Welcome to the Science Podcast for May 28, 2021. I'm Sarah Crespi.

Each week, we feature the most interesting news and research published in Science and the sister journals. First up, neuroscientist, Lucia Melloni, talks about a group effort to make the hard problem of consciousness easier while shaking up the practice of science at the same time. Next up, researcher TC Chakraborty, tells us about why it's important to measure air temperature on the ground in cities rather than from satellites when trying to understand urban heat islands.

One of the toughest problems in science may be how consciousness works. What exactly is consciousness and how do we determine if someone is conscious or something is conscious or not? This week, Lucia Melloni and her colleagues Liad Mudrik, Michael Pitts, and Christof Koch wrote an insight piece on a new way to tackle these questions. Hi Lucia!

Hi, Sarah, how are you?

I'm good, I'm thinking a lot about thinking right now. Why is this such a hard problem, consciousness?

We understand consciousness really well from the first person perspective. This is probably the thing that we now the most. We know that when we wake up, we are there, when we go to sleep, we are not there. And for us, it's very clear what consciousness is. Now, can I know whether you are conscious? And that I cannot, because I cannot actually be in your own experience. I am trapped in my own. And that's the puzzle of science because we want to measure things, we want to look at observables, and so how do you get at measuring feelings and this sense of experience that is so there for us, but maybe not be all that clear for others.

This is definitely an interesting problem, but why is it an important problem?

I can tell you actually how I came to understand this and it was a pretty difficult experience. The partner of my sister had an accident, and he became brain dead. This is devastating when you see somebody and they're brain dead. What is really more difficult to swallow is the fact that, with all of these machines, so they seem to actually breathe, they are warm and he even... Because you can have reflexes... He even moved when I say goodbye to him. It was so weird. How do I know that he's not there? The next piece that made me understand how difficult the problem was, which is that night, I am a lucid dreamer, that night, I woke up in my conscience and I started wrestling with this moment and I understood that I was really, really there but then in my lucid dreaming moment, it came to my attention that, well, if somebody sees me from the outside, I am not there in a sense, like I'm not moving.

So how could it be that somebody who was warm, moving, wasn't there. I was not moving, I was warm, but I was there. And how can you tell? Cases like him happen all the time. People have brain injuries, and it's very difficult to determine whether or not they are conscious. Take babies, take animals, and this defines our ethical decisions as well. So in this case, life support was withdrawn. So you see, I mean, it's a scary moment.
0:03:15.4 SC: Yeah. It's a real problem and it's a scary problem, yeah.

0:03:17.8 LM: It's a scary moment.

0:03:19.7 SC: Yeah. Well progress has been made to some extent. There are certain things you can do at the bedside that say, "Okay, this person probably has some consciousness in there," and there are new ideas and theories that experiments show are going in the right direction.

0:03:34.5 LM: Correct.

0:03:35.0 SC: But what you talk about in this article is a little bit like the Large Hadron Collider approach, this huge science project to kinda get answers now. Why do you think that's needed at this point in time?

0:03:47.7 LM: For many years, people did not dare to study consciousness because how do you study the unobservable, the unmeasurable. It's true that for yourself, of course it exists all the time. It's undeniable, but for science it's actually difficult to measure. Around the 1990s Christof Koch put, forward this idea of looking for the neural correlates of consciousness. Can we try to narrow down where in the brain, the brain lights up, or there's more activities in the neurons, or they get more synchronized or what have you, that relates to consciousness. A large research program was launched, and so now we're at the situation where we have theories. They actually make very nice predictions, but in some sense contradictory predictions. So as a scientist, you cannot stop by wondering, well, how come? If the predictions are different, they cannot all be true at the same time.

0:04:38.6 SC: So you have camps. People who have theories that make predictions, but they contradict each other, so maybe neither camp alone would say, "Well, why don't we spend some time thinking about other people's theories?"

0:04:52.0 LM: They actually were brave enough and said, "Okay, so let's try to to look either for confirmation or for disproof." And now we're in the situation where you could say that, "Well, we might not necessarily know per se how consciousness fits in the brain, but at least we might be able to say which one of those theories explains the data that we have gathered, up until now, better." And the hope is by doing that, you can narrow down the search.

