Valentyn Stadnytskyi, Ph.D.

Behind the Mask

June 29, 2021

Barr: Good afternoon. Today is June 29, 2021. My name is Gabrielle Barr, and I'm the Archivist with the Office of NIH History and Stetten Museum. Today, I have the pleasure of speaking with Dr. Valentyn Stadnytskyi. Dr. Stadnytskyi is a research fellow in the Laboratory of Chemical Physics at the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK). Today, he's going to speak about some of his COVID research and experiences. Thank you for being with me.

Stadnytskyi: Thank you, Gabrielle.

Barr: When did you and the others in your lab begin conceiving of and preparing for your study that looked at SARS-CoV-2 transmission via speech generated respiratory droplets?

Stadnytskyi: It all started pretty early. One of the driving forces behind these initial ideas was Dr. Adriaan (Ad) Bax, who is Section Chief of the Nuclear Magnetic Resonance (NMR) Spectroscopy Group at the Laboratory of Chemical Physics. He was very interested in what was going on—specifically, why this is spreading and what's happening. He had a postdoc who is a professor right now at Wuhan University. They casually talked about things and the faculty ex-postdoc alerted him that in Wuhan, people are walking around but no one is sneezing and coughing. It's not like everyone is symptomatic. They didn't cough, but it's spreading. It was a question as to how this works. We are all familiar with covering your cough or your nose, but somehow it was spreading differently. At the same time, we could hear in the news that U.S. health care workers were told to look for three major symptoms—a fever, shortness of breath, and cough. But there were some inconsistencies. It was like, “Wait, how does it spread if no one's coughing on me?” Ad was really interested in that. His wife is actually a linguist, so she told us that when we talk, we do produce these speech droplets. Sometimes you can see them. When I talk like this, this big fireball or cannonball lands on the keyboard. We have all experienced that. But she said that there is more. Our initial idea was to visualize it. Can we tell people that we produce numerous speech droplets? We couldn't find anything like that on YouTube. We knew we wanted to make a YouTube video to alert the public that it's out there. We needed to do it. Ad was really instrumental in driving this very initial stage. My adviser and I were preparing for our trip to Chicago, where we do experiments on a synchrotron. We thought it was all going to pass. We were kind of brushing it away because we were busy with something else. Then our trip to Chicago got canceled, because it was at the end of March and the lockdown started. We were like, “Wait a second, so we don't go to Chicago anymore. What do we do?” We really jumped on this. That's how it started. There wasn’t really any preparation. As a scientist, you just talk about things—[including] some inconsistencies. That's how it all evolved. Then we started to work on it.

Barr: How surprising of a premise was it that mere talking could lead to infecting others? Has that ever been spoken about with other diseases?

Stadnytskyi: That's a very good question. I'm a physicist by training—a physicist and a laser and optical scientist. I really work with nonliving objects. I measure photons and electrons. I don't really think about these things. It all started with the idea of the speech droplets. This was interesting, but is it real? Can it be? And was it ever done before? We’ve all heard about some airborne diseases like tuberculosis and airborne measles. When we actually did experiments, you're like, “Wow, there's a lot of speech droplets and amount of fluid that we produce while speaking.” It's not about how much fluid, it’s about the frequency. Right now, I'm talking to you, and every word I say produces droplets. If I talk for an hour, I'll produce thousands of them. That's what the New England Journal of Medicine paper was about, where we showed how many droplets we produce on average per second, to kind of extrapolate. Then it became, “Wow, this small production per second leads to a large accumulation over time.” Initially it was interesting to look at it as a scientist. That’s what you do. You have an idea and try it, but then you realize how big it is.

Barr: Can I ask you a question that's kind of an aside? Do people produce the same number of droplets generally, or do certain people produce more droplets than others? Are certain languages more conducive to more droplets per hour than other languages?

Stadnytskyi: This is a very good question. Indeed, people produce different a number of droplets. For example, I just had coffee. Coffee is a diuretic; it dries out your mouth. When that happens, you don't have that much fluid in your oral cavity. You actually produce less droplets. If I keep hydrated, I'll produce more droplets. With languages, there have been studies. That's something that I haven't talked about. One of the very first studies about speech drops was done a little under 100 years ago, in the 1930s and 1940s. They didn't use lasers or anything—they were much simpler. But there were studies from a long, long time ago just showing qualitatively that there might be this “dirty air” type of concept. Speaking of different people, indeed, we produce different numbers of droplets. Different languages and different sounds produce different amounts of droplets. It all has to do with how our mouths—our teeth and tongue—interact instead of our oral cavity. If you think about when you blow a bubble, we have two wet surfaces, and there's a little bit of film of liquid between them that you can blow, and it bursts. This happens all the time when I talk. It happens with my mouth, my teeth, and my tongue. The different sounds in different languages will make different interactions. Different people have different accents. That's what makes this field kind of difficult because you don't want to say that one language is worse than another. It's really complicated. It's a really complex problem.

