Understanding the Effects of Space Missions on Human Health and Behavior

Space scientists speculate that we will likely set foot on mars in the next two decades, yet we know little about how our brains and bodies change and respond to the space environment and the use of medications that go along with space missions. In the past couple years the growth of commercial space flight missions conducting health research on civilians has created an exciting new avenue to understand human health and behavior in microgravity. New tools are being developed to learn spaceflight specific molecular, physiological, and behavioral changes in a human body and to test medicines beyond our planet. We are talking to Dr. Mathias Basner of University of Pennsylvania, who studies astronaut behavioral health on long-duration space missions. In the discussion we will be understanding the various effects of microgravity on human health, cognition and behavior.

Full Transcript:

Shweta Mishra: Welcome to CureTalks, today we are going to explore a very exciting area and that is understanding how our health and behavior, gets affected by the microgravity environment in space. I'm Shweta Mishra and I'm honored to have Dr. Mathias Basner join us today from the University of Pennsylvania. Dr. Basner is a Professor in the Department of Psychiatry and Director of the Unit of Experimental Psychiatry in the Division of Sleep and Chronobiology at the University of Pennsylvania. Joining Dr. Basner on the panel are Matt Gaidica, an officer in the US Air Force and a fellow of the Academy of Bioastronautics performing Postdoctoral research supported by TRISH and NASA at the University of Michigan. And we have David Stanley, who is an author, writer and a teacher passionate about everything science. Welcome to CureTalks David, Matt and Dr. Basner, it's a pleasure to have you all here.

Dr. Mathias Basner: Thank you very much.

Shweta Mishra: Thank you. Dr. Basner, now is the most exciting time in terms of everything space with frequent space flights being launched each pushing the boundaries of how far we can go in space and what we can do in space and all the more interestingly with civilians on board, I mean, astronauts, go to space after rigorous training and today we have civilians like William Shatner who is 90 plus going to space. So, what do you think as a researcher about civilians going to space who may not be as fit and maybe not as trained as an astronaut.

Dr. Mathias Basner: I think it's great. I actually think spaceflight should be open to everyone or almost everyone. I mean you have to be somewhat healthy not super healthy as astronauts. So you certainly don't need to be a Superman or Superwoman to go into space. And as you alluded to, we are closer to the space for everyone then you would think. I think in 2022, it was a record year for space flight, we had 180 successful rocket launchers to orbit, the most ever, and 44 more than in 2021. We also have the first all civilian mission in 2021 and that was the Inspiration 4 Mission. We were actually part of that mission in terms of the research and that demonstrated that we can send civilians on orbital missions into space and bring them back safely. And the great thing for research is that with this rapidly expanding capacity to send humans into space, we can learn a lot because we always said that small end problem in space flight that we only have very few astronauts who go up in space. So, the number of subjects we can do our investigations on has been very small as still fewer than 600 unique people who have flown into space. So, with this civilian space flight, we are really opening up, that we can do a lot of research on a lot of people in a short period of time and this will likely be short duration space flight but it's nevertheless going to be very interesting.

Shweta Mishra: Thank you, for sharing your thoughts, Dr. Basner. And the fact that space science is behind several Innovations that we use every day in our lives and we take it for granted. And also, the fact that zero gravity experiments have already further our understanding of so many diseases, right? So, it all compels us to be optimistic about it. So, thank you for that. Dr. Basner, so one of the long-term goals of many of the major space programs is to land people on Mars, but we know that space fliers have to go through the hazards of radiation, weightlessness, being remote and isolated and even when they are in the lower orbit, all of this happens, and it all affects human behavior. So, could you share some interesting observations about how our behavior and cognition gets affected by space environment?

