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Article

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«Somebody's noises are another person's signal:» Art, Neuroscience, and Radio Astronomy

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Abstract

Cogito in Space is an interdisciplinary art project that sends «thoughts» to outer space. The project, led by artist Daniela de Paulis, involves neuroscientists, radio operators and radio astronomers. They use brain waves collected by the neuroscientists in an electroencephalogram (EEG) scan while the person being scanned watches images of the Universe and Earth from space with a virtual reality headset. This data is converted into a stream of sound, and then transmitted by the radio operators to non-targeted points in the sky using the Dwingeloo radio telescope in the Netherlands. This article examines the dialogue that *Cogito* crafted between art, radio astronomy and neuroscience. From a sociology of science perspective, I argue that this dialogue is a poetic reinterpretation of scientific instruments used by neuroscientists and radio astronomers. With poetic, I refer broadly to the process of creating a set of symbols that weave connections between social worlds. These symbols' interpretations remain open-ended, and exist in the interstices between the empirical and the speculative. Thus, while becoming

vehicles of artistic expression, scientific instruments are re-interrogated in a new framework of meaning. I characterise the central ideas of the project, its process of design and its performance based on interviews with the members of the collaboration; participant observation during an academic presentation and a performance at the Dwingeloo radio telescope in November, 2018; and documentary analysis of reports and publications from the project.

Keywords

Art, radio astronomy, neuroscience, sociology of science, instruments, experiment

«Lo que para una persona es ruido, para otra es señal»
Arte, neurociencia y radioastronomía

Resumen

Cogito in Space es un proyecto artístico interdisciplinario que envía «pensamientos» al espacio exterior. En el proyecto, dirigido por la artista Daniela de Paulis, participan neurocientíficos, operadores de radio y radioastrónomos. Utilizan ondas cerebrales recogidas por los neurocientíficos en un electroencefalograma (EEG) mientras la persona escaneada observa imágenes del Universo y la Tierra tomadas desde el espacio con un visor de realidad virtual. Estos datos se convierten en una corriente de sonido y, a continuación, los operadores de radio los transmiten a puntos del cielo no marcados utilizando el radiotelescopio Dwingeloo en los Países Bajos. Este artículo explora el diálogo que Cogito ha creado entre arte, radioastronomía y neurociencia. Desde una perspectiva de la sociología de la ciencia, sostengo que este diálogo es una reinterpretación poética de los instrumentos científicos utilizados por los neurocientíficos y los radioastrónomos. Con poética me refiero principalmente al proceso de crear un conjunto de símbolos que establecen conexiones entre mundos sociales. Las interpretaciones de estos símbolos están abiertas y permanecen en los intersticios entre lo empírico y lo especulativo. Así, mientras se convierten en vehículos de expresión artística, los instrumentos científicos vuelven a interrogarse en un nuevo marco de significado. Caracterizo las ideas centrales del proyecto, su proceso de diseño y su ejecución basándome en entrevistas con los colaboradores del proyecto; observación participante durante una presentación académica y una presentación en el radiotelescopio Dwingeloo en noviembre de 2018; y análisis documental de informes y publicaciones del proyecto.

Palabras clave

Arte, radioastronomía, neurociencia, sociología de la ciencia, instrumentos, experimento

«As you come in, we bring this machine to life.» With those words, artist Daniela de Paulis welcomed our group as we entered the control room of the Dwingeloo radio telescope on November 5th, 2018 for a unique event that aimed to send brain waves into space.

The event marked the first on-site live performance *Cogito in Space*, an interdisciplinary art project and «experiential narrative sending thoughts into outer space as radio waves» (de Paulis 2019, 197). The project, led by the artist, involves neuroscientists, radio operators and radio astronomers and began in 2014 (de Paulis 2014 and 2017). They use brain waves collected by the neuroscientists in an electroencephalogram (EEG) scan while the person being scanned watches images of the Universe and Earth from space with a virtual reality headset. This data is converted into a stream of sound, and then transmitted by the radio operators to non-targeted points in the sky using the radio telescope.