0:05:15.2 SC: So you have to design something that rules things out or rule things in, and everyone has to agree on the terms?

0:05:22.4 LM: Exactly. And so one of the things that we did which I am also very proud of, and this has something to do with even the large team of people, is that, okay, Stan, Julian, Christof, they stick out their neck for their theories, but then they say, "Okay, let's actually ask other scientists who are experts to collect the data because whether we like it or not, we have unconscious biases." They were even braver.
0:05:45.9 SC: Right, this gets ahead of the reproducibility problem, it also makes for very big science when you do something like that.

0:05:51.7 LM: This is very futuristic. There's many things that you want to do to solve a problem. You want to have theories to start with, of course, because you want to know like, "Okay, so what are my hypothesis?" You want to derive predictions, put out the experiments, but you also want to rely on the results that you have and to do that, the best is to say that, "Look, I get the best data that I can, in the largest number that I can, and I try to reproduce my result in an independent sample." Then if one theory gets confirmed, and the other one gets dis-confirmed, that brings a lot of weight.

0:06:24.4 SC: Can we talk a little bit about the theories that are being brought head-to-head here?

0:06:29.6 LM: We are only testing two of them. One of them is global neuronal workspace theory. They think of their brain as actually two kind of processors, if you want. One, which is a series of modules that independently and automatically process information. It can respond automatically to a face without actually really seeing it, or response to a motion without necessarily seeing it. The cost that you pay is that there is no crosstalk between all of those different modules, and that's the idea of the global neuronal workspace, so in essence the information has to come in an integrated fashion into this global workspace to be distributed to every single other module, and by doing that being conscious in a sense. Now, where is this workspace because it could be anywhere in the brain. What happens is that, the theory predicts and also the experiments have been showing that it seems that it's actually in certain areas of the brain, in particular, in frontal and parietal.

0:07:25.5 SC: Okay, that's global workspace. What is the opponent in this boxing match?

0:07:30.7 LM: The opponent is integrated information theory, and it's a very different approach. Integrated information theory is a theory that really starts from phenomenology. So what Giulio and colleagues did was to think about what are the properties of any conscious experience, and they defined five properties that needs to be present in every experience, then they turned these into so called like axioms. How can you translate this into any physical system that will actually have this? And then when they defined that, what they understood consciousness would be is a set of cause-effect structures. They defined this cause-effect structure and then they looked at where in the brain neurons have more cause-effect power, and they came up based on theoretical arguments that it should be more in the back of the brain. And so in essence at the end of the day, you could tell one of the differences between these two series is that one is more like towards the front and parietal cortex, whereas the other one is towards the back.

0:08:28.5 SC: You staked out territory in the brain, what do you do to rule in or rule out which area is important for consciousness?

0:08:35.9 LM: So we have a number of experiments in which we are testing the number of hypotheses, so one of those is where in this case, more front or more back, but also the kind of activities that you would expect for consciousness. Integrated information theory would predict that so long your experience is on, the activity in your brain will be on. If it is one second, it would be one second, if it is to two seconds, it will two seconds and so on and so forth. Global neuronal
workspace theory would say no, it will be at the beginning and at the end, and of course, okay, if something is longer, then the off activity will take longer.

0:09:07.8 SC: Alright, so the actual experimentation is going to be presenting images and looking at when things turn on and off, but also where those things are located in the brain, that's the other main thrust?

0:09:19.3 LM: Correct.

0:09:20.0 SC: So where exactly are we in this process? It sounds like you have teams and you have experimental design.

0:09:28.5 LM: Yeah, there are six teams in the world that will be collecting in parallel. Every team is doing the very same experiment. You could not imagine how difficult it is to make sure that every experiment in every lab is the same, including that the instructions of the subjects are being the same, that the participants are doing the same.

0:09:48.3 SC: Yeah, in different languages.

0:09:49.9 LM: In different languages so it took forever and was the work of an amazing set of post docs and students during the COVID year where the labs were shut down, where it was extremely difficult to collect data, to get participants, and this is where then it becomes the big science on the one hand but also the futuristic idea because eventually you would really want to run experiments like what we're doing, making sure that everyone is doing these things the same way. And so we are now collecting the first data, the students and the post docs are working extremely hard now on creating the analysis.