Dr. Mathias Basner: Yeah, absolutely. So, we call space flight or space an isolated, confined and extreme environment with several environmental, operational and psychological stressors that can affect astronaut behavioral health. And some of these stresses are really unique to the spaceflight environment, like microgravity or the lack of gravity, floating around on the ISS, for example. You mentioned the radiation, but also non 24 hours light-dark cycles and some of them we have on earth as well, can be very stressful up there. Astronauts are not getting enough sleep on a chronic basis, for example. And without that gravity vector our vestibular organ doesn't have the input that it has on Earth. And typically, that senses the position of our head in space. So, astronauts need to adapt pretty quickly to that new environment. And in terms of the brain, we call that brain plasticity. So, the brain has to rewire itself and then adapt to the new environment and that takes some time. And actually, often is accompanied by nausea. So actually, the very first few days in space flight can be pretty miserable. Of course, we have medications for that, but that's also one thing for commercial and civilian space flight, we kind of have to make sure that that is a pleasurable thing and because the adaptation can be somewhat of a bad experience. Also, our body fluid shift had worked without that gravity vector, and they actually compress the brain at the top of the skull. You may know that our brain is swimming in a spinal fluid, or CSF. And these spaces have also been shown to increase during spaceflight, and they actually were still increased nine months after astronauts return to Earth. And all of these things can affect cognition. Although, aside from a sensor motor adaptation cognitive impairment in spaceflight is really anecdotal at this point. And there may be a few reasons for that. One is obviously that astronauts are highly trained, highly selected population so they are somewhat resilient, they have a reserve capacity, before we see a cognitive decline, we may also actually be using the wrong tools to measure the cognitive impairment. And I think we will talk later about the cognitive test battery that we developed for NASA here at PENN. And then the other thing I already mentioned, the studies are pretty small, we have that small end problem. So, smaller effects, you typically need larger sample sizes, and that is a tough thing to get in space flight.

Shweta Mishra: Great. All right. Yeah, thank you so much, and you just mentioned the cognitive test battery and I have a question about it. So can you briefly talk about what that is and how it is helpful? And to my limited understanding, it is a set of tests that is administered to astronauts, to test their spatial and visual functions, is that right?

Dr. Mathias Basner: Exactly. So, we started developing this battery at PENN with my colleagues, David Dinges and Ruben Gur here at PENN about ten years ago or so. And we said, we need something that is better than what NASA was using at the time, which is the WinSCAT battery, six tests taken from the A & M battery, very centric on working memory and not really broad, not really looking at all the cognitive domains that we think are relevant for space flight. So, we developed cognition, it's 10 brief cognitive tests, that cover a range of cognitive domains. We designed it specifically for high performing astronauts because we already talked about this, these are highly selected good performers. And whenever you develop a cognitive test battery, you're walking this thin line. If it's too easy, it's boring and you get like ceiling effects. And if it's too hard, it's frustrating. So, rather than taking an off-the-shelf test battery that is geared towards the normal population, we developed one specifically for astronauts. And we're looking at things like memory, sensory motor, speed, attention but also things like emotional recognition, risk decision-making, and mental flexibility. Again, all things that we believe are really relevant for spaceflight. We already know the brain areas that are primarily recruited by each of these tests and that's important because we don't have neuroimaging capability yet in space where you can imagine that it would be really expensive to get an MRI on the space station. So, we can make these links indirectly because we know which brain areas the individual tests are recruiting. We also generated 15 unique versions of the battery. A typical neuropsychological test battery will have two versions. One for diagnosis, one to see whether your treatment is working, but we knew that we need to monitor astronauts constantly on the way to Mars and back. So, we developed these 15 unique versions and we delivered this battery a couple of years ago to NASA and it's now part of NASA standard of measures, which means that every astronaut who signs up, will do it on the space station and every research study on the ground will use this test battery minimally. Obviously, other researchers can use different test batteries, but we want to have, NASA wants to have this battery in everyone. So, we can pull the data across all the different astronauts and research subjects and make comparisons.

Shweta Mishra: Thank you. That's very intriguing, Dr. Basner. And my last question is that I just want to talk to you about the NASA Twin study, that you have been a part of and from my understanding it was a study where we were trying to compare identical twins, one of whom was sent to the ISS and one was genetically matched Ground Control. Can you talk about that interesting study a little bit?