This article examines the dialogue that *Cogito* crafted between art, radio astronomy and neuroscience. From a sociology of science perspective, I argue that this dialogue is a poetic reinterpretation of scientific instruments used by neuroscientists and radio astronomers. With poetic, I refer broadly to the process of creating a set of symbols that weave connections between social worlds. These symbols' interpretations remain open-ended and exist in the interstices between the empirical and the speculative. Thus, when operating as vehicles of artistic expression, scientific instruments become «epistemically problematic again» (Rheinberger 2013, 202).

I will characterise the central ideas of the project, its process of design and its performance based largely on interviews with the protagonists: artist Daniela de Paulis; neuroscientists Robert Oostenfeld, Stephen Whitmarsh and Guillaume Dumas; radio operator Michael Sanders; radio astronomer Roy Smits; and space writer Frank

White.¹ The article is also based on documentary analysis of reports and publications from the project, observations during a presentation by de Paulis at the International Astronautical Congress of 2018, and participation in the November 2018 performance in ASTRON, the Netherlands Institute for Radio Astronomy.

Sociological Research on Art and Science

Art is an increasingly important field of interest for Science and Technology Studies (Salter, Buri and Dumit 2017). In this article, I focus my analysis on four crucial areas for sociological research.

First, the diverse meanings of experimentation. Hans-Jörg Rheinberger's work on experimental systems in science provides a framework to study research practices and knowledge claims in art (2013). As experiments are «essential tools of both science and art» (Aloi 2019, 10), an examination of collaborations needs to be attentive to the varying contents that artists and scientist adjudicate to this practice.

Second, the uses of technologies and instruments. Following Rheinberger again, some things «become silenced as objects of research and live their lives as unquestioned technicalities» (1997, 226). There is a fruitful line of inquiry in examining how artistic practices re-interrogate scientific instruments as unquestioned technicalities. In artistic contexts, instruments retain their capacities to stabilise and measure, but also enter in new contexts more comfortable with complexities and speculations. Additionally, artists create links between instruments that rarely interact with each other. While there is a body of research about art and neuroscience (Supper 2013, Wilkes and Scott 2016, King 2018), there are no precedents at the time of writing this article about an artistic project that brings together neuroscience and radio astronomy.

Third, the perspectival nature of interdisciplinarity. Within and across fields, collaborations are heterogeneous (Fitzgerald and Callard 2015) and involve different visions «stemming from the intersection of participating social worlds» (Star and Griesemer 1989, 396). In consequence, sociological studies need to ask how artists and scientists can dialogue with varying degrees of consensus. Another question worth pursuing is what happens to scientists' practices once they go back to their «day jobs» after working with artists.

Fourth, space as a special theme for collaborations. A matter to interrogate here is if and how scientists and artists working together in space-related themes are more open to dealing with uncertainty and even speculation. In my observations of *Cogito*, and also as a result of my own research with space scientists in other contexts,

I am puzzled by the notion of «virtual cosmonautics.» Even in the most solemnly respected forms of planetary science and astronomy – fields frequently critical of human spaceflight (Van Allen 2014) – I have found a longing to create a physical connection with space like the one for which *Cogito* aims. Just before we climbed the stairs towards the control room in Dwingeloo, we were directed to a plaque with the name of pioneer radio astronomer Grote Reber.² Behind the plaque laid a part of his ashes that were distributed over the big radio observatories in the world. This instantly reminded me of astronomer Clyde Tombaugh's ashes that are on NASA's New Horizons probe that flew by Pluto, the planet he discovered. More than assuming that this longing is an innate drive, a sociological question here is about the institutional settings that provide licences for these quests.

«Exploring the Cosmos with the Mind»

A foundational idea of *Cogito*, in the words of the artist, is that space exploration is not only about the «outer unknown,» but it is about «exploring ourselves in this bigger dimension that is also part of ourselves» (de Paulis 2018a). She references three main influences that converged in the project: what she calls the «Dualistic Problem in Contemporary Cosmology,» Frank White's *The Overview Effect*, and *Solaris* (the novel by Stanislaw Lem and the film by Andrei Tarkovsky).