Barr: That's really fascinating. Back to the crux of this interview, which is about your work with COVID-19. Will you please relay how you went about conducting your experiment, including the kinds of tools and equipment you employed as well as the metrics you used to evaluate your result?

Stadnytskyi: One thing I want to mention is that we don't do these types of experiments on a regular basis. We just had an idea and went for it. A lot of these things were done while we were developing this technology and thinking about how to present our research.

Barr: That must have been hard.

Stadnytskyi: My adviser Philip Anfinrud, Ph.D. and I are more laser and optical scientists. We know about light scattering and all kinds of things like that, which gave us the edge and skills to say that we can probably see these speech droplets. Let me just tell you a few short stories about how Ad Bax, the Chief of the NMR section, came to us and asked if we thought it's a good idea to just put in some fluorescent dye, which will light up when we speak into a beam. I was in my advisors’ office. We didn’t think we needed that. The speech droplets will light up when they get into this sheet of light or slab of light. We can think about it that way. An analogy that all of us have probably experienced is to imagine that it's early morning and its very sunny outside. You have this dark room, and your blinds and shades are closed. There is this small crack in your curtains, and you have this beam of light getting into your room, with all of these dots flying around. You can see it very well because the room was dark and there's this very bright light. This was kind of the idea. We took it further and asked how we can make our “sun”—in this case, a laser. It's a well-controlled source, so we can make whatever we want out of it. We can take a volume of space and eliminate it as light, then our dark room became a dark box, completely pitch dark inside. If you look into it, you can't see anything.

Barr: How big was the box?

Stadnytskyi: The box was 240 liters, which I would need to convert into cubic feet. It was around 20 by 20 inches and 20 inches tall—two feet by two feet. A little bit larger than a person. Right in the center there was this light sheet. If you look inside the two cut outs, you can’t see anything. But there’s a light inside. We designed it in a way that we could make it this improved analogy of dark and a light shining in. But then when a speaker from the other side talks, you see all these droplets that have been produced. Then we put cameras in. Instead of doing it visually, we put the cameras on and now we have a stream of data. We can look at it and analyze frame by frame, looking at those pointed objects like a dot. A dot lights up, or we can see its particle moving along. We wrote a code to analyze it, capture, and count how many we were producing. You asked about metrics and equipment. Our initial idea was to do it qualitatively to show that they are there. But then we figured out that by making this very dark box, we can actually count them. We wrote home-built software to actually count these objects—the bright streaks—in a frame of a video stream. Then we were able to say that in every second, this many droplets exist in the box. The metric is kind of simple—we just counted them.

Barr: Did you do all the circuitry yourself, like installing the light and installing the cameras? What was that like?

Stadnytskyi: I mean, it was an interesting experience because what we do in the lab to begin with is kind of building instruments. That's going to give me that skill to say, “Okay, here's a problem. Let's find what we have in the lab and just put it together to do what we want to do.” Actually, our camera was an iPhone. An iPhone was just something that one of us had. It could be any smartphone camera. The smartphone cameras can have very good sensitivity to detect these objects. We went with what we had. We built our first box, that you will probably get from us, from an Amazon cardboard box. We just took a box, did cut outs in there, and painted it black inside. And that's it. We just took whatever we had and went with that because we realized what the importance would be. We wanted to tell people that we’ve got to do something about it.

Barr: Did you do different iterations of design? Did it take you a while to get things exactly where you wanted them placed?

Stadnytskyi: Yeah, there were multiple iterations. But I think the core idea was quite simple. There were some iterations on how to make the inside of the box as dark as possible.

Barr: How did you make it as dark as possible?

Stadnytskyi: If you take the room analogy, when you have light getting into a room, eventually it hits something. It can be a bed; it can be a wall. Then it scatters. The inside of your room is now illuminated with this background light. To get rid of that background illumination, we cut this entrance slit through which light comes in, and an exit slit through which light exits. It doesn't have anything inside, except those speech droplets that we wanted to observe. This allowed us to really reduce any background inside. Then we painted it black, so that if there is any scattering, it gets absorbed by the paint and it doesn't scatter into the camera. Those were the kind of things that we worked on. Of course, there were some different iterations of how to make the slits scatter the least amount of light. There are some challenges with that.

Barr: Will you say a little bit about what some of the challenges were?