0:10:23.0 SC: And this has been pre-registered?

0:10:25.4 LM: We have this so called pre-registration. So everything, the idea has to do with in the open science framework, so everything is set before, it's going to be released now, everyone will know about it and on top of that, we will release all of this data to everyone.

0:10:39.9 SC: So what if everybody is wrong, is that...

0:10:43.0 LM: That's great!

0:10:43.7 SC: That's great, okay.

0:10:44.6 LM: That's great! When do we learn? In science, when do we learn? When things go wrong, you have to think about it again because this means what you had thought about before, it wasn't the proper explanation. Once the data are public, then anyone in the world will be able to download these data and look into those data in whatever way they want. They can test their own hypothesis.
0:11:06.6 SC: And they can use your methods too.

0:11:08.3 LM: Yeah, exactly. And that's the part where you can think of accessibility. A high school kid can download the data and play around with them. Getting access to equal data is very rare, it's very difficult, so very few people actually have access to those or getting access to fMRI data is extremely expensive, the same thing for EMG, like all of these techniques, they are either rare or very expensive. So a lot of people in the world don't have access to this, so now we're giving it.

0:11:33.3 SC: So how do you see a result like this feeding back to how we set up this problem in the first place, say, we do see strong evidence for one of these theories, what do you do next to, for the bedside, for the human experience, for thinking about consciousness?

0:11:50.0 LM: Both of these theories have measures that they have been pushing forward for evaluating consciousness either for instance in babies or in vegetative patients or in people under anesthesia. Now, as you know it's very hard to validate those measures because consciousness is not behavior per se, this is experience, so then in some sense, you need to have a theory to make these inferences, like are you conscious or not. If we can prove one theory more than the other, then that in turn also creates more reassurance on the mixed measures that they have promoted. Also the theories will advance because it's not that the theories are explaining everything, so then you can also just take them to the next level.

0:12:30.0 SC: Yeah, this is a big science project, labs all over the world. How is this funded?

0:12:36.3 LM: Another thing that is very peculiar about this experiment and this project is oftentimes, scientists come up with an idea and then they write a grant. In this case, these projects do came about the other way around, so it was the Templeton World Charity Foundation, and in particular, a very talented program officer called Dawid Potgieter who actually thought about this idea as a way to accelerate research on consciousness. He came up with idea, put people together, convinced the trustees, he got the money, we applied for that grant, we got the money, and it's now we're doing it. But had it not been for him, this project would not have happened. You know, I feel the results are a very nice way in which you can use resources in a conscious way because now we're spending a lot of money in actually doing this, but it's money that it will be well spent because then anyone will not have to do this experiment or will be able to get access to these studies, and to these results, and to these data, and then continue doing research on them for the years to come.

0:13:40.0 SC: We've touched on big science a lot but mostly in terms of coordinating labs and how much funding it takes but also a lot of people are involved.

0:13:50.0 LM: As you know, science is sometimes a very difficult game. It's a game of names, and sometimes, and they are actually trying to go against that system, to say, "Look, I will be in a 31st publication and I will hope that my career progresses." At the end of the day, the people who are the bravest are the post docs and PhD students, and the masters students who are actually trusting us and they are working on a daily basis on this project, they are really actually making it happen. But I'm very oftentimes sad about this project is that, my name gets to be there, Liad's name, Mike,
Christof, whatever, but then these people who are working and they are really putting their careers on the line, and I'm believing in this, they just don't get named.

0:14:39.5 SC: Lucia, Thank you so much.

0:14:41.0 LM: You're very welcome. It was a really fun conversation and you know, I hope that you also had fun.

0:14:45.2 SC: Lucia Melloni is a group leader in the Department of Neuroscience at the Max Planck Institute for Empirical Aesthetics. You can find a link to the article we discussed at sciencemag.org/podcast. Stay tuned for my chat with TC Chakraborty about using tens of thousands of citizen weather stations to better understand urban heat islands.