De Paulis frames the following concern as the «Dualistic Problem»: «As cosmology progresses in further discovery of the universe, the role of the mind in the interpretation of the picture of 'reality' remains largely unknown» (de Paulis 2019, 199). The existential effects that confronting the immense scales of the universe, since humans cannot have direct sensory experience, are an open question. The artist uses that question to make the leap towards virtual space travel: «Radio waves allow us to travel with our thoughts much farther and faster than our senses, through a realm of abstract cosmological spaces» (Ibid).

The Overview Effect, in turn, is a term coined by White in the 1980s. He uses it to characterise «the cognitive shift happening in the mind of the astronauts after witnessing the sight of the Earth from outer space» (de Paulis 2019, 200). White became a consultant and collaborator and de Paulis draws on his notion to explore how «the way we understand Earth is extremely subjective.»

And, finally, regarding *Solaris*, the artist chose it as the first fictional reference of someone transmitting brain activity towards a planet and undergoing a complex psychological experience as a result (de Paulis 2019, 203).

1. Unless otherwise stated, all quotes from the collaborators are taken from the interviews conducted in August, 2019.

2. For a history of the Dwingeloo radio telescope and its role in the development of radio astronomy, see Woerden and Strom, 2007.

Considering this breadth of influences and ideas, the project also needed some demarcations. First, de Paulis took distance from space outreach. As she states it, her interest was not to be an advocate, but to pose questions about the suitability of humans for space travel. Second, although she is involved with the Search for Extraterrestrial Life (SETI) community, she took distance from them in this project. Two stances are at stake in this distancing. One is a critique of the rational and mathematical representation of humans in SETI and a move towards a more complex and contradictory portrayal (de Paulis 2018b). The second stance also entailed a technical decision in the design phase. There is controversy within SETI and METI (Messaging Extraterrestrial Intelligence) about sending messages because this entails potentially *becoming detectable*. Thus, the team decided not to target a particular celestial object in the transmission of brain waves. They agreed to keep *the transmitting antenna still and spread the signal across the sky* (de Paulis 2019, 204). However unlikely, there is a will in *Cogito* about «a potential extraterrestrial intelligence» decoding and reconstructing the signal. And, third, though not denying its speculative nature, the project was eager to differentiate itself from «pseudoscience.» The understanding of this aspect among the collaborators deserves a closer look, as it was essential for their interaction.

Ideas about Scientific Rigour

De Paulis states that, as an artist, she values «scientific accuracy» (2019, 203). The neuroscientists appreciated the fact that *Cogito* was not about what they call «pseudoscience,» and she let them guide her on crucial choices:

They were very clear with me: they wished to avoid any reference to quantum consciousness or any other hot topics, simply because it is very speculative (...) I went along because I wanted the scientific aspect of the project to be very solid, very accurate. And this why I decided to use this lab grade EEG device as opposed to other commercial devices.

From the side of the neuroscientists, all three praised the artist's interest in engaging seriously with their field. They knew each other before as colleagues and collaborators in other art projects, particularly in work combining neurophysiological recordings with music and visuals (Whitmarsh 2017).

As a result of these experiences, Dumas developed a critical view on the use of neuroscience as «a fancy way of adding something to media art.» He does not see himself playing the role of the neuroscientist *that puts brain stuff in their art* without questioning narratives about it. «Of course,» he adds, this is not just a problem of the artists, and many neuroscientists «also play the game because it is fun.» In his words,

To me, there is a level of rigor that has to be reached and Stephen [Whitmarsh] was in line with me on that. Although I think he also plays with the performativity aspect (...) I was motivated to join the

Cogito project with the aim of making it as rigorous as possible, and really pushing what science and technology are able to do right now and trying to reach the limits of that.

Oostenveld, with a background in physics, was also intrigued by the opportunity to work with an instrument outside his field: a radio telescope. He refers to the moment when they started discussing de Paulis' ideas:

There was a serious neuroscientific twist to *Cogito*. Not using EEG as a gadget but sending high quality EEG data into space. I think that was what strongly motivated me to start collaborating with Daniela on this project. There are a lot of people who think EEG is cool, but they basically only think of it as a gadget, whereas I am doing EEG professionally, for my work, as one of the research methodologies.