Stadnytskyi: Imagine that you have a sheet of light, and it has very hard edges. If I take something like a box that has a very hard edge, it doesn't work like that. Whenever you have a hard edge, diffraction will smear it out. The light does not want to have a hard edge. It will leak in there. This object will start smearing out. If you make it very nice and hard-edged in one place, then the light starts diverging. If we make a hard edge this way [moves hands outward and upward], it starts diverging and slowly getting wider, wider, and wider. It's a very fundamental limitation that optics have. It's called diffraction. The light does not want to stay within the boundaries. It wants to leak outside, so that we had to clear and clean it. Then there's some diffraction effects. Whenever you have a hard edge, light diffracts, and it will change its direction. That was something we did not want, because that gets inside of our box, it illuminates the box inside, and we get light captured by the camera, which was reducing our ability to detect those scattering objects that you want to look at.

Barr: Can you talk a little bit about what it was like for you to develop the algorithm? How long did it take you and what were some of your considerations? Or was it just a standard algorithm that you often use?

Stadnytskyi: No, it was not a standard algorithm. I had to develop it from scratch. It's very possible that there are some solutions out there that I could have used, but quite often in science, it's sometimes faster and easier to write something on your own. The idea I had was to have a frame. If you just imagine, a video stream is a sequence of static pictures, every picture has a certain number of pixels horizontal and vertically. It's a square with some number of photons and some intensity. You can now imagine it as a landscape with a sharp peak. Now each peak is my object that I want to look at. I said "Okay, how about I take this landscape and draw a horizontal line." Everything above this horizontal plane is something statistically significant. It's something that is about my noise, because when I don't have any particle, it's pitch dark. It's just zero—sea level. You have sea level, and then you have these mountains—that's your signal. I said, "Okay, let me just cut at 100 feet height." Everything above is my object. You can think about a contour map. Now I can find where the object is, and I counted them. That is kind of a very simple explanation of how the algorithm was done. It's actually pretty slow. I had to parallelize my algorithm—I had to take every frame and use high performance computing and analyzation so you can do multiple frames at a time. For one of our papers for Proceedings of the National Academy of Sciences, we have collected video for 90 minutes, 60 seconds in a minute, and it was, I think, 24 frames in a second—90 times 60 times 24 is a large number. The frames were pretty big as well, so it was actually pretty time consuming. It took overnight, with a computer running multiple processes at the time, to process data. But back then the question was whether we make it fast and efficient, or get the job done and get numbers out—so we can actually see numbers and say, "Oh, this is important."

Barr: What were some of your observations?

Stadnytskyi: There are a few key observations we made, and we published them sequentially in a few papers. The first major observation was that we produce speech droplets. We qualitatively took a bunch of pictures to show people. The second step was to actually count them and do some quantitative analysis. That was published in the New England Journal of Medicine paper, where a volunteer spoke into this box, and you can see the individual objects, individual streaks of light—dots—going through the light sheet. I specifically call them "dots" of light, because at that time, we knew there should be these speech droplets produced by the volunteer.

Barr: Is the volunteer part of your lab, or was he just a random person that participated?

Stadnytskyi: The volunteer was Philip Anfinrud, Ph.D., my postdoctoral advisor. He was and is a part of the study. He was our volunteer. We actually eventually did it with several people who were part of the study. And all of us produced droplets, which was one of the questions we had prior. We published some data on four people. But we did not compare different human subjects. This is a different field. It's kind of beyond our scope. It's not really our field to make these human-to-human comparisons. The fact is, here we produced droplets. In the New England Journal of Medicine paper, I counted them, and showed how many we do per second. In the Proceedings of National Academy of Science (PNAS) paper, we have done a follow up experiment where a volunteer talked into a box. He populated the box with the speech droplets. Then we saw them and observed them for 90 minutes. We saw the decay of a number of those speech droplets in the box minute by minute. This was a very important experiment, because what we could not measure—and what we cannot even measure directly right now; we're still working on it—is the size of these objects we produce. The camera does not tell us how big they are, so there's some measurements that have to be done. The PNAS paper addressed that because we could watch them falling. The idea was the object just falls down. The large drops fall down faster; the small ones fall downs slower. That's what we found out—that it takes around eight to 14 minutes for these objects to actually fall.

Barr: That's quite a bit of time.

Stadnytskyi: Exactly. That was very important information because imagine you are in an elevator. You talk to someone and then you leave and someone else walks in. They have no knowledge that you have been in the elevator and that you had been talking in there, but now this second person is susceptible to all the speech droplets the first person has produced. That's why masking was so important. We were advocating that if you wear a mask, you as a speaker can stop those speech droplets from being emitted into open space. And on the other end, the receiving side, if we're masked, we can protect themselves from inhaling those things.

