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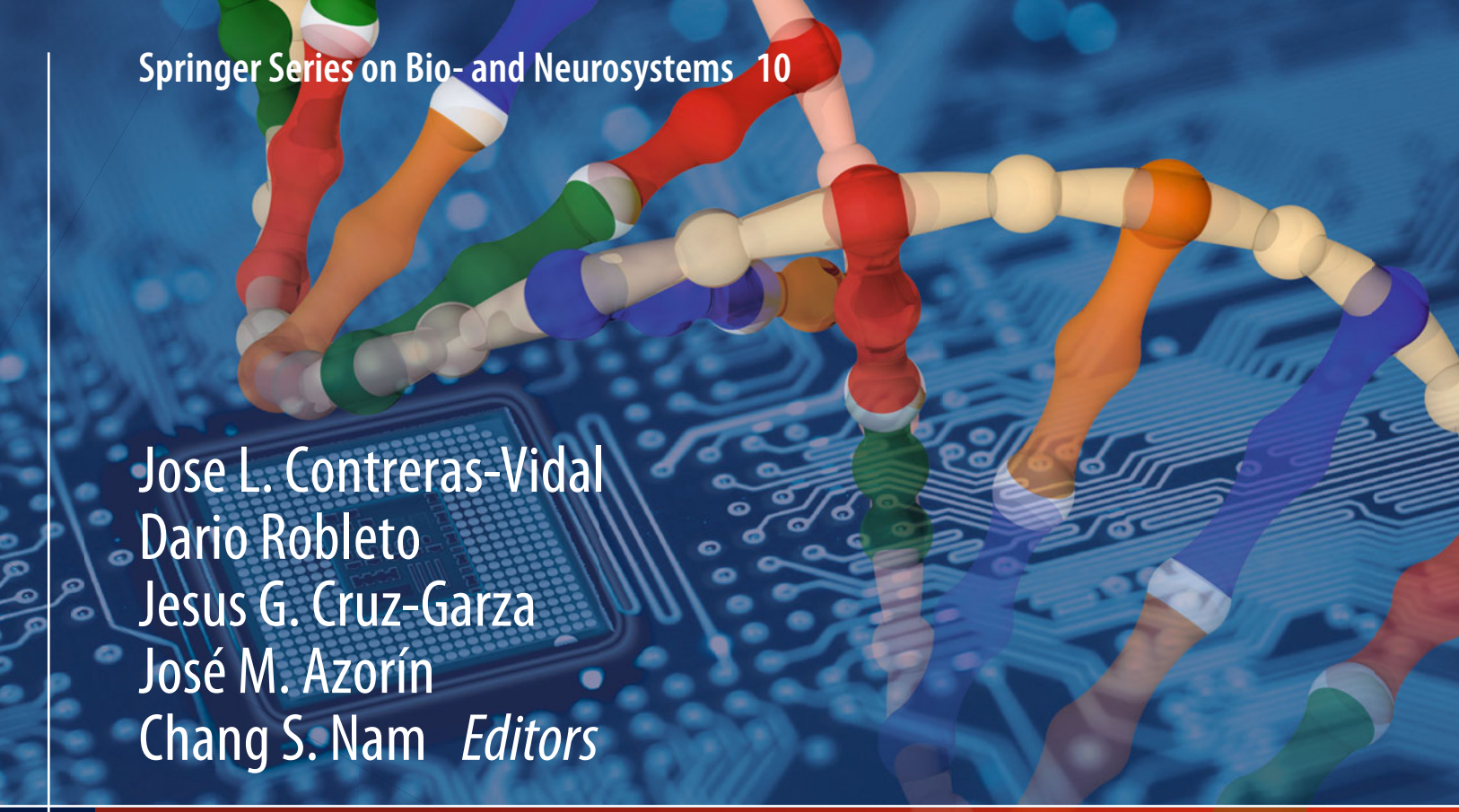

Jose L. Contreras-Vidal
Dario Robleto
Jesus G. Cruz-Garza
José M. Azorín
Chang S. Nam *Editors*

Mobile Brain–Body Imaging and the Neuroscience of Art, Innovation and Creativity

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Series Editor's Foreword

Studying brain activities when people create art or perceive art is a fascinating area that opens new directions in bio- and neuro systems research and related technologies.

