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One hundred years of performing live brains, 1920–2020

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6. Synchronizing Two Dynamic Brains: Art–Science Experiments and Neuroscience in the Wild, 2013-2019

On a November night in 2013, a friend (subject P.) and I (F.), participated in an experiment. In Amsterdam’s EYE Filmmuseum, our heads were fitted with EEG-measuring caps, and we stepped into a darkened screening room. Positioned in the middle of the space was an illuminated dome with two chairs facing each other inside. We were invited to take a seat. P. and I had been told that each side of the dome would light up with a real-time projection of our faces (she would see me, I would see her), but only if the EEG-measuring software had detected “brainwave synchronization.” Our task was to play and experiment with our mutual interaction to see if we could turn the visualizations on or off. Stepping into the dome, I could not remember the exact assignment: something about “being on the same wavelength” or “feeling in sync.” I felt a bit giddy. Facing P., I tried not to move too much, as we had been told this could interfere with the EEG recording. Sometimes I would see a flash of her projected face on the half dome in front of me, accompanied by loud electronic buzzes. We tried closing our eyes only to realize we would not be able to see the visual feedback. We tried thinking of the same things: blue, the sea. We carefully held hands. The visualization did not seem to correspond to anything we tried. Aware that other friends were in attendance, I felt joyfully competitive even though I was “failing,” and I anticipated telling them about the experience. I felt slightly awkward. I wondered if she felt the same. Her face told me she did, delightedly uncomfortable, but the visualization did not appear.

Titled *Mutual Wave Machine*, this “crowd-sourcing neuroscience experiment” was conducted by cognitive neuroscientist Suzanne Dikker and digital-media artist Matthias Oostrik as part of the 2013 Museumnacht in Amsterdam.¹ [figure 6.1] Its main question was: “What can the brain tell us about what it means to be ‘on the same wave length’ with another person?,” hypothesizing that “your brainwaves are more in sync with those of another person when you are feeling connected to that person.”² By 2019, Dikker and Oostrik have performed the experiment at fourteen locations worldwide (including the Silicon Valley Contemporary Arts Festival, Athens’ Benaki museum, and Lowlands Festival in the Netherlands), and over five thousand people have participated. Each pair of subjects, after sitting in the dome together, is asked to fill out a questionnaire recording their

¹ Suzanne Dikker, *Mutual Wave Machine*, 2013.

² Suzanne Dikker, Karina Kirnos, and Siena Oristaglio, “Neuroscience Exclusives. Digital Mai Exclusives Package,” (Marina Abramovic Institute, 2014). n.p.

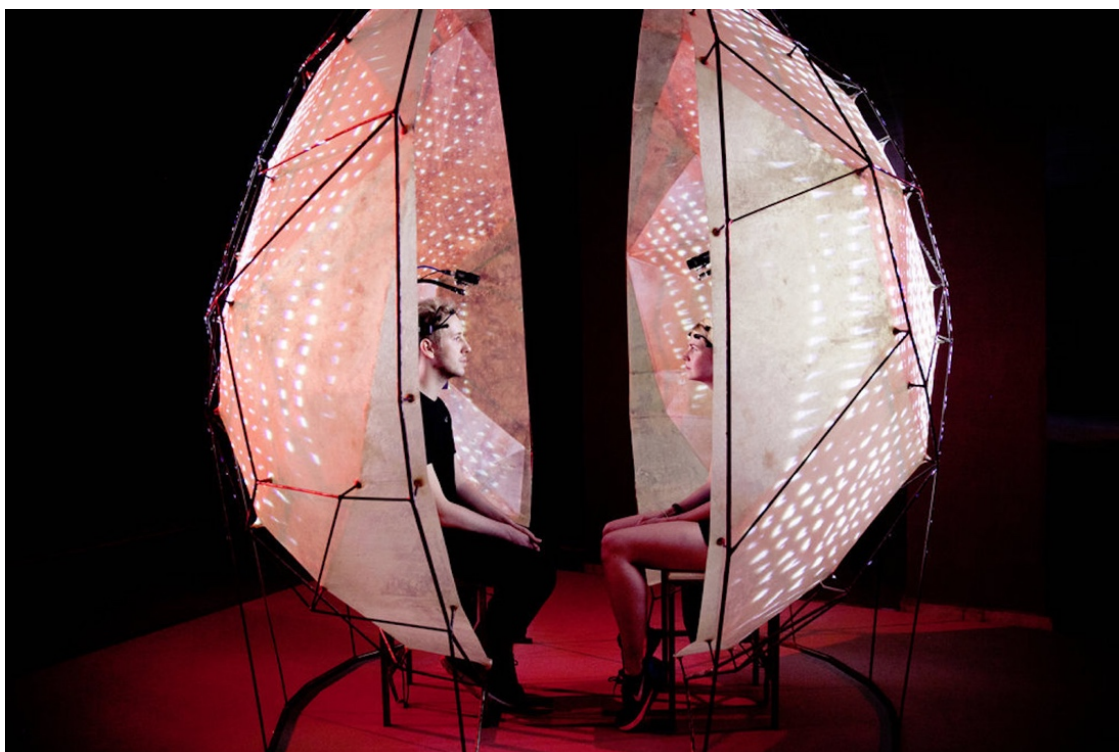


Figure 6.1 Suzanne Dikker and Matthias Oostrik, *Mutual Wave Machine*, 2014 (photograph).

age, gender, and handedness, and asking about their relationship (how long they know each other, what their relation is). Additionally, each participant is asked to evaluate whether they felt a strong connection with their “brainwave partner” and to describe what strategies of connecting supposedly worked. Cross-correlating the results of hundreds of measured pairs, the results of the study were published on a special website dedicated to the project in 2019. A preliminary scientific article based on the measured data was also released online that year.³ Dikker (based at New York University and Utrecht University) and other researchers have also implemented the technical and experimental knowhow gained during this experiment in other research, such as in a study of the behavior of multiple EEG-wearing high-school students in a classroom setting, published in *Current Biology* (2017) and the *Journal of Cognitive Neuroscience* (2018).⁴

Mutual Wave Machine connects very different temporalities: the micro-temporality of moment-to-moment changes in the brain and the lifetime duration of personal relationships. In

³ Dikker, *Mutual Wave Machine*. #results. Pawel J. Matusz et al., “Are We Ready for Real-World Neuroscience?,” *Journal of Cognitive Neuroscience* 31, no. 3 (2019).

⁴ Suzanne Dikker et al., “Brain-to-Brain Synchrony Tracks Real-World Dynamic Group Interactions in the Classroom,” *Current Biology* 27, no. 9 (2017); Dana Bevilacqua et al., “Brain-to-Brain Synchrony and Learning Outcomes Vary by Student–Teacher Dynamics: Evidence from a Real-World Classroom Electroencephalography Study,” *Journal of Cognitive Neuroscience* 31, no. 3 (2018).

order to examine the neural basis of social interaction, the researchers hypothesize about the EEG-activity patterns of two subjects engaged in mutual interaction, as this activity potentially correlates with feelings of “being in sync,” as well as with the qualities and quantities of familiarity: knowing each other as a friend, lover, or enemy, for example; or knowing each other for over ten years, for less than an hour, or not knowing each other at all. With its audacious proposal of connecting the neural and the social, *Mutual Wave Machine* is an example of research in the field of social neuroscience, which emerged around 2000. Particularly, the experiment is part of a recent subfield of social neuroscience that uses new computational approaches to measure the nerve activity of two or more interacting people at the same time, what is called “two-body neuroscience.” As Dikker and colleagues explain in their 2019 paper about *Mutual Wave Machine*, the novelty and promise of this field is that it allows “measuring communication ‘live.’”⁵

In this context, as the authors explain, measuring “live” means an approach that allows for a more comprehensive understanding of the neural basis of social interaction by examining realistic human interactions that cannot be captured in conventional laboratory experiments. *Mutual Wave Machine* introduces this new form of liveness as part of an emerging – and, as I will explain, also contested – field that examines the phenomenon of “brain-to-brain synchronization.” Focusing on the contemporary field of brain-to-brain synchronization, this chapter shows how new ways of performing knowledges and novel forms of liveness result in new and also tendentious forms of “live brains” today.

Mutual Wave Machine is but one example of the many and varying new manifestations of the active brain outside the scientific laboratory since the shift from the “Decade of the Brain” in the 1990s to what some researchers have called the new, twenty-first “Century of the Brain.”⁶ In the first decade of this new century, perhaps the most circulated brain image was the colorful *Brainbow* (first published in 2007): a microscopic cross-section of a mouse brain showing individual neurons lighting up in ninety different fluorescent shades.⁷ [Figure 6.2] Scientists and science writers have praised the “technicolor” aesthetics of *Brainbow*, which allowed it to win a number of imaging competitions.⁸ The emergence, in the past two decades, of such scientific imaging competitions and image exhibition platforms - in which scientists and artists often share the stage - demonstrates

⁵ Pawel J. Matusz et al., “Are We Ready for Real-World Neuroscience?,” *ibid.* (2019): 3.

⁶ Rafael Yuste and George M. Church, “The New Century of the Brain,” *Scientific American* 310, no. 3 (2014).

⁷ Flora Lysen, “Technokittens and Brainbow Mice. Negotiating New Neural Imaginaries,” in *Speculations on Anonymous Materials; Nature after Nature; Inhuman: [Fridericianum, Kassel, September 29, 2013 - June 14, 2015]*, ed. Susanne Pfeffer (London; Kassel: Koenig Books, 2018).

⁸ Alison Abbott, “Colours Light up Brain Structure,” *Nature News*, 31 October 2007.

the continuing importance of image-oriented research and visual mediations in twenty-first century neuroscience.⁹

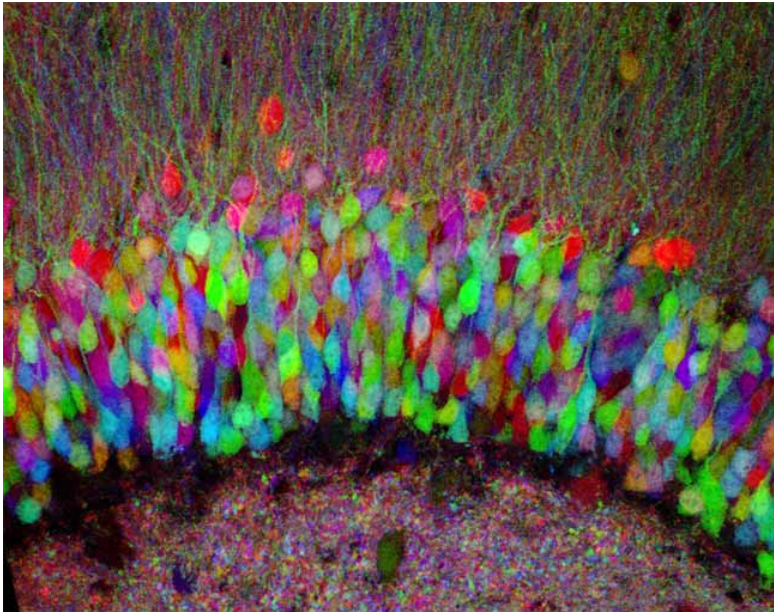


Figure 6.2 Jean Livet, et. al., *Brainbow* image of dentate gyrus, 2007

Yet, from the 1990s until today, the public circulation and performance of the active brain also continues to change shape in relation to new media platforms and new forms of mediation that impact the dynamic of conducting and performing brain research. A striking example, in this respect, is the 2011 publication of research into human perception by Jack Gallant and co-researchers at the University of Berkeley, California, who asked subjects to watch Hollywood movie trailers in an fMRI-scanner to subsequently predict what subjects had viewed based on their measured brain activity, creating blurry, dream-like image predictions based on a database of randomly selected *YouTube* clips.¹⁰ Whether this research heralds the possibility of a type of “mind reading” or “brain decoding” - opening up what Gallant calls a “window into the movies in our minds” – researchers are currently debating.¹¹ Notwithstanding, the operationalization and circulation of Gallant’s research certainly reveals new and mindboggling metaphorical circuits of

⁹ Andrea Gawrylewki, Jennifer Leman, and Liz Tormes, “The Brain in Images: Top Entries in the Art of Neuroscience,” *Scientific American* (2019).