Dr. Mathias Basner: Yeah, absolutely. So, this was a great study. And it was NASA's first step into the world of omics because they had never done this before. It's the problem if you have, you can easily identify astronauts. So, if you're doing things on their genome, it's a dicey thing. So, this was NASA's first step into this realm. And I think I can say for sure that Scott and Mark Kelly, those were the two twins are the two most thoroughly investigated astronauts ever. We were a team of ten principal investigators, and we took blood, urine, stool samples during all phases of the mission. And then we looked at the epigenomic, metabolomics, transcriptomics, proteomics, and molecular changes and we also looked at cardiovascular physiology and a cognitive performance that's what I was doing in this study again with our cognition test battery that we just talked about. And I could quote Mark Watney from the book, The Martian, he said we science the shit out of out of Scott and Mark and I mean that quite literally because we took stool samples and we investigated changes in the gut microbiome. So, what we saw there were numerous changes in the way genes were expressed in telomeres, these are the ends of the chromosomes that are believed to indicate biological age, exposure to stress and environmental influences and in the gut microbiome and many, many more. And we believe that a lot of these changes actually part again of normal adaptation to the new environment. But the question always is at what point does adaptation turn into mal-adaptation, right. Unfortunately, so far only four humans have consecutively spent more than one year in space, so we really don't know what happens to humans when we send them to Mars and NASA's design reference Mission to Mars actually right now is 1000 days. So that's almost three years and we've only investigated again a handful of subjects for more than four years, we simply need more data to conclude whether long-duration spaceflight is really truly safe to humans. Now, most of the effects that we saw in Scott Kelly actually returned to pre-flight levels shortly after his return to Earth, however, some of the effects persisted and these include the effects we measure with our cognition test battery. So, while his performance in flight was actually relatively stable during the 340 days he spent in space, we saw a significant drop in cognitive performance after his return to Earth. And in fact, we could still observe these effect 180 days after his return. This is when we took the last measurements. So, they were by no means transient, and this is actually in line with what Scott reported himself. He said it took a much longer to recover compared to his earlier 180-day mission that he spent on the ISS and obviously this period of a mission can be mission critical. So, for example, , if we have a crew and that crew lands on Mars, that is a mission critical phase. And we really need them to perform at their best during this phase of the mission. And our admittedly, very limited data at this point suggest that that may not be the case, this is why we have cognition in general, because we as humans are really bad at self assessing our performance. So, we need something objectively to assess their performance. And it's so relevant in space flight, because we need astronauts to perform at their best every time, all the time because tiny mistakes can lead to catastrophic failures and loss of the mission and the loss of the equipment. And we by all means want to avoid that.

Shweta Mishra: Absolutely, thank you so much. That's so fascinating to hear about and I wish I had more time for some follow-ups on this one. But I really want to bring Matt and David in this discussion. So, now, I will invite, Matt. Matt, please take it away with your questions.

Matt Gaidica: Sure. Dr. Basner, good to speak with you today. So, about this, this battery that you have. You've done extensive work. One of the questions that I'm always curious about is, where does performance come from. And I don't know if there is a simple answer, or if this is going to be, it comes from a ton of things together, but from your view, and from the research that you've done with this test battery, where would you say performance comes from?

Dr. Mathias Basner: Where performance comes from? So, well it's obviously the brain and it's a functioning brain and we already talked about that training in certainly matters as well. So, this is why we select astronauts, we train them extremely well before they go on their first space flight, so that we can be sure a lot of the things are happening actually already automatically and they don't have to think about it anymore. So that the brains really concentrate on the important things and that's also why I think we talked about this Reserve capacity that many astronauts have and that we only start seeing actual declines in performance, when other people that are not as highly trained or as proficient would already show these deficits much earlier. I don't know whether that answers your questions fully but…

Matt Gaidica: It's a intentionally lose question just to see perhaps where your mind were. So, I like to think about sleep often and in that context of, can we use sleep, because you can either focus on the reaction time or the thing at the critical milliseconds, which a performance occurs or countermeasures, that occur way before that, that might just make you more performant at a particular moment. I'm curious what your thoughts are on not only sleep as a countermeasure or a performance enhancer, what types of sleep might be most important but with the advent of wearables, and whether or not we need to be tracking sleep better using electrophysiology or if the watch is going to be the way that we do it. That's just how it is. And we're just going to deal with the machine learning algorithms that tell us whether it's deep or light sleep?

