the more you begin to like it.

But what I'm interested in is how learning occurs. And it turns out that learning does not occur with repetition but with variability. In other words, the more different ways you tell people something, the more people are able to infer the underlying structure of what you tell them and then to generalize those to new instances of the same grammar.

Now our question becomes now--

[VIDEO PLAYBACK]

PROFESSOR: And that's where I stop for here, because we can look at that online. And I want you to just get as excited for our two guest speakers who are going to be talking on Zoom on Friday and after after break here on campus. So we're going to be talking primarily in the next couple of classes about the work. Well, first, Claire Arthur is going to present her own work, and then we'll be talking about two major figures in music cognition.

One is Carol Krumhansl and her landmark book,*Cognitive Foundations of Musical Pitch,* which is all about, how do we process pitch? How do we think, how do we put it into particular areas? And so that's pretty important for music cognition. But it's also formed her work on this, formed the basis for every computational-- or almost every-- yeah, I can't say the wrong things-- for the most widely-used key detection and key algorithm finding mechanisms.

So here, this is our favorite BWV 66.6, looking at different sizes of amount of memory that we have. And we can see that-- where is it-- at certain things, A major is coming up. And then we're moving from one key to another as our cognition goes. So we'll be looking into her work.

The second major figure is David Huron, whose name might have appeared as a secondary author of one of the articles that you may have discussed on your midterm. And his landmark book, *Sweet Anticipation, Music and the Psychology of Expectation,* you're going to have access to this book totally on the website by Friday.

But I feel like if there's one thing worth spending your money to own in a physical copy, coming out of this class, it's this book. First off, it's not too expensive. It's, like, $22 or something. But it's just amazing, the types of things-- and it talks about his own work, but mostly, it's a collection of the greatest hits of music cognition also by others.

And so this is a particular experiment that I think's really great. Balinese musicians and American musicians were given a Balinese melody that was there. And they were betting on whether or not-- I believe it was-- the next note goes up or down after that. And you can see the Balinese musician-- and so this is how uncertain they are. So lower is more certain.

The Balinese musicians, when they hear this traditional Balinese thing, they're just doing great. They're making money, head over heels. And then, boom, uncertainty goes up when it goes into a different direction, because this was a crafted melody designed to do that-- and so being able to check out things like that.

We'll also be looking a little bit at rhythm and rhythmic uncertainty and the types of things that music cognition might tell us for how to generate rhythm. So this is a this is a slightly complex graph. But actually, I think it's the simplest way to explain this diagram.

Say you have three notes. Whatever three notes they are, say that their total durations sum up to 1. And then you can figure out how much, what percentage, or what fraction of the duration each of the notes takes up. Oh gosh. Let's see. That's 1/2. What's that? That's 3/8. Thank you. And that's 1/8. And then you can place each of them between 1 and 0 on this chart. And this triangular chart lets you show the proportion of each of three things at the same time.

And one of the things that comes out of this is that there's not one point where people perceive-- so there's one point where it should be exactly, right? So 2-1-1 should be exactly here on the 25% axis for one, on the 25% axis for another, and the 50% for a third one. So it should be right here. And 3-1-4 in this way-- 3/8, 1/8, 4/8 should be right here.

And one of the things that cognitive studies has shown is that people perceive things a little bit differently. So this entire region of playing is perceived in this experiment as the 2-1-1 or 1/2, 1/4, 1/4. Whereas the region that was perceived as 3-1-4 actually does not include the mathematically correct 3/8, 1/8, 4/8.

And so we'll look at experiments that try to chart the whole landscape of rhythmic perception. And you can imagine that that could also be useful if you're generating music-- that when you generate patterns and you want people to hear them and you don't want it to sound computer, you might do something else.

But the title of the book's called *Sweet Anticipation.* And by far, I think the most interesting for me part of this is studying anticipation, expectation, and surprise. And so I was playing when you all walked in a piece by Peter Schickele, "PDQ Bach," fake Bach humorist. And what I love is a little experiment here, where we're going to be playing something that breaks expectations.

Now, you'll hear some laughter on the soundtrack. That's probably also physical things are happening on stage that we can't see because it's just an audio version. But listen to what people find funny musically and how it has to do with the breaking of expectations. So you're going to be listening to a little thing this is about.

We're going to start about 20 seconds before this figure. So there's going to be a bunch of other things. And maybe just look for a second yourself on what expectation might be broken here.

[PETER SCHICKELE, "CONCERTO FOR HORN AND HARDART"]

[STRING INSTRUMENTS PLUCKING]

[VIOLINS PLAYING]

[LAUGHTER]

[STRING INSTRUMENTS PLUCKING]

[VIOLINS PLAYING]

[LAUGHTER]

[STRING INSTRUMENTS PLUCKING]

You hear the accompaniment in the wrong places.

[VIOLINS PLAYING]

[LAUGHTER]

[VIOLINS PLAYING]

[LAUGHTER]

[VIOLINS PLAYING]

[LAUGHTER]

[VIOLINS PLAYING LONG NOTE]

[LAUGHTER]

[VIOLINS PLAYING]

[LAUGHTER]

Shows a particular expectation for how things might be going and stuff. Oh. And these are our two guests. They're both named Claire. They're in alphabetical order, though. Claire Arthur will be coming first, coming from Georgia Tech, and Claire Pelofi coming from NYU's Music and Audio Research Laboratory.

I'm bringing in guests in part because this is something-- music cognition is something I think is really, really important. But it's probably the weakest topic for me as a teacher in this field. So you should be getting this information from people who do it much better than me. So that's great. We have seven minutes left. Who wants to program an unlock, and who wants to go early? Unlock? Go?

OK, great. Have a great time. Have a great break. And I don't want to start a new topic in seven minutes either. So have a good-- sorry. I'll see you after break in person, but I'll see you all on Friday. So thank you.