As for the collaborators in Dwingeloo, they also identified opportunities in the project. Smits, a radio astronomer by training, saw it as a way to expand his outreach work with the radio telescope and as a unique possibility to bring together fields of science:

Science has gone to such great depths now, our knowledge has extended so far, that it is almost impossible to have people understanding the complete overview and having scientists talking about it. Because it is so detailed, so specific, it is even difficult to get all the astronomers of different disciplines together to talk about optical things along radio astronomers.

Radio operator Sanders (PC4M) recalls de Paulis presenting her project in one of the quarterly meetings with the volunteers at CAMRAS (C.A.Muller Radioastronomie Station), the organization in charge of maintaining and operating the radio telescope. «The big work she did was winning them over,» he said. Before *Cogito*, she had already conducted research in the radio telescope, trained as an amateur radio operator (IUOIDY), and worked with the «Moonbounce» technique (de Paulis 2016). According to Sanders, they agreed that the project involved *an interesting new concept*, and, above all, it was not threatening: «You know people are scared that they do not get bad press, that it, that they are not seen in a negative way on the 9 o'clock news (...) They didn't see that as a threat; it was serious art.» When I asked in our interview what they meant by «serious art,» he answered:

99% of the volunteers come from a scientific or technical background. They perceived «this is serious, the people involved have a good reputation.» And they said «Ok, it makes sense, it has a message.» But they did not seem really interested in the art. They find it interesting, but for most it was just «Ok, it's there, and we facilitate it.» During the performance, CAMRAS board members and volunteers signed up to assist the artist for tasks and some attended the performance.

According to these accounts, the institutional support and the collaborators' involvement initially centred on criteria they could recognise and value in their own terms. The spotlight was on the instruments, the credentials of those involved, and the outreach possibilities. While generating curiosity among collaborators, their evaluative gaze was not mainly towards the philosophical framing and the larger hypothetical ideas of the project. However, these distinctions would prove to be more flexible once the collective work began.

What to transmit? In which circumstances? How to capture it? How to transmit it?

Cogito's central ideas are about «thoughts traveling to space» and «exploring the cosmos with the mind.» While many natural and social scientists would agree that the complexity of human thought cannot be reduced to or even contained by brain waves (Vidal and Ortega 2017), the choice of brain waves is precisely the recognition of the unique complexities of the mind as revealed by the engagement with the scales of space. Thoughts and mind are conceived as unprocessed non-verbal «stream of consciousness» as understood by William James: flow of «multitudinous thoughts and feeling which pass through the mind» (de Paulis 2019, 203). This stream, in her view, is what could be captured by the EEG as the unarticulated activity of the brain without need for interpretation.

Operationally, the idea of representing the entire dynamics of the brain (de Paulis 2019, 202) entailed placing 32 electrodes that record electrical signals with the EEG scan on the participants' heads. The artist and the neuroscientists agreed on the need to capture «good quality data,» but also in transmitting that which they could not interpret or fully understand. According to Whitmarsh:

We abandoned this whole extracting idea and found a way to transmit raw signal. Everything. If it's noisy, it's noisy. If you blink your eyes and it creates noise, so be it. Somebody else can take care of that. I think Daniela found a nice line where the project is more about what we don't know (...) And I was very comfortable at that point to not do any pre-processing. Signal and noise.

The VR visuals that participants would watch while being scanned were also crucial to the design. The images were created by filmmaker Sandro Bocci and combine experimental footage – using «special effects with physical processes (non-CGI)» (de Paulis 2018a) – with actual images of Earth. One is the Blue Marble image taken by Apollo astronauts from the Moon, and the rest is footage of Earth from the International Space Station. The 8-minute piece was created around *The Overview Effect*. The images also aim to induce «the sensation of being one with the universe and the source of all spiritual energy,» and «a more introspective journey into the perception of our place in the cosmos» (de Paulis 2019, 202).

The critical technical challenge was the compression of the brain waves into a mono sound that could be converted to a radio signal and transmitted in real time to space. According to Dumas:

We could have done a gimmick sonification and broadcast it in a poetic way. But for me it was about how we can make it both interesting from an aesthetic point of view and relevant from a scientific and technical point of view.

