ENDNOTE

At the Crossroads of Art and Science

Neuroaesthetics Begins to Come into Its Own

A dancer steps onto the stage, her head encased in a white skullcap embedded with 64 electrodes, each designed to record and transmit signaling information from a different part of the brain (Fig. 1). Off to one side, a trio of graduate students pores over the data appearing on a laptop screen.

It's a performance, yes. But it's also research, probing a question that gets at the very heart of what it means to be human.

The question of creativity and the brain isn't new. But as mobile brain-body imaging (MoBI) technology has advanced, the field has reached a turning point. About 60 neuroscientists, performers, visual artists, engineers and others from around the globe converged on a resort in Cancun, Mexico, in late July 2016 for the 2016 International Conference on Mobile Brain-Body Imaging and the Neuroscience of Art, Innovation and Creativity [1], a first-of-its-kind attempt to forge a common purpose by promoting audience-driven discussions whose content was provided by the participants themselves rather than the traditional agenda aligned with speaker presentations.

Author Contreras-Vidal, conference co-chair and the Hugh Roy and Lillie Cranz Cullen professor of electrical and computer engineering at the University of Houston, was not sure what to expect when he began planning the conference, which invited people from a variety of complementary fields—almost evenly split between the arts and the sciences—to talk about their work, identify challenges and opportunities at the intersection of art and science, and set goals for the field's future. A selected group of 30 university graduate students and postdoctoral fellows attended, as well, covered by a grant from the National Science Foundation.

Fig. 1. *Your Brain on Dance.* Mobile Bain-Body Imaging (MoBI) technology allows simultaneous recording of brain activity and movement gestures of freely performing individuals, as in the case of flamenco dance professor Miriam Phillips in this image. (© Audrey Grayson. Photo: Carlos Landa.)

The students and postdocs, with funding from the National Science Foundation that made their presence possible, provided tangible evidence of growing interest in the field, not just among academics and artists but from the funding agencies who will be needed to support this work in the future.

The conference agenda addressed six broader impact areas:

- How do the creative arts and aesthetic experiences engage the brain and mind and promote innovation?
- How do art-science collaborations employ aesthetics as a means of problem-solving and how do they create meaning through aesthetic problem-solving?
- How can museums and other public venues engage the public and facilitate interdisciplinary discourse and innovation in science, technology, engineering, arts and math (STEAM)?
- How can the creative arts and neuroscience promote understanding of social cognition, improve health and advance education?
- How are mobile brain-body imaging (MoBI) technologies changing science, arts and innovation?
- How can brain-computer interfaces (BCIs) provide direct access to neural activity about intentionality and emotional intelligence in the creative arts?

Among the questions raised early in the conference: How can researchers ensure that artists and their institutions—museums, theater groups, etc.—are full partners in the work, not only serving as research subjects but also helping to design and interpret the studies?

The roadmap ahead will not answer all those questions, but simply agreeing on a full partnership between scientist and artist has been a crucial first step. It is a rare opportunity when a scientific field's advancement largely depends on developing long-term and meaningful relationships and collaborations with artists and arts institutions. One of the challenges moving forward will be how the field stays true to its rigorous scientific roots while remaining open to new ways of thinking within the arts. Similarly, the arts will need to remain open to the possibility that a neuroscientific understanding of the creative process can enrich their practice. Author Robleto, a Houston-based conceptual artist known for his deeply researched artistic exhibits, noted in an in-

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Fig. 2. *The Creative Brain*. Houston-based conceptual artist Dario Robleto, wearing MoBI technology, plays a variation of exquisite corpse, a collaborative, chance-based game made famous by the Surrealists in the 1920s. (© Audrey Grayson. Photo: Carlos Landa.)

terview between panel presentations, "The perceived notion that the sciences and the arts are fundamentally different in their methods and expectations will be challenged, leading to innovative new approaches in both respective fields" [2].

Not every question can be answered by science, Anjan Chatterjee, professor of neurology at the University of Pennsylvania and a member of the Center for Cognitive Neuroscience, noted. For those that can, artists can provide crucial input into the framing. "The nature of the question becomes critical," Chatterjee, a panelist at the conference, said in an interview. "If you can distill certain kinds of questions that are tractable by science, then you have a domain for collaboration" [3].

For Robleto, this collaboration can have many dimensions, from practical to poetic, historical to philosophical. For example, by philosophically challenging how and if creativity can be quantified in a scientific process, and looking to historical precedents of similar debates, practical needs within the laboratory can be addressed. At first glance it may not seem obvious how the arts can help with the "distillation" and "tractability" aspects of experimental neuroscience. But it has been through discussion and the effort of building a common language across fields, and the first-hand experience of participating as a test subject in MoBI studies (Fig. 2), that Robleto realized how the artist's experience of the creative process can be in tension with the scientific assumptions of it. This realization is an important step in the arts' ability to aid in refining scientific working definitions of creativity and aesthetics, which can lead to improved experimental design, and even the post-experiment evaluative process.