Perhaps the citation referenced in this book: "The uncertain nature of art has its advantages. It leads to constant experiment and questioning" (Harold Rosenberg, 1972) best describes the aim and the achievement of the book.

These are questions that research in bio- and neuro systems need to answer in the future, such as:

- How does the brain work differently when people create paintings or perceive pictures?
- How does the brain work when people create or perceive music?
- What is the healing power of art and how it can be utilised for mental health problems?
- Can people create paintings and music through their brain signals only using brain–computer interfaces (BCI)?
- What is the role of neurotechnology in art and the impact of art on new neurotechnology?
- How can we understand the dynamic interaction between biological molecules, like antibodies, brain activities and creativity?
- How people synchronise their brain activities when communicate between each other and what is the advantage and the disadvantage of that?

These and many other questions are addressed in this book from different perspectives, such as personal experience, scientific experiments, visual presentation, commentaries, open questions, speculations for the future and that makes the book an interesting reading setting new challenges to science, art, technology and the society.

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Foreword

The limits of my language are the limits of my world.
—Ludwig Wittgenstein

Based on the lives we live, we all speak a multitude of languages. The variances in our professional languages can seem as simple as differences in accents or as complicated as learning a new alphabet.

Exploring the intersections between art and neuroscience can seem to require fluency in two dramatically different languages. Although the languages may differ, deep similarities exist between the disciplines. Both incorporate experimentation, investigation of humanity's biggest questions, and perpetual work to understand more fully our world and the lives of those who inhabit it. Recognizing these similarities, despite any linguistic differences, those who learn the language of the other and work in the shared space between the arts and neuroscience can more fully examine and celebrate such elusive topics as creativity, understanding, memory, and motion.

Working with art museum visitors, I frequently witness the wonders of artistic experience. Through our teen artist program, I observe students visually rendering and emotionally processing their lives through the medium of paint, sculpture, or photography. During a bilingual toddler story time, I watched children form language and create meaning through the shapes and colors depicted in the art around them. Leading a tour for visitors with dementia, I witnessed participants who respond to the artwork with dramatically increased verbal engagement and who are able to form and access memories in ways not possible outside of the museum.

Through these observations and countless others, I am a researcher. I research the ability of the arts to inform and reflect the lives of visitors. Yet, my research focuses on observation and lacks the element of explanation. As described by Juliet King, Associate Professor in the Art Therapy Department at The George Washington University and Adjunct Associate Professor in the Department of Neurology at the Indiana University School of Medicine, building a more complete understanding will require the observations of educators, artists, and art therapists *alongside* the research and observations of colleagues in the neurosciences.[1] This shared work will determine how it is that art plays a significant role in making meaning and in recovering memory. In the space between art and science, current and future practitioners and researchers will determine how artistic practices influence and are influenced by neurology.

A frequent obstacle to collaborations between art and neuroscience has been the too often disconnected spaces in which the disciplines work. As institutions are striving to break down isolated work in academics, university museums can provide one public space for scientific experimentation. In their 2018 talk "Museum as Laboratory", artist Dario Robleto and Professor Jose L. Contreras-Vidal, Ph.D., Director of the Noninvasive Brain–Machine Interface

[1]King, Juliet. "A Revitalized Synthesis: Art Therapy, Neuroscience and Mobile Brain–Body Imaging." 49th Annual Conference, American Art Therapy Association, November 1, 2018, Miami, FL. Conference Presentation.

Systems Lab at the University of Houston, spoke about their collaborative experiment at The Menil Collection in Houston in 2016 and the benefits to using Mobile Brain–Body Imaging technology to study artistic experiences in public spaces.[2] For scientists, working in a museum, rather than a traditional laboratory setting, provides real-life experiences to monitor and evaluate. For the museum, public experiments can expand the educational role of the institution and create opportunities for visitors to learn about current brain imaging technologies, as well as consider—and possibly observe—this intersection between their art experience and their neurology. At a university art museum, these benefits multiply as students at all levels of learning—undergraduate through post-doctoral—engage in the process.

