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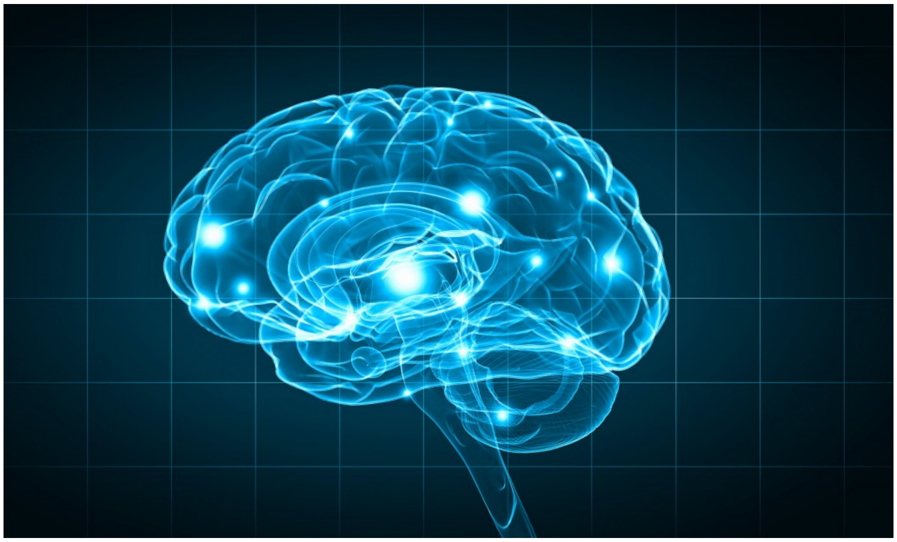

How Close Are We To Being Able To Model the Brain?

By Jeffrey M. Bradshaw · July 4, 2016

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Editor's Note: The following is Part 5 in a series that expands upon a presentation given at the Second Interpreter Science and Mormonism Symposium: Body, Brain, Mind, and Spirit at Utah Valley University in Orem, Utah, 12 March 2016. A book based on the first symposium, held in 2013, has recently been published as Bailey, David H., Jeffrey M. Bradshaw, John H. Lewis, Gregory L. Smith, and Michael L. Stark. Science and Mormonism: Cosmos, Earth, and Man. Orem and Salt Lake City, UT: The Interpreter Foundation and Eborn Books, 2016. For more information, including free videos of these events, see http://www.mormoninterpreter.com. To see the previous article, click here.

In the previous article in this series, we assessed the prospects of success of programs that seek to enhance or ultimately re-embody the brain in silicon, concluding that nearly every mainstream scientist who studies the topic agrees, at least, that the many remaining challenges will not be overcome "in the near future."[i] Among these difficulties is the fact that before you can upload a brain, you need to be able to model it adequately. In this article we touch briefly on two examples, human vision and memory, to illustrate the formidable challenge of modeling the brain's structure and functions.

The Challenge of Modeling the Structure of the Brain

Figure 1[ii]

In January 2014, I took this photo outside the headquarters of the Defense Science Organization (DSO) in Singapore. It was created in 2003 by a famous local sculptor named Han Sai Por (1943-) who entitled it *Tropical Brain Forest*. Originally, the brains were painted brightly in pink and green to mirror the theme. Although the foldings of the cerebral cortex are beautiful to behold, the real complexity of the brain cannot, of course, be fully appreciated from a superficial perspective.

Figure 2[iii]

Three months later, I paid a visit to Jim Olds, Director of the Krasnow Institute for Advanced Study at George Washington University, head of the Directorate for Biological Sciences for the National Science Foundation, with whom I had served on the External Advisory Board for the Cognitive Science Program at Sandia National Laboratory. He showed me this 2012 sculpture, entitled *Mental Floss*. The sculpture is a network model of just a small part of a rodent brain, the hippocampus.