For the neuroscientists, transmitting brain signals to space was entirely new. Their work had to incorporate decisions about the frequency encoding of the EEG, but also the constraints of another scientific instrument outside their world. As recalled by Sanders:

They did not know what a radio telescope could transmit, so I had to disappoint them. They wanted the whole spectrum. I said, well,

this is the part you get, and you have to figure out how to squeeze in the EEG signals. We had big discussions on what to take and what to leave out. It's very technical, but it means that in real life you have to make choices.

Encoding the EEG into a single audio channel was a complex task according to Whitmarsh:

We found this really smart way of doing it. There is amplitude modulation of the EEG and then there is frequency modulation in between to map the 3D coordinates of the electrodes. If you record this signal in some kind of fidelity, you can plot the spectrum and see there are these clear lines that happen exactly every so many hertz and create a slight sort of change. The pattern, which is artificial, intersperses with a clearly natural brain signal. It is a very beautiful sort of combination using two different ways of encoding information by frequency and amplitude (...) I think the question was both about engineering and neuroscientific. An engineer could have done this if you tell them exactly what to do. But we had to figure out what to do, and that was a scientific question.

The result was what they called «Code for Interstellar Transmission.» Details of this development, as well as its antecedents, are described by Whitmarsh in his blog (2017). Throughout this development, the team decided that the project would be open source (Whitmarsh 2019), and constantly had to decide where to aim for precision and where to accept ambiguities.

The entire process involved several weekends working on site in Dwingeloo. Dumas remembers that these weekends were «not only about geeking and playing with computers and brain waves, but also discussing the broad scope of the project.» Along those lines, Whitmarsh states:

We could connect personally because otherwise you are there just to solve a problem, but at the end of the day it happens in this interaction between people who get to know each other.

All members highlight the technical challenges of *Cogito* and how each one contributed, from their expertise, in collectively finding «creative solutions.» Collaborations like this one create a community of practice that renders the boundaries between forms of expertise porous. *Cogito* is an example of the great deal of permeability in terms of modes of thinking and practical engagements among the team. However, porosity also has limits. While the artist could become an amateur radio operator, and Dwingeloo has an institutional space for this form of practice, there is no single antecedent to my knowledge of an artist becoming an «amateur neuroscientist» and participating in the life of a laboratory under that label. And, if we think of expertise as the capacity to tinker inside technical objects of one's own field, only the neuroscientists could sonify the brain waves in cooperation with radio engineers.

Performing *Cogito*

The live performance of November 5th, 2018 comprised an entire day of activities for the 40 attendees, structured in a way that we moved

from the broad ideas of the project towards its actual presentation.

The first half of the day involved a symposium in the ASTRON auditorium moderated by art critic Josephine Bosma, with interventions by Frank White, historian and anthropologist Fred Spier, retired NASA astronaut Nicole Stott, the artist, and the three neuroscientists.

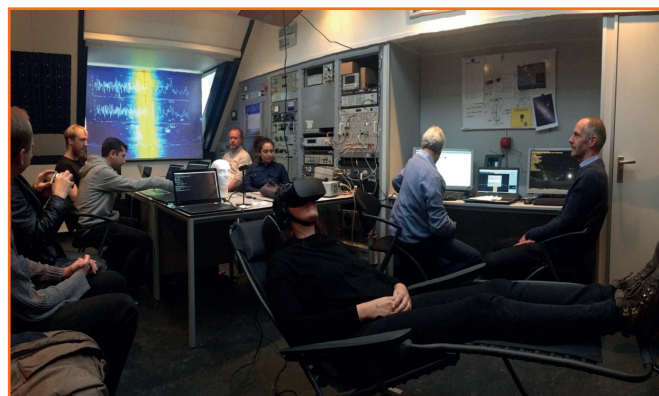
White opened the day with his current perspective on *The Overview Effect*. For him, the act of sending our brain waves to space is part of «becoming citizens of the universe.» In our interview, he mentioned that he initially saw the project as two parts: the brain scans as «the science part,» and the transmission into outer space as «the art part.» His interest focused on the first, considering that he would like to complement his studies of astronauts' testimonies after their spaceflights with measurement of brain activity in response to images of the Earth from outer space. However, since attending the performance, he has become more interested in the second part and with the ideas of «communicating with extraterrestrials and with the universe.»