¹⁰ Shinji Nishimoto et al., “Reconstructing Visual Experiences from Brain Activity Evoked by Natural Movies,” *Current Biology* 21, no. 19 (2011).

¹¹ Yasmin Anwar, “Scientists Use Brain Imaging to Reveal the Movies in Our Mind,” *Berkeley News*, 22 September 2011. “Brain Reading,” in *Neuroforensics: Exploring the Legal Implications of Emerging Neurotechnologies: Proceedings of a Workshop*, ed. Lisa Bain, et al. (Washington, D.C.: The National Academies Press, 2018). For a skeptical view of mind reading research, including Gallant’s image prediction experiment, see Nikolas Rose, “Reading the Human Brain How the Mind Became Legible,” *Body & Society* 22, no. 2 (2016).

contemporary brainmedia by which a *YouTube*-powered experiment of an envisioned *YouTube*-like mind actually circulates on *YouTube*.¹² [Figure 6.3]

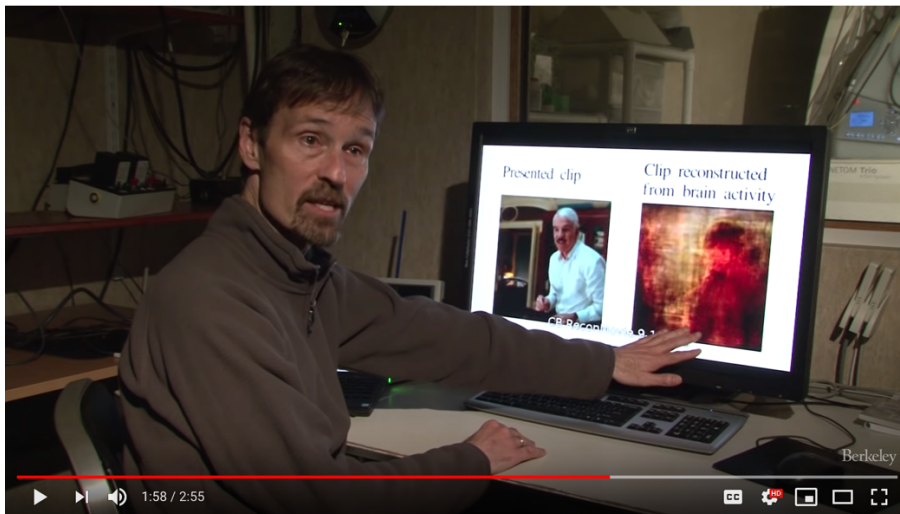


Figure 6.3 Jack Gallant explaining prediction of visual perception in movie viewing fMRI-experiment, c. 2011 (still of a *YouTube* video)

In this chapter, *Mutual Wave Machine* functions as an evocative crossroads for my examination of new assemblages of brainmedia in contemporary neuroscience. As a public art–science installation the work aptly exemplifies new ways of performing knowledges in neuroscience as it developed since the 2000s, representing the new relations between artists and scientists, new ways of conducting experiments (“crowd-sourcing neuroscience,” for example), new platforms and forms to present science, and new spheres for science reporting.

First I explain why and how an analysis of contemporary neuroscience through the lens of art–science practice is fruitful and why such an examination should steer away from a simplistic critique of neuro-hype. Secondly, I situate *Mutual Wave Machine* in the emerging field of brain-to-brain synchronization research and as part of a broader discourse on what researchers call “real-world” neuroscience, “real-life” neuroscience, or “neuroscience in the wild”: a recent movement towards a more ecologically valid and “naturalistic” experimental practice. As a crowdsourcing neuroscience experiment that allows for measuring many brains, *Mutual Wave Machine* is an example of how this vision of real-world social neuroscience pairs with the promise of exploratory big-data science. I argue that public practices of crowdsourcing neuroscience allow scientists to link crowdsourced (big-data) neuroscience and “citizen science.” This prompts questions about what

¹² UC Berkeley, “Vision Reconstruction.” Laura Matthews, “Scientists Turn Brain Images into Youtube Videos,” *International Business Times*, 24 November 2011.

type of citizens – citizens with brain-data – are interpellated by such artistic, “live,” crowdsourced performances. In the third part, I analyze the relation between *Mutual Wave Machine* as an art–science experiment and as a scientific experiment. I observe a disjunction between the multi-layered media experiences this “real-world” neuroscience experiment affords and the way mediation is ultimately treated in the scientific analysis of brain-to-brain experiments. In the fourth and final part, I turn to the notion of “synchronization” that is prevalent and often even central in two-body neuroscience experiments. By offering a media-historical analysis of the concept of synchronization in social-interaction research, I explain how issues of harmonization, affect, and operability are sedimented in the conceptualization and practice of current social-neuroscience research. My plea here is for a new sensitivity to media histories when conceptualizing live brains in reflections on current neuroscience.

Investigating new forms of neuroscientific life

Mutual Wave Machine is but one recent example of a large number of EEG-based artworks that have started to populate galleries, tech conferences, and a variety of art-meets-science events in the past decade.¹³ Because consumer-grade EEG-headsets (with lyrical names such as Neurosky, Emotiv, and Muse) have become more affordable and widely distributed, mindfulness practitioners, gamers, and artists have started to use them to experiment with sonifications and visualizations of the EEG-data.¹⁴ Consider, for example, Stelarc’s performance *Spectacle of Mind* (2010), in which the performance artist wore an EEG headset to create a “brainwave-generated” art piece, a surrealist-looking animation of his own face projected on a huge screen.¹⁵ Or Lisa Park’s much-publicized installation *Ennoia* (2013), in which EEG measurements cause buzzing noises and ripples on the surfaces of a number of water basins, depending on the level of the performer’s concentration.¹⁶ Or the installation *E.E.G. KISS* (2014-ongoing) by artists Hermen Maat and Karen Lancel, which stages two kissing subjects while their measured EEG-activity is made audible and perceptible.¹⁷ Quite a number of these works conjure meditative atmospheres and intricate chains of technical

¹³ For an (inexhaustive) overview, see Mirjana Prpa and Philippe Pasquier, “Brain-Computer Interfaces in Contemporary Art: A State of the Art and Taxonomy,” in *Brain Art: Brain-Computer Interfaces for Artistic Expression*, ed. Anton Nijholt (Cham: Springer International Publishing, 2019).

¹⁴ For examples and further analysis, see Flora Lysen, “Kissing and Staring in Times of Neuromania: The Social Brain in Art-Science Experiments,” in *Artful Ways of Knowing, Dialogues between Artistic Research and Science & Technology Studies*, ed. Trevor Pinch, Henk Borgdorff, and Peter Peters, Routledge Advances in Art and Visual Studies (London & New York: Routledge, 2019).

¹⁵ Stelarc, *Spectacle of the Mind*, 2010. Casey, Karen.

¹⁶ Lisa Park, *Ennoia*, 2013.

¹⁷ Karen Lancel and Hermen Maat, *E.E.G. KISS*, 2014 -ongoing. Karen Lancel and Hermen Maat, “E.E.G. Kiss,” <https://www.lancelmaat.nl/work/e.e.g-kiss/>. Flora Lysen, “Neurofutures of Love,” *Baltan Quarterly* (2016).

mediation that remind us of the media environments and visions of circuited selves discussed in Chapter 5. Yet the current field of EEG experimentation is more diverse. While some artists use existing EEG devices to create evocative displays of scientific data, others employ EEG headbands to ultimately question and expose the black-boxed assumptions in (patented) consumer EEG software that sort brain activity according to (contested) labels such as “bored,” “excited,” “meditation,” or “frustration.”¹⁸

In relation to this broader field of EEG art, *Mutual Wave Machine* stands out in the way its dimensions of spectacle, reflection, and scientific experimentation continuously intersect. Its creators emphasize the work’s heterogeneous status: part scientific experimentation meant to result in publishable research; part vehicle for public engagement with science that shows the messy work of scientific experimentation; part attractive, immersive experience that allows for exploration and play.¹⁹ The experimenters aim to *do* and to *show* research into brain-to-brain synchronization within an evocative, aesthetic setting. Though I question notions of engagement and experience as they are attached to performances of crowdsourced neuroscience in this chapter, *Mutual Wave Machine* (2013–2019) introduces a productive site for reflection as an art–science experiment, because it is both part of (public) neuroscientific research, as well as a work of art that offers potential reconfigurations of, or reflections on, this very research.

I emphasize this duality because current critical accounts of neuroculture have dismissed the public presentation of the iconic, beautifully exhibited active brain all too easily. Since the 1990s’ “decade of the brain,” a number of authors have voiced concerns about what Nikolas Rose and Joelle Abi-Rached call “pedagogies of brain awareness”²⁰ – that is, the multifarious ways in which media events, exhibitions, workshops, and public installations may prime laypeople to become, in Martyn Pickersgill’s term “ready to talk” about the brain and make them inclined to understand everyday behavior from a neurological perspective.²¹ In a similar vein, Davi Thornton has argued that exhibitions of the brain help saturate public discourse with biological and

¹⁸ For a more elaborate discussion and overview, see “Kissing and Staring in Times of Neuromania: The Social Brain in Art-Science Experiments.” About contested data-measuring of consumer-grade headsets, see N. N. Y. Chu, “Brain-Computer Interface Technology and Development: The Emergence of Imprecise Brainwave Headsets in the Commercial World,” *IEEE Consumer Electronics Magazine* 4, no. 3 (2015).

¹⁹ Suzanne Dikker, Suzan Tunca, and Sean Montgomery, “Using Synchrony-Based Neurofeedback in Search of Human Connectedness,” in *Brain Art: Brain-Computer Interfaces for Artistic Expression*, ed. Anton Nijholt (Cham: Springer International Publishing, 2019). On showing science in action, see *Crowdsourcing Neuroscience* (https://www.youtube.com/watch?v=pyIs6Synf_k: *Imagine Science Films*, 2014), *Interview with Exhibition Footage and Brain Activity Animation*.