Chatterjee has been interested in neuroaesthetics for more than a dozen years, writing in the *Journal of Cognitive Neuroscience* in 2010 that the field was gaining momentum [4]. But six years later, he noted it in some ways is still in its infancy: "I hope it continues to grow. As it becomes better known, there is a kind of validity it takes on, which means funding agencies would be open to this type of research."

For now, Chatterjee said, neuroaesthetics remains impractical as a primary course of study, despite applications for psychology, neuroscience and other, more established fields. "My advice to students is to pick one of those more traditional domains and do your neuroaesthetics work, but frame it within the traditional domain," he said.

Panelist Arne Dietrich, associate professor of psychology and chair of the Department of Social and Behavioural Sciences at American University in Beirut, is also cautious about the field's future, citing the disparate experiences and expectations from both sides: "I think progress will be very, very slow" [5], he said after the panel, which considered **"**How the creative arts and aesthetic experiences engage the brain and mind and promote creativity and innovation." "We are very far from one another. What a scientist can capture, in the arts, is very impoverished in terms of what we consider true artistic expression."

Not that the author of *How Creativity Happens in the Brain* [6] isn't interested in the potential. As Dietrich wrote in 2015 in *Psychonomic Bulletin & Review*, "Creativity has a dubious distinction in the psychological sciences. It is hard to think of a mental phenomenon so central to the human condition for which we have so little understanding as to how the brain does it" [7].

Dietrich, who joined Chatterjee and other conference panelists for the discussion on "How the creative arts and aesthetic experiences engage the brain and mind and promote innovation," later predicted a "slow rapprochement on both sides that will take years and years before tangible things come out that we can collaborate on" [8].

Still, the mood at the conference was optimistic as scientists and artists from around the globe pondered topics ranging from the biology of creativity to demonstrations of mobile brain-body imaging technologies and discussions about how museums and other public venues can use STEAM to engage the public.

Contreras-Vidal's lab develops algorithms based on electrical activity in the brain; much of the lab's research involves helping people with disabilities, including those who seek to regain movement by "walking" in exoskeletons powered by their own thoughts or those who want to use bionic hands. He branched out into neuroaesthetics several years ago, collaborating with the campus's contemporary Blaffer Art Museum to pursue more interdisciplinary work and introducing the concept to a broader audience with a groundbreaking 2014–15 collaboration with Robleto at the Menil Collection

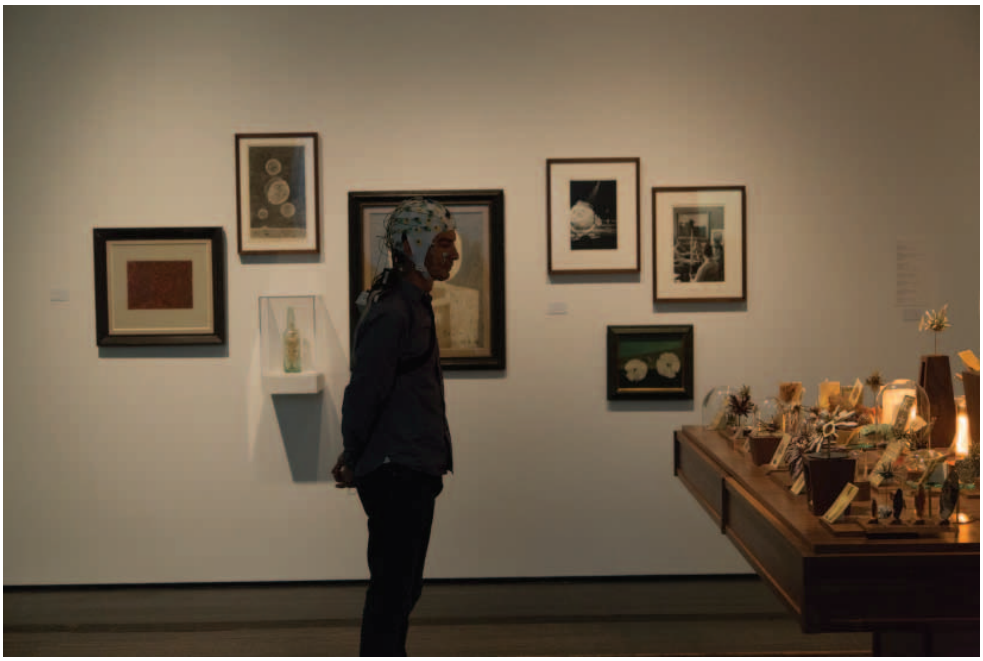

Fig. 3. *Your Brain on Art.* Studying the brain response to art (known as the emerging field of neuroaesthetics) is not new to science; however, prior studies have been restricted to highly controlled experimental settings such as university laboratories that impose severe constraints on action, cognition and emotion. With the advent of MoBI technology, it is now possible to study neuroaesthetics in natural complex settings such as art museums, as shown by the participant in this image. (© Audrey Grayson. Photo: Carlos Landa.)

in Houston: Brain activity data was collected from 431 people using mobile EEG headsets as they viewed Robleto's solo show, "The Boundary of Life Is Quietly Crossed," a sculptural installation that included both visual and aural representations of the heart.