Dr. Mathias Basner: Yeah. So again, I have studied sleep basically for all of my career and it is super important for cognitive performance during the day but also for overall well-being and health. And for sleep to be beneficial it really needs two components, it needs to be long enough and it needs to be of high quality. So, sleep that is too short or fragmented will actually decrease our performance. And one of the most sensitive tests that actually my colleague, David Dinges, he had been developed is the Psychomotor Vigilance Test is based on simple reaction time, but it's super sensitive to sleep loss. So, if you're not getting enough sleep or your sleep is fragmented, we will see longer reaction times as you mentioned, and we call those relapses of attention or microsleeps and we enter some state that we call wake state instability. So, we have a top-down drive to stay awake that is fighting a bottom-up drive to fall asleep and it's a little bit comparable to drowning, right? So, once we are under water, we can voluntarily stop breathing for a while, but at some point, that drive to breathe in become so massive, because oxygen levels decrease in the blood and CO_2 increases that we inhale regardless and the same is true with sleep. And what happens there is then you fall asleep behind the wheel and those accidents tend to be much more severe than standard car crash but because you're driving into that tree, there's no evasive manoeuvre because you're sleeping and then you see really bad accidents. But I agree that nowadays, you have your Fitbit or your Apple watch telling you how much sleep you got. And not only you slept X hours, but it tells you so much deep sleep, so much rapid eye movement or dream sleep and this is pretty new. There have been several studies actually showing that self-reported estimates of sleep are longer than what we measure with those Smartwatches or fit bit's and that is longer than what we measure with full polysomnography. Polysomnography means we're putting electrodes on the scalp next to the eyes under the chin to measure the brain's activity that actually allows us differentiating, different sleep stages and looking at sleep architecture or very brief awakenings from sleep. So, because of that disconnect between subjective test assessment, again, with the same thing with the with a cognitive testing and the object of assessments, I prefer any objective measure of sleepover subjective. But I also agree that these machine learning algorithms, they're getting better every day. And these watches are not only watching movement, but they used to a number of years ago. Now, they're measuring heart rate, they are measuring blood oxygen concentration, they are measuring temperature. So, they're getting better and better because there is an association between the sleep architecture, on the one hand and all these things that happen in the periphery. However, in the end I'm with Allan Hobson who said at some point sleep is of the brain, by the brain and for the brain. So, we might as well measure the brain activity and not rely on some sort of sensor that we play somewhere else to tell us what's happening in our brains. So, we Really want to look at the brain activity. And the problem in spaceflight, is that so far, we really had a handful of studies that actually did polysomnography with measuring the EEG in spaceflight. And, they have seen some changes in microstructure of the sleep, but we definitely need more measurements. And the good thing there is very much like, with a smart watches, it's getting easier and more or less invasive to measure actually brain activity day by day. So, we're literally almost there when we have a small sensor, and you attach that to your forehead, and you can get a proper polysomnography almost and look at the brain directly. There's actually I think there's a Canadian study right now using the so-called dream headband that it's very easy to put that on. It's pretty comfortable to wear. And astronauts condone that in the evening and off it in the morning. And, I'm hoping that we'll get more data on what astronauts brains are actually doing when they're sleeping in space flight.

Matt Gaidica: Great answer. So, the last thing that I think about when I think about sleep architecture and the potential of perhaps modifying it or building it into an astronaut's lifestyle is the wide range of sleep phenotypes or ways that other animals sleep. So, my question to you is if you were thinking about designing astronauts sleep, through some way whether it's optogenetics or ultrasound, what are the most interesting sleep phenotypes out in the wild, let's say the polyphasic sleep of a rat or the torpor hibernation of squirrels, the minimal sleep time that a migrating bird or elephant gets? What would you pull from and how would you design sleep for an astronaut?