²⁰ Nikolas Rose and Joelle M. Abi-Rached, *Neuro: The New Brain Sciences and the Management of the Mind* (Princeton, New Jersey: Princeton University Press, 2013), 22.

²¹ *Ibid.*; Martyn Pickersgill, Sarah Cunningham-Burley, and Paul Martin, “Constituting Neurologic Subjects: Neuroscience, Subjectivity and the Mundane Significance of the Brain,” *Subjectivity* 4, no. 3 (2011): 357. See also Ortega and Vidal, *Neurocultures*.

neurological ways of thinking: “visitors are interpellated as neurobiological citizens, understanding their thoughts and behaviours as neurobiologically correlated.”²² The curators of the 2012 exhibition *Brain: The Mind as Matter* (Wellcome Collection, London) also point to these potential governing powers: brains displays will instantly become part of a “political economy of brains,” they argue, whether “the curator goes with the ideological grain or against it.”²³ These dynamics of neuro-governmentality and neuro-centrism that come with exhibited brains are facilitated, some contend, by a particular beguilement on the part of the public that Sabrina Ali and colleagues have called “neuroenchantment,” i.e. laypeople’s “sub-judicious fascination with brain science.”²⁴ Non-experts may be too easily persuaded to overestimate the present state of neuroscience knowledge and take up a neuro-centrist perspective on behavior and the self. The authors propose the public should be protected against such neuroenchantment through education in critical thinking.

While I think a consideration of governing brains and fascinated publics is crucial, my analysis in this chapter goes against an all-too-sweeping critique of the enchanting powers of exhibited neuroscience or the seduction of the layperson. Instead, my aim in analyzing *Mutual Wave Machine* and other art–science works is to contribute to a deeper understanding of the modes of reasoning in current synchronization research (as part of social neuroscience) that are intricately tied to the (art and media) forms through which research is performed.

Art–science work is particularly suitable for this analysis, as it may be emblematic of contemporary forms of “scientific life” (to use Steven Shapin’s term), i.e. new structures of researching, experimenting, funding, and demonstrating in scientific practice today.²⁵ Shapin points to a new form of industrial-scientific entrepreneurship (exemplified in his research by San Diego’s venture-capital funded bio-tech sector) in which whether a project will yield results is increasingly uncertain. He explains that a central element of this new scientific life, characteristic of late modernity, is the preoccupation with creating “pictures of possible worlds-to-come” and “technoscientific and economic future making.”²⁶ In order to build (new forms of) trust and authority, entrepreneurial science frames research sites as creative playgrounds and places new emphasis on the charisma of individual researchers. It is through the creative personalities of researchers – the scientist-entrepreneur and scientists as performance artists – that these fields can best embody and build visions of the future, accentuating play and fun in research praxis.

²² Thornton, *Brain Culture. Neuroscience and Popular Media*, 70.

²³ Marius Kwint and Richard Wingate, “Curating the Brain,” *Interdisciplinary Science Reviews* 38, no. 3 (2013): 196.

²⁴ Sabrina S. Ali, Michael Lifshitz, and Amir Raz, “Empirical Neuroenchantment: From Reading Minds to Thinking Critically,” *Frontiers in Human Neuroscience* 8 (2014).

²⁵ Steven Shapin, *The Scientific Life: A Moral History of a Late Modern Vocation* (Chicago, Illinois: University of Chicago Press, 2008).

²⁶ *Ibid.*, 309, xv.

Art–science installations and performances have emerged as a key form of future making, and are especially prevalent in cognitive neuroscience as it interfaces with developers of EEG devices and BCI-software producers. On occasion, academically-trained entrepreneurs and entrepreneurial neuroscientists also work as media artists, developing their visualizations and sonifications of brain activity in tandem with artistic installations, and demonstrating their work at hybrid academic-, public-, and industry-oriented art–science events.²⁷ Hence artists are an integral part of these future-making practices. The question, then, is which futures such art–science experiments project, and how specific forms of future making allow for some futures over others.

A real-world neuroscience with hyper-stakes

Research into brainwave synchronization such as pursued with the *Mutual Wave Machine* is still exploratory. To date, little is known about the significance of what is variably called “neural coupling,” “inter-brain synchrony,” or “brain-to-brain synchronization”²⁸ Between 2010 and 2019, over 140 studies of brain-to-brain activity were published, with evocative titles like “‘Stay Tuned’: Inter-Individual Neural Synchronization During Mutual Gaze and Joint Attention”; “On the Same Wavelength: Face-to-Face Communication Increases Interpersonal Neural Synchronization”; “Teams on the Same Wavelength Perform Better: Inter-Brain Phase Synchronization Constitutes a Neural Substrate for Social Facilitation”; “Getting into Sync: Data-Driven Analyses Reveal Patterns of Neural Coupling That Distinguish among Different Social Exchanges.”²⁹ While scholars have long investigated synchronization processes in social behavior (‘being in sync’ in the sense of walking at the same pace or speaking at the same speed), research correlating these observations and the phenomenon of brain-to-brain synchronization is now picking up.

“Brain-to-brain” measurements were sparked by new technological and computational inventions: the ability to scan two brains simultaneously, a process called “hyperscanning.”³⁰

²⁷ For an example of this form of “neuroscientific life” in the field of neuro-gaming, see Lysen, “The Interface Is the (Art)Work.”

²⁸ Suzanne Dikker et al., “On the Same Wavelength: Predictable Language Enhances Speaker–Listener Brain-to-Brain Synchrony in Posterior Superior Temporal Gyrus,” *The Journal of Neuroscience* 34, no. 18 (2014); Guillaume Dumas et al., “Inter-Brain Synchronization During Social Interaction,” *PLOS ONE* 5, no. 8 (2010); Johanna Sängler, Ulman Lindenberger, and Viktor Müller, “Interactive Brains, Social Minds,” *Communicative & Integrative Biology* 4, no. 6 (2011). As of yet, there is no shared definition for measuring brain-to-brain activity. Synchronization or “hyperconnectivity” means that there are “statistically significant correlations or covariances between different brain signals.” Fabio Babiloni and Laura Astolfi, “Social Neuroscience and Hyperscanning Techniques: Past, Present and Future,” *Neuroscience & Biobehavioral Reviews* 44 (2014): 80. About the lack of a shared definition, see Difei Liu et al., “Interactive Brain Activity: Review and Progress on EEG-Based Hyperscanning in Social Interactions,” *Frontiers in Psychology* 9 (2018): 4.

²⁹ According to my 2019 Pubmed search for articles including the term “hyperscanning.” See two review papers in 2014 and 2018, Babiloni and Astolfi, “Social Neuroscience and Hyperscanning Techniques,” 80. About the lack of a shared definition, see Liu et al., “Interactive Brain Activity.”

³⁰ Babiloni and Astolfi, “Social Neuroscience and Hyperscanning Techniques.”

Starting around 2010, hyperscanning (both with EEG and fMRI) has been hailed as a paradigm shift in studying social cognition, opening up a whole new field that is (with different inflections) called “two-body-neuroscience,” “second-person neuroscience,” or “2P-neuroscience.”³¹ EEG hyperscanning, which uses portable headsets that allow relatively regular body movements, is especially viewed as making it possible to study interpersonal cognition in its natural state for the first time.³² As two-body neuroscience researcher Guillaume Dumas speculates, these new investigations of inter-brain relationships may even be a breakthrough in tackling the infamous “hard problem” of consciousness by developing a notion of mental states that is not bound to one brain but can be measured as “collective consciousness.”³³ Clearly, the stakes in hyperscanning research are exceptionally high.

By promising new insights into the neural basis of interpersonal-interaction dynamics in more natural settings, researchers in brain-to-brain synchronization respond to concerns about the ecological validity of social-interaction research in social neuroscience. Since its rise around 2000, social neuroscience has been critiqued for drawing conclusions about the “social brain” on the basis of experiments that simulate personal interaction in too-artificial laboratory settings, such as the narrow space of the fMRI scanner.³⁴ The recent enthusiasm about the more naturalistic possibilities of hyperscanning (especially with EEG) is part of a broader discourse in cognitive neuroscience about “real-world” or “real-life” practices: the importance of studying brain/mind functioning in more ecologically valid settings – going out of the lab, into the real world.³⁵

Advocating more attention to the “real world,” a 2019 paper with the title “Are we Ready for Real-world Neuroscience?” authored by Pawel Matusz, Alexander Huth, Catherine Perrodin, as well as *Mutual Wave Machine* creator Suzanne Dikker launched the term “real-world neuroscience” to denote a shared impetus behind a number of new approaches in developing a more ecologically valid neuroscience.³⁶ In the field of perception and social-behavior research, Alexander Huth explains, this means a shift from the “20th-century mindset” of controlled

³¹ Leonhard Schilbach et al., “Toward a Second-Person Neuroscience,” *The Behavioral and Brain Sciences* 36, no. 4 (2013): 404; Riitta Hari and Miiamaaria V. Kujala, “Brain Basis of Human Social Interaction: From Concepts to Brain Imaging,” *Physiological Reviews* 89, no. 2 (2009); Guillaume Dumas, “Towards a Two-Body Neuroscience,” *Communicative & Integrative Biology* 4, no. 3 (2011).

³² Francisco J. Parada and Alejandra Rossi, “Commentary: Brain-to-Brain Synchrony Tracks Real-World Dynamic Group Interactions in the Classroom and Cognitive Neuroscience: Synchronizing Brains in the Classroom,” *Frontiers in Human Neuroscience* 11 (2017): 1; Liu et al., “Interactive Brain Activity.”

³³ Dumas, “Towards a Two-Body Neuroscience,” 351.

³⁴ Ruth Leys, “How Did Fear Become a Scientific Object and What Kind of Object Is It?,” *Representations* 110, no. 1 (2010); Rose and Abi-Rached, *Neuro*; Simon Cohn, “Making Objective Facts from Intimate Relations: The Case of Neuroscience and Its Entanglements with Volunteers,” *History of the Human Sciences* 21, no. 4 (2008).

³⁵ See Simone G. Shamay-Tsoory and Avi Mendelsohn, “Real-Life Neuroscience: An Ecological Approach to Brain and Behavior Research” *Perspectives on Psychological Science* 14, no. 5 (2019).