[music]

0:15:13.1 SC: You've probably heard of the urban heat island effect. This is the idea that urban areas with less greenery and more heat holding materials like cement and pavement are warmer than the surrounding countryside. But how much warmer and how to change the heat scape of a city are still very much up for debate. TC Chakraborty is a PhD candidate at Yale University focusing on land, atmosphere interactions and urban climatology. He's here to talk about his Science Advances paper on this topic. Hi, TC.

0:15:44.2 TC Chakraborty: Hi Sarah.

0:15:44.7 SC: This paper looks at different ways to measure how warm urban areas are looking at both land based weather stations and satellites. Why did you think there might be a difference in the way these two different approaches read the temperature of a city?

0:16:00.1 TC: Air temperature is rarely available over cities when we actively don't put weather station in cities. So we have air temperature measurements in airports which is not where people live. Because of this, we try to use both land surface temperature and air temperature over 340 urban clusters in Europe to kind of compare these two estimates of urban heat island.

0:16:25.1 SC: Are satellites measuring air temperature or land surface temperature?

0:16:28.7 TC: Satellites measure surface temperature which is we have emission of radiation from the land and the satellites kind of convert that into some estimate of temperature.

0:16:38.9 SC: Okay.

0:16:40.3 TC: Yeah.

0:16:41.0 SC: That is very different than having a thermometer on a roof of a building.

0:16:43.9 TC: Exactly. But we don't have the measurements so it's been easier for the community
to work with land surface temperature especially if you want to compare the urban heat island for hundreds and thousands of cities.

0:16:56.1 SC: Right. So it's easy to compare, but it maybe not getting at exactly what's happening in a city. For that you looked to land based weather stations but there aren't very many in cities. Why is that the case?

0:17:11.3 TC: Normally, we don't want weather stations in cities because those are not put into the climate record because that doesn't give us the actual climatological mean temperatures. There was a lot of studies earlier trying to figure out how urban weather stations may be affecting the global warming race that we were measuring. So we have actively put these weather stations away from cities. And because of that, we cannot study the urban heat island.

0:17:38.1 SC: So you're excluding urban heat islands from your global calculations. But hey, what if you wanna know about urban heat islands? You got to do something else? What did you guys do instead? How did you attempt to get these temperature measurements?

0:17:50.5 TC: So it is true that we don't have standard like research grade sensors in cities but recently a lot of people have been putting their own private weather stations, and you can buy these from different companies. And they have thousands of these weather stations which people have put up in their backyard. So these are just citizen weather stations. And while they are not as high end in terms of research, grade and quality control, they do provide a lot of information about not just the overall air temperature in cities, but also the variability throughout the city, which is important.

0:18:25.7 SC: Where you're getting this temperature data from the land, is from people buying these instruments, putting them up in their backyard on their roof. How sure are you that they're using them consistently and that the readings that you get are reliable?

0:18:40.5 TC: We do evaluate the measurements against the rural weather stations, so standard rural weather stations, and generally find that they are okay, there is a positive bias in the crowd source data. Part of the reason for the positive bias is that many of these weather stations don't have radiation shields, and the radiation shields basically prevent the sensors from heating up. However, this issue we would assume is similar for both urban and rural areas. I think the other issue right now with the crowdsourced weather stations is that while they are available at a much larger scale than ever before and they are more than any traditional weather station network, there is a lack of metadata, whether a station has a radiation shield or not, whether a station is under a tree in the backyard, whether it's near a fence.

0:19:32.2 SC: It also helps to have a lot of these data sources, you have tens of thousands in your analysis.

0:19:37.5 TC: We started with almost 100,000 stations, but after a lot of quality control, we were left with a little over 50,000 stations for over 340 clusters. This is what makes it I think, more comprehensive than a lot of previous studies.
0:19:51.5 SC: Right. We should mention that the research that you did here at the time that you captured these data was during an extreme heat event in Europe. Why was that a good time to tap into this resource, these citizen science temperature stations?