Barr: How small are the droplets you were able to capture? They're different sizes, and some are big droplets, but there are also very tiny particles that people produce—like aerosols or something that stay in the air for longer.

Stadnytskyi: Right. One thing that we need to keep in mind is that when we produce the speech droplets, when they exit my mouth, they are hydrated. They are made of around 99% water. The droplet is big, and then pretty fast, in under seconds, it actually shrinks to a very small object. We saw that a speaker could produce an object from 11 to 27 micrometers—so it's pretty small objects. After dehydration, they would shrink to a few microns—three to four microns. Between eight- and fourteen-minutes kind of corresponded to the falling rate of four- and three-micron object. That's our direct measurement. We have some other unpublished data that shows that we could detect objects as small as a micrometer, or even smaller. One thing we need to keep in mind is that the virus by itself, this SARS-CoV-2 virus, is from around 80 nanometers to 100 nanometers. It's 0.2 microns, so these droplets potentially can have virus embedded in them.

Barr: Oh, that's very interesting. How have you and the others you've worked with contended with some critiques of your initial experiment, including critiques of some of your equipment and methodology, and the critiques on being able to generalize?

Stadnytskyi: This is a very good question. I'm a physicist. I work in the Laboratory of Chemical Physics. A lot of things that we do are working with nonliving objects. As I mentioned before, I measure photons, electrons, and I study proteins. When we were entering this field, it's more of a human subject and medical field. We don't have much experience with that. We had a lot of help from Christina Bax, who is the daughter of Adriaan Bax. She was a medical student. Now she has graduated, and she's a medical doctor. She was very instrumental in helping us navigate these waters. How do we talk to the medical community? How do we show our results? In our New England Journal of Medicine paper, we repeated some of the experiments three times with the same volume to show reproducibility. For me, when I see a video where a speaker talks into a laser sheet, and the sheet lights up, there's always this droplet sliding up. And I see correlation between the motion of a mouth and the sound in a video. I'm saying this is a fact. But in the medical community, because you want to compare different subjects, it's hard to draw conclusions about how this one individual and this one experiment affects billions of people. That we could not do. And we were very open about it, saying, “Look, what we are showing is that the speech droplets exist, and they can be produced, and of course, we understand that there’s going to be a human-to-human variability.” We were pretty open about it, and we did get critique like that. But the facts stay the facts—that they are there. The question of how it affects later transmission, that’s something that’s difficult for us to address directly—that kind of indirect measurement that says, “Look, it's there, but what does it mean?” We can only speculate. We can only provide some ideas or some theories on how it affects things. That's what we actually did in the Journal of Internal Medicine. We recently published a review paper where we read a ton of literature about this. We found a lot of compelling evidence showing that the speech droplets should be the main contributor, and the main carrier of virus.

Barr: What skills and expertise do you think that your team possesses that allowed you to look at SARS-CoV-2 and its transmission differently than other groups who have different kinds of knowledge?

Stadnytskyi: I don't want to say that we had some unique expertise. As I mentioned before, we were well experienced with lasers and optics and scattering, with the software and data imaging analysis. We had technical skills, we had appropriate equipment in the lab, we had experience with how to take a laser beam and shape it into whatever shape you want, and how to analyze data. And I guess we also had this mindset and a view that I personally kind of struggled with. As a scientist, you work on something, and you want to know more about it. You get to be laser focused on your task at hand—just measuring the speech droplets, these objects, and then thinking about what it means and what the implications are. As we acquired some knowledge from the outside—everything from the physiology of our breathing system and our lungs, virology, or about the SARS-CoV-2 virus and how it infects our cells—at the very beginning, this was all interesting. But I was trying to be laser focused and shield myself from all of those questions that I had in my head. It looked interesting, but let's just focus on this. This is another skill that a scientist needs to have and kind of prioritize—to say, “This was at hand, let’s just do work on this.”

Barr: Do you have plans to continue the study? Or have you continued working on it? Can you speak a little bit about how you have continued since some of your initial papers came out last year?

Stadnytskyi: We have some ideas of what we can do differently and better. We are actually working on an apparatus that might allow us to measure a wider range of sizes, and potentially cover a larger range. Potentially it might allow us to say more about particles. The challenges are that it's difficult to manage these objects directly. They're very small. We have currently been working with the Acting Medical Director at NIDDK, who works in the gastrointestinal endoscopy field. When you do an endoscopy, you put the endoscope in a person's mouth. They were interested in whether any of these procedures produce these droplets. We actually have done some research on that and collected some data showing that yes, it does produce droplets—so this technology has other applications. But it might require a bigger team to actually make it more accessible to other fields. I wanted to make one thing clear—what we did, in a sense, has nothing to do with SARS-CoV-2 or this current pandemic. In a sense, what we are detecting is not a virus in a particle, what we're detecting is speech particles, and then they can carry all kinds of viruses.