³⁶ The paper resulted from a 2017 “real-world neuroscience” panel at the Cognitive Neuroscience Society conference. Matusz et al., “Are We Ready for Real-World Neuroscience?”

laboratory experiments towards a twenty-first century practice of “less-controlled experiments using ethologically relevant, natural behavior.”³⁷

Real-world neuroscience, as proposed in 2019, studies living subjects with brains “in the wild” by proverbially moving “out of the lab.” Exiting the laboratory here means devising new types of less-controlled experiments or constructing new (public, artistic, experimental) labs (a practice that is always complementary to more established laboratory experimentation, the authors underline). This move has recently become possible, as Huth and Dikker explain, because of new computational modelling (premised on computational power, data gathering, and data storage) that can start to grapple with the complexity of the many factors affecting a less-controlled experiment. Researchers interested in real-world neuroscience base their research on data-driven analysis (often described as “exploratory data analysis”).³⁸ Researching “real-world” actions with data-driven approaches is helpful, as Huth explains, because neuroscience is at a loss in complex situations (such as social interaction or navigating an environment): “except in very few cases, we don’t know which hypotheses to test. The space of hypotheses is too big, and we know too little about the system. This is why we need real-world/natural experiments: to show us the general shape of the hypotheses space efficiently, instead of shooting in the dark with controlled experiments.”³⁹ This “real-world” approach to behavioral and social neuroscience requires assembling large datasets (such as measuring many museum visitors with the *Mutual Wave Machine* experiment) that may, as Suzanne Dikker puts it, “inspire and inform subsequent laboratory experimentation,” by potentially revealing novel correlations that spur new hypotheses.⁴⁰

This “real-world neuroscience” is characteristic of a broader data-driven approach to social neuroscience following a data-centric logic by which researchers produce, as Sabina Leonelli puts it, “vast quantities of data in the hope that they might yield unexpected insights.”⁴¹ This approach has critics. In 2017, for example, a group of reputable neuroscientists led by John Krakauer criticized behavioral neuroscience in a much-cited article entitled “Neuroscience Needs Behavior: Correcting a Reductionist Bias” over what they described as a flawed epistemic prioritization of data-gathering over

³⁷ Huth, Alexander, “Real-world neuroscience” state of the field: Q&A. in *ibid.*, 330.

³⁸ Ralph Adolphs, “Investigating the Cognitive Neuroscience of Social Behavior,” *Neuropsychologia* 41, no. 2 (2003): 122; Danilo Bzdok and B. T. Thomas Yeo, “Inference in the Age of Big Data: Future Perspectives on Neuroscience,” *NeuroImage* 155 (2017); Yves Frégnac, “Big Data and the Industrialization of Neuroscience: A Safe Roadmap for Understanding the Brain?,” *Science* 358, no. 6362 (2017); Ralph Adolphs et al., “Data-Driven Approaches in the Investigation of Social Perception,” *Philosophical Transactions of the Royal Society B: Biological Sciences* 371, no. 1693 (2016).

³⁹ Huth, Alexander, in Matusz et al., “Are We Ready for Real-World Neuroscience?,” 335. As Matusz puts it, an “exploration-confirmation scientific investigation cycle.” *Ibid.*

⁴⁰ Dikker, Suzanne in: *ibid.*, 331.

⁴¹ Sabina Leonelli, *Data-Centric Biology: A Philosophical Study* (Chicago: University of Chicago Press, 2016), 3. Whether data-driven social neuroscience has moved from an “exploratory” mode of experimentation to a “gathering mode” is a pertinent question for further analysis. See Ulrich Krohs, “Convenience Experimentation,” *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences* 43, no. 1 (2012).

hypothesis-building.⁴² Current studies were not invested enough, they argued, in developing conceptual frameworks that hypothesize the relation between neural data and behavior through “careful dissection of behavior into its component parts or subroutines,” a practice that should be “epistemologically prior” to neurophysiological measuring.⁴³ Instead, the authors noted, behavioral neuroscientists (including social neuroscientists) were too preoccupied with acquiring big data sets through technologically demanding procedures and with managing the deluge of data they themselves produce.⁴⁴ Yet, without “well-characterized behavior and theories,” the authors warn, “brains and behavior will be like two ships passing in the night.”⁴⁵ *Mutual Wave Machine* is located in this contested domain of data-driven real-world neuroscience and navigates such vexed issues of reductionism in behavioral neuroscience in implicit and evocative ways.

If real-world neuroscience proposes a move out of the lab into the real world, *Mutual Wave Machine* connects this to another move “out of the lab, into public space.”⁴⁶ In their proposal for crowdsourcing neuroscience that enables acquiring the bigger and more diverse datasets necessary to perform real-world neuroscience, the researchers connect this approach to notions of public engagement with science, even speaking of “citizen science.”⁴⁷ In doing so, *Mutual Wave Machine* joins a number of recent neuroscience projects that have invoked the power of the crowd in conjunction with notions of “citizen science.” One example that has received a great deal of attention in recent years is the rise of “serious” online (neuroscience) games such as *EyeWire* and *Mozaik*, which have gamified image-recognition tasks (determining the outlines of a neuron in a microscopic image, for example).

In professional neuroscience publications, such crowdsourcing games receive enthusiastic welcomes. In a 2016 paper in *Neuron*, Jane Roskams and Zoran Popović describe current neurobiology as a big data challenge that is best tackled by new technological infrastructures and aided by a “new generation of expert citizen neuroscientists.”⁴⁸ When researchers speak about serious games as a way to give “power to the people” and to create a “World Cup of Neuroscience” that allows everyone to “contribute to brain research,” they echo the language by which game makers hope to mobilize volunteers to participate in online citizen-science projects. Analyzing such

⁴² John W. Krakauer et al., “Neuroscience Needs Behavior: Correcting a Reductionist Bias,” *Neuron* 93, no. 3 (2017).

⁴³ The danger is a “granularity mismatch between levels that prevents substantive alignment between different levels of description.” *Ibid.*, 481, 88.

⁴⁴ *Ibid.*, 481. See John Krakauer, interview by Ana Gerschenfeld, 23 November 2017, 2017.

⁴⁵ Hypothesizing about behaviour should come epistemologically *prior* to neuroscience research. Krakauer et al., “Neuroscience Needs Behavior,” 484.

⁴⁶ Dikker, *Crowdsourcing Neuroscience*. @ 0:43.

⁴⁷ Matusz et al., “Are We Ready for Real-World Neuroscience?,” 2.

⁴⁸ Jane Roskams and Zoran Popović, “Power to the People: Addressing Big Data Challenges in Neuroscience by Creating a New Cadre of Citizen Neuroscientists,” *Neuron* 92, no. 3 (2016): 660, 63.

mobilization narratives and structures, Dick Kasperowski and Thomas Hillman point to the way crowdsourcing games rhetorically craft a hybrid profile for the citizen scientist: a gamer who is both a distributed epistemic subject that contributes to a small piece of the bigger puzzle, as well as an individual discoverer who helps scientists with analytical tasks.⁴⁹

In the wake of enthusiastic reporting about citizen neuroscientists analyzing data, *Mutual Wave Machine* belongs to a different category of crowdsourced science based on public experiments or gaming apps (such as *The Great Brain Experiment*) employed to gather large sets of participants' cognitive data.⁵⁰ By invoking the notion of "citizen science" in the context of cognitive data gathering, the idea of contributing or participating now suggests a different, hybrid epistemic subject.⁵¹ Here, the citizen participant is envisioned to both voluntarily provide cognitive (and other) data and engage with science on display. The subject of this cerebral citizen science is viewed as doubly involved in contributing to the "public good," both by offering information and by becoming an informed citizen. Referring to the latter element, Dikker has emphasized the potential of *Mutual Wave Machine* to critically educate and engage participants through "science in the making." As she explained during a 2019 lecture on "Neuroscience in the Wild," it is important that visitors and participants witness the technical set-up of measuring brain activity. By seeing the raw EEG signal during the headset adjustments, "it becomes very intuitive that we're not dealing with a mind-reading device," i.e. that "you need do a lot of interpretation before those squiggly lines become meaningful." This is important, because "there's a lot of misunderstandings [...] about what we can tell from our neuroscience findings."⁵² Hence, similar to readers of magazine and newspaper reports on new EEG technologies in the 1930s (as described in Chapter 3), the citizen participant of crowdsourced neuroscience today is interpellated as a critical assessor of the status of the science on display. Yet just *how* participants interpret what they see is a question that remains actively suspended. What becomes evident from my analysis is that while part of their critical abilities are assumed, they are not quite enabled.

⁴⁹ Dick Kasperowski and Thomas Hillman speak of "epistemic subjects" and a potential for "epistemic tension" in the example of the online citizen science project Galaxy Zoo. Dick Kasperowski and Thomas Hillman, "The Epistemic Culture in an Online Citizen Science Project: Programs, Antiprograms and Epistemic Subjects," *Social Studies of Science* 48, no. 4 (2018): 584.

⁵⁰ As an example of crowdsourced neuroscience at a Toronto art festival, see Natasha Kovacevic et al., "My Virtual Dream?: Collective Neurofeedback in an Immersive Art Environment," *PLOS ONE* 10, no. 7 (2015). On the *Great Brain Experiment* Harriet R. Brown et al., "Crowdsourcing for Cognitive Science – the Utility of Smartphones," *ibid.* 9 (2014).

⁵¹ On heterogeneous notions of "citizen science" as well as a critical view of the historiography of the term, see Bruno J. Strasser et al., "Citizen Science? Rethinking Science and Public Participation," *Science & Technology Studies* 32, no. 2 (2019).

⁵² Suzanne Dikker, *Cmbc 2019 Workshop - Neuroscience in the Wild* (<https://www.youtube.com/watch?v=ISeOWAAglQ02019>).

What is left out in *Mutual Wave Machine* and its para-texts is the connection between the two poles of this cerebral citizen science: subject volunteering and critical engagement. While the volunteer subject offers their data as part of a crowdsourced, data-driven approach to real-world social neuroscience, the participant of *Mutual Wave Machine* gains little insight into what it means to be one of thousands of subjects in this study, nor to what ends these data will be used. The project does little to prompt reflection on its fundamental reliance on big-data neuroscience, its data gathering, data journeys, data infrastructures, and data interpretation, and the ultimate directionality of big-data social neuroscience in finding biomarkers for normal and abnormal social behavior.⁵³ In fact, this grey zone at the heart of citizen neuroscience speaks to a broader difficulty of how to address “data subjectivity” in contemporary research where the weight has shifted to cross-correlations and analysis after data gathering.⁵⁴ While critical-data scholars have demonstrated alternative engagements with data, it is unclear what “citizen agency” or “public engagement” could be available to subjects of crowdsourced neuroscience.⁵⁵ Addressing this difficulty, Mike Michael and Deborah Lupton state: “publics are, in varying degrees, both the subjects and objects of knowledge, both authors and texts, simultaneously informants, information and informed. [...] What exactly counts as knowledge or understanding where the data themselves are continually in flux for both lay people and experts?”⁵⁶

These issues are not directly addressed in *Mutual Wave Machine*. By performing crowdsourcing as art-science experiment, the authors propose their own kind of engagement, away from discussions of data gathering, towards a positive evocation of public participation and engagement with art–science. Scholars of science and technology studies (STS), as well of participatory art, have extensively discussed notions of the “participatory” and the “engaged” in relation to governance, legitimization, popularization, and hierarchical power dynamics in imagining publics for science and the arts.⁵⁷ In light of these ongoing debates, *Mutual Wave Machine* proves a particularly interesting case because it re-envision the museum space as a vanguard “real world” neuroscience

⁵³ Investigating research into data-centric biology, Sabina Leonelli observes an epistemic frame that separates “content” and “context,” and that pays some attention to the space of the laboratory, but almost none to what she calls “data-journeys.” Leonelli, *Data-Centric Biology*, 179-80.