0:20:06.6 TC: That allows us to look at two issues when we look at land surface temperature. So when we are talking about heat stress, air temperature is more important than land surface temperature, and because of this, we wanted to check whether during a heat wave where the effect of urban heat stress would be maximum, the air temperature-based urban heat islands are comparable to the satellite-based urban heat islands and we found that it's not.

0:20:33.7 SC: So the satellites are measuring one thing, the land-based stuff is measuring something else, and that's really important when you're worried about people's health, 'cause heat waves in Europe have been deadly.

0:20:43.3 TC: Exactly.

0:20:44.4 SC: So what did you see, and we say we're already kind of hinting that there's a difference here. But what were the numbers like when you compared the ground-based measurements with the satellite-based measurements during a heat wave?

0:20:56.3 TC: When we are comparing the urban heat island which is just the contribution of organization to the local temperature, we found that the average over the day the surface-based urban heat islands were six times higher than the canopy urban heat island which is the air temperature-based urban heat island, and this was consistent across cities, consistent for both day and night, so it's a pretty strong result in terms of the directionality of these two variables.

0:21:24.7 SC: The effect of urban heat islands appeared larger when measured from satellites. What are we talking here in terms of degrees Celsius?

0:21:32.3 TC: So what we do is we take an urban temperature and we subtract it from a rural background, and the rural background is usually a region around the city, and what we found is that, again, average over the day, the surface-based urban heat island was almost 1.5 degrees Celsius, while the urban heat island from air temperature was closer 0.25 to 0.3 degrees Celsius.

0:21:54.8 SC: What do you think the mechanism is that makes these two different ways of measuring the temperature of cities different?

0:22:01.7 TC: The air temperature heat island and the surface temperature heat island are different quantities and they are affected by different components of the surface energy budget. What we found was that elevation was more important for the air temperature heat island while albedo, which is the reflectivity of the urban surface was more important for the surface urban heat island. However, evapotranspiration was important for both, but it plays a much stronger role for the surface urban heat island.

0:22:31.8 SC: So how many trees are evapotranspiration as a reflection of how much plant life
there is going on in the city?

0:22:38.0 TC: Exactly. How much green space you have and all that.

0:22:41.4 SC: Time of day was also really important for understanding these results, right?

0:22:45.2 TC: Right. We looked at two specific variables which have been debated quite a lot in the urban climate community, one being evapotranspiration and the other being aerodynamic roughness which is a proxy for how easily cities cool down through convective cooling. Basically, what we found was that during daytime, cities cool down through convective cooling, but during night time, they can actually heat up through convective cooling by bringing warmer air from a loft. And this is interesting because this is an observational evidence for something that has been looked at in the previous studies primarily using models, and the models have a lot of uncertainties in how they represent urban areas.

0:23:26.9 SC: It sounds to me that now that we have more information on what is actually happening with air temperature and cities, we can do more to solve urban heat island problems. What are some of the recommendations that might come out of research like this?

0:23:40.6 TC: So the big one is still urban vegetation. You can reduce the air temperature using urban vegetation, however, it is to be noted that urban vegetation can also increase humidity which also plays a role in heat stress. The second factor we found important was roughness, so you can actually restructure cities and make them taller, like basically make them grow vertically, and thus allow cities to cool down through convective cooling, which is very different from a lot of the previous literature and what has been recommended. So I think that was a very interesting result of the study.

0:24:16.3 SC: Alright, thank you so much, TC.

0:24:17.8 TC: No worries, Sarah. Thank you for this.

0:24:19.8 SC: TC Chakraborty is a PhD candidate at Yale University focusing on land, atmosphere interactions and urban climatology. You can find a link to the science advances paper we discussed at sciencemag.org/podcast.

0:24:34.6 SC: And that concludes this edition of the Science Podcast. If you have any comments or suggestions for the show, write to us at sciencepodcast@aaas.org. You can listen to the show on the Science website at sciencemag.org/podcast. On the site, you'll find links to the research and news discussed in the episode, and of course, you can subscribe anywhere you get your podcast. This show was edited and produced by Sarah Crespi with production help from Podigy, Megan Cantwell and Joel Goldberg. Transcripts are by Scribie and Jeffrey Cook composed the music. On behalf of Science magazine and it's publisher AAAS, thanks for joining us.