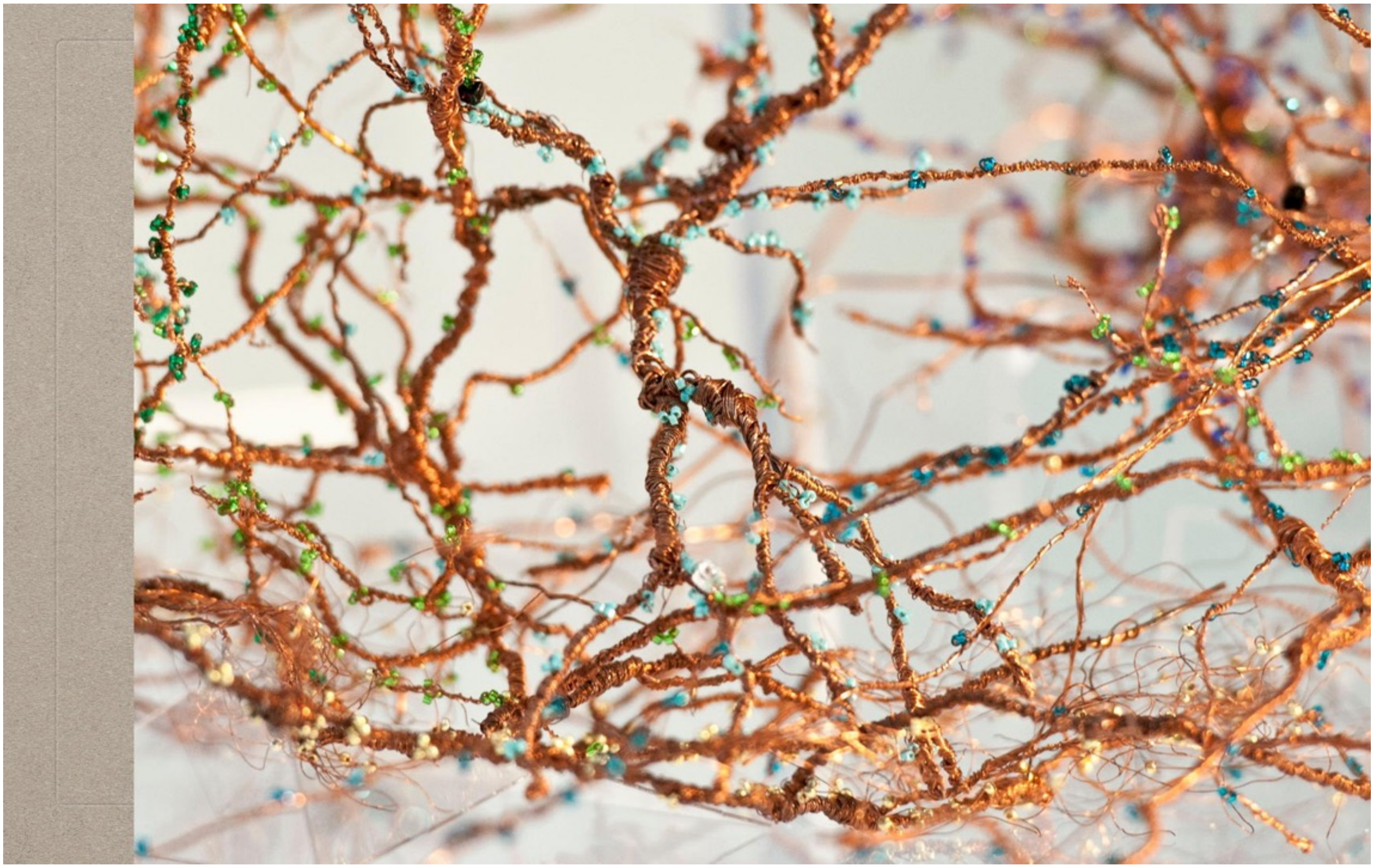

Figure 3[iv]

This photo gives some idea of the detailed work that went into the making of the sculpture:[v]

> The team [who created the sculpture, led by Professor Giorgio A. Ascoli,] selected 13 representative neuronal morphologies of the major hippocampal areas (dentate gyrus, CA3, CA1, and enthorhinal cortex), color-coding their complex axons (output trees) and dendrites (input trees).

Figure 4[vi]

> The neurons were scaled and registered in virtual reality against a three-dimensional reconstruction of the rodent hippocampus. … The resulting model included excitatory projection neurons, inhibitory local neurons, and a sample of their characteristic potential circuit neurons.