⁵⁴ See a discussion on data-subjectivity in Jacob Metcalf and Kate Crawford, “Where Are Human Subjects in Big Data Research? The Emerging Ethics Divide,” *Big Data & Society* 3, no. 1 (2016). And the “data divide” between individuals and data collectors in Mark Andrejevic, “Big Data, Big Questions | the Big Data Divide,” *International Journal of Communication* 8, no. 1 (2014): 1674. And specifically in the context of neurodata, see Dara Hallinan et al., “Neurodata and Neuroprivacy: Data Protection Outdated?,” *Surveillance and Society* 12, no. 1 (2014).

⁵⁵ Helen Kennedy, Thomas Poell, and José van Dijck, “Data and Agency,” *Big Data & Society* 2, no. 2 (2015): 6.

⁵⁶ Mike Michael and Deborah Lupton, “Toward a Manifesto for the ‘Public Understanding of Big Data’,” *Public Understanding of Science* 25, no. 1 (2016): 109.

⁵⁷ Georgina Born and Andrew Barry, “Art-Science. From Public Understanding to Public Experiment,” *Journal of Cultural Economy* 3, no. 1 (2010); Ian Welsh and Brian Wynne, “Science, Scientism and Imaginaries of Publics in the UK: Passive Objects, Incipient Threats,” *Science as Culture* 22, no. 4 (2013); Claire Bishop, “Delegated Performance: Outsourcing Authenticity,” *October* 140 (2012).

laboratory. In this sense, it is not only the public but also the institution that is called to perform a civic (scientific) duty. As Dikker et al. state: “Institutions such as museums, galleries, or any other organization where the public actively engages out of self-motivation, can help facilitate this type of ‘citizen science’ research, and support the collection of large datasets under scientifically controlled experimental conditions.”⁵⁸

Within the walls of this new museum-cum-laboratory, “engagement” gains new meaning: the subject is not just an engaged participant of an immersive artwork, or an engaged reviewer of science, but also an engaged experimental subject. In the context of cognitive science, “task-engagement” refers to the levels of motivation and attendance to experimental assignments (a vital issue, since many cognitive-science experiments can be tedious and boring, and inattentiveness makes data unreliable). Festivals and museum environments not only offer atmospheres for potentially higher levels of task-engagement, but also allow scientists access to large pools of self-motivated and engaged subjects⁵⁹ – though some might not have the right type of attitude as Dikker notes. At several recording sites, she recounts, “visitors did not treat the experience as a scientific experiment but rather as a curiosity (e.g., taking selfies instead of interacting with each other).”⁶⁰ Instead of being task-engaged, some visitors exhibited social-interaction behavior typical of museums – selfie-taking – that cannot be contained in a “real world” laboratory after all.

When works of art become scientific papers: Neurocentrism revisited

Mutual Wave Machine is a flickering, buzzing, and illuminated contraption that envelopes two people in order to performatively meld their mind/brains together for ten minutes at a time. As an immersive and interactive art–science experiment, it persuasively conjures the imaginary media and media imaginaries that have been attached to brainwaves for more than a century. In a world of vibratory energies and ubiquitous media technologies, the human nervous system was invoked as the pre-eminent site of influence, excitation, and breakdown long before the rise of EEG, as I discussed in previous chapters. Sometimes conceived as a mediating apparatus itself, it was always intimately part of the energetic-media-technological fabric of modern life. This conception is strikingly mirrored in the *Mutual Wave Machine* dome: the installation places its “brainwave partners” amidst multi-sensory turbulence. Facing each other, you also see brightly flashing images that provide feedback on your performance; hear loud buzzing sounds; are aware of others waiting in

⁵⁸ Suzanne Dikker et al., “Crowdsourcing Neuroscience: Inter-Brain Coupling During Face-to-Face Interactions Outside the Laboratory,” *bioRxiv* (2019): 2.

⁵⁹ On motivation in a crowdsourced neuroscience experiment by Kovacevic et al., “My Virtual Dream”.

⁶⁰ Dikker et al., “Crowdsourcing Neuroscience,” 38.

line; feel the measuring equipment squeezing your head; sense the technical assistants ready to jump in; know the room is full of spectators; glimpse the luminescence of phone screens; feel your itchy scalp wearing a brain device. Whereas much EEG art results in meditative spaces where colorful blobs augment a desired state of concentration, *Mutual Wave Machine* offers a site of overstimulation, displaying a decidedly modern “real-world” neuroscience. However, although it evokes real-life media intensity, I argue that there is a strange disjunction between the real-world experiences it invokes and the data it ultimately models to compute brain-to-brain synchronization.

What we see during art–science experiments is not necessarily what we get in scientific operationalization. Even if sound and light are integral to the experience of social interaction in the dome, subsequent data processing removes the synchronization effects of audio-visual stimuli from the potentially “social” brain-to-brain synchronization measurements.⁶¹ The rationale behind this filtering is that while two people seeing and hearing the same thing may elicit similar brain activities, such synchronization is not necessarily “social,” so stimulus-induced synchrony is viewed as a separate “low-level” measurement of synchrony that may influence actually “social” brain-to-brain synchronization, the latter hypothesized as corresponding to “high-level” measurements (necessary for cognitive inference, for example).⁶² Brain-to-brain synchronization, as we now see, is operationalized in highly circumscribed ways, building on prior theories about specific EEG frequencies and particular brain areas connected to social cognition (in previous social-neuroscientific papers).⁶³ Synchronization’s “social” element in *Mutual Wave Machine*’s complex, stimuli-heavy, “real-world” environment is difficult to pin down – and is based on previous research on localizing social cognition in the brains. Ultimately, the media-environmental and mind-melding *form* of this real-time artistic medium has a tendentious relation to the *content* of the scientific paper in which it results.

A similar tension – between the art and the science of synchronization research – emerges when we turn to the notion of feedback enacted by the experiment. While the striking visual feedback imagery on the dome is a structuring element of the installation – telling us how in sync

⁶¹ Matusz et al., “Are We Ready for Real-World Neuroscience?” 6; Dikker et al., “Crowdsourcing Neuroscience.”

⁶² “Crowdsourcing Neuroscience,” 8.

⁶³ There is a calibration of brain-to-brain synchronization research with social neuroscience approaches to the individual “social brain.” Sociologist Svenja Matusall has noted the fundamental and paradoxical methodological individualism at the core of social-neuroscience research. When social neuroscientists study social behavior, including synchronization, their frame of reference is to measure how such stimuli are processed and localized in one single “social brain.” Social interactions, then, are experimental stimuli to examine processes that take place in individuals and to hypothesize about neural structures related to sociality. Svenja Matusall, Ina Maria Kaufmann, and Markus Christen, “The Emergence of Social Neuroscience,” in *The Oxford Handbook of Social Neuroscience*, ed. Jean Decety and John T. Cacioppo (Oxford: Oxford University Press, 2011); Svenja Matusall, “Social Behavior in the “Age of Empathy”?”—a Social Scientist’s Perspective on Current Trends in the Behavioral Sciences,” *Frontiers in Human Neuroscience* 7 (2013).

we are with our partner – the 2019 paper based on the experiment reveals that what visitors see is in fact a meaningless measure, a minimal kind of feedback that is mainly geared towards keeping participants motivated.⁶⁴ And how could it be otherwise? If the *Mutual Wave Machine's* aim is to explore what brain-to-brain synchronization is (if it is a meaningful measure in relation to social behavior at all), at this stage it would be impossible to give feedback on a fact that is itself in the making. Yet, the suggestion of feedback, signals an even more central conundrum in the field of brain-to-brain synchronization.

The presence of feedback in this art–science experiment points to the feedback imaginary that fundamentally structures the field of brain-to-brain synchronization and that of social neuroscience more broadly. Part of a longer history of brain-trigger circuits and feedback interfaces (sketched in Chapters 4 and 5), acquiring visual or auditory feedback on brain-to-brain synchronization is the imagined horizon of this research field. Exemplary in this respect is a 2017 paper by psychiatrist Kai Vogeley discussing the promise of two-body neuroscience. He sketches a future of hyperscanning neurofeedback that would allow people “to observe both their own and the interactants brain activity during the ongoing interaction in real time. This would substantially enrich simple face-to-face encounters and would allow us to perform intervention studies, for instance, non-verbal communication training in persons with ASD” [Autism Spectrum Disorder].⁶⁵ This feedback medium for ‘being in sync’ is a future vision; other hyperscanning researchers are more prudent in projecting future applications of brain-to-brain synchronization. Yet, brain-to-brain research frequently invokes a potential usefulness to the study of mental disorders such as autism (construed as a social-cognition disorder).⁶⁶ The fundamental premise and impetus of synchronization research is the idea that brain-to-brain synchronization patterns may become *neuromarkers* to predict social behavior.⁶⁷ *Mutual Wave Machine* shows us – evocatively and implicitly – how feedback imaginaries, paired with a vision of localizing social behavior – are at the core of the brain-to-brain synchronization paradigm.

⁶⁴ “Although this setup makes ‘brain synchrony’ intuitive to the general public, it is highly unlikely that these instantaneous band-limited correlations map onto inter-brain synchrony between the participants in a meaningful way.” Dikker et al., “Crowdsourcing Neuroscience,” 11.

⁶⁵ Kai Vogeley, “Two Social Brains: Neural Mechanisms of Intersubjectivity,” *Philosophical Transactions of the Royal Society B: Biological Sciences* 372, no. 1727 (2017).

⁶⁶ Both Suzanne Dikker and Guillaume Dumas, for example, are working on autism-related projects.

⁶⁷ Takahiko Koike, for example, hypothesizes that inter-brain effects may be a marker for the quality of a learning process, or “for the quality of social communication in our daily life.” The crux of the synchronization-as-neuromarker proposal is that “inter-brain effects could provide better markers of behavior and psychological perspective than activations within a single brain,” a hypothesis that, as Koike states, is a topic for future studies. Takahiko Koike, Hiroki C. Tanabe, and Norihiro Sadato, “Hyperscanning Neuroimaging Technique to Reveal the “Two-in-One” System in Social Interactions,” *Neuroscience Research* 90 (2015): 29.

My analysis of the relations between the form of art–science and the content of brain-to-brain synchronization research flags two tensions. Firstly, the artistic presence of (deceptive) feedback signals carries the implicit promise of finding neuromarkers for synchronization that fundamentally structures this field. Secondly, even though the piece presents social cognition in a remarkably media-intensive “live” and “real-life” installation that seems to meld minds, the “social brain” that is ultimately enacted through this scientific paradigm is based on an individual and localization-oriented social neuroscience. My observations on what is left out of art–science experimentation (or what is only implicitly evoked but epistemologically structural) are supported by the discussion and critique of brain-to-brain synchronization research in the past years. A number of researchers of enacted, extended, embodied, and affective (4EA) perspectives on cognition have not been impressed by the promises of two-body neuroscience.