Spier, proponent of *Big History*, discussed the different cultural impact of the Earthrise photo taken by astronauts in the Apollo 8 mission in the US and Europe. In a conversation with the artist, recorded as part of the documentary being filmed that day, White and Spier agreed in the unique connection that humans feel to the image of Earth and space when it is taken by another human. In this context, White referred to astronauts as «the sensing organs of humanity.»

Afterwards, Stott took part via Skype. She talked about her spaceflight experience saying that the most important implication was that «space brought me back to Earth.» And over the years, as there have been uncrewed missions sending pictures of space, «our favorite pictures are the ones that allow us to see ourselves in there, to make a connection to home.»

In the afternoon there was a walk through the heath around Dwingeloo under the guidance of planetary scientist and filmmaker Maarten Roos. The walk, mixed with discussions of cosmology and *Big History*, «aimed to inspire a sense of belonging to Earth before «virtually» leaving the planet» (de Paulis 2009, 206-207).

As we entered the control room in the radio telescope, the volunteer selected by the artist was sitting on what de Paulis calls a «gravity chair.» As the neuroscientists adjusted the EEG cap and the VR set, the artist described what was to follow. Pointing at a screen, she showed how the radio telescope was directed towards the Betelgeuse star and that, with the Earth's rotation, the signals about to be collected would start «drifting into space.» Once the equipment was in place, she pronounced the identifier code of the radio station and thus began the collection/transmission.



Neuroscientists normally work with scans in controlled experimental settings. They also focus on specific areas of the brain, involve many subjects, and look for averages to make statistical models. In *Cogito*, while relying on the instrument's accurate performance, the aim is the complete opposite: to create an irreproducible instance. Each performance is meant to be unique and the focus lies on the idiosyncrasies of each person's response to the experience and visuals, not in their similarities. In addition, the actual EEG data is not recorded or stored, but simply transmitted and not subject to further analyses.

According to the team, each person has very different brain activity in response to the VR imagery. However, there is a perceived convergence as signals become quite loud and active when the images begin to show the curvature of the Earth. The neuroscientists refuse to make considerations about this perceived pattern since the process precisely does not take place in an experimental setting. The artist describes the transmission in the following words:

The sound produced by brain activity created hypnotic and repetitive patterns that generated a meditative mood inside the cabin: people experiencing the event seemed to draw their attention inwards and join the participant in her intimate journey with the mind in outer space (de Paulis 2019, 207).

Sitting next to the person being scanned, my thoughts were less meditative. I kept wondering about this particular ritual that, enabled by technology, ultimately manifests varieties of spiritual longings like those of space instruments carrying remains of astronomers.

Regarding the sound, it was imbued with decisions and was produced to enable a sensory experience. For the writing of this article I consulted sound engineer María Elisa Ayerbe and musician Andrés Gualdrón who described it as a «metallic machine-like mid frequency drone,» and the loudest moment (apparently when the person begins to see images of Earth) as a «high-pitched strident glitch.» Gualdrón highlighted how «if you vary any of those frequencies, the whole thing would sound entirely different.»

Soon after the performance, Whitmarsh wrote on his blog that he moved his *Cogito* folder to «finished projects.» Although the collaboration has not ended, he says:

It's important to have this moment where we can pat ourselves on our backs, and realize that we did it! In the end, it was quite a smooth operation, especially given the mix of people, places, thoughts, technology and art (Whitmarsh 2018).

After *Cogito*

Starting from the premise that this is not the aim of art, I would like to pose here the question about the effects that collaborating with artists brings to the practice of scientists. A full examination of those effects is beyond the scope of this article, but here I follow the reflections of the collaborators.

A first step in getting a sense on the matter is the characterization of their work environments and concerns about credibility. Along these lines, I asked how they talked about *Cogito* with their colleagues. For Oostenveld:

Initially, I wasn't sure how to present this to my colleagues because it was so unusual. Weird in a way. But I started mentioning it and getting really positive responses. People got interested in different aspects, technical but also artistic. Over the years I have learned to be more open about it, not expecting my colleagues to have a negative attitude towards art, because it is very uncommon for neuroscientists in my setting to discuss their hobbies or what they do outside their regular work.