Barr: What implications does it have for other kinds of disease spread?

Stadnytskyi: The problems are where these droplets are produced. In this most recent Journal of Internal Medicine paper published in May, we talked about how there's speaking, breathing, coughing, and sneezing—the four most common respiratory activities—and they come from different parts of our respiratory system. Different viruses affect different parts of our respiratory system. I don't want to get into the details, but to answer your original question about where this goes and whether I want to continue pushing this field, we will see. I don't have an answer to that. We'll see where it goes. There are some challenges that we need to address first.

Barr: Are you involved in other any other COVID research or initiatives?

Stadnytskyi: Not really, only within the lab and one with gastro—the GI endoscopy project. It's quite time consuming. It's not like you write code, or you make some device, and you just give it to people to use. It's at such an infant stage. It requires a lot of work on our side. We don't have a big team working on this. That's something that one can think about—do we expand the capabilities, maybe hire more people, and expand the team to actually work on this more, or have more people working on this?

Barr: As a person, what have been some personal opportunities and challenges that COVID has presented for you? You're also living through the pandemic, in addition to working through the pandemic.

Stadnytskyi: This is a very good question. I guess I was maybe lucky that, because of this COVID project that I was involved with, I had a unique opportunity to actually continue to work throughout the pandemic, and actually come into my office, which I think partially shielded me from some of the struggle that people have had. Despite that, what I have learned is how to prioritize work, how to do time management, and then some new skills about teleworking and working from home. My wife and I read some books and did some research on how to design our home, so we have designated spaces for different tasks. The dining table is for dining. There's an office table to do work. We don't mix and match. If you are in one environment working from home—and I did some work from home—it's difficult if you do multiple tasks in one place. If you eat, watch TV, work, and read books in one location, it's difficult to switch between different tasks. Efficiency goes down. You really need to differentiate and make these "islands." This is something that was really interesting to realize. I feel like that's something that my wife and I have learned. Now our apartment is designed that way. We have separate places to do different things, which has really enabled us to work more efficiently.

Barr: That's great. Did you continue working on some of your non-COVID projects at all last year?

Stadnytskyi: A little bit, but not really. It was really devoted to the COVID-19 speech droplet project. As I mentioned at the very beginning, we do a lot of research at a synchrotron in Chicago, and until a few weeks ago, we could not go there. When you can't do your main research, you want this pandemic to be over. We were working hard on providing some of this evidence to alert the public and policymakers that we've got to do something about it. This is a potential pathway to slow down and decrease the duration of the pandemic.

Barr: Has there been something that you enjoy that has made the pandemic a little bit easier to cope with?

Stadnytskyi: My wife and I really like hiking and outdoor cycling, so we really took advantage of that. We would go cycling almost all the time, several times per week, and go hiking. It was Thanksgiving 2020 when, instead of us meeting with other people, which we couldn't do, we just went to downtown Washington, D.C. and cycled around the National Mall. It was a really amazing experience because it was empty. It was quite interesting to just be there and see all of the buildings in downtown D.C. with very little people. The streets were empty—there were no cars. We just cycled in the streets. It was amazing.

Barr: That's interesting. What have you found most rewarding about this experience?

Stadnytskyi: This is a very tricky question. Growing up in Ukraine I remember a saying that what doesn't kill you makes you stronger. This was very hard. These are very hard times. We, as humans, you. know we can adapt. I was forced to have certain skills and do certain adaptations during the pandemic that I will take with me—like I was saying about my house and some time management and how to prioritize work. And one thing that was of course absolutely rewarding, that I probably should have started with, was how impactful this work was! I know that some of this research was circulated at NIH, because we had to get feedback. I know that CDC [Centers for Disease Control and Prevention] was alerted to some of our research and [so was] the White House. As far as I know, our very first New England Journal of Medicine manuscript was read somewhere in the CDC and White House. That was used to eventually recommend masks.

Barr: Well, that's a great feeling.

Stadnytskyi: Yeah. We were able to convince people and show some evidence that this is real.

Barr: Is there anything else that you would like to share or add?

Stadnytskyi: No, I think that's all.

Barr: Thank you very much for your research. I hope that you, your lab mates, and your family continue to stay safe and continue to be successful.

Stadnytskyi: Thank you, thank you. You, too.

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