Writing in 2013, researchers Shaun Gallagher, Daniel Hutto, Jan Slaby, and Jonathan Cole dismissed hyperscanning’s radical claims as a “normal science” of neural correlates dressed in new garb, for example.⁶⁸ Brain-to-brain research ultimately harks back to the same “classical computational models, representationalism, localization of function” that single out “measurable brain activation as the most relevant *explanans*.”⁶⁹ Instead, the authors argue, not the brain (or two or more brains) should be the explanatory unit of interaction, but “a dynamic relation between *organisms*, which include brains.”⁷⁰ From the perspective of 4EA researchers, cognitive science gives the brain too foundational a priority – even in brain-to-brain studies – and thus strengthens a neuro-centric reductionism. Countering these objections, hyperscanning researcher Leonard Schilbach and colleagues stress that if social neuroscientists refrain from the “neo-phrenological attempt to isolate brain regions,” then measuring brain-to-brain activity is in fact a valid part of investigating the nature of social cognition.⁷¹ What is most fundamental about the hyperscanning approach –crucially allowing it to “go social” – they emphasize, is the possibility for “innovative experimental setups to investigate social interaction [...] in more ecologically valid ways.”⁷² *Mutual Wave Machine*, as an art–science experiment, partakes in this emphasis on innovative setups for a neuroscience of the “real-world.” And yet, a deeper dive into the artwork-turned-research demonstrates the limits of two-body neuroscience in capturing the real world it has conjured.

⁶⁸ Shaun Gallagher et al., “The Brain as Part of an Enactive System,” *Behavioral and Brain Sciences* 36, no. 4 (2013): 422. This is part of a broader debate on the pitfalls of “methodological individualism” when neuroscience turns to social interaction. See John Cromby, “Integrating Social Science with Neuroscience: Potentials and Problems,” *BioSocieties* 2, no. 2 (2007); Shaun Gallagher, “Decentering the Brain: Embodied Cognition and the Critique of Neurocentrism and Narrow-Minded Philosophy of Mind,” *Constructivist Foundations* 14, no. 1 (2018): 15.

⁶⁹ Gallagher et al., “The Brain as Part of an Enactive System,” 422.

⁷⁰ Ibid.

⁷¹ Leonhard Schilbach et al., “A Second-Person Neuroscience in Interaction,” *ibid.*: 445.

⁷² Ibid.

The allure of synchronization: Towards a critical media history of being on the same wavelength

Notions of synchronization are at the heart of contemporary EEG-hyperscanning research. Interpersonal interaction is predominantly framed as *social synchronization* – described in terms of “tuning,” “being on the same wavelength,” or “getting in sync” – and the neural dynamics underlying these social modes have been similarly hypothesized as a manifestation of attunement: a *brain-to-brain synchronization*. This current focus has not gone unnoticed: in a 2019 article in *Nature Reviews Neuroscience*, Elizabeth Redcay and Leonhard Schilbach wrote that the field of two-body neuroscience is “heavily dominated by a search for synchrony, or mirroring, between brains.”⁷³ Synchronization is today’s central relationality underpinning the search for the neural basis of social interaction.

If forms of liveness imbue research into the active brain with a sense of presentness, hereness, nearness, nowness, and directness, the logic and rhetoric of synchronization cuts across these dynamics by offering a simultaneity as well as a togetherness. Understood as an alignment that is more than just temporal, synchronization connects to the twenty-first century form of liveness described in this chapter: the desire to see brain-to-brain dynamics unfold as they happen, but not in one brain: in two interacting brains. Synchronization pairs with this “real-life” or “real world” liveness to be achieved through hyperscanning technology and less controlled, naturalistic settings. In this final part of the chapter, I sketch the contours of the contemporary “allure of synchronization” in social neuroscience in a back and forth between synchronization’s neuroscientific present and its (brainmedia-historical) past.

A first and central observation on the prevalence of synchronization is its strong connection to notions of harmonization. While there is no shared definition of synchronization in current papers in the field, concepts of alignment and positive accord are abundant. In hyperscanning experiments, being socially “in tune” is often literally postulated as an in-tune-ness on a brain-to-brain to level, and connected to individual mechanisms for empathy, mutual understanding, and trust.⁷⁴ When synchronization experiments are performed in naturalistic settings (such as teacher–pupil or therapist–client interactions), synchrony is predominantly connected to a good rapport between subjects.⁷⁵ Such positive effects are perhaps naturally central.

⁷³ Elizabeth Redcay and Leonhard Schilbach, “Using Second-Person Neuroscience to Elucidate the Mechanisms of Social Interaction,” *Nature Reviews Neuroscience* 20, no. 8 (2019): 502-3. For an alternative approach see Sebastian Wallot et al., “Beyond Synchrony: Joint Action in a Complex Production Task Reveals Beneficial Effects of Decreased Interpersonal Synchrony,” *PLOS ONE* 11, no. 12 (2016).

⁷⁴ About the lack of a definition for synchronization, see “Beyond Synchrony,” 1.

⁷⁵ Ibid.

As psychologist Sebastian Wallot and colleagues remark, the majority of synchronization experiments are in fact “focused on interpersonal coordination as an end in itself.”⁷⁶ The dominant presence of synchronization in two-body neuroscience is surprising, as it is not the only phenomenon that *could* be examined through hyperscanning. The dynamic between two people interacting (“interpersonal action coordination”) is broader than synchronization alone (think of turn-taking for example). Moreover, on the neural level brain-to-brain synchronization is but one of many possible “real-time neural dynamics” that may be involved.⁷⁷ One of the reasons that research into behavioral synchronization (such as synchronous tapping, swinging, or mimicking) dominates in this field is perhaps simply because it is technologically easier to execute.⁷⁸ But there are other fundamental reasons for synchronization’s appeal, both in its connection to a very current “real-world” neuroscience and its resonance with a deeper media-historical genealogy.

Contemporary synchronization discourses and practices are part of a longer media-historical lineage that go back to the 1920s, the era I have identified in this thesis as that of “liveness” connected to brain research. It is by reading synchronization through the twentieth century media-history of “tuning,” “being on the same wavelength,” and “being in sync” that I propose we can best understand the interpretative resources that give it particular appeal in the present. Synchronization’s association with harmonization or attunement actually goes back far beyond the twentieth century. The OED cites a figurative use of “to put in tune” in 1530, denoting: “To bring into a proper or desirable condition; to give a special tone or character (esp. of a good kind) to.”⁷⁹ Yet, importantly, this musical and string-related usage acquired decisively new meaning with the rise of radio in the 1920s (the OED notes a first example in 1926), when “to tune” also meant that individuals could be “mentally receptive,” a state of being that was envisioned as *preceding perception* by the human senses.⁸⁰ Analogously, the expression “being on the same wavelength” originates from that same era of radio-technical discourse, and implied a type of “mutual understanding.”⁸¹ This wavelength analogy of social interaction, first noted by the OED in a 1925 novel about a pair of doppelgangers, specifically emphasized a person-to-person situation.⁸² The

⁷⁶ Ibid.

⁷⁷ Redcay and Schilbach note “interaction dynamics” are broader than behavioral synchronization and “neural synchrony is just one possible neural signature of dynamic, reciprocal social interaction and may not capture the distinct and complementary roles that are inherent to dyads in everyday interactions.” Redcay and Schilbach, “Using Second-Person Neuroscience to Elucidate the Mechanisms of Social Interaction,” 502-3. For an alternative approach “beyond synchrony,” see Wallot et al., “Beyond Synchrony.” Tao Liu and Matthew Pelowski, “Clarifying the Interaction Types in Two-Person Neuroscience Research,” *Frontiers in Human Neuroscience* 8 (2014).

⁷⁸ Dumas, “Towards a Two-Body Neuroscience,” 350.

⁷⁹ Oxford English Dictionary, “Tune, V.2” (Oxford University Press).

⁸⁰ 3. *figurative*. To become mentally receptive to, or aware of; to comprehend. Const. as preceding sense.” Ibid.

⁸¹ “2. *figurative* with allusion to radio reception, implying (esp. mutual) understanding; esp. in to be on the same wavelength (as someone else), to understand each other.” “Wavelength, N.” (Oxford University Press).

⁸² OED marks the first uses as Norman Venner’s *The Imperfect Imposter* of 1925. Ibid.

expression “in sync” emerged with sound cinematography (1929) and later with television (1939). Being in or out of sync in a figurative sense arose during television’s heyday, first noted in John Steinbeck’s 1961 *Winter of Our Discontent* when the protagonist knows that *something* is going on: “I just feel it. Hair on the back of my neck kind of itches. That’s a sure sign. Everybody’s a little out of synch.”⁸³

Located at the intersection of the social and the neural, contemporary conceptions of brain-to-brain synchronization are impacted by these media-technical etymologies. By imagining the social through the (media-)technical, these expressions imbue social interaction with specific interpretative resources that may only be implicit in contemporary research, but are conceptually foundational nonetheless. I have mentioned the dimension of “proper” accord: when synchronization turns into *harmonization*. Moreover, imagining interaction as a type of technical optimization – “tuning” – means that it can be controlled or modulated: synchronization gains *operability*. And finally, through the longtime connection of waves with the realm of the mental, synchronization is often understood as working *affectively*, as preceding conscious perception.

These intersecting meanings attached to synchronization – harmonic, operable, and affective – crisscross the history of EEG research as it has interfaced with the study of social synchronization from the early twentieth century until today. Yet this longer history of synchronization has been obscured by contemporary two-body neuroscientists, who have sketched their own lineage of the synchronized brain and the social subject. Hyperscanning researchers often only mention one curious, parapsychological antecedent of present-day synchronized EEG recordings: a 1965 study of twins that showed simultaneous alpha rhythms without physical contact.⁸⁴ After this first erratic attempt, as neuroscientists Fabio Babiloni and Laura Astolfini tell the story, hyperscanning approaches were “rapidly forgotten in the scientific community, and remained so for about 40 years.”⁸⁵ By invoking this historical study as a “bizarre” forerunner of present-day two-body neuroscience, researchers aim to distance themselves from a naïve interpretation of synchronization research as a literal “communication channel” between two subjects [Figure 6.4].⁸⁶ Hyperscanning researcher Guillaume Dumas emphasizes this in a poetic

⁸³ ”b. gen. Esp. in *in sync, out of sync*. Also *figurative*.” 1961 J. Steinbeck, *Winter of our Discontent* II. xiv. 278, cited in “*Sync, N. And V.*” (Oxford University Press).

⁸⁴ T. D. Duane and Thomas Behrendt, “Extrasensory Electroencephalographic Induction between Identical Twins,” *Science* 150, no. 3694 (1965). It is beyond this chapter’s scope to sketch the interface between ESP research, EEG measurements, and synchronization research. Such an analysis would involve a view of the work that goes into positioning EEG as an objective measure of paranormal synchronization phenomena (such as remote viewing). Such a study would span from early 1930s research until today and involve a number of established academic EEG researchers. See also Andrew Pickering’s (equally footnoted) comments in Pickering, *The Cybernetic Brain*, 416.

⁸⁵ Babiloni and Astolfi, “Social Neuroscience and Hyperscanning Techniques,” 78.