Dr. Mathias Basner: Well, I don't think I have a great answer for you here but because it's simply not the way it works, right? It would be so great if you could just switch between those phenotypes and use the one that that that that suits us best. But that's simply not the way evolution works, right? It was like, it's always like, it's optimizing what that species is. Is it like a night active species, a day active species, etc. So, on Earth we as humans aren't trained to the 24 hours a day with a sleep period of around 7-8 hours and a wake period of 16 to 17 hours and our internal body clock is located in the suprachiasmatic nucleus of the hypothalamus, it is primarily trained by sunlight. And for astronauts, actually, we need to make sure that they stay in train to the 24 hours day or when they are on Mars, it is actually a 24.6 hour day and humans still can be trained 24.6 hours a day, if it gets much longer, or much shorter, we can't really in train to that anymore and we start free running on our own internal body clock. So, in the way we can do that is we can provide them with the right lighting, the right spectral composition, right intensity and right timing to make sure that they stay in train to the 24-hour day. We were part of the so-called Mars 500 study that was a like a simulated Mission to Mars in an isolation facility in Moscow. And there it was not the case; one of the six crew members was actually free running because he couldn't in train to the 24 day with a lighting that was provided and he was actually living at 25 hour day. So, you can imagine that that's not great because every 12 days, it will be the biological night for him when it is the biological day for the rest of the crew. And obviously you want to like schedule Mission Critical Task during the biological day and he will be performing at his worst when everybody else will be performing at his best. And obviously, we also need to provide the crew with sufficient sleep opportunity to make sure that they maintain their cognitive performance. This is a problem on high temp ISS operations where astronauts really tend to not get enough sleep like one every six and a half hours which is not enough to really sustain cognitive performance and alertness in the long run. And it will likely, there'll be a less of a problem on a mission to Mars because that's more, they're more, the question is, how do we keep the crew engaged? How do we provide them with meaningful work? Because it's otherwise, it's just a boring trip, not much is happening, right? They are just like sitting there, you can compare it to a bus ride into work. And there's only so many things you can do, right? I think one thing that would be great, especially talking about that trip to Mars, is if humans could hibernate like Bears, right? And that's, science fiction. We know that all from the science fiction movies like they hop into that thing, and the water comes up and then they just go to sleep and like a year later they are woken up again. Unfortunately, I don't think I don't want to say we will never get there but it will take much more time for us to get there. But TRISH which is the Translational Research Institute For Space Health is funding the first two studies looking into that in humans and actually one idea is actually to cool humans down when they're sleeping. So, they're basically lower the metabolism so that they are using less oxygen, they have to consume less food and that will be so important because it's so expensive to take those consumables to Mars. So, you could design a much smaller space craft etc. if only the humans would like consume that much energy. So, that's a first step into why don't we cool them down a little and see what happens? And perhaps, that's something that actually astronauts can sustain and that would help us get them to Mars safely and with few resources.

Matt Gaidica: I'll pass it off there. Thank you.

Shweta Mishra: Thank you, Matt. Great questions. Great listening to you both. Next up, we have David Stanley on the panel. David, please take over.

David Stanley: Sure. This is very cool. I just got to say that. Since we're talking about night and stimulation of the brain and trying to keep people on that 24-hour clock, let me ask my second question first, because it sort of fits in with that. Here on Earth, we don't sleep well as you and Matt have said, we use excess caffeine, we have lousy sleep habits, we use our phones and tablets in bed that screws up our natural sleep cycles. So, are we dependent then on those external cues for sleep initiation in a circumstance like a trip to Mars? Are there any kind of drug interaction, I shouldn't say interaction, are there any Pharmaceuticals that might help improve healthy, sleep cycles? So, how do you encourage a prescribed support proper sleep for the Astronauts?