Initial findings from the research, published in the open access journal *Frontiers in Human Neuroscience*, established that useable brain data can be collected outside of a controlled laboratory setting, yielding real-world information about what happens in the brain as people observe artwork [9]. Robleto was among the coauthors on the paper.

"I want to ensure it really is real-world research, that we haven't just moved the lab to another setting," Contreras-Vidal said after the conference [10]. But he acknowledges an essential truth complicating the question: Data collected in one setting, or from one person, won't provide all the answers. "How do you account for the individuality of people as you collect brain activity?" he asked. "The activity won't be uniform, even in similar situations." His research, funded by the National Science Foundation [11], is investigating neural variability during aesthetic and creative experiences in complex natural settings—such as the Blaffer Art Museum and the Menil Collection—of thousands of participants to address the challenge of individual differences in studying creativity (Fig. 3).

Those and other questions created tensions at the conference, although Contreras-Vidal said they were "good" tensions, evidence of a desire to find solutions.

Technology will be part of those solutions—Contreras-Vidal and other researchers say creating MoBI neurodevices that can both measure brain activity "in action and in context" and serve a rehabilitative purpose is a key goal. MoBI technology allows researchers to link large-scale temporal activity maps of neural circuits to quantifiable behavioral paradigms and understand the modulation in neural activity as a function of realistic, complex environments. But beyond the technology, researchers at the conference and beyond grapple with a more human question—how do you work in true collaboration with people from dissimilar fields? There isn't even agreement on what constitutes "data" from which to draw conclusions.

"For me, the artwork that we do is the data, the new datapoints to understand creativity," Monica Lopez-Gonzalez, cofounder and scientific and artistic director of La Petite Noiseuse Productions and a lecturer at Johns Hopkins University, said in an interview at the conference [12]—music created in response to external stimuli, rather than brain activity captured via MoBI. Lopez-Gonzalez is an artist and a trained cognitive neuroscientist. Her cofounder is an artist and a biologist. "We collaborate with ourselves in the sense that we have artistic knowledge and scientific knowledge and take elements of that to create a new hybrid discipline," Lopez-Gonzalez said. "It's not, I'm a scientist, I need an artist to help me out. Or I'm an artist, I have a scientific question."

But Dietrich suggested that "hybrid discipline" may not be so easy to find. "A lot of people are interested in how the arts and sciences can inform each other," he said. "The creative process, of course, occurs in both. That is part of where we can find a common language" [13].

Conferences such as that in Cancun can help. "When you engage with people who have different ideas, different cultures, it broadens your horizons," Dietrich said. "Unless we broaden our horizons, we may miss the forest for the trees" [14].

As one way to broaden horizons, Contreras-Vidal invited three visual artists—Robleto, Jo Fleischhauer and Lily Cox-Richards—to serve as the first Artists-in-Residence in Neuroaesthetics at the Cullen College of Engineering at the University of Houston, an honorary position that gives the artists access to Contreras-Vidal's laboratory and also spurs interaction between the artists and engineering students and faculty members. "Just because I give you a problem and record how many solutions you come up with, that doesn't necessarily tell me anything about how creative you are,"

Contreras-Vidal said. "Creativity is context dependent and highly individual."

The Artists-in-Residence program is a step toward finding the common language conference participants called for, as well as an acknowledgment that science alone cannot find the answers. As Robleto sees it, through the artist-in-residence program, artists can act as "embedded" observers and participants in a field that, while outside their own, has much to do with their concerns. In addition to the expected refinement of definitions and experiment design that the artist can contribute to the scientist, artists can have a unique opportunity to enrich their own understanding of their working processes through the lens of the neural underpinnings of aesthetics and creativity, and can incorporate the technologies of this field into these processes in unexpected ways. Artists have traditionally embraced and often upended the original intended uses of technologies and ideas within science and engineering, and the groundbreaking possibilities within MoBI will likely produce more such instances.

Understanding creativity and innovation is becoming a national priority in the United States. There is a growing wave of funding programs to support interdisciplinary projects related to art and science, engineering, humanities and medicine frontier collaborations, from the National Academies Keck Futures Initiative—a project of the National Academies of Sciences, Engineering and Medicine—to the National Science Foundation, and more recently the Institute of Museum and Library Services, to name a few. Perhaps a new period of unified knowledge—in which art and science become one again—will lead to a new Renaissance in the 21st century.

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