⁸⁶ “Bizarre,” in Riitta Hari et al., “Centrality of Social Interaction in Human Brain Function,” *Neuron* 88, no. 1 (2015): 187. “Communication channel” in Babiloni and Astolfi, “Social Neuroscience and Hyperscanning Techniques,” 80.

video presenting brain-to-brain synchrony to a broader audience: “There is nothing magical here,” it is through the action-perception flow that people form a “coherent system.” “Each exchange is an opportunity to overcome our individuality,” and it is in this non-magical yet enthralling way that “we are more connected than we think.”⁸⁷

Separating the field of two-body neuroscience from extraordinary or even magical views on extra-sensory communication, this demarcation work by contemporary neuroscientists is necessary because the realm of studying non-verbal, pre-reflective, and “automatic” synchronization behavior – as part of the domain of affect – has a contentious proximity to the field of parapsychology. What this obscures, however, is a much longer history of correlating micro-temporal measurements of the active brains of two or more people interacting with the microscopic changes of their interacting bodies, in which notions of the harmonic, the operable, and the affective intersect.



Figure 6.4 Guillaume Dumas, Two-body neuroscience, Face-to-phases, 2013 (illustration)

Two-body neuroscience has developed its own visual language to represent brain-to-brain synchrony, by means of lines drawn between brain areas with similar measures of brain activity. See Figure 6.4.

⁸⁷ Dumas, “Towards a Two-Body Neuroscience.”; Guillaume Dumas and L. Halard, *Phi (Subtitled)* (<https://www.youtube.com/watch?v=PPbH6CMw2bU2012>); Alejandro Pérez et al., “Differential Brain-to-Brain Entrainment While Speaking and Listening in Native and Foreign Languages,” *Cortex* 111 (2019).

To understand present-day hyperscanning research, we have something to gain from a closer analysis of the controversial (and oft-footnoted, but arguably little-read) work of William Condon and W.D. Ogston. Starting in 1967 at the psychiatric institute of the University of Pittsburgh, they recorded the EEG and muscle activity of interacting subjects while simultaneously studying their gestures and utterances through high-speed cameras that allowed a frame-to-frame comparative micro-analysis of these simultaneous records.⁸⁸ Synchronization was a structuring feature of both the technical apparatus and the correlative analysis these researchers proposed in their study of social interaction. Condon and Ogston reported on tentative synchronous patterns, “harmonious patterns of change,” in both speech, body, motion, EEG, and EMG.⁸⁹ A correlative approach between the social and the neural, with a central emphasis on synchronization, was both *proposed* and *produced* by these sync technology approaches. Doing simultaneous measurements had a specific appeal: the possibility of also applying the behavioral segmentation approach (the macro level) “in search for patterns in artifacts at the micro level.”⁹⁰ In the 1980s, Condon started to speak of behavior as a “wave phenomenon:” movements, gestures, and speech were understood as hierarchically organized waveforms exhibiting characteristic periodicities.⁹¹ Naturally, he argued, such waveforms “suggests that they may be produced by similarly synchronized brain processes.”⁹²

Condon’s analysis of microscopic biological and behavioral “characteristics” opened his work up to a particular bio-typological project. In 1970, he reported on frame-to-frame analyses of films of patients with aphasia, Parkinsonism, petit mal, stuttering, schizophrenia, and childhood autism, of which “many were found to display patterns of change that differed in subtle ways from the harmony characteristic of normal behaviour.”⁹³ In a similar vein, in the 1980s, he extended his analysis of interactional synchrony and micro-behavioral rhythms towards “cultural rhythms,” arguing that “those having different cultural rhythms are unable to really ‘synch-in’ fully with each other.”⁹⁴ In this line of reasoning, he contrasted typical rhythms of “black behavior” (who moved

⁸⁸ William S. Condon and W. D. Ogston, “A Segmentation of Behavior,” *Journal of Psychiatric Research* 5, no. 3 (1967); William S. Condon, “Method of Micro-Analysis of Sound Films of Behavior,” *Behavior Research Methods & Instrumentation* 2, no. 2 (1970).

⁸⁹ “Method of Micro-Analysis of Sound Films of Behavior,” 54.

⁹⁰ Condon and Ogston, “A Segmentation of Behavior,” 232. Ultimately, in Condon’s work, it was not the level of neural waveforms that took center stage, but behavioral and gestural measures. In 1984, he would emphasize that “the higher and the lower level emerge *together* and are discovered *through* the analysis of behavior. The nature of behavioral organization, then, is a fundamental issue and must be dealt with by any investigator purporting to analyze human behavior and communication at the microlevel.” William S. Condon, “Communication & Empathy,” in *Empathy II (Psychology Revivals)*, ed. Joseph D. Lichtenberg, et al. (Abingdon: Routledge, 1984), 43.

⁹¹ “Communication: Rhythm and Structure,” in *Rhythm in Psychological, Linguistic and Musical Processes*, ed. J.R. Evans and M. Clynes (Springfield, Illinois: Thomas, Charles C., 1986), 67.

⁹² *Ibid.*

⁹³ “Method of Micro-Analysis of Sound Films of Behavior,” 54.

⁹⁴ “Cultural Microrhythms,” in *Interaction Rhythms: Periodicity in Communicative Behavior*, ed. Martha Davis (New York: Human Sciences Press, 1982).

with “greater intensities”) with that of whites.⁹⁵ While several researchers critiqued Condon’s methodological approaches and found they could not replicate his findings, the normative aspects of his bio-typological “wave” analysis did not seem to face equal resistance.⁹⁶ Some researchers suggested that scholarship on micro-behavioral para-linguistic elements should be more analyzed in relation to the *content* of spoken utterances.⁹⁷ But Condon’s work – and other work on micro-analysis and interactional synchrony – clearly fitted with a reigning and popular and cultural emphasis on the “hidden messages” of body language, the dimension of the paralinguistic, the realm of the affective.⁹⁸

As the scholarly analysis of “mutual waves” in social brains has a long history, *Mutual Wave Machine* and brain-to-brain synchronization research at large deserve more historical comparative attention. Turning to Condon helps to understand the allure and biopolitical tensions attached to this academic field and raises questions about the promise of using synchronization activity as a neural signature for social behavior, as well as the contemporary reappearance of a cultural emphasis on “visceral literacy,” i.e. reading elements of social interactional behavior outside the purview of language and symbolic mediation.⁹⁹

It also shows how brain-to-brain synchronization research, sheerly through its shared investigatory focus – synchronization – offers intuitive connections between the very disparate analytical levels in social neuroscience: interpersonal behavior and measuring the electrical activity of nerve cells. Between two people “feeling in sync” and their measured levels of “brain-to-brain synchronization” are countless influencing factors: social conventions and etiquette, for example, or setting and atmosphere. By suturing these explanatory levels, synchronization rhetoric fits the rationale that has been fundamental to social neuroscience since its inception: “integrating” social, cognitive, and biological explanations, which social neuroscientist John Cacioppa has outlined as the field’s fundamental “doctrine of multilevel analysis.”¹⁰⁰ Characteristic of this doctrine is one

⁹⁵ Ibid., 66.

⁹⁶ J.J. McDowall, “Interactional Synchrony: A Reappraisal,” *Journal of Personality and Social Psychology Today* 36, no. 9 (1978).

⁹⁷ Condon also compared verbal and non-verbal behavior, but with an emphasis on microscopic elements of non-verbal behavior. William S. Condon, “Sound-Film Microanalysis: A Means for Correlating Brain and Behavior,” in *Dyslexia: A Neuroscientific Approach to Clinical Evaluation*, ed. F. H. Duffy and Norman Geschwind (Boston: Little, Brown, 1985). Fully unpacking this issue is beyond the scope of this chapter.

⁹⁸ See Condon and Ogston, “A Segmentation of Behavior,” cited in Michael B. McCaskey, “The Hidden Messages Managers Send,” *Harvard Business Review*, November 1979.

⁹⁹ Mark Andrejevic, “Reading the Surface: Body Language and Surveillance,” *Culture Unbound: Journal of Current Cultural Research* 2, no. 1 (2010).

¹⁰⁰ The “doctrine of multilevel analysis” in John T. Cacioppo and Gary G. Berntson, “Social Psychological Contributions to the Decade of the Brain: Doctrine of Multilevel Analysis,” *American Psychologist* 47, no. 8 (1992). See also Kevin Ochsner and Matthew Lieberman, “The Emergence of Social Cognitive Neuroscience,” *ibid.* 56, no. 9 (2001), cited in Matusall, Kaufmann, and Christen, “The Emergence of Social Neuroscience,” 13. For an example of

article explaining the science behind *Mutual Wave Machine* which takes the reader through various synchronization levels step by step: from synchronizations between oscillating *neurons*, to synchronizations of the activity of *single brains* due to external stimuli (entrainment), to new hyperscanning measurements of *brain-to-brain* synchronization, and finally the phenomenon of *interpersonal* (social) synchronization.¹⁰¹ By crafting such natural affiliations between levels, the bridges between them can be more easily assumed or projected to future investigation.

The allure of synchronization also has a longer history in the world of art–science experimentation. In 1972, David Rosenboom created a project remarkably similar to *Mutual Wave Machine*. Exhibited at Vancouver Art Gallery, his installation *Vancouver Piece* allowed two EEG-fitted participants to face each other, separated by a two-way mirror. [figure 6.4]. If simultaneous alpha activity was measured, they would see a reflection of their own face seemingly projected on the shoulders of the person in front. “The intended effect,” Rosenboom explained, “was to open the participants’ consciousness of self to enable them to explore ideas about shared identity.”¹⁰² He had developed his ideas on synchronization in tandem with EEG researcher Lester Fehmi of Stony Brook University, who further developed the idea into a patented feedback course which he used in training management executives, people with social anxieties, and meditation practitioners.¹⁰³

I mention these dispersedly networked conceptions of synchronization – from strange alpha-correspondences between twins to Condon’s bio-typological psychiatry research, Rosenboom’s art installations, and Fehmi’s management-focus training – to sketch synchronization’s varying historical affiliations to the affective, the operable, and the harmonic. These histories are very closely interconnected from the 1960s to hyperscanning practices today. Rosenboom, who started hypothesizing about using the new micro-temporal ERP measurements in musical compositions in the 1970s (as discussed in chapter 5), recently collaborated with hyperscanning researcher and neurotech entrepreneur Tim Mullen. In 2014 they created *Ringling Minds*, a musical multi-person EEG-feedback piece that employs hyperscanning measurements

social neuroscience’s bridging-“levels” narrative, see Guillaume Dumas, J. A. Scott Kelso, and Jacqueline Nadel, “Tackling the Social Cognition Paradox through Multi-Scale Approaches,” *Frontiers in Psychology* 5 (2014).

¹⁰¹ Dikker, Tunca, and Montgomery, “Using Synchrony-Based Neurofeedback in Search of Human Connectedness,” 164-8.

¹⁰² David Rosenboom and Tim Mullen, “More Than One—Artistic Explorations with Multi-Agent Bcis,” *ibid.*, 122-3.