David Stanley: That's actually a great question and one that NASA has been fighting with for many many years. Again, we talked about this a little bit earlier, astronauts actually also live a 24-hour day on the International Space Station. But because the ISS is flying really fast around the earth, they have a sunrise and a sunset, every 90 minutes. So, the most important external cue that is synchronizing us humans the 24-hour day on Earth which is sunlight that doesn't really work for them. So, NASA recently exchanged the fluorescent lighting that they had on the ISS with LED lighting and that systematically changes not only the light intensity but also the spectral composition. So very much it's mimicking the sunlight day on Earth, so there's like more brighter blue light in the morning and there is lower intensity red light at the evening and that actually helps the astronauts stay in train to the 24-hour day. But it also helps them actually fall asleep. Because as you mentioned light exposure is actually suppressing melatonin excretion and melatonin helps us fall asleep and stay asleep. So, what we're doing on Earth with having our tablets or watching movies on a 75 inch screen, exposing ourselves to a lot of light, that is actually a wreaking havoc on our circadian rhythms and our sleep. Also, what NASA does, the astronauts actually have a protected sleep time on the ISS from 9:30 p.m. to 6 a.m. right? That's eight and a half hours, which is plenty of time. However, the astronauts are not using that, they are making the same mistakes that we make on Earth. They work too much. They prioritize other things oversleep, and on average, and I mentioned that they only get six to six and a half hours per night of sleep which is not enough to sustain high levels of cognitive performance and awareness. They also consume caffeine during the day like we do on Earth to counteract the sleepiness from not getting enough sleep and the caffeine then affects the quality of their sleep and it's really this vicious cycle, right? Then you feel more sleepy during the day. You consume more caffeine. We actually did a study in twenty four astronauts on the ISS where we could show that across the four quarters of the mission that we looked at, caffeine consumption was creeping up. Actually, the Italians at some point brought an espresso machine up on the ISS and I think it broke after the first like 20 shots of espresso. So, that translates to a translates to a single shot of espresso to like 30,000 dollars or so. So, that's even more expensive than Starbucks. So, in terms of drug interactions there's many drugs that actually interfere with sleep. I mean, obviously, there's many sleep promoting drugs and I think Physicians are prescribing them way too often so many many people actually addicted to those drugs and at some point, they stopped working, but it just gets used to them. But many of them also kind of change sleep architecture. So, they will selectively suppress deep sleep or REM sleep, or dream sleep and that can also have consequences for sleep being not restorative. Sleep aids are actually the number one medication consumed by astronauts in space and the second one is then painkillers, like ibuprofen. But we believe actually that the astronauts primarily take these sleep meds to make sure that they fall asleep fast and get maximum use of their short sleep. However, we know surprisingly little about how these drugs work in space relative to Earth. So, there's something like called pharmacokinetics and pharmacodynamics that is how fast are these drugs taken up by the body, are they distributed within the body? What is the half-life, that is how fast does the body get rid of these drugs? And there is almost no research in this area. I know that because a couple of years ago we proposed such a study and unfortunately was never funded. So, I think that would be really interesting to see how are these drugs metabolised in space relative to Earth. Do we have to give higher concentrations, lower concentrations and then actually we talked about that earlier will be great to have polysomnography of these astronauts and see what does it do with their sleep. I hope that answers.

David Stanley: It does. It sounds like microgravity really plays havoc with our knowledge base in space, doesn't it? All right, I have one more question. So, I remember because I'm old enough to remember this stuff as far back as mercury, they were very concerned about cognitive deficiencies and most of that concern, I later learned was about O2 levels. Kind of like, when climbers are going up above the 8,000-meter peaks, in the Himalayas, they have demonstrable cognitive issues because they've tested them. But the ISS that has a pretty bubble Earth-like atmosphere and there's still issues. So, maybe it's not so much about the O2 levels in your mind, maybe it's more about the rising and falling of CO2 levels throughout the day. And my second part of that question is, do they show overtime kind of a consistent degradation of this cognitive ability? Or does it really kind of track against the rising and falling CO2 levels in the ISS?