Dumas categorizes the responses he usually gets from his colleagues when he discusses his collaborations with artists in four groups:

Some just they say «Oh, that's cool.» It resonates with movies like *Contact* and *Arrival* and pop culture. There are other people who think it is a way of exploring new ideas without the constraint of academia, but those people are a minority. There are some people who just say «it is crazy,» and don't understand the point. And there are also people interested in the message we want to convey.

However, considering the breath of the project, there remains a question about which aspect scientists communicate to their colleagues. According to Whitmarsh:

With *Cogito* there is so much going on. When I talk about it, I talk about the radio telescope, that we are able to transform the brain activity into radio waves. They ask «why?» and «where are you targeting?» People always presume that it is for someone else, that it is for extraterrestrials to measure and to decode. That is a really strange conversation. Putting it in terms of poetry when it is more about transmitting our minds and it is more about us traveling through, this how Daniela writes about it. I never got it. Linguistically, I get it. But I really cannot wrap my head around it. The idea of our mind expanding into the universe is beautiful poetry, but I can't communicate that. I cannot communicate the poetry.

For radio astronomer Smits, the project is always about outreach and, in fact, it is «a nice way to distinguish whether an astronomer has a mindset of outreach or not.» And the radio operator said that he usually does not talk about his hobbies with his colleagues.

When I asked the neuroscientists directly if participating in this project had any impact on their research practices, there was a convergence among them that this was a good way to explore new ideas and interdisciplinary connections. Dumas sees his engagement with art as part of a broader philosophical reflection about his work, and as a way to have a more critical approach to his object of study. Whitmarsh mentioned that he will write a grant proposal with scientists working on making music with EEG. He now uses his synthesizer

and music to teach neuroscience. «So, things are starting to become potentially more intermixed.» Oostenveld is currently using VR and biofeedback in a project about training police officers to deal with stressful situations. In his words:

These are things that I had been working on with Daniela. That is when you realize that you are using part of the skills and techniques that we developed in *Cogito* in a scientific setting rather than the other way around. That increased the appreciation of my colleague researchers for this project.

They all mentioned rediscovering a sense of respect for other fields of knowledge. In Oostenveld's words:

I am now much more awed by radio astronomers and by the artists, and how they do they work. Other people are doing their work just as seriously. The seriousness with which all parties approached the project makes me humbler: realizing that neuroscience is not everything and there are lots of disciplines that are as serious and perhaps more serious and more important.

Conclusion

The intangibility of space exploration that *Cogito* evokes entailed technical and scientific expertise for its materialisation; the willingness of all sides to tinker with the poetics and the procedures; and the resourceful ability to bring together worlds, fields of knowledge, infrastructures, and instruments. The project, an experiment in itself, was based on hundreds of «micro experiments» performed throughout the process. Every step had moments of openness and closure regarding jurisdictions of expertise, and moments of plasticity and recalcitrance of the techniques and instruments.

Working with artists gives scientists an institutionally accepted licence to cross certain speculative thresholds. This project summoned all the involved to what they could not confirm nor discard: virtual human space travel, the vastness of the universe as an experience, and the existence of some interpreters of unarticulated human signals «out there.» While exploring these territories unconstrained (in principle) by the standards of their disciplines, the scientists also retained their grounds as experts to participate with the precision and rigor of their knowledge and instruments.

In each step of the process, those instruments were imbued with human decisions which entailed relying on their capabilities as scientific tools, but also stretching them as vehicles of artistic expression. In consequence, and borrowing Rheinberger's words again, this is what experimentation ultimately is about: «the digressions and transgressions of smaller research units below the level of disciplines, in which knowledge has not yet become labelled and classified, and in which new forms of knowledge can take shape at any time» (2011, 315).

As we walked into the radio telescope's control room for the performance, the machine indeed came to life. It was both instrument and place, brain lab and stage, a kind of spaceship and a protective

Earth cradle. And, perhaps more importantly, the machine came to life in the unspoken agreement between the creators and the participants to not settle for a single interpretation of the event. I see this article as part of the social life of the work of art. And just like in art, in the natural and social sciences – as eloquently put by Whitmarsh – «somebody's noises are another person's signal.»

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