The realities of this combined work are as complicated as they are critical. Recognizing the logistical barriers to interdisciplinary work and the immense rewards that collaborative projects can offer, the *2016* and *2017 International Conferences on Mobile Brain–Body Imaging and the Neuroscience of Art, Innovation, and Creativity* created opportunities for experts in both fields to convene. Thought-leaders and practitioners exploring connections between art, neuroscience, engineering, media, industry, education, and medicine assembled to share research and knowledge, as well as to identify challenges and opportunities of their work. Most importantly, the community that gathered developed shared plans for future experimentation and exploration that supports cooperative efforts between disciplines.

This book represents dedicated work and the enthusiastic spirit of these convenings. Like the conferences, this text celebrates a multitude of backgrounds and expertise, giving equal significance to the scientific theory and evidence represented, as well as holding critical space for the artistic experience and representation. The impact of this work on educational settings is spotlighted and is one of several case studies on how this work directly impacts individuals and communities.

Most significantly, this wide-ranging and deeply collaborative text encourages all readers to learn from these critical partnerships, to speak multiple languages, and to join the conversation.

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[2]Robleto, Dario and Jose L. Contreras-Vidal. “Museum as Laboratory”. Nasher Museum of Art at Duke University, January 31, 2018, Durham, NC. Public Lecture.

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Jose L. Contreras-Vidal
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Part V How Disruptive Neurotechnologies Are Changing Science, Arts, and Innovation

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Abbreviations

a2RU	Alliance for the Arts in Research Universities
ADHD	Attention-deficit/hyperactivity disorder
aFILM	Anchored Filling-In Lightness Model
AHLTA	Armed Forces Health Longitudinal Technology Application
AI	Artificial Intelligence
AIR	Artist-in-residence
AoW	Art of War
AR	Augmented Reality
ART	Adaptive Resonance Theory
ATR-N	Art Therapy Relational Neuroscience
AUT	Alternative Uses Test
B2AI	Brain to Art interfaces
BCI	Brain–Computer Interface
BHLAW	Blurred highest luminance as white
BOA conference	Brain on Art conference, the short name used for the 2016 and 2017 International Conferences on Mobile Brain–Body Imaging and the Neuroscience of Art, Innovation and Creativity held in Cancun (July 24–27, 2016) and Valencia (September 10–13, 2017)
BRAIN Initiative	Brain Research through Advancing Innovative Neurotechnologies Initiative
CAD	Computer-aided design
CARE	Choices, Agenda, Resources, and Emotions
CCPT	Child Centered Play Therapy
CREATE	Creative Embodiment, Relational Resonating, Expressive Communicating, Adaptive Responding, Transformative Integrating, and Empathizing and Compassion
DARPA	Defense Advanced Research Projects Agency, USA
DASER	D.C. Art Science Evening Rendezvous
DMI	Digital musical instrument
DMN	Default Mode Network
DoD	Department of Defense, USA
DSP	Digital signal processes
EEG	Electroencephalography/Electroencephalogram
EMG	Electromyography
ERP	Event-Related Potential
ERSP	Event-related spectral perturbations
ESSA	Elementary and Secondary Education Act, the Every Student Succeeds Act
ETC	Expressive therapies continuum
FAÇADE	Form-And-Color-And-DEpth
FFT	Fast Fourier Transform

fMRI	Functional magnetic resonance imaging
FTD	Frontotemporal dementia
GAD-7	Generalized Anxiety Disorder 7
HCI	Human-computer interaction
HD	High definition
IEEE Brain Initiative	Institute for Electrical and Electronics Engineers Brain Initiative
IOP	Intensive Outpatient Program
IRB	Institutional Review Board
ISO	Intrepid Spirit One
IT	Inferotemporal cortex
IUCRC BRAIN	NSF Industry-University Cooperative Research Center for Building Reliable Advances and Innovation in Neurotechnology
LASER	Leonardo Art Science Evening Rendezvous
LGN	Lateral geniculate nucleus
LH	Left hemisphere
MEG	Magnetoencephalography
MoBI	Mobile Brain–Body Imaging, also referred to as Mobile Brain/Body Imaging
mPFC	Medial prefrontal cortex
MRI	Magnetic resonance imaging
mTBI	Mild Traumatic brain injury
NAFKI	National Academies Keck Future Initiative
NEA	National Endowment for the Arts, USA
NICoE	National Intrepid Center of Excellence
NOAH	National Organization for Arts in Health, USA
NSF	National Science Foundation, USA
OEF	Operation Enduring Freedom
OFC	Orbitofrontal cortex
OIF	Operation Iraqi Freedom
PARIESA	Practice and Research in Enactive Sonic Art
PCA	Posterior Cortical Atrophy
PCL-M/C	PTSD checklist-military and civilian
PDC	Partial Directed Coherence
PET	Positron emission tomography
PFC	Prefrontal cortex
PH	Psychological health
PHQ-9	Patient Health Questionnaire-9
PPA	Primary progressive aphasia
PPC	Posterior parietal cortex
PPI	Patient public involvement
PSD	Power spectral density
PTSD	Post traumatic stress disorder
qEEG	Quantitative electroencephalography
REM	Rapid eye movement
RGB	Red, green, blue
RH	Right hemisphere
SAR	Synthetic aperture radar
SM	Service Member
STEAM	Science, technology, engineering, art, and mathematics
STEAMM	Science, technology, engineering, arts, math, and medicine
STEM	Sciente, technology, engineering, and mathematics
SVM	Support vector machine

TBI	Traumatic brain injury
TTCT	Torrance Test of Creative Thinking
UDP	User Datagram Protocol
VA	Veteran Affairs
VR	Virtual Reality
WPA	Works Progress Administration

Introduction: The Confluence of Art, Neuroscience, and Creativity Through Mobile Brain–Body Imaging

Jose L. Contreras-Vidal, Jesus G. Cruz-Garza, Dario Robleto, José M. Azorín, and Chang S. Nam

Creativity and the experience of aesthetic reflection are two of the most profound mysteries of the human brain, both enabling us to continually innovate through problem-solving and express complex emotions that help define what it means to be human. The burgeoning field of neuroaesthetics offers a unique possibility to work in a genuinely interdisciplinary way, revealing a multilayered understanding of art and the brain. This book emerges from the *International Conferences on Mobile Brain–Body Imaging (MoBI) and the Neuroscience of Art, Innovation and Creativity*, the so-called Brain on Art conferences, held in Cancun, Mexico (2016) and Valencia, Spain (2017), respectively, to explore these topics. This book represents an intertwining of disciplines that investigate not only their products—art and data—but also something more substantive and unique, as we argue for the vital importance of lasting collaboration and dialogue between our fields.

Recognizing the increasingly cross-disciplinary nature of many scientific, artistic, educational, and medical challenges of our time, the Brain on Art conferences aimed to identify the opportunities for collaboration between these respective fields. Such partnerships promote innovation and novel problem-solving by challenging disciplines to think outside their area. Many topics were explored by both scientists and artists such as an overview of the field of neuroaesthetics; the advancements of MoBI technology in studying creativity in action and in context; neuroeducation; ongoing efforts to understand the brain through reverse engineering; engineering personalized creative art therapies; and a call for the value in artists and scientists working to engage the public's interest and involvement in cutting edge neuroscience. Additionally, various interactive programs at the nexus of the arts and sciences were designed to demonstrate the possibilities of these cross-disciplinary collaborations. For example, in an ongoing collaboration that incorporates the tradition of artist-designed games and "actions", an experimental design model for brain imaging and acquisition was performed. With the conference's emphasis on building the infrastructure to sustain long term, outside the box collaboration, a Doctoral/Postdoctoral Consortium Program was run in parallel with the single-track conference. This allowed trainees from the arts, science, and engineering fields to explore and develop their research interests in a workshop guided by a multidisciplinary panel of distinguished researchers, artists, and innovators. Moreover, the consortium provided the following:

- A curated setting where students and trainees could present their work in poster format and meet other students while engaging with established researchers from around the world.
- A rare opportunity for students to receive guidance and feedback on their current research from experts outside their field, promoting networking and career development.
- An opportunity to contribute to the conference goals through active participation and interaction with other students and researchers.
- Research collaboration and exploration at the nexus of the arts and science through the Brain–Computer Interface (BCI) Designers Hackathon.

The long-term goal of the Brain on Art conference series is to develop a Strategic Plan or Roadmap (refer to Part VII of this book for details) that (1) provides global leadership on collaboration between the creative arts, science, engineering, medicine and the humanities, (2) advances health

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