Dr. Mathias Basner: That's a great question. It's still one of the big problems that the space agencies are trying to tackle. So, CO2, that's what we exhale, right? We inhale 02, we exhale, CO2 or carbon dioxide and in closed environments, like a spacecraft or the International Space Station, that needs to be removed from the otherwise, it would just increase increase increase, and at some point life would no longer be sustainable. Those of you who are old enough, who know, the Apollo 13 movie or know about the Apollo 13 mission, that was the big problem and they actually had to build a new device when they moved over into the other module to extract the CO2 from that atmosphere. CO2 is a very important respiratory stimulator. So that increases in our blood levels, that tells our body we have to take deeper breaths and more breath. And at high concentrations, it can cause headaches or dizziness or even death. Now, interestingly the cognitive effects in the more relevant exposure range, they far less pronounced. We actually did a controlled laboratory study at Johnson Space Center and we found no relevant effects of CO2 up to concentrations of five thousand parts-per-million which is a equivalent to three point eight millimetre mercury and the CO2 levels are outside, when you go outside outdoors around 400 PPM so it's like and the ISS is actually controlled at 4000 PPM so they try to keep the level below 4000 PPM which is still 10 times higher than what we have outside. However, the problem is that in microgravity the density difference-based airflow is non-existent. And if the astronaut is in poorly ventilated area of the ISS, so-called CO2 pockets build around them, you can think about that they are exhaling CO2 and the CO2 is not going anywhere. It's not being transported anywhere; it just accumulates around their head. And then there's much higher concentrations than what potentially the sensor will measure somewhere on the ISS, and this is very poorly investigated. We know very little about these pockets and you could actually imagine that when they're sleeping in their crew quarters, right? They are in their sleeping bag; they have tethered themselves to the wall that these CO2 pockets build and we just actually completed a research study showing that CO2 in the bedroom is responsible for increased sleep fragmentation. Actually, I want to leave that here. I always like to during these events, I always like to have one practical thing for listeners, if you are in your bedroom, leave the door to the hallway open, don't close it because CO2 will accumulate in the bedroom and will lead to increased sleep fragmentation. Just leave the door open, so there's an exchange with a hallway and the rest of the house and that can really help. There is actually one study on the ISS that found a higher incidence of headaches with increasing CO2 concentrations. But we actually recently showed in a study where we, again it's the same study of the 24 astronauts on the ISS and we connected the performance on that reaction time test that we talked about earlier. We gathered all the information on the on the ISS environment, O2 level, CO2 levels, noise levels, radiation and the astronauts did the test, they also filled out self-report scales. We looked at things like what were they doing on these days? How many people were there on ISS? And we build a predictive model on astronaut performance and actually that model showed that astronaut performance tended to be slightly better at higher levels of CO2. Again, in that relatively low exposure range once you get to very high levels, you do see decrements in cognitive performance and we explaining that by the fact that CO2 is a central nervous system stimulant. It stimulates the respiratory centres and at least in this range of being slightly increased, it could actually be stimulating cognitive performance. So, CO2 is still, it's also actually being implicated in a syndrome where we see changes to the back of the eye in, astronauts. So, there's still some things, we need to find out about CO2 and what it does to astronauts before we can say we end the clear and CO2 is no longer a problem for astronauts.

David Stanley: So real quick, I know I said no follow-ups but I'm sorry, I got to ask this question. So, one molecule of oxygen O2- 32 grams, 1 molecule of CO2- 44 grams and you are in microgravity and so the carbon dioxide has nothing to pull, no gravity but to pull the CO2 away from our face, which of course in our everyday life here on Earth, that’s what happens. Is that correct?

Dr. Mathias Basner: You know what I mean I’m a physician not a physicist, I don’t know Matt, whether you know that or not. Microgravity is working on everything in the ISS, right? And this is why I mentioned earlier that we don’t have these forces that are naturally mixing up things like we do have on Earth, we don’t have the atmosphere. But again, I’m no physicist, I don’t know what’s exactly behind those things.

Matt Gaidica: Okay. All right. I’m done no more questions..

Shweta Mishra: Alright. Thank you, David. Thanks. Great questions. With that I think it’s time to wrap up the talk today. Dr. Basner, thank you such an exciting session and lot of facts and interesting observations you shared with us. Thank you so much. Matt and David, thanks for your very interesting questions and thanks for guiding the panel with them. We will make this talk available on curetalks.com And we also thank the University of Pennsylvania. So, until we meet next time, everybody thank you so much and have a great day.

Thank you.