¹⁰³ Rosenboom and Mullen cite a 1971 conference paper with Lester Fehmi (at the conference for Humanistic Psychology in Washington D.C.) as the first conceptualization of what was called “contingent” group feedback. *Ibid.*, 120. In the 1970s, Fehmi would further develop his work on feedback, including notions of synchronization, in various biofeedback consulting and training contexts (he tested his methods on management executives, for example, and eventually trademarked his “Open Focus Training”, which is still practiced today). Lester G. Fehmi, “EEG Biofeedback, Multichannel Synchrony Training and Attention,” in *Expanding Dimensions of Consciousness*, ed. A. Arthur Sugarman and Ralph E. Tarter (New York, N.Y.: Springer, 1978).

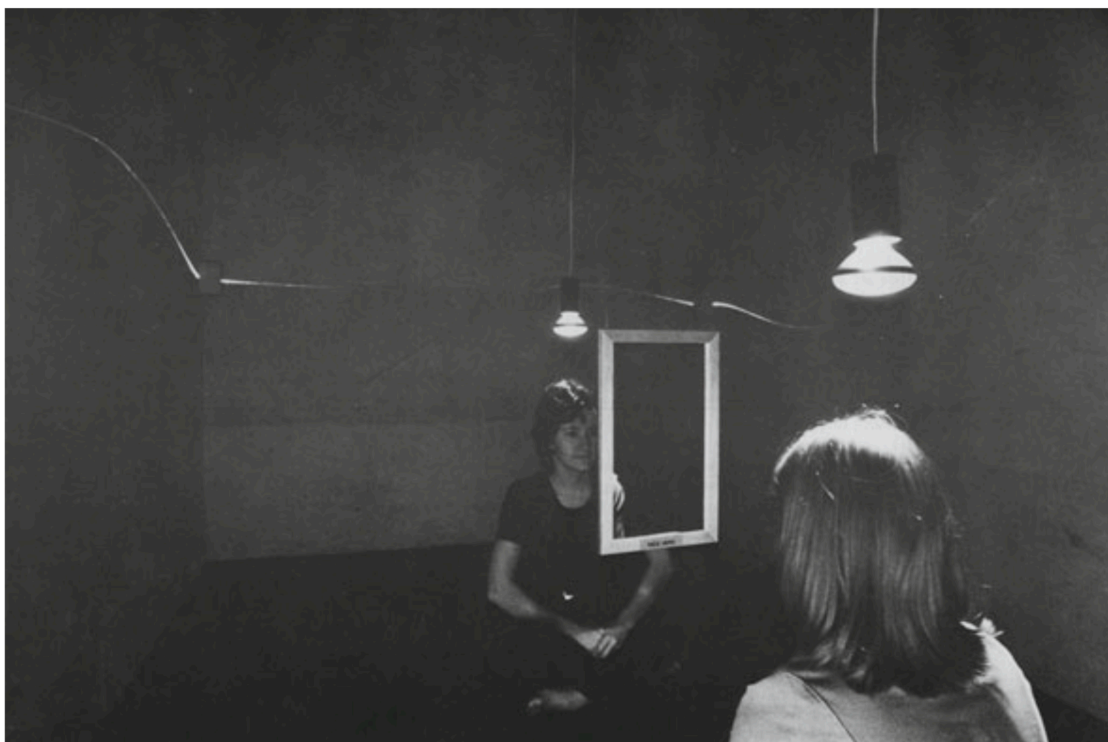


Figure 6.5 Two museum attendees participating in David Rosenboom's Vancouver Piece at the Vancouver Art Gallery, 1972 (photograph)

to record multiple participants during a live musical performance and use the changes in the music to give the participants synchronization feedback. Writing about *Ringing Minds* and other multi-person musical pieces, the creators describe synchronization between multiple EEGs as though generated by a “hyper-brain” or “group mind” that produces a “collective neural response” that allows for “effective” practice and “positive results.”¹⁰⁴ What those results may be is left undetermined, but they are associatively linked to notions of harmony, creativity, and feeling in sync.

Mullen continues to use hyperscanning technology for his San Diego-based firm Intheon, which offers software packages and computational databases to companies interested in measuring real-time EEG data or doing offline analysis of EEG measurements. The company aims to work, he explained, like an online speech-recognition platform: by acquiring more and more EEG-data, the detection algorithms for states like “emotion” or “frustration” will get better and better. As he explained in a recent interview, “We need more and more data, out there [...] in the wild of the world, which is not the lab. So one of the key things is making the world the laboratory.”¹⁰⁵

¹⁰⁴ Rosenboom and Mullen, “More Than One—Artistic Explorations with Multi-Agent Bcis,” 126, 35, 28, 20.

¹⁰⁵ Tim Mullen, *Neurotech Anytime, Anywhere* (<https://www.youtube.com/watch?v=NJmopBvbALs>: Simulation | Transtech, 2018), #248.

Artists, then, are instrumental in creating visions for a real-world neuroscience in which “the possible-world-to-come” (to use Shapin’s term) is the world as laboratory. Mullen teams up with artists for performances and installations that show intricate visualizations and sonifications of the EEG data in real-time and often do so in multi-person, brain-to-brain synchronization settings. Similar to *Mutual Wave Machine*, Mullen’s art–science collaborations are key to neuroscientific future making, creating a vision of a world in which everybody would continuously contribute their EEG (and other bio-) data. A world in which we would instantly see who is on the same wavelength – and who is not.

Conclusions

In this chapter, I analyzed the art–science experiment *Mutual Wave Machine* to study the new forms of liveness and performances of knowledge that characterize the emerging field of two-body neuroscience. New hyperscanning technologies (simultaneously measuring two brains as they interact) and portable EEG devices have enabled exploring new brain-to-brain measurements of active brains. In this experimental practice, researchers hail the possibility of studying social interaction in less controlled and more naturalistic settings outside of the conventional laboratory, aiming to measure communication ‘live’. This new form of liveness in two-body neuroscience connects to a broader concern in current neuroscientific discussions on the urgency of what is called a “real-world neuroscience” that studies human behavior in a more ecologically valid way.

This new discourse and form of liveness – “real world” liveness – is fundamentally connected, as I have explained, with social neuroscience’s big data-centered approach. *Mutual Wave Machine* signals the search for, and testing of, new forms of “crowdsourcing neuroscience,” that allow the harnessing of large amounts of brain activity data necessary to conduct a “real world” neuroscience. It frames crowdsourcing in a narrative of “citizen science” – out of the lab, into public space. *Mutual Wave Machine* specifically proposes a cerebral citizen science that evokes a hybrid epistemic profile for its participants: both a volunteer experimental subject contributing to an important scientific field and an informed critical reviewer of science. Yet, while the art–science project invites participants to look critically at the “messy” situation of measuring and acquiring data, it does little to engage subjects with the way individual recordings become part of a bigger bio-typological project of developing neuromarkers for social-interaction behavior. How a distributed epistemic subject of big-data cognitive science could be engaged with art–science remains an open question, but I have shown how artistically crowdsourcing neuroscience shifts this discussion to opportunities for museums to “contribute” to “real world” neuroscience instead.

An immersive art–science installation that gives feedback on participation, *Mutual Wave Machine* allows visitors experience moment-to-moment interaction anew and conjures a complex experimental environment that foregrounds the multi-sensory and media-impacted dimension of social contact. Its evocation of feedback, I argued, is a promissory gesture, revealing a “feedback imaginary” at the heart of the scientific program of two-body neuroscience. Moreover, I observe a tension between the art and the science of representing complex social interactions: the invoked multi-layered and media-impacted experiences can hardly be modelled within the scientific framework of brain-to-brain analysis. This observation is connected to a broader critique of social neuroscience by a number of scholars who have pointed to reductionist and neuro-centric approaches in current research into interpersonal interaction.

Finally, I analyzed what I call the allure of synchronization by sketching a longer history of synchronization that points to the influence of media-historical conceptions of “being on the same wavelength,” “tuning,” and “being in sync” employed by researchers correlating brain activity with social activity. This media-impacted conception of synchronization, which originated in the 1920s, imbues the study of social interaction with notions of harmony, operability, and affect. A number of artists and scientists investigate social interaction as a type of synchronization, and these programs show the different conceptualizations and research directions, including an objectionable one towards racial “wave” categorizations in the 1980s. My observations here are meant to signal an urgent need, in the light of present-day synchronization research, for more critical historical analysis.

Taking stock of my examination of *Mutual Wave Machine* as a crowdsourcing neuroscience art-science experiment, I have examined it as an exemplary case to unpack epistemic tensions and discourses at the heart of two-body neuroscience. Moreover, I positioned it as part of a broader trend of scientists collaborating with artists (or scientists becoming performers and installation artists themselves), a practice that is at the heart of new forms of “neuroscientific life” preoccupied with “future making.” These new artistic and performance-oriented forms of promissory science are especially prevalent in social neuroscience as it interfaces with the development of EEG devices and BCI software. One promise that *Mutual Wave Machine* enacts is the longstanding projection that one day, EEG records will be legible as neural signatures of social interaction and even be used in real-time feedback devices. The other important promise that becomes visible through my analysis is the way that (artistic) crowdsourcing neuroscience experiments propose and produce an image of the “world as laboratory,” a vision that underpins the project of “real world” neuroscience.

Despite my critical view on art–science experiments in this chapter, I think *Mutual Wave Machine* should be regarded as exemplary in one other sense. It positively demonstrates the first

steps of how art–science project could discuss science in the making (with *Mutual Wave Machine*, this takes place through scientists’ in-class visits as well as a special website to communicate results). Though “engagement” is a contentious notion, as I argued in light of the rhetoric of citizen science, there are critical ways to conduct “neuroscience in public” that should be further explored. All too often, visitors are merely invited to marvel at a technological set-up and feel giddy while providing EEG data that enable bio-databases at scales that are incongruous with the intimate interactive experiences on offer. The course of action, I propose, should not only be to develop new forms of “engagement,” but also and especially new forms of art–science experimentation.

In the past decade, project-based teams of neuroscientists, sociologists, and anthropologists have set out to experiment with new interdisciplinary configurations in the field of cognitive science. Felicity Callard and Des Fitzgerald have described some first attempts in various European research projects to bring together researchers from the humanities, social sciences, and neurosciences in efforts to “reshape and reimagine the conceptual and empirical contours” of cognitive neuroscientific experiments.¹⁰⁶ We cannot speak of a movement yet; interdisciplinary projects are exceptionally time-consuming and dependent on scarce and often temporary funding schemes. But it is precisely now that such interdisciplinary experiments to understand the brain in action and science in the making could pair up with another scholarly development of the past decade: the shaping of new norms and forms, as well as support structures, for art–science collaboration. The time for a new direction in art-neuroscience is now.

¹⁰⁶ Felicity Callard and Des Fitzgerald, “Entangling the Medical Humanities,” in *The Edinburgh Companion to the Critical Medical Humanities*, ed. Anne Whitehead, et al. (Edinburgh: Edinburgh University Press, 2016), 44. *Rethinking Interdisciplinarity across the Social Sciences and Neurosciences* (New York: Palgrave Macmillan, 2015).