

## INVOICE

Invoice Number : G-003  
Invoice Date: 3/19/2016 (revised)  
Bill to: Los Angeles County Museum of Art  
Attn.: Joel Ferree  
For: Art + Technology Lab Grant / Milestones #3-4

### Completed Work (Milestone #3: January-March 2016):

artist's fee for prelim. devel. of Neuroscientific Workplace (1-3/2016): \$ [REDACTED]  
artist's fee for prelim. devel. of Roadable Synapse (1-3/2016): [REDACTED]  
fashion shoot expenses (March 2016): [REDACTED]  
travel for fashion shoot and Lab presentation (3/2016): [REDACTED]  
artist's fee for fashion shoot and Lab presentation (3/2016): [REDACTED]  
subtotal: [REDACTED]

### Impending Work (Milestone #4: March-August 2016):

artist's fee for advanced devel. of Neuroscientific Workplace (3-8/2016): [REDACTED]  
equipment and materials for Neuroscientific Workplace (3-8/2016): [REDACTED]  
programming or fabrication time for Neuroscientific Workpl. (3-8/2016): [REDACTED]  
artist's fee for advanced devel. of Roadable Synapse (3-8/2016): [REDACTED]  
materials for Roadable Synapse (3-8/2016): [REDACTED]  
travel for Roadable Synapse (3-8/2016): [REDACTED]  
subtotal: [REDACTED]

TOTAL DUE: [REDACTED]

Payable to: Jonathan Keats (working as Jonathon Keats)  
Address: [REDACTED]

Thank you.

## **SUPEREGO SUITS**

by Jonathon Keats

LACMA Art+ Technology Lab

2015-16

*Summary Report #3 - Revised*

*March 19, 2016*

### Part I - Completed Work

In the six months since I submitted my previous summary report, I have made significant progress in three related areas of research and development: (1) neuroscientific couture, (2) the neuroscientific workplace, and (3) neuroscientific vehicle design. I will describe each of these in turn.

#### 1) Neuroscientific Couture

I have conceived, designed and prototyped four different garments exploring four different ways in which fashion might be augmented by recent breakthroughs in neuroscience. These include:

- (i) sunglasses with irises designed to open and close in time with the wearer's breathing, augmenting the wearer's presence by boosting interoception;
- (ii) bracelets that position the wearer in a 'power pose', causing the release of hormones such as testosterone to augment self-assurance;
- (iii) rings that extend the wearer's reach, mentally enlarging the wearer's sense of personal influence by stretching the wearer's body schema;
- (iv) high-heel shoes that dynamically alter the wearer's height to enhance the wearer's autonomy, bolstering the wearer's belief in his/her own free will.

For each of the above, I have conducted extensive research, reviewing the neuroscientific literature and relevant technological developments. I have also made multiple sketches and drawings and fabricated prototypes by hand in my studio. The prototypes reflect two stages of development: manual and automatic. (For instance, I've made one set of high-heel shoes that must be adjusted with a wrench and a second set operated by rudimentary robotics.) Finally I've outlined and sketched future stages of development for each of these four speculative garments, describing the sensors that will be needed for them to operate autonomously and advanced actuation systems to improve their performance. (Again taking my high-heel shoes as an example, I've outlined a future version that will hydraulically raise and lower the wearer's feet based on detection of the wearer's gaze.)

Earlier this month I orchestrated a fashion shoot on the LACMA campus in collaboration with the photographer Elena Dorfman. My four manual prototypes were worn individually and in combination by the model Anna Sophia Moltke. A selection of nine images from this shoot will be pitched to fashion magazines by the LACMA press office, ideally to be featured in a *Vogue* or *W* fashion spread. The images will be accompanied by a short essay authored by me, explaining the work and underlying ideas.

In an Art + Technology Lab talk on March 5th, I presented the neuroscientific couture project to LACMA visitors. My presentation included drawings and first and second-generation prototypes (the latter modeled live by Anna Sophia Moltke), as well as images from the fashion shoot. In my talk, I explained the neuroscientific rationale for the garments and also discussed my philosophical and artistic motivations (e.g., to provoke discussion about how technological augmentation impacts our humanity.) The same subjects were covered in a LACMA Unframed blog post published on January 18th.

Finally I have consulted with SpaceX about the application of the above concept to future spacesuits. I've conducted two conversations with SpaceX engineers, and have developed a working proposal. At this time, I am not pursuing this aspect of my research, but I hope to do so after work on the Neuroscientific Workplace is complete.

*(Note: My fashion essay and SpaceX proposal are included with this report. High-resolution photos from the fashion shoot will be provided separately by Elena Dorfman. Additional documentary and archival materials, including the Keynote presentation for my Lab talk and video of the talk, are already in the Lab archive. All of my prototypes are currently on loan to the Lab, where they will be kept through August. I have offered to donate one prototype to LACMA, and am awaiting a decision on which object is preferred.)*

## (2) The Neuroscientific Workplace

As an extension of my research on interoception, I have conceived and begun to develop a speculative workplace of the future in which office lighting modulates employee concentration and collaboration. Ultraviolet light will fade in time with employees' breathing, causing bleached garments to glow. Depending on how the lighting is directed, this will increase self-identification or facilitate identification with co-workers by inducing an out-of-body experience.

The first phase of research and development was conducted in conversation with Gensler architect Philippe Paré and colleagues. In addition to several lengthy conference calls, this phase has included authorship of a detailed project proposal and user story, supported by several feasibility studies conducted in my studio. Although Gensler will not be involved in the second stage, I will be collaborating with Spire, a San Francisco-based wearable computing company that manufactures a breathing app. More details are provided below in Part II.

*(Note: The Neuroscientific Workplace proposal and user story are both included with this report.)*

## (3) Neuroscientific Vehicle Design

As noted in my previous summary report, I have begun to discuss the development of a neuroscientific concept car with John Suh at Hyundai Ventures. Initially I planned to implement vehicular versions of some of the garments described in Part I (such as a car seat that would optimize the driver's mood to match road conditions). Following a meeting at the Hyundai Ventures office in Menlo Park, I have reworked the concept

extensively. The idea now is to facilitate total identification of driver with the vehicle such that the driver is able to experience engine operation and road conditions as if the car were the driver's own body. (For instance, engine speed will be experienced as metabolic activity as actuated by modulation of oxygen flow in the passenger compartment.) I call my concept car the Roadable Synapse.

In order to develop my new automotive idea conceptually, I've supplemented my neuroscientific research with research on automotive engineering and human physiology. (The former was greatly aided by John Suh's expert guidance.) Next steps on the Roadable Synapse are detailed in Part II.

*(Note: Both versions of my concept car proposal are included with this report. My correspondence with John Suh is already on file at the Lab.)*

## Part II - Impending Work

Over the next several months, my work will be focused on development of the Neuroscientific Workplace and Roadable Synapse. I will work on both projects simultaneously, balancing them as needed.

### (1) The Neuroscientific Workplace

The Neuroscientific Workplace will be installed in the Art + Technology Lab later this year. Two participants will work in the prototype space, in full view of the public. Their interactions will be recorded by LACMA surveillance cameras, and they will evaluate their own neuroscientifically augmented performance by filling out weekly questionnaires. This material will all become part of the project archive and select portions will be accessible online. In addition, the public will be invited to a presentation in which I'll explain the Neuroscientific Workplace and discuss the implications (including the intentionally dystopian undertones).

In preparation, I will need to develop/facilitate the following: (a) the design, (b) the technology, and (c) the architectural installation. Work on the design will include experiments with lighting, bleaches and pigments. Work on the technology will require integration of three discrete systems – breathing detection, smart lighting, and locational beacons – all of which will need to communicate instantaneously. (I am simultaneously exploring high-tech versions using digital signals sent via WiFi and other options that would be more manual.) Work on the architectural installation will include the development of floor plans and models, and design or selection of furnishings.

To support project development, I am proposing a budget of [REDACTED]. This includes [REDACTED] for the time I have spent between January and present on preliminary development, [REDACTED] for the time I will spend between now and August on advanced development, [REDACTED] for equipment and materials, and [REDACTED] to pay for programming expertise *or* to pay for my own prototyping and fabrication time if I build an analog/manual apparatus myself. (As noted in Part III, I will request an additional [REDACTED] to cover my time and expenses for final implementation in September.)

## (2) The Roadable Synapse

This week, I will start working on initial conceptual prototyping of the Roadable Synapse with John Suh and Ryan Ayler at Hyundai Ventures. At least initially, we will focus on the creation of a mock-up, concentrating on the hybrid engine system. As articulated in a recent email exchange, my work will likely include the following: (a) provide conceptual guidance on all aspects and stages of the project; (b) undertake informal experiments with heating, cooling, humidity and oxygen flow (using myself as an experimental subject); (c) design the cockpit environment and user experience at a non-technical level (by providing e.g., conceptual sketches, flow charts, user stories, and models); (d) author the project narrative and design collateral printed materials (which might potentially include a 'supplement' to the Hyundai hybrid electric vehicle user manual in the form of an artist's book); and (e) develop the artistic framework and context (in collaboration with LACMA). Any automotive-grade engineering and construction will be undertaken by Hyundai. (The scope of Hyundai's engineering commitment is still to be determined.)

For the above work on the Roadable Synapse, I am proposing a budget of [REDACTED]. This includes [REDACTED] for the time I have spent between January and present on preliminary development, [REDACTED] for the time I will spend between now and August on advanced development, [REDACTED] for materials needed to make artist models and maquettes, and [REDACTED] for travel expenses.

*(Note: A conceptual development document for the neuroscientific workplace installation is included with this report.)*

## Part III - Anticipated Work

The following is a list of milestones, both completed and proposed, which has been revised to reflect higher-than-expected expenses for the fashion shoot and also my impending focus on both the Neuroscientific Workplace and the Roadable Synapse.

### Milestone #1 (Completed / Paid):

Neuroscientific Couture background research and conceptual drawings / July-August / [REDACTED] ([REDACTED] for artist's time)

### Milestone #2 (Completed / Paid):

visit to LACMA to scout photo shoot / September / [REDACTED] ([REDACTED] for travel expenses)  
PLUS  
handmade prototype fabrication of Neuroscientific Couture garments by artist / September-January / [REDACTED] ([REDACTED] for artist's time + [REDACTED] for materials)

### Milestone #3 (Completed / Not Paid):

photo shoot of model wearing Neuroscientific Couture prototypes and Lab talk / March / [REDACTED] ([REDACTED] for photographer and shoot + [REDACTED] for artist's travel + [REDACTED] for artist's time)  
PLUS

phase-one development of Neuroscientific Workplace / January-March / [REDACTED] ([REDACTED] for artist's time)

PLUS

phase-one development of Roadable Synapse / January-March / [REDACTED] ([REDACTED] for artist's time)

Milestone #4 (Currently Underway / Not Paid):

phase-two development of Neuroscientific Workplace / March-August / [REDACTED] ([REDACTED] for artist's time + [REDACTED] for equipment and materials + [REDACTED] for software programming or hardware prototyping/fabrication)

PLUS

phase-two development of Roadable Synapse / January-March / [REDACTED] ([REDACTED] for artist's time + [REDACTED] for materials + [REDACTED] for travel)

Milestone #5 (Anticipated / Not Paid):

Installation + Documentation of Neuroscientific Workplace at A+T Lab and public presentation / September / [REDACTED] ([REDACTED] for artist's time + [REDACTED] for travel)

Potential Future Milestones (post-grant)

construction and exhibition of working Roadable Synapse prototype with Hyundai  
further development and exhibition of Neuroscientific Workplace with Gensler  
development of neuroscientific spacesuit with SpaceX

## APPENDIX: SUPPORTING DOCUMENTS

*All documents referenced in the report are included in the following pages.*

## BESPOKE NEUROSCIENCE

by Jonathon Keats

In 18th century Europe, fashionable women and men wore garments tailored to shape their posture and gait. Though society has since dispensed with bodices and busks, we still depend on clothing to mold us. The structure of a suit and height of a heel change how we feel. Our behavior is modified, and that alters how other people perceive us.

Which is to say that fashion has hardly advanced in centuries – at least psychologically – a surprising state of affairs given that knowledge about the brain has grown exponentially. In an age of head scans and neural implants, why not augment fashion with neuroscience? That's the premise of the speculative designs I'm creating at the LACMA Art + Technology Lab.

Shown here as unwieldy early prototypes, my designs enlist four different aspects of current neuroscientific research to attain four distinctive psychological effects. I've created a pair of sunglasses with irises designed to open and close in time with the wearer's breathing – augmenting her presence by increasing awareness of her internal state – a phenomenon known in neuroscience as interoception. My spiral bracelets position the wearer in a 'power pose', causing the release of testosterone, a hormone associated with self-assurance. My telescopic rings extend the wearer's reach, mentally enlarging the sense of personal influence by modifying her body schema. And mechanical heels dynamically adjust the wearer's stature to exceed the height of anyone she encounters; by putting her in superhuman control of her bodily state, my elevator shoes enhance the wearer's belief in her own free will.

As fanciful as these concepts may be in the domain of fashion, my neuroscientific clothing shares much in common with wearable computing. A wearable such as an internet-connected smartwatch changes who you are by networking your brain to billions of others, seamlessly boosting your knowledge. As with bracelets that automatically tweak your aggression or shoes that dynamically modulate your sense of free will, your whole being is altered by the technology on your body.

Only it doesn't seem that way. While there was much debate about bionic enhancement in the 1960s – when enhancement was equated with invasive surgery – modern wearables allow us to become cyborgs effortlessly, and they effortlessly update us with every software upgrade. By envisioning devices that directly determine how we perceive ourselves – automatically 'optimizing' our personalities to fit some sort of skewed sociopathic ideal – my speculative designs take our bionic lives to an unsettling extreme.

As an experimental philosopher, that's my intention. Through wearable computing and sensor-laden smart fabrics, neuroscience *is* the future of fashion – and it'll be much more slickly seductive than the objects modeled in these pages. Perhaps neuroscientific couture will improve us. Maybe it'll be dehumanizing to have our character decided by our wardrobes. Technologists and fashion designers will soon be able to give us character prostheses, but it's up to all of us to choose who we want to be as a species.

*The LACMA Art + Technology Lab is a program to support new artist projects that engage technology and science. Jonathon Keats is a recipient of a 2015-16 Lab grant.*





**THE NEUROSCIENTIFIC SPACE SUIT PROJECT**

Proposal for a Collaboration with SpaceX  
in Association with  
the LACMA Art + Technology Lab

by Jonathon Keats  
October 2015



## PROJECT OVERVIEW

"I didn't feel like a giant. I felt very, very small." With those words, Neil Armstrong encapsulated the experience of standing on the Moon and looking back to Earth in the summer of 1969. His diminished sense of self wasn't only on account of the 238,900 miles he'd traveled, or the pressurized space suit that more than doubled his weight. Even for a test pilot of his mental discipline, the effect of visiting another celestial body was psychologically alienating.

Armstrong's 46-year-old insight is directly relevant to our future. If we are to become a space-faring multi-planetary species, we will need to address not only the ballistics of getting people safely to Mars, but also this psychological challenge of making them feel at home.

Nothing in the evolution of *Homo sapiens* has prepared us to live beyond the world where we originated. However, just as materials science is addressing the physiological requirements of survival outside Earth's atmosphere, neuroscience can be enlisted to facilitate our mental adjustment. Braving the Red Planet to build a new civilization from scratch, Martian pioneers will benefit immeasurably from neuroscientifically-tailored space suits.

In collaboration with SpaceX, I propose to design and create the neuroscientific space suit of the future, an experimental garment that will explore the psychological issues raised by space colonization. Crucially, the neuroscientific space suit will be a working prototype, not merely a showcase of speculative design. The latest neuroscientific research and cutting-edge technology will be enlisted. My contribution as an artist and experimental philosopher will be to develop the space suit conceptually and to ensure that it operates philosophically as a basis for dialogue about how we can become fully ourselves beyond our natural realm.

Like a concept car, the neuroscientific space suit will be both a research platform and an artifact for exhibition. It will serve internally as a creative inspiration for SpaceX engineers and externally as a tangible vision of life on Mars. The latter goal is as practically important as the former, and as ambitious: The suit will encourage the public to think seriously about what it will take to occupy another planet – one small step toward habitation.

## SPACE SUIT FEATURES

The neuroscientific space suit will be structurally derived from suits currently in use or under development, enhanced with three experimental technologies creatively derived from recent neuroscientific research. Notable features will be as follows:

### Torso: Cardiopulmonary Feedback for Amplified Presence

The sense of self originates deep within the body. Interoception, the perception of vital signs including heartbeat and breathing, is the underlying mechanism of self-identification.<sup>1</sup> In order to make the wearer feel fully present on Mars, and to fuse identification of the wearer with the space suit, robotics in the torso will sense and amplify the throbbing sensation of the wearer's heart by gently pounding the chest at precisely the same beat. Likewise, the wearer's breathing will be subtly amplified through the gentle application of periodic pressure to the chest. Colonizing Mars, interplanetary pioneers will encounter deeply unfamiliar conditions in a hostile environment more than 30 million miles from Earth. Enhanced interoception can counteract the sense of alienation.

### Limbs: Kinesthetic Adjustment for Emotional Enhancement

Emotion is modulated by hormones. Two of the most significant are testosterone (which is associated with confidence) and cortisol (which correlates with stress level). Recent laboratory research shows that posture influences testosterone and cortisol production: an open pose hormonally increases the feeling of confidence, while stress increases when the body is closed.<sup>2</sup> Building a future civilization on another planet will depend on the right balance of self-assurance and caution. The neuroscientific space suit will keep the wearer in the optimal zone by monitoring hormones in skin perspiration and dynamically altering posture with robotics in the arms and legs. The body will be subtly opened and closed to maintain a stable mood – which may be fine-tuned by sensing how adeptly the wearer is moving and by monitoring surrounding hazards – adjusting the wearer to be more relaxed or more vigilant as appropriate during the process of planetary construction.

### Full Body: Haptic Interaction for Augmented Relationships

Mirror neurons are fundamental to shared experience and a basis for empathy. When you see another person acting, your own neurons fire as if you were performing the action. The same is the case when you observe another person's pleasure or pain; their facial expressions will vicariously elicit pleasant or painful feelings.<sup>3</sup> Mirror neurons are therefore largely responsible for social cohesion. Such cohesiveness will be critical for people collaboratively creating a Martian civilization, as will emotional bonding and

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<sup>1</sup> See "Just a heartbeat away from one's body: interoceptive sensitivity predicts malleability of body-representations" by M Tsakiris et. al. *Proc Biol Sci.* 2011 Aug 22;278(1717):2470-6. doi: 10.1098/rspb.2010.2547. See also "Turning body and self inside out: visualized heartbeats alter bodily self-consciousness and tactile perception" by JE Aspell et. al. *Psychol Sci.* 2013 Dec;24(12):2445-53. doi: 10.1177/0956797613498395 and "Breathing and sense of self: visuo-respiratory conflicts alter body self-consciousness" by D Adler et. al. *Respir Physiol Neurobiol.* 2014 Nov 1;203:68-74. doi: 10.1016/j.resp.2014.08.003.

<sup>2</sup> See "Power posing: brief nonverbal displays affect neuroendocrine levels and risk tolerance" by DR Carney et.al. *Psychol Sci.* 2010 Oct;21(10):1363-8. doi: 10.1177/0956797610383437. See also "Preparatory power posing affects nonverbal presence and job interview performance", by AJ Cuddy et. al. *J Appl Psychol.* 2015 Jul;100(4):1286-95. doi: 10.1037/a0038543.

<sup>3</sup> See "Mirror neurons and their function in cognitively understood empathy" by A Corradini et. al. *Conscious Cogn.* 2013 Sep;22(3):1152-61. doi: 10.1016/j.concog.2013.03.003. See also "Towards a unifying neural theory of social cognition" by C Keysers et. al. *Prog Brain Res.* 2006;156:379-401. PMID: 17015092

compassion. However the protective requirements of space suits will interfere with direct physical contact and undermine the ability to see other people's bodies and faces. The neuroscientific space suit will reinforce mutual understanding and empathetic connection by robotically mirroring other people's actions. Sensors in one person's suit will trigger actuators in the suit of someone else whenever the latter is looking directly at the former. The actuation will be subtle, but sufficient to cause equivalent neurons to fire. (For pleasure and pain, the actuators will gently adjust facial expression.) The same sensors and actuators will also provide a surrogate for physical touch: Pat a colleague's suit and they'll feel a pat on their back.

In the neuroscientific space suit, all of the above technologies will be fully functional; the suit will be suitable for internal experimentation at SpaceX. A second version may be tailored specifically for exhibition – with the robotics and electronics exposed – and programmed to operate automatically, so that the innovations can be readily appreciated in a museum.

## **IMPLEMENTATION PLAN**

I propose to conceive, build and exhibit at least one prototype neuroscientific space suit in collaboration with SpaceX over a two-year period beginning in January 2016.

During the first six months, concurrent with the second half of my LACMA Art + Technology Lab grant, I propose to develop viable design specs and create a conceptual blueprint for the suit. This exploratory period – which will depend on periodic consultation with select SpaceX engineers, but will not require significant use of SpaceX resources – will culminate in a June 2016 in-house presentation at SpaceX headquarters. At the presentation I will show preliminary working drawings, illustrating how the latest biomedical and aerospace technologies can be incorporated into a protective garment to provide the neuroscientific enhancements outlined in the previous section.

In order to develop a conceptual blueprint and prepare working drawings, I would anticipate interacting with SpaceX engineers with the following areas of expertise:

- sensors (e.g., vital sign and muscle movement monitoring)
- robotics (e.g., bionic actuators and artificial muscles)
- motion detection systems (e.g., video tracking and analysis)
- power systems (e.g., batteries and energy harvesting)
- space suit construction (e.g., pressurized suit design and systems integration)

After my June presentation, and depending on full commitment by SpaceX, I will work closely with SpaceX engineers between July 2016 and June 2017 on building, testing and refining a physical space suit based on the conceptual blueprint. The suit will be subject to rigorous internal experimentation.

Following a detailed internal presentation in June of 2017, I will work with the SpaceX Marketing & Communications Department and the LACMA Art + Technology Lab on public exhibition of the space suit in major art and science museums worldwide. In addition to the space suit and working drawings, the exhibition will include an interactive robotic platform for people to experience some of the effects of wearing the suit – giving them a feel for their multi-planetary future.

## ABOUT JONATHON KEATS

Acclaimed as a "poet of ideas" by *The New Yorker* and a "multimedia philosopher-prophet" by *The Atlantic*, Jonathon Keats is an experimental philosopher, artist, and writer based in San Francisco and Northern Italy. His conceptually-driven interdisciplinary projects explore all aspects of society through science and technology. In recent years, he has built a camera to take a continuous thousand-year-long exposure of the changing landscape at Arizona State University; opened a photosynthetic restaurant serving gourmet sunlight to plants at the Crocker Art Museum; exhibited extraterrestrial abstract artwork decoded from Arecibo Observatory radiotelescope data at the Judah L. Magnes Museum; and applied quantum mechanics to banking – coaxing money into a quantum superposition to be shared by everyone – at Rockefeller Center. He is the recipient of a 2015-16 Art + Technology Lab Grant from the Los Angeles County Museum of Art (LACMA), where he is applying neuroscience to fashion, and he is concurrently developing an epic work of technology-driven land art in collaboration with the Long Now Foundation and the Nevada Museum of Art. Exhibited internationally, Keats's projects have been documented by PBS, Reuters, and the BBC World Service, garnering favorable attention in periodicals ranging from *Science* to *Flash Art* to *The Economist*. His latest book, *Forged: Why Fakes Are the Great Art of Our Age*, was published last year by Oxford University Press, which will also publish his forthcoming book on the legacy of Buckminster Fuller in 2016. He is represented by Modernism Gallery in San Francisco and by Baang+Burne in New York.

### Select Media Coverage of Previous Art Projects:

Multi-Project *SciArt in America* interview (2001-2014)

<http://read.uberflip.com/i/253207/30>

Multi-Project *Space.com* Gallery (2006-2012)

<http://www.space.com/14649-jonathon-keats-space-art-photos.html>

The Millennium Camera, Arizona State University / *Slate* (2015)

[http://www.slate.com/articles/technology/future\\_tense/2015/03/experimental\\_philosopher\\_jonathon\\_keats\\_millennium\\_camera\\_experiment.html](http://www.slate.com/articles/technology/future_tense/2015/03/experimental_philosopher_jonathon_keats_millennium_camera_experiment.html)

The Millennium Camera, Amherst College / *Associated Press* (2015)

<http://bigstory.ap.org/article/c50dc46f3873460ea95872b2b0dfc315/picture-it-1000-year-exposure-showing-changing-earth>

Deep Time Photography / *The Atlantic* (2015)

<http://www.theatlantic.com/entertainment/archive/2015/06/future-library-century-camera-art/395675/>

Pangaea Optima / *Fast Company* (2015)

<http://www.fastcoexist.com/3051877/a-crazy-plan-to-literally-move-the-worlds-continent-to-create-climate-consensus>

The Century Camera Project / *Next City* (2014)

<http://nextcity.org/daily/entry/hidden-cameras-in-berlin-record-100-years-of-urban-development>

Microbial Associates / *The San Francisco Chronicle* (2014)

<http://www.sfgate.com/bayarea/article/Breaking-the-mold-S-F-artist-says-bacteria-make-5830567.php>

Spacetime Industries / *The Atlantic* (2013)

<http://www.theatlantic.com/entertainment/archive/2013/10/controlling-the-space-time-continuum-with-art/280354/>

The Quantum Bank / *Hyperallergic* (2013)

<http://hyperallergic.com/73297/what-happens-when-you-cross-banking-with-physics/>

The Epigenetic Cloning Agency / *Nature* (2012)

<http://blogs.nature.com/news/2012/10/epigenetics-inspires-philosophical-experiments.html>

The Microbial Academy of Sciences / *Wired* (2012)

<http://www.wired.com/underwire/2012/01/keats-microbial-academy/>

**The Photosynthetic Restaurant / *The Wall Street Journal* (2011)**

<http://blogs.wsj.com/ideas-market/2011/04/29/tree-huggers-put-your-love-to-the-test/>

**The First Copernican Art Exposition / *Science* (2011)**

<http://www.sciencemag.org/content/334/6054/295.summary>

**Quantum Entanglements / *Leonardo* (2011)**

[http://www.mitpressjournals.org/doi/abs/10.1162/LEON\\_a\\_00640](http://www.mitpressjournals.org/doi/abs/10.1162/LEON_a_00640)

**The Local Air & Space Administration / *ArtInfo* (2010)**

<http://www.blouinartinfo.com/news/story/278298/how-artist-jonathon-keats-tapped-moon-water-before-nasa>

**Travel Documentaries for Plants / *The New Yorker* (2010)**

[http://www.newyorker.com/talk/2010/03/15/100315ta\\_talk\\_gopnik](http://www.newyorker.com/talk/2010/03/15/100315ta_talk_gopnik)

**Universes Unlimited / *New Scientist* (2008)**

<http://www.newscientist.com/blogs/shortsharpscience/2008/10/the-makeyourownuniverse-kit.html>

**The Atheon / *Wired* (2008)**

<http://www.wired.com/wiredscience/2008/09/can-science-rep/>

**OuijaVote / *Gizmodo* (2007)**

<http://gizmodo.com/315167/ouijavote-2008-opens-door-to-paranormal-democracy-arguably-better-than-diebold>

**Pornography for Plants / *Reuters* (2007)**

<http://www.reuters.com/article/2007/09/07/us-plants-porn-idUSN0720247820070907>

**Agrifolk Art / *Outside* (2007)**

<http://www.outsideonline.com/outdoor-adventure/The-School-of-Sap.html>

**The First Intergalactic Art Exposition / *The San Francisco Chronicle* (2006)**

<http://www.sfgate.com/bayarea/article/BERKELEY-Art-and-Slinkies-reach-for-the-sky-2491895.php>

**Speculations / *KALW Radio* (2006)**

[http://www.prx.org/pieces/15573-speculations-real-estate-meets-string-theory/floating\\_piece](http://www.prx.org/pieces/15573-speculations-real-estate-meets-string-theory/floating_piece)

**The God Project / *KQED TV* (2004)**

<http://www.kqed.org/arts/programs/spark/profile.jsp?essid=4504>

**Brain Trust / *BBC World Service* (2003)**

[http://news.bbc.co.uk/2/hi/uk\\_news/magazine/3217423.stm](http://news.bbc.co.uk/2/hi/uk_news/magazine/3217423.stm)

**The Law of Identity / *Legal Affairs* (2002)**

[http://www.legalaffairs.org/issues/March-April-2003/scene\\_marapr03\\_slater.msp](http://www.legalaffairs.org/issues/March-April-2003/scene_marapr03_slater.msp)

More details on these projects and links to extensive media coverage are available on request.



**THE NEUROSCIENTIFIC WORKPLACE**

Proposal for a Speculative Design Project  
in partnership with  
Gensler  
and the LACMA Art + Technology Lab

by Jonathon Keats

in collaboration with  
Philippe Paré and Elizabeth Brink

–Revised–  
October 20, 2015

## CONCEPTUAL OVERVIEW

In 2013, a landmark Gensler survey determined that only one in four employees of U.S. companies work in optimal office environments. The finding was all the more noteworthy because workplace design has repeatedly been shown to impact everything from corporate productivity to creative problem-solving. "Our research shows that providing an optimal work environment is an opportunity to improve business performance, engage employees, and drive innovation and the productive spread of ideas," the Gensler researchers wrote. "To effectively drive performance, these environments must continue to evolve."<sup>4</sup>

Architects strive to achieve these goals at the organizational level, and novel approaches – such as activity-based workspaces – have proven highly successful. Surveys and other sociological tools are essential to workplace evolution. Yet there remains another level at which workplace dynamics can progress. To totally optimize employee output, designers need to leverage the insights of neuroscience.

In conjunction with the LACMA Art + Technology Lab, I propose to work with Gensler architects and designers on a speculative design project that will conceptually explore the neuroscientific future of workplace optimization. The Neuroscientific Workplace will probe the biological limits of environmental design, and will also philosophically examine the desirability of office optimization. Presented to the public in settings ranging from museums to arts festivals, the project is intended to foster a dialogue about the future of work in a time of disruptive change.

The Neuroscientific Workplace will build on a key finding in the 2013 Gensler report – the insight that "effective workplaces balance focus and collaboration." To achieve this dynamic balance neuroscientifically, the project will enlist recent laboratory research on interoception – the internal perception of vital signs – speculatively deployed through lighting design.

Interoception is the underlying mechanism of self-identification in humans, the foundation of our sense of self. It's also highly vulnerable to manipulation.<sup>5</sup> Laboratory experiments have shown that a subject will believe him- or herself to be closer to a distant object if the object changes in luminosity at the exact rhythm of the subject's breathing – in effect eliciting an out-of-body experience. In the Neuroscientific Workplace, this phenomenon will be exploited to augment both the extent of collaboration with colleagues and the intensity of focus on individual tasks.

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<sup>4</sup> Statistics and quotes come from Gensler's *2013 U.S. Workplace Survey: Key Findings*.

<sup>5</sup> For recent research on interoception, see the following papers: "Breathing and sense of self: visuo-respiratory conflicts alter body self-consciousness" by D Adler et. al. *Respir Physiol Neurobiol*. 2014 Nov 1;203:68-74. doi: 10.1016/j.resp.2014.08.003. "Just a heartbeat away from one's body: interoceptive sensitivity predicts malleability of body-representations" by M Tsakiris et. al. *Proc Biol Sci*. 2011 Aug 22;278(1717):2470-6. doi: 10.1098/rspb.2010.2547. "Turning body and self inside out: visualized heartbeats alter bodily self-consciousness and tactile perception" by JE Aspell et. al. *Psychol Sci*. 2013 Dec;24(12):2445-53. doi: 10.1177/0956797613498395.

## I. Collaboration

Employees' engagement with colleagues is crucial to a company's success. Gensler's 2013 workplace survey cites an MIT study in which researchers were "able to predict 35% of a team's performance simply by measuring the number and quality of face-to-face interactions between team members." What if these interactions were not merely face-to-face? What if workers were able temporarily to trade places?

Interoceptive out-of-body experiences have the potential to make face-to-face interactions into occasions of deep psychological interchange with colleagues, facilitating an unprecedented level of collaboration. To achieve this, employees will all be outfitted with belt-mounted breathing sensors and RFID tags. In addition, every morning on arrival at the office, their clothing will be lightly dusted with a colorless powder that fluoresces under invisible ultraviolet light. The RFID will track exactly where in the office they are. When they pause in front of a colleague and start talking, an overhead ultraviolet spotlight will cause their clothing to subtly fluoresce in time with their colleague's breathing, and their colleague's clothing to fluoresce in time with their own breath. During their conversation, each person will interoceptively identify with his or her co-worker. Neuroscientifically, colleagues' identities will temporarily overlap, allowing ideas to be exchanged with unprecedented fluidity.<sup>6</sup>

In cases where three or more people are together – or during a meeting – the projection system will be voice-activated. Whenever someone is speaking, his or her breathing pattern will be projected onto everyone else. In this way, the speaker will be addressing a distributed self.<sup>7</sup>

## II. Focus

According to the Gensler Workplace Survey, a full 53% of employees are distracted by colleagues when trying accomplish solo work. For all the benefits of a highly collaborative office environment, there are crucial stretches of time where workers need to concentrate. The challenge is exacerbated by the compactness of many offices, and the sheer number of distractions. What people need is a means of focusing on themselves – of being fully present in their own personal workspace.

The interoceptive mechanisms that facilitate group interaction can equally be enlisted for personal seclusion. Instead of illuminating colleagues, breathing can illuminate a cubicle,

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<sup>6</sup> All of the above is technically feasible. Several fitness trackers, such as the Spire ([www.spire.io](http://www.spire.io)), have the ability to monitor breathing unobtrusively. RFID is already ubiquitous in employee ID cards, and can be spatially tracked with a high degree of accuracy. Voice activation can be facilitated with directional microphones (and may even be possible by hacking the fitness tracker). Precision control of office lighting is becoming increasingly common for ecological reasons, with the most advanced systems coming from Philips: [www.newscientist.com/article/mg22730342-100-the-office-where-the-lights-talk-to-your-smartphone](http://www.newscientist.com/article/mg22730342-100-the-office-where-the-lights-talk-to-your-smartphone) Many substances fluoresce in UV light, though some research will be required to determine the ideal substance for this purpose. And integration of these systems will require software expertise.

<sup>7</sup> These concepts may also be beneficial for telepresence, heightening the sense of togetherness. Of course, in the case of video projection, breathing-associated illumination could be digitally superimposed, and each screen could be personally calibrated.

a desk space, even a laptop and fingertips. Directed UV lighting can make the worker fluoresce in time with his or her breathing to amplify sense of self, and can also make the task at hand fluoresce so that the employee identifies with work to be achieved.

Moreover, a dynamic system of interoceptive lighting can fluidly stream from the individual to the team and back again. Abrupt changes in focus from solo work to group interaction may be distracting and stressful. Lighting can be coordinated to smooth these transitions, optimizing periods of introversion and extroversion in time with a preset agenda: a circadian clock for the corporate superorganism. At the extreme, interoceptive lighting might even be manipulated to subliminally control an entire workforce.

Clearly neuroscientific office design could be liberating or repressive, and clearly different people will have different opinions of what should be permissible. While interoceptive lighting may not be the way in which neuroscience ultimately enters the workplace, some kind of neuroscientific intervention is practically inevitable. The conversation stimulated by the Neuroscientific Workplace project is therefore both pertinent and important.

The Neuroscientific Workplace is design at its most speculative, and speculative design is our first and best chance to influence the future. Through the combination of my practice as an independent conceptual artist and Gensler's work as a global architectural thought leader, we have the potential to provoke public engagement in a subject that ultimately will impact everyone.

## IMPLEMENTATION PLAN

The Neuroscientific Workplace will be developed in four phases between October 2015 and December 2016, beginning with internal research and culminating in public presentation. Based on preliminary conversations with Gensler, the four phases are expected to be as follows:

### Phase I: Background Research (October-December 2015)

Implementation of the Neuroscientific Workplace will depend on research into wearable respiratory sensors, locational beacons, directional voice detection, intelligent lighting systems, and fluorescing materials, as well as integration of these components into an adaptable office space. In this first phase, currently underway, each of these components will be researched and potential sources will be identified. Potential partner relationships with technology companies will also be explored.

### Phase II: Experimental Development and Troubleshooting (January-March 2016)

Based on Phase I research, materials and equipment for the Neuroscientific Workspace will be acquired and experimentally integrated to achieve basic functionality. Lighting fixtures will be developed to selectively illuminate people and furnishings. Fluorescing powders will be tested on work clothes and furnishings under varied lighting conditions. Wearable breathing sensors will be integrated with locational beacons and microphones. Software will be developed to integrate respiratory, locational and auditory data with light output. Systems will be tested for reliability, and redesigned as needed. Simultaneously, a preliminary office floorplan will be developed and appropriate furnishings will be selected and sourced.

### Phase III: In-House Implementation (April-June 2016)

A prototype Neuroscientific Workplace will be set up in a section of the Gensler Los Angeles headquarters, where Gensler employees will be the first people to experience it. Gensler employees will be given wearable breathing sensors / locational beacons, and will have their clothing dusted with fluorescing powder every morning. During the first part of Phase III, systems will be refined based on feedback from employees and observation of employee behavior. When refinements have been made and systems are fully functional, system parameters will be experimentally adjusted to determine the effect of neuroscientific intervention on productivity, power dynamics, etc. A second version will be installed in the LACMA Art + Technology Lab, where LACMA personnel will be invited to participate in further experimentation.<sup>8</sup> Workplace behavior will be documented photographically and on video. Data will be collected, analyzed and visualized. At the end of Phase III, analysis and visualizations will be encapsulated in an artist's book. A short video about the Neuroscientific Workplace will also be produced.

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<sup>8</sup> The Lab might also serve as an initial platform for public engagement (including a joint presentation about the project by Gensler and Jonathon Keats). LACMA will also have the opportunity to be the first institution to host Phase IV.

#### Phase IV: Public Exhibition (July-December 2016 and beyond)

The Neuroscientific Workspace will travel to museums, festivals and biennials.<sup>9</sup>

Crucially, the workplace will not be presented as an architectural model or showroom, but rather as a working office: Standard office furnishings – including a conference table, desk space and a water cooler – will be installed inside a museum gallery, which will also be rigged with a neuroscientific sensor-and-lighting system akin to the one at Gensler. A sort of coworking space of the future, the office will be made available to local start-ups as a temporary workplace, with the provision that museum visitors will be invited to observe employees at work, and that a video feed will be streamed to the museum website.<sup>10</sup> Companies will sign up for a one-week slot, with up to twenty-five workers relocating to the museum during office hours. Over the course of the week, lighting parameters will be continuously adjusted and optimized based on observation by museum visitors and online viewers, who will be invited to fill out questionnaires. (In other words, museum patrons will become neuroscientific supervisors of the workers.) Collected data will form an archive, which will be publicly available in perpetuity.<sup>11</sup>

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<sup>9</sup> During Phase III, curators will be invited to view the Neuroscientific Workspace at Gensler as a way of initiating discussions about public exhibition. The artist's book and video will also serve as tools for proposing exhibitions in museums as well as art and design festivals including the Ars Electronica and the Venice Architectural Biennale.

<sup>10</sup> The office might be enclosed in glass to provide sufficient privacy for people to work while letting museum-goers peer in. This arrangement has proven viable at the Smithsonian American Art Museum, where conservators can be seen at work behind glass. See for example <http://www.npr.org/templates/story/story.php?storyId=5525121> If a glass enclosure is not viable, museum visitors could view the gallery through an interactive video feed.

<sup>11</sup> Ideally this archive will be kept at the Art + Technology Lab, subject to prior approval by LACMA.

## ABOUT JONATHON KEATS

Acclaimed as a "poet of ideas" by *The New Yorker* and a "multimedia philosopher-prophet" by *The Atlantic*, Jonathon Keats is an experimental philosopher, artist, and writer based in San Francisco and Northern Italy. His conceptually-driven interdisciplinary projects explore all aspects of society through science and technology. In recent years, he has built a camera to take a continuous thousand-year-long exposure of the changing landscape at Arizona State University; opened a photosynthetic restaurant serving gourmet sunlight to plants at the Crocker Art Museum; exhibited extraterrestrial abstract artwork decoded from Arecibo Observatory radiotelescope data at the Judah L. Magnes Museum; and applied quantum mechanics to banking – coaxing money into a quantum superposition to be shared by everyone – at Rockefeller Center. He is the recipient of a 2015-16 Art + Technology Lab Grant from the Los Angeles County Museum of Art (LACMA), where he is applying neuroscience to fashion, and he is concurrently developing an epic work of technology-driven land art in collaboration with the Long Now Foundation and the Nevada Museum of Art. Exhibited internationally, Keats's projects have been documented by PBS, Reuters, and the BBC World Service, garnering favorable attention in periodicals ranging from *Science* to *Flash Art* to *The Economist*. His latest book, *Forged: Why Fakes Are the Great Art of Our Age*, was published last year by Oxford University Press, which will also publish his forthcoming book on the legacy of Buckminster Fuller in 2016. He is represented by Modernism Gallery in San Francisco and by Baang+Burne in New York.

### Select Media Coverage of Previous Art Projects:

Multi-Project *SciArt in America* interview (2001-2014)

<http://read.uberflip.com/i/253207/30>

Multi-Project *Space.com* Gallery (2006-2012)

<http://www.space.com/14649-jonathon-keats-space-art-photos.html>

The Millennium Camera, Arizona State University / *Slate* (2015)

[http://www.slate.com/articles/technology/future\\_tense/2015/03/experimental\\_philosopher\\_jonathon\\_keats\\_millennium\\_camera\\_experiment.html](http://www.slate.com/articles/technology/future_tense/2015/03/experimental_philosopher_jonathon_keats_millennium_camera_experiment.html)

The Millennium Camera, Amherst College / *Associate Press* (2015)

<http://bigstory.ap.org/article/c50dc46f3873460ea95872b2b0dfc315/picture-it-1000-year-exposure-showing-changing-earth>

Deep Time Photography / *The Atlantic* (2015)

<http://www.theatlantic.com/entertainment/archive/2015/06/future-library-century-camera-art/395675/>

The Century Camera Project / *Next City* (2014)

<http://nextcity.org/daily/entry/hidden-cameras-in-berlin-record-100-years-of-urban-development>

Microbial Associates / *The San Francisco Chronicle* (2014)

<http://www.sfgate.com/bayarea/article/Breaking-the-mold-S-F-artist-says-bacteria-make-5830567.php>

Spacetime Industries / *The Atlantic* (2013)

<http://www.theatlantic.com/entertainment/archive/2013/10/controlling-the-space-time-continuum-with-art/280354/>

The Quantum Bank / *Hyperallergic* (2013)

<http://hyperallergic.com/73297/what-happens-when-you-cross-banking-with-physics/>

The Epigenetic Cloning Agency / *Nature* (2012)

<http://blogs.nature.com/news/2012/10/epigenetics-inspires-philosophical-experiments.html>

The Microbial Academy of Sciences / *Wired* (2012)

<http://www.wired.com/underwire/2012/01/keats-microbial-academy/>

The Photosynthetic Restaurant / *The Wall Street Journal* (2011)

<http://blogs.wsj.com/ideas-market/2011/04/29/tree-huggers-put-your-love-to-the-test/>

**The First Copernican Art Exposition / *Science* (2011)**

<http://www.sciencemag.org/content/334/6054/295.summary>

**Quantum Entanglements / *Leonardo* (2011)**

[http://www.mitpressjournals.org/doi/abs/10.1162/LEON\\_a\\_00640](http://www.mitpressjournals.org/doi/abs/10.1162/LEON_a_00640)

**The Local Air & Space Administration / *ArtInfo* (2010)**

<http://www.blouinartinfo.com/news/story/278298/how-artist-jonathon-keats-tapped-moon-water-before-nasa>

**Travel Documentaries for Plants / *The New Yorker* (2010)**

[http://www.newyorker.com/talk/2010/03/15/100315ta\\_talk\\_gopnik](http://www.newyorker.com/talk/2010/03/15/100315ta_talk_gopnik)

**Universes Unlimited / *New Scientist* (2008)**

<http://www.newscientist.com/blogs/shortsharpscience/2008/10/the-makeyourownuniverse-kit.html>

**The Atheon / *Wired* (2008)**

<http://www.wired.com/wiredscience/2008/09/can-science-rep/>

**OuijaVote / *Gizmodo* (2007)**

<http://gizmodo.com/315167/ouijavote-2008-opens-door-to-paranormal-democracy-arguably-better-than-diebold>

**Pornography for Plants / *Reuters* (2007)**

<http://www.reuters.com/article/2007/09/07/us-plants-porn-idUSN0720247820070907>

**Agrifolk Art / *Outside* (2007)**

<http://www.outsideonline.com/outdoor-adventure/The-School-of-Sap.html>

**The First Intergalactic Art Exposition / *The San Francisco Chronicle* (2006)**

<http://www.sfgate.com/bayareal/article/BERKELEY-Art-and-Slinkies-reach-for-the-sky-2491895.php>

**Speculations / *KALW Radio* (2006)**

[http://www.prx.org/pieces/15573-speculations-real-estate-meets-string-theory/floating\\_piece](http://www.prx.org/pieces/15573-speculations-real-estate-meets-string-theory/floating_piece)

**The God Project / *KQED TV* (2004)**

<http://www.kqed.org/arts/programs/spark/profile.jsp?essid=4504>

**Brain Trust / *BBC World Service* (2003)**

[http://news.bbc.co.uk/2/hi/uk\\_news/magazine/3217423.stm](http://news.bbc.co.uk/2/hi/uk_news/magazine/3217423.stm)

**The Law of Identity / *Legal Affairs* (2002)**

[http://www.legalaffairs.org/issues/March-April-2003/scene\\_marapr03\\_slater.msp](http://www.legalaffairs.org/issues/March-April-2003/scene_marapr03_slater.msp)

More details on these projects and links to extensive media coverage are available on request.



## **The Neuroscientific Workplace**

### **Preliminary User Story**

by Jonathon Keats – January 12, 2015

In the neuroscientific workplace, there are several designated spaces where people can have interoceptive interactions (i.e., interactions in which each person's breathing pattern is projected onto others' bodies by overhead ultraviolet lighting). There are also many designated spaces for interoceptive isolation (in which people see their own breathing).

The spaces for interoceptive interaction are architecturally defined by ceiling-mounted beaded curtains, which screen out some ambient light but don't completely hide the people inside. There are three categories of interactive space: (1) spaces for two people to sit across from each other in lounge chairs; (2) spaces for three or four people to stand in a conversational circle; and (3) spaces where as many as ten people can sit around a conference table. In each of these spaces, the position of participants is predefined (either by the position of furniture or by footprints on the floor) so that ceiling-mounted spotlights can be preadjusted to project onto their bodies. The control system needs therefore only to determine who is standing/sitting in each position and which person is speaking. Based on these data, each person's wearable breathing monitor is accessed and the breathing signal is sent to the appropriate UV light(s), which are programmed to fade in time with respiration. (Note: In cases where two people are seated across from each other, the breathing pattern of each person is constantly projected onto the other. In cases where there are three or more people, the primary speaker's breathing pattern is projected onto everyone else. The primary speaker is defined as the person doing the majority of speaking in any given minute-long timeframe.)

The spaces for interoceptive isolation are individual desks with UV desk lamps that fade in time with the user's breathing, causing the user's own hands to glow in time with his or her respiration. The desks are distributed throughout the office and are not pre-assigned to users. Anyone can sit anywhere. The control system identifies the person seated at a given desk, queries his/her breathing monitor, and sends the data to the desk lamp.

For both of the system described above, the following components are essential: (1) smart lighting (Zumtobel); (2) personal breathing monitors (Spire); and (3) locational beacons (Gimbal/Qualcomm). These components need to be coordinated by a control system as follows: (1) A user's smartphone picks up a signal from a locational beacon; (2) the smartphone transmits the user's beacon-identified location to a central computer system together with the user's realtime breathing pattern as measured by the user's Spire; (3) the central computer system directs the breathing pattern to the smartlight(s) corresponding to the beacon's location; (4) the smartlight(s) emulate the user's breathing pattern in realtime by fading in sync with the user's breathing, projecting the user's breath onto his/her conversational companion(s) or onto his/her own hands. In cases where three or more people are in a conversational circle or around a conference table, their Spires are additionally used to determine who is speaking (by monitoring the effect of speech on breathing). The system determines the primary speaker by measuring the amount of

speaking done by all participants in a given minute, assigning the following minute of respiratory control over all of the lighting to the one who has spoken most.

Communication between components is by Bluetooth (for short range connection between smartphone, Spire and locational beacon) and by WiFi (for long-range communication between smartphone and the central computer system. The central computer system needs also to have a user-friendly interface that allows for parameters to be remotely adjusted. Adjustable parameters include: (1) responsiveness of lighting to breathing; (2) intensity of lighting; (3) timeframe of speech control; (4) emphasis on interaction versus isolation through adjustment of the previously-mentioned three parameters.

The central computer system needs to record all of the above data (including breathing patterns and locations for all users) so that office interactions can be analyzed and reconstructed. In addition, the central computer system should be able to access overhead video cameras, which are mounted in all lighting positions to visually record people's placement and movement.

A note on UV lighting and fluorescence (based on preliminary experiments by Jonathon Keats): Illumination is probably best achieved by 365nm LEDs, which must be able to fade in time with breathing. All users will need to wear bleached white shirts/blouses/dresses (or bleached shirts/blouses/dresses that are primarily white) as the bleach will fluoresce in group interactions. Bathrooms will have dispensers for hand lotion containing nontoxic fluorescing dye, which will cause hands to glow under UV light.

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The above user story is intended as the most basic scenario for the neuroscientific workplace. All functions and parameters are open to discussion and improvement. Furthermore, central control might be handled by the Zumtobel smartlighting system, or might be separately handled by a dedicated computer or server, possibly using a system such as If This Than That ([ifttt.com](http://ifttt.com)), or programmed from scratch.

Future more advanced versions of the neuroscientific workplace might include robotically-actuated smartlighting that can illuminate and track users anywhere in the office. More advanced versions will be developed as resources and opportunities become available.

**THE ROADABLE CORTEX**  
Proposal for a Neuroscientific Concept Car  
in Collaboration with Hyundai Ventures

by Jonathon Keats  
August 2015



## PROJECT OVERVIEW

According to a new *Business Insider* report, 10 million driverless cars are expected to hit the road within the next five years. Google and Apple are racing to join the automotive industry. Traditional car manufacturers are investing billions of dollars in R&D.

There are many reasons to believe that the car of the future will be autonomous. If so, we should expect people to identify less and less with their vehicles. Self-driving cars will be more viable as a service than as a product, becoming as anonymous as taxis. As artificial intelligence increases, we might completely lose the ability to drive, not to mention the opportunity. Movement will be strictly algorithmic. Roads will be off-limits to humans.

However the driverless car is not a foregone conclusion. There are technological and cultural reasons why driving may persist for the foreseeable future. Every driverless accident provokes questions about safety and responsibility. And we should remember that the self-driving car has been promised repeatedly since the 1950s, when General Motors collaborated with RCA on an autonomous Thunderbird. Four decades later, Congress mandated that driverless cars would be on highways by 1997. Like roadable aircraft, the driverless car seems forever on the horizon.

What if the future of the car is *not* driverless? How might the car of 2020 take advantage of current technologies? How might the automotive industry evolve most intelligently? How might drivers benefit from cutting-edge science? In collaboration with Hyundai Ventures and the LACMA Art + Technology Lab, I propose to develop a concept car to explore these crucial questions – and to present a decidedly unexpected answer.

If the self-driving car is not the next stage in automotive evolution, then we can expect cars to remain personal possessions, potent expressions of the driver's identity as much as they're practical means of transportation. In fact, it's likely that our identification with our vehicles will intensify, much as has happened with other personal technologies such as computers and cellphones. Cars will increasingly become a part of us, a cognitive extension of ourselves. They will become as intimate as wearables. Sensors will make cars more attentive to our desires, and robotics will make us more attuned to their requirements. On the road, the driver and car will operate as a physically and mentally unified man-machine hybrid. Driving will become both safer and more natural.

This is a future driven by automotive neuroscience rather than artificial intelligence. It will be achieved by applying breakthrough neuroscientific research to the engineering of everything the driver sees and touches, from the windshield to the seat to the steering wheel. And because many of the essential technologies are already available, facets of this future can be prototyped and experienced right now.

The world's first neuroscientific concept car, the Roadable Cortex will present five dramatic ways in which the driving experience may be augmented in next-generation passenger vehicles. The fully-operational automobile will provide an opportunity for the public to view and experience features that may soon be available, and offer a chance for engineers to gauge consumers' reactions in advance. More important from an artistic standpoint, the Roadable Cortex will present in tangible and fully roadable form a vision of future transportation distinct from driverless clichés. An original artwork conceived by

an experimental philosopher and shown in museums, the vehicle will provoke discussion about what we really want from technology – and what technology can become as it evolves into a manifestation of ourselves.

## VEHICLE FEATURES

The Roadable Cortex will be built on the chassis of a conventional late model sedan, which will be enhanced with five speculative technologies creatively derived from recent neuroscientific research. Notable features will be as follows:

### Cardiovascular Seatbelt (for Amplified Presence)

The sense of self originates deep within the body. Interoception, the perception of vital signs such as heartbeat, is the underlying mechanism of self-identification.<sup>12</sup> In order to make the driver feel fully present in the cockpit, and to fuse identification of the driver with the automobile, robotics in the seatbelt will sense and amplify the throbbing sensation of the driver's heart by gently pounding the chest at precisely the same beat.

### Pulmonary Windshield (for Augmented Intelligence)

Like heartbeat, breathing is perceived through interoception. Laboratory experiments have shown that a subject will believe himself to be closer to a distant object if the object changes in luminosity at the exact rhythm of the subject's breathing – in effect eliciting an out-of-body experience.<sup>13</sup> The Roadable Cortex will take advantage of this phenomenon by manipulating the driver's perception of road features through the windshield. Coated with electroactive SPD,<sup>14</sup> the windshield will subtly darken and lighten in time with the driver's breathing when the driver is headed in the optimal direction according to GPS computations of route and traffic information. As the driver veers off route, the tinting will fall out of sync with the lungs. Operating in tandem with the seatbelt – which will pound more vigorously as the destination is approached – the windshield will provide the driver with an augmented sense of direction by providing a guided out-of-body experience.

### Kinesthetic Driver's Seat (for Emotional Enhancement)

Emotion is modulated by hormones. Two of the most important while driving are testosterone (which is associated with confidence) and cortisol (which correlates with stress level). Recent laboratory research shows that posture influences testosterone and cortisol production: an open pose hormonally increases the feeling of confidence, while stress increases when the body is closed.<sup>15</sup> Optimal driving depends on the right balance of self-assurance and concern. The Roadable Cortex will keep the driver in the optimal zone by monitoring hormones in perspiration on the steering wheel and dynamically altering posture with robotics in the seat. The body will be subtly opened and closed to

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<sup>12</sup> See "Just a heartbeat away from one's body: interoceptive sensitivity predicts malleability of body-representations" by M Tsakiris et. al. *Proc Biol Sci.* 2011 Aug 22;278(1717):2470-6. doi: 10.1098/rspb.2010.2547. See also "Turning body and self inside out: visualized heartbeats alter bodily self-consciousness and tactile perception" by JE Aspell et. al. *Psychol Sci.* 2013 Dec;24(12):2445-53. doi: 10.1177/0956797613498395.

<sup>13</sup> See "Breathing and sense of self: visuo-respiratory conflicts alter body self-consciousness" by D Adler et. al. *Respir Physiol Neurobiol.* 2014 Nov 1;203:68-74. doi: 10.1016/j.resp.2014.08.003.

<sup>14</sup> For more information on SPD, see [http://www.smartglassinternational.com/downloads/SPD\\_SmartGlass\\_Data.pdf](http://www.smartglassinternational.com/downloads/SPD_SmartGlass_Data.pdf) Liquid Crystal is another smartglass technology that might be used instead.

<sup>15</sup> See "Power posing: brief nonverbal displays affect neuroendocrine levels and risk tolerance" by DR Carney et.al. *Psychol Sci.* 2010 Oct;21(10):1363-8. doi: 10.1177/0956797610383437. See also "The ergonomics of dishonesty: the effect of incidental posture on stealing, cheating, and traffic violations" by AJ Yap et. al. *Psychol Sci.* 2013 Nov 1;24(11):2281-9. doi: 10.1177/0956797613492425.

maintain a stable mood – which may be fine-tuned by sensing surrounding traffic and adjusting the driver to be more relaxed or more vigilant depending on road risks.

#### Haptic Steering Wheel (for Extended Awareness)

When a tool is taken in hand, the brain considers it part of the body. The phenomenon, which depends on vision and the body's sense of its own position, has been found to be remarkably robust in laboratory experiments. Subjects wielding laser pointers have been shown to mentally incorporate light beams reaching as far as thirty meters away from where they're standing.<sup>16</sup> Haptic steering will take advantage of the malleability of body schema, making the driver's brain integrate the entire vehicle as a physical extension of him- or herself. Robotics in the electric steering wheel will provide haptic feedback from the point-of-view of the car chassis, which will be additionally experienced by haptic manipulation of the feet through the electric gas and brake pedals. The illusion will be further enhanced by dashboard-mounted ultrahaptic actuators that will envelop the driver's arms and legs in a persistent haptic hologram.<sup>17</sup> The driver will feel the curvature of the road and air pressure from passing vehicles. The car body will become a second skin.

#### Somatic Thermostat (for Integrated Wellbeing)

Belief in free will isn't all in the mind. Psychological experiments have shown that it's influenced by physical wellbeing. For instance, people's sense of their own free will diminishes when they're thirsty or tired.<sup>18</sup> Inside the concept car, the thermostat will modulate the driver's sense of free will. The thermostat will be programmed to lower the driver's comfort level when his or her will is actually imperiled by low gas or engine trouble. It will also do so when the driver isn't navigating the car safely (since the consequences of poor driving can jeopardize free will permanently). Through climate control, the wellbeing of the driver will be harmonized with the wellbeing of the vehicle.

In the Roadable Cortex, all of the above technologies will be fully functional; the vehicle will be engineered for road testing by the media and the public. However the robotics and electronics will be exposed so that the innovations can be readily appreciated in a museum or on a showroom floor. In such hands-off conditions, car doors will be open and the mechanisms will be programmed to operate automatically. Viewers will see the seat robotics in motion and the windshield tint fluctuating, experiencing the car of the future vicariously.

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<sup>16</sup> See "Compressing perceived distance with remote tool-use: real, imagined, and remembered" by CC Davoli et. al. J Exp Psychol Hum Percept Perform. 2012 Feb;38(1):80-9. doi: 10.1037/a0024981.

<sup>17</sup> See <http://ultrahaptics.com> for details on ultrahaptic technology.

<sup>18</sup> See "Embodied free will beliefs: some effects of physical states on metaphysical opinions" by MR Ent et. al. Conscious Cogn. 2014 Jul;27:147-54. doi: 10.1016/j.concog.2014.05.001.

## **TENTATIVE DESIGN AND PRODUCTION TIMELINE**

September 2015 - August 2018

### Stage 1 (September-December 2015)

project planning and refinement in collaboration with Hyundai Ventures  
agreement on three-year plan and budget

### Stage 2 (January-March 2016)

conceptual development of vehicle in collaboration with Hyundai Ventures  
production of preliminary computer renderings in collaboration with Hyundai engineers

### Stage 3 (March-July 2016)

development of five new vehicle technologies with engineers  
production of stand-alone functional prototypes by Hyundai

### Stage 4 (July 2016)

joint presentation and demonstration at LACMA Art + Technology Lab (public event)

### Stage 5 (July-September 2016)

testing and refinement of stand-alone functional prototypes by Hyundai  
design of in-vehicle prototypes with engineers  
refinement and finalization of computer renderings of vehicle with engineers

### Stage 6 (September-November 2016)

development of functional prototypes inside working concept car by Hyundai

### Stage 7 (November-December 2016)

testing and refinement of concept car in collaboration with engineers

### Stage 8 (January-February 2017)

joint presentation and demonstration of concept car at LACMA Art + Technology Lab  
presentation of concept car at Detroit Auto Show and CES by Hyundai Ventures  
joint presentation of concept car to U.S. media (press conference)

### Stage 9 (February 2017 - August 2018)

exhibition of concept car at major U.S. museums

### Stage 10 (August 2018)

permanent installation of concept car at Hyundai's GAC automobile museum in Korea



## ABOUT JONATHON KEATS

Acclaimed as a "poet of ideas" by *The New Yorker* and a "multimedia philosopher-prophet" by *The Atlantic*, Jonathon Keats is an experimental philosopher, artist, and writer based in San Francisco and Northern Italy. His conceptually-driven interdisciplinary projects explore all aspects of society through science and technology. In recent years, he has built a camera to take a continuous thousand-year-long exposure of the changing landscape at Arizona State University; opened a photosynthetic restaurant serving gourmet sunlight to plants at the Crocker Art Museum; exhibited extraterrestrial abstract artwork decoded from Arecibo Observatory radiotelescope data at the Judah L. Magnes Museum; and applied quantum mechanics to banking – coaxing money into a quantum superposition to be shared by everyone – at Rockefeller Center. He is the recipient of a 2015-16 Art + Technology Lab Grant from the Los Angeles County Museum of Art (LACMA), where he is applying neuroscience to fashion, and he is concurrently developing an epic work of technology-driven land art in collaboration with the Long Now Foundation and the Nevada Museum of Art. Exhibited internationally, Keats's projects have been documented by PBS, Reuters, and the BBC World Service, garnering favorable attention in periodicals ranging from *Science* to *Flash Art* to *The Economist*. His latest book, *Forged: Why Fakes Are the Great Art of Our Age*, was published last year by Oxford University Press, which will also publish his forthcoming book on the legacy of Buckminster Fuller in 2016. He is represented by Modernism Gallery in San Francisco and by Baang+Burne in New York.

### Select Media Coverage of Previous Art Projects:

Multi-Project *SciArt in America* interview (2001-2014)

<http://read.uberflip.com/i/253207/30>

Multi-Project *Space.com* Gallery (2006-2012)

<http://www.space.com/14649-jonathon-keats-space-art-photos.html>

The Millennium Camera, Arizona State University / *Slate* (2015)

[http://www.slate.com/articles/technology/future\\_tense/2015/03/experimental\\_philosopher\\_jonathon\\_keats\\_millennium\\_camera\\_experiment.html](http://www.slate.com/articles/technology/future_tense/2015/03/experimental_philosopher_jonathon_keats_millennium_camera_experiment.html)

The Millennium Camera, Amherst College / *Associate Press* (2015)

<http://bigstory.ap.org/article/c50dc46f3873460ea95872b2b0dfc315/picture-it-1000-year-exposure-showing-changing-earth>

Deep Time Photography / *The Atlantic* (2015)

<http://www.theatlantic.com/entertainment/archive/2015/06/future-library-century-camera-art/395675/>

The Century Camera Project / *Next City* (2014)

<http://nextcity.org/daily/entry/hidden-cameras-in-berlin-record-100-years-of-urban-development>

Microbial Associates / *The San Francisco Chronicle* (2014)

<http://www.sfgate.com/bayarea/article/Breaking-the-mold-S-F-artist-says-bacteria-make-5830567.php>

Spacetime Industries / *The Atlantic* (2013)

<http://www.theatlantic.com/entertainment/archive/2013/10/controlling-the-space-time-continuum-with-art/280354/>

The Quantum Bank / *Hyperallergic* (2013)

<http://hyperallergic.com/73297/what-happens-when-you-cross-banking-with-physics/>

The Epigenetic Cloning Agency / *Nature* (2012)

<http://blogs.nature.com/news/2012/10/epigenetics-inspires-philosophical-experiments.html>

The Microbial Academy of Sciences / *Wired* (2012)

<http://www.wired.com/underwire/2012/01/keats-microbial-academy/>

The Photosynthetic Restaurant / *The Wall Street Journal* (2011)

<http://blogs.wsj.com/ideas-market/2011/04/29/tree-huggers-put-your-love-to-the-test/>

**The First Copernican Art Exposition / *Science* (2011)**

<http://www.sciencemag.org/content/334/6054/295.summary>

**Quantum Entanglements / *Leonardo* (2011)**

[http://www.mitpressjournals.org/doi/abs/10.1162/LEON\\_a\\_00640](http://www.mitpressjournals.org/doi/abs/10.1162/LEON_a_00640)

**The Local Air & Space Administration / *ArtInfo* (2010)**

<http://www.blouinartinfo.com/news/story/278298/how-artist-jonathon-keats-tapped-moon-water-before-nasa>

**Travel Documentaries for Plants / *The New Yorker* (2010)**

[http://www.newyorker.com/talk/2010/03/15/100315ta\\_talk\\_gopnik](http://www.newyorker.com/talk/2010/03/15/100315ta_talk_gopnik)

**Universes Unlimited / *New Scientist* (2008)**

<http://www.newscientist.com/blogs/shortsharpscience/2008/10/the-makeyourownuniverse-kit.html>

**The Atheon / *Wired* (2008)**

<http://www.wired.com/wiredscience/2008/09/can-science-rep/>

**OuijaVote / *Gizmodo* (2007)**

<http://gizmodo.com/315167/ouijavote-2008-opens-door-to-paranormal-democracy-arguably-better-than-diebold>

**Pornography for Plants / *Reuters* (2007)**

<http://www.reuters.com/article/2007/09/07/us-plants-porn-idUSN0720247820070907>

**Agrifolk Art / *Outside* (2007)**

<http://www.outsideonline.com/outdoor-adventure/The-School-of-Sap.html>

**The First Intergalactic Art Exposition / *The San Francisco Chronicle* (2006)**

<http://www.sfgate.com/bayareal/article/BERKELEY-Art-and-Slinkies-reach-for-the-sky-2491895.php>

**Speculations / *KALW Radio* (2006)**

[http://www.prx.org/pieces/15573-speculations-real-estate-meets-string-theory/floating\\_piece](http://www.prx.org/pieces/15573-speculations-real-estate-meets-string-theory/floating_piece)

**The God Project / *KQED TV* (2004)**

<http://www.kqed.org/arts/programs/spark/profile.jsp?essid=4504>

**Brain Trust / *BBC World Service* (2003)**

[http://news.bbc.co.uk/2/hi/uk\\_news/magazine/3217423.stm](http://news.bbc.co.uk/2/hi/uk_news/magazine/3217423.stm)

**The Law of Identity / *Legal Affairs* (2002)**

[http://www.legalaffairs.org/issues/March-April-2003/scene\\_marapr03\\_slater.msp](http://www.legalaffairs.org/issues/March-April-2003/scene_marapr03_slater.msp)

More details on these projects and links to extensive media coverage are available on request.

**THE ROADABLE SYNAPSE**

Proposal for a Neuroscientific Concept Car  
in Collaboration with Hyundai Ventures  
and the LACMA Art + Technology Lab

by Jonathon Keats  
-REVISED-  
February 24, 2016



## PROJECT OVERVIEW

According to a recent *Business Insider* report, 10 million driverless cars are expected to hit the road within the next five years. Google and Apple are racing to join the automotive industry. Traditional car manufacturers are investing billions of dollars in R&D.

There are many reasons to believe that the car of the future will be autonomous. If so, we should expect people to identify less and less with their vehicles. Self-driving cars will be more viable as a service than as a product, becoming as anonymous as taxis. As artificial intelligence increases, we might completely lose the ability to drive, not to mention the opportunity. Movement will be strictly algorithmic. Roads will be off-limits to humans.

However the driverless car is not a foregone conclusion. There are technological and cultural reasons why driving may persist for the foreseeable future. Every driverless accident provokes questions about safety and responsibility. And we should remember that the self-driving car has been promised repeatedly since the 1950s, when General Motors collaborated with RCA on an autonomous Thunderbird. Four decades later, Congress mandated that driverless cars would be on highways by 1997. Like roadable aircraft, the driverless car seems forever on the horizon.

What if the future of the car is *not* driverless? How might the car of 2020 take advantage of current technologies? How might the automotive industry evolve most intelligently? How might drivers benefit from cutting-edge science? In collaboration with Hyundai Ventures and the LACMA Art + Technology Lab, I propose to develop a concept car to explore these crucial questions – and to present a decidedly unconventional answer.

If the self-driving car is not the next stage in automotive evolution, then we can expect cars to remain personal possessions, potent expressions of the driver's identity as much as they're practical means of transportation. In fact, it's likely that our identification with our vehicles will intensify, much as has happened with other personal technologies such as computers and cellphones. Cars will increasingly become a part of us, a cognitive and emotional extension of ourselves. They will become as intimate as wearables. Sensors and robotics will align their mechanical requirements with our personal desires. On the road, the driver and car will operate as a physically and mentally unified man-machine hybrid. Driving will become safer, less stressful and more natural.

This is a future driven by automotive neuroscience rather than artificial intelligence. It will be achieved by applying neuroscientific research to every aspect of the vehicle, from the engine to the driver's seat. And because many of the essential technologies are already available, facets of this future can be prototyped and experienced right now.

As the world's first neuroscientific concept car, the Roadable Synapse will present six dramatic ways to augment the driving experience in next-generation passenger vehicles. Though technologically diverse, all are unified by one core idea: On the road, the car is the driver's body, and the driver is the car's mind. This principle has always

been implicit in vehicle design, but interaction between man and machine has remained narrowly mechanistic. Even today, there's a cognitive disconnect. Drivers have little sense of what their vehicle is physically experiencing beyond what can be seen through the windshield or read on dashboard dials. The Roadable Synapse will engage the mind organically by neuroscientifically linking the internal workings of engine and chassis to the driver's own internal body state.

Fully operational, the Roadable Synapse will provide an opportunity for the public to view and experience features that may soon be available, and offer a chance for engineers to gauge consumers' reactions in advance. More important from an artistic standpoint, the Roadable Synapse will present in tangible and fully roadable form a highly speculative vision of future transportation distinct from driverless clichés. An original artwork conceived by an experimental philosopher and shown in museums, the vehicle will provoke discussion about what we really want from technology – and what technology can become as it evolves into an extension of ourselves.

## VEHICLE FEATURES

The Roadable Synapse will be built on the chassis of a late model Hyundai Sonata hybrid or plug-in hybrid sedan, which will be modified to interface directly with the operator's nervous system. Realtime vehicular data will be conveyed to the driver in the following ways:

### Vehicle Speed

The vehicle speed will be conveyed to the driver by altering the driver's perception of time. Adjustment of time perception will be acoustic, based on the psychological phenomenon that people perceive time to move more slowly when emotionally aroused by stimulating music. Driving will be accompanied by an adjustable electronic soundtrack that can be made more emotionally invigorating by increasing the tempo when the car speeds up, and less invigorating by decreasing the tempo when the car slows down. (The soundtrack style will be selected by the driver from MP3 files in the driver's musical library, which will be modified by sound filters.) From the driver's perspective, more will seem to happen within a given time increment, equivalent to the fact that the car covers more distance when traveling more swiftly.<sup>19</sup>

### Autobody Aerodynamics

The aerodynamics of the moving vehicle will be experienced by the driver through adjustment of the spatial distribution of sound in the passenger compartment. Piezoelectric sensors distributed over the surface of the automobile will measure the flow of air currents. These data will be used to adjust the pitch of hundreds of small piezoelectric speakers distributed throughout the car's interior. All speakers will simultaneously play the soundtrack mentioned above, but the pitch will be slightly higher in locations where the outside air velocity is greater. By means of binaural source localization, the driver will be able to sense the complex interaction of the vehicle with the external environment.<sup>20</sup> The driver will thereby integrate the entire automobile into his or her body schema, perceiving the entire vehicle as a physical extension of him- or herself.<sup>21</sup>

### Transmission Gear Ratio

The driver will also internalize shifts in transmission gear ratios through acoustics. As the transmission shifts into lower gear, the musical soundtrack will increase in pitch – and will decrease in pitch as the transmission shifts into higher gear – reflecting the fact that the car is expending greater energy to achieve a given speed.

### Hybrid Powertrain Dynamics

The driver will sense the dynamics of the hybrid vehicle's electric motor and internal combustion engine through two independent yet interrelated phenomena: homeostasis

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<sup>19</sup> For research on the relationship between time perception and music, see for example <http://www.ncbi.nlm.nih.gov/pubmed/23143915>

<sup>20</sup> For an overview of binaural space localization, see for example <http://www.ncbi.nlm.nih.gov/pubmed/25726265>

<sup>21</sup> For an overview of the malleability of body schema, see for example <http://www.ncbi.nlm.nih.gov/pubmed/18539248>

and metabolism.<sup>22</sup> When the gasoline engine is exclusively powering the car, the driver's blood oxygen level will be boosted by pumping pure oxygen into the passenger compartment – raising the driver's metabolism – while air conditioning will simultaneously decrease the ambient temperature of the passenger compartment such that metabolic activity is channeled into thermogenesis.<sup>23</sup> When the electric motor is exclusively in use, the oxygen pump and air conditioning will both shut down and the car's heater will be activated to raise the ambient temperature of the passenger compartment – providing a thermal alternative to thermogenesis by the body's metabolic engine.<sup>24</sup> Combined engine and motor use will be reflected in the dynamic combination of oxygenation, heating and air conditioning. Other essential aspects of hybrid operation will be conveyed through the systems described in the next two paragraphs.

### Battery Reserve

The driver's experience of powertrain dynamics will be supplemented by the ability to sense changes to the battery reserve. As the battery discharges and the energy reserve decreases, passenger compartment humidity will increase, diminishing the body's ability to retain heat (and intensifying dependence on metabolic thermogenesis whenever the passenger compartment cools). When the battery reserve increases through regenerative braking or engine-actuated charging, the passenger compartment will be dehumidified, decreasing the metabolic expenditure required to maintain homeostasis.

### Fuel Reserve

Interoception will be enlisted to provide the driver with an internalized sense of the car's fuel reserve.<sup>25</sup> As the gas tank runs low, rumbling will be induced in the driver's stomach, simulating gastric motility to interoceptively signal that the driver is hungry. The rumbling sensation will be actuated by ultra-low-frequency infrasound from a subwoofer attached to the seatbelt, which will rest against the driver's abdomen. Rumbling will commence when the tank is one quarter full, increasing in amplitude and frequency as the tank empties out.<sup>26</sup>

### Driving Efficiency

The driver will feel the efficiency of driving behavior proprioceptively through the positioning of limbs.<sup>27</sup> When driving efficiently – as measured by the car's instant fuel economy gauge and/or hybrid system gauge – the driver will be positioned comfortably in relation to the steering wheel and foot pedals. Inefficient driving, in which the driver is using too much power, will push the seat forward so that movement feels awkwardly overbearing. At the opposite extreme, where the car is just coasting, the driver will be made to recline.<sup>28</sup>

### Tire Air Pressure

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<sup>22</sup> Attuning the driver to power and energy flow has the potential to augment the driver's ecological awareness.

<sup>23</sup> For research on the relationship between blood oxygen and metabolism, see for example <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3063979/>

<sup>24</sup> For research on the relationship between temperature and thermogenesis, see for example <http://physrev.physiology.org/content/86/2/435.long>

<sup>25</sup> Interoception is the body's perception of its own internal organs. For an overview of interoception, see for example <http://www.ncbi.nlm.nih.gov/pubmed/12965300>

<sup>26</sup> For research on the relationship between gastric motility and hunger, see for example <http://www.ncbi.nlm.nih.gov/pubmed/21342212>

<sup>27</sup> For an overview of proprioception, see for example <http://physrev.physiology.org/cgi/pmidlookup?view=long&pmid=23073629>

<sup>28</sup> Attuning the driver to efficiency has the potential to augment the driver's ecological awareness.

The vestibular system will provide the driver with an internalized sense of tire pressure. When pressure is low in a given wheel, the whole car seat will tilt in that direction, such that the driver feels unbalanced.<sup>29</sup>

### Driving Automation

When the driver opts to automate vehicle operations (e.g., automatic transmission, cruise control, lane change assist, etc.) the driver's alertness will be adjusted. The driver's circadian clock will be set to daytime wakefulness when these operations are manual, and to nighttime restfulness when they're set to automatic. Circadian rhythms will be calibrated by controlling the amount of ambient light passing through an electroactive windshield.<sup>30</sup> At night, a similar effect will be achieved by modulating the brightness of the headlights as well as lighting within the passenger compartment.<sup>31</sup>

### Vehicle Malfunction

The driver will internalize vehicle malfunction through an increase in the stress-inducing hormone cortisol. The more that basic functionality of the car is threatened, the more that cortisol levels will be raised. Conversely when the car is running well, the body will be made to produce a higher level of testosterone, a hormone correlated with self-confidence. Cortisol and testosterone levels will both be modulated by dynamically altering the driver's posture with robotics in the seat, applying recent scientific research on power poses. To augment cortisol, the body will be confined in a "closed" position. To increase testosterone, the body will be allowed to spread out.<sup>32</sup>

In the Roadable Synapse, all of the above technologies will be fully functional; the vehicle will be engineered for road testing by the media and the public. However the robotics and electronics will be exposed so that the innovations can be readily appreciated in a museum or gallery. (It will look like a prototype.) In hands-off conditions, car doors will be open and the mechanisms will be programmed to operate automatically. In addition, a separate cockpit may be built so that viewers can experience features of the Roadable Synapse directly.

Following the successful completion of the Roadable Synapse, and pending discussion with Hyundai, work will begin on a Phase II concept car called the Roadable Cortex. This more advanced concept car will combine all of the technologies described above with a non-invasive dry-electrode brain-machine interface that will allow the driver's brain to operate the car without any physical movement. In this way, the reintegration of car and driver as the body and mind of the same hybrid vehicle will be completed. The human and machine will operate as a single flesh-and-metal organism sharing the same nervous system.

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<sup>29</sup> For an overview of the vestibular system, see for example <http://www.ncbi.nlm.nih.gov/pubmed/23648598>

<sup>30</sup> For more information on electroactive glass, see [http://www.smartglassinternational.com/downloads/SPD\\_SmartGlass\\_Data.pdf](http://www.smartglassinternational.com/downloads/SPD_SmartGlass_Data.pdf) Liquid Crystal is another smartglass technology that might be used instead.

<sup>31</sup> For research on the relationship between the circadian clock and light, see for example <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4254760/>

<sup>32</sup> For research on the relationship between posture and hormone production, see "<http://www.ncbi.nlm.nih.gov/pubmed/20855902>" For specifics on car seats, see <http://pss.sagepub.com/content/24/11/228>



## **PROPOSED DESIGN AND PRODUCTION TIMELINE**

### **Phase I – January-December 2016**

#### Stage 1 (January-February 2016)

project planning and refinement  
agreement on Phase I plan and budget  
conceptual development of vehicle

#### Stage 2 (February-April 2016)

completion of preliminary functional diagrams and design sketches by Jonathon Keats  
production of preliminary computer renderings by Hyundai engineers

#### Stage 3 (April-June 2016)

development of informal physical models of vehicle technologies by Jonathon Keats  
prototyping of vehicle technologies by Hyundai engineers  
production and testing of stand-alone functional prototypes

#### Stage 4 (June-August 2016)

development of functional prototypes inside working concept car by Hyundai engineers  
collaborative testing and refinement of concept car

#### Stage 5 (September 2016)

joint presentation and demonstration of concept car at LACMA Art + Technology Lab  
joint presentation of concept car to U.S. media (press conference)

#### Stage 6 (September-December 2016)

presentation of concept car at art-and-technology festivals and automotive trade shows  
planning for concept car to be exhibited in museums

### **Phase II – January - December 2017**

(pending further discussion between Hyundai Ventures and Jonathon Keats)

#### Stage 1 (January-February 2017)

project planning and refinement  
agreement on Phase II plan and budget  
conceptual development of vehicle

#### Stage 2 (February-April 2017)

completion of preliminary functional diagrams and design sketches by Jonathon Keats  
production of preliminary computer renderings by Hyundai engineers

#### Stage 3 (April-June 2017)

development of brain-machine interface with Hyundai engineers

production and testing of stand-alone functional prototype

Stage 4 (June-August 2017)

integration of brain-machine interface into working Phase I concept car

testing and refinement of Phase II concept car

Stage 5 (September 2017)

joint presentation and demonstration of concept car at LACMA Art + Technology Lab

joint presentation of concept car to U.S. media (press conference)

Stage 6 (September-December 2017)

presentation of concept car at art-and-technology festivals

arrangements for concept car to be exhibited in museums alongside Phase I car

# THE NEUROSCIENTIFIC WORKPLACE

## Potential Technical Approaches

by Jonathon Keats  
March 19, 2016

### Overview

Four different approaches to the Neuroscientific Workplace are outlined below. These are organized by degree of automation, with the most automated version described first. Each of these descriptions enumerates specific advantages and disadvantages. In general, the advantage to greater automation is that more technically advanced systems will accentuate the plausibility of neuroscientific control entering the workplace in the near future. The advantage to less automation is that more awkwardly primitive systems will accentuate the philosophical implications. Aspects of these systems may potentially be combined. Also, regardless of which system is installed, prototypes of other versions may also be exhibited.

### I. Philips Hue / Estimote / Spire / Smartphone

**Concept:** Based on triangulation of Estimote beacons, a smartphone app triggers Spire to control dimming of a given Hue color bulb in time with a given user's breathing. Bulb color is preset to simulate blacklight using the Hue app. (Alternately a Hue white light bulb is used in combination with an LED-color-corrected Congo Blue gel.) See below for more detailed specs.

**Potential Advantages:** (1) The system is purely electronic, integrating existing open-API hardware. (2) The system will work without the need for UV dyes.

**Potential Challenges:** (1) An app will need to be developed to integrate these systems. (2) System latencies will need to be minimized. (3) AC power will be required in the conversational pod. (4) Most apps that actively control Hue require that the smartphone always be on with the app launched, rapidly draining the battery.

**Potential Disadvantages:** Neither Hue bulbs nor filters can emit a true UV light.

**Potential Next Steps:** (1) Determine feasibility of app development given hardware APIs and development costs. (2) Reengage Spire. (3) Test white light / gel combination.

### II. Philips Hue / Estimote / Smartphone / Microphone / Stethoscope

**Concept:** Dimming of a given set of Hue bulbs is controlled by a user's smartphone using a preexisting Hue app such as Hue Disco or Hue Party. These apps correlate dimming with microphone sound level. For purposes of the Neuroscientific Workplace, a stethoscope diaphragm is modified to be worn under the shirt and implanted with a microphone that plugs into the user's smartphone. The relevant Hue bulb from the user set is activated based on the user's proximity to an Estimote beacon (as triggered by IFTTT). An alternative to the use of stethoscope and disco app would be to modify a Hue dimmer remote control to be actuated by breathing. Bulb color is preset to simulate blacklight using the Hue app. (Alternately a Hue white light bulb is used in combination with a Congo Blue gel.)

**Potential Advantages:** The system uses working off-the-shelf software, which is likely to be more stable than custom software.

**Potential Challenges:** (1) Input from the stethoscope may be noisy. (2) Controls for these apps tend to be limited, which may make the desired effect difficult to achieve. (Hue white light bulbs with gels may be easier to work with.) (3) System latencies will need to be minimized. (4) Most apps that actively control Hue require that the smartphone always be on with the app launched, rapidly draining the battery.

**Potential Disadvantages:** (1) Each user will require a separate Hue bridge and bulb set. (2) Seating will need to be preassigned or multiple bulbs will be required in each location. (3) Neither Hue bulbs nor filters can emit a true UV light.

**Potential Next Steps:** (1) Prototype one stethoscope device and experiment with the stethoscope device and disco apps. (2) Experiment with modifications to the Hue fader remote control. (3) Test white light / gel combination.

### **III. Battery-Powered Ultraviolet LEDs / Force Sensitive Resistors**

**Concept:** Battery-powered ultraviolet LED fixtures are dimmed by controlling battery current with wearable force-sensitive resistors (FSRs). Each user wears an FSR under the belt or bra. The FSR has a cord that the user must manually connect to the appropriate lighting fixture, causing the fixture to dim in time with breathing. (Alternately LED power might be controlled by a plug-in version of the stethoscope/microphone setup described above.)

**Potential Advantages:** (1) The system will emit true UV light, creating more selective glow of both bleached clothing and UV-dyed hands. (2) The system will not need to be plugged into a wall socket and also will not depend on potentially unreliable WiFi and Bluetooth signals. (3) There will be minimal latencies.

**Potential Challenges:** (1) Input from FSRs may be noisy. (2) Resistance-based LED dimming may be problematic.

**Potential Disadvantages:** (1) Users will need to plug in rather than being automatically connected (though this may also be an advantage for the reasons articulated in the overview). (2) Batteries will need to be recharged on a regular basis.

**Potential Next Steps:** (1) Test the dimming capabilities of battery-powered UV LEDs. (2) Prototype one FSR-controlled lighting fixture.

### **IV. Compact Fluorescent Blacklights / Mechanical Apertures / Breathing Masks**

**Concept:** Dimming is manually actuated by breathing into a tube through a breathing mask, with inhalation and exhalation powering the motion of a radial shutter apparatus affixed in front of a compact fluorescent blacklight fixture. Users engage in brief breathing sessions at the start of a collaborative engagement and as needed for purposes of concentration during solo work.

**Potential Advantages:** (1) The system will emit true UV light, creating more selective glow of both bleached clothing and UV-dyed hands. (2) The system will not depend on potentially unreliable WiFi and Bluetooth signals. (3) There will be minimal latencies. (4) Operation of the system will be immediately comprehensible to visitors. (5) The system will directly connect to the neuroscientific couture project, which also uses an aperture-based system in the interoceptive sunglasses.

**Potential Challenges:** (1) The mechanical system will need to be built in a way that is reliable over a long period of time with minimal maintenance. (2) The shutter system will need to be smooth enough to be breath-controlled.

**Potential Disadvantages:** (1) Everything will be manual (though this may also be an advantage for the reasons articulated in the overview). (2) The experience will be limited to breathing sessions (though this may enhance the absurdism in a desirable way).

**Potential Next Steps:** (1) Test the visual effects of shutter-actuated dimming. (2) Prototype one breath-controlled shutter mechanism.

### **References for App Development**

iOS API / SDKs: <https://developer.apple.com/ios/>

Android API / SDKs: <http://developer.android.com/index.html>

Philips Hue API / SDKs: <http://www.developers.meethue.com/>

Estimote API / SDKs: <http://developer.estimote.com/>

Spire Website: <https://www.spire.io/>

Hue Disco App: <http://www.vandenbrakel.nl/app/hue-disco/>

Hue Party App: <http://hueparty.com/>

IFTTT Maker Space: <https://ifttt.com/maker>

### **Triggers and Actions for Hue/Estimote/Spire App Configuration**

If User A is in sector  $x,y$  (as defined by Smartphone A triangulating user location relative to fixed Estimote beacons), then Smartphone A sends Hue-readable breathing data from Spire A to the Hue lightbulb assigned to sector  $x,y$ . If User A moves to sector  $x_1y_1$ , then Smartphone A stops sending breathing data to the Hue lightbulb assigned to sector  $x,y$  and starts sending the data to the bulb assigned to sector  $x_1y_1$ . Note: To be Hue-readable, Spire breathing data must be converted into a Hue dimming command (with inhalation increasing brightness and exhalation decreasing brightness). Breathing must be converted to dimming in realtime (with a latency of less than 0.5 seconds). A latency of up to 1 minute is acceptable for triggering of lighting by locational beacons.

# THE NEUROSCIENTIFIC WORKPLACE

## Potential Technical Approaches

by Jonathon Keats  
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### Overview

Four different approaches to the Neuroscientific Workplace are outlined below. These are organized by degree of automation, with the most automated version described first. Each of these descriptions enumerates specific advantages and disadvantages. In general, the advantage to greater automation is that more technically advanced systems will accentuate the plausibility of neuroscientific control entering the workplace in the near future. The advantage to less automation is that more awkwardly primitive systems will accentuate the philosophical implications. Aspects of these systems may potentially be combined. Also, regardless of which system is installed, prototypes of other versions may also be exhibited.

### I. Philips Hue / Estimote / Spire / Smartphone

**Concept:** Based on triangulation of Estimote beacons, a smartphone app triggers Spire to control dimming of a given Hue color bulb in time with a given user's breathing. Bulb color is preset to simulate blacklight using the Hue app. (Alternately a Hue white light bulb is used in combination with an LED-color-corrected Congo Blue gel.) See below for more detailed specs.

**Potential Advantages:** (1) The system is purely electronic, integrating existing open-API hardware. (2) The system will work without the need for UV dyes.

**Potential Challenges:** (1) An app will need to be developed to integrate these systems. (2) System latencies will need to be minimized. (3) AC power will be required in the conversational pod. (4) Most apps that actively control Hue require that the smartphone always be on with the app launched, rapidly draining the battery.

**Potential Disadvantages:** Neither Hue bulbs nor filters can emit a true UV light.

**Potential Next Steps:** (1) Determine feasibility of app development given hardware APIs and development costs. (2) Reengage Spire. (3) Test white light / gel combination.

### II. Philips Hue / Estimote / Smartphone / Microphone / Stethoscope

**Concept:** Dimming of a given set of Hue bulbs is controlled by a user's smartphone using a preexisting Hue app such as Hue Disco or Hue Party. These apps correlate dimming with microphone sound level. For purposes of the Neuroscientific Workplace, a stethoscope diaphragm is modified to be worn under the shirt and implanted with a microphone that plugs into the user's smartphone. The relevant Hue bulb from the user set is activated based on the user's proximity to an Estimote beacon (as triggered by IFTTT). An alternative to the use of stethoscope and disco app would be to modify a Hue dimmer remote control to be actuated by breathing. Bulb color is preset to simulate blacklight using the Hue app. (Alternately a Hue white light bulb is used in combination with a Congo Blue gel.)

**Potential Advantages:** The system uses working off-the-shelf software, which is likely to be more stable than custom software.

**Potential Challenges:** (1) Input from the stethoscope may be noisy. (2) Controls for these apps tend to be limited, which may make the desired effect difficult to achieve. (Hue white light bulbs with gels may be easier to work with.) (3) System latencies will need to be minimized. (4) Most apps that actively control Hue require that the smartphone always be on with the app launched, rapidly draining the battery.

**Potential Disadvantages:** (1) Each user will require a separate Hue bridge and bulb set. (2) Seating will need to be preassigned or multiple bulbs will be required in each location. (3) Neither Hue bulbs nor filters can emit a true UV light.

**Potential Next Steps:** (1) Prototype one stethoscope device and experiment with the stethoscope device and disco apps. (2) Experiment with modifications to the Hue fader remote control. (3) Test white light / gel combination.

### **III. Battery-Powered Ultraviolet LEDs / Force Sensitive Resistors**

**Concept:** Battery-powered ultraviolet LED fixtures are dimmed by controlling battery current with wearable force-sensitive resistors (FSRs). Each user wears an FSR under the belt or bra. The FSR has a cord that the user must manually connect to the appropriate lighting fixture, causing the fixture to dim in time with breathing. (Alternately LED power might be controlled by a plug-in version of the stethoscope/microphone setup described above.)

**Potential Advantages:** (1) The system will emit true UV light, creating more selective glow of both bleached clothing and UV-dyed hands. (2) The system will not need to be plugged into a wall socket and also will not depend on potentially unreliable WiFi and Bluetooth signals. (3) There will be minimal latencies.

**Potential Challenges:** (1) Input from FSRs may be noisy. (2) Resistance-based LED dimming may be problematic.

**Potential Disadvantages:** (1) Users will need to plug in rather than being automatically connected (though this may also be an advantage for the reasons articulated in the overview). (2) Batteries will need to be recharged on a regular basis.

**Potential Next Steps:** (1) Test the dimming capabilities of battery-powered UV LEDs. (2) Prototype one FSR-controlled lighting fixture.

### **IV. Compact Fluorescent Blacklights / Mechanical Apertures / Breathing Masks**

**Concept:** Dimming is manually actuated by breathing into a tube through a breathing mask, with inhalation and exhalation powering the motion of a radial shutter apparatus affixed in front of a compact fluorescent blacklight fixture. Users engage in brief breathing sessions at the start of a collaborative engagement and as needed for purposes of concentration during solo work.

**Potential Advantages:** (1) The system will emit true UV light, creating more selective glow of both bleached clothing and UV-dyed hands. (2) The system will not depend on potentially unreliable WiFi and Bluetooth signals. (3) There will be minimal latencies. (4) Operation of the system will be immediately comprehensible to visitors. (5) The system will directly connect to the neuroscientific couture project, which also uses an aperture-based system in the interoceptive sunglasses.

**Potential Challenges:** (1) The mechanical system will need to be built in a way that is reliable over a long period of time with minimal maintenance. (2) The shutter system will need to be smooth enough to be breath-controlled.

**Potential Disadvantages:** (1) Everything will be manual (though this may also be an advantage for the reasons articulated in the overview). (2) The experience will be limited to breathing sessions (though this may enhance the absurdism in a desirable way).

**Potential Next Steps:** (1) Test the visual effects of shutter-actuated dimming. (2) Prototype one breath-controlled shutter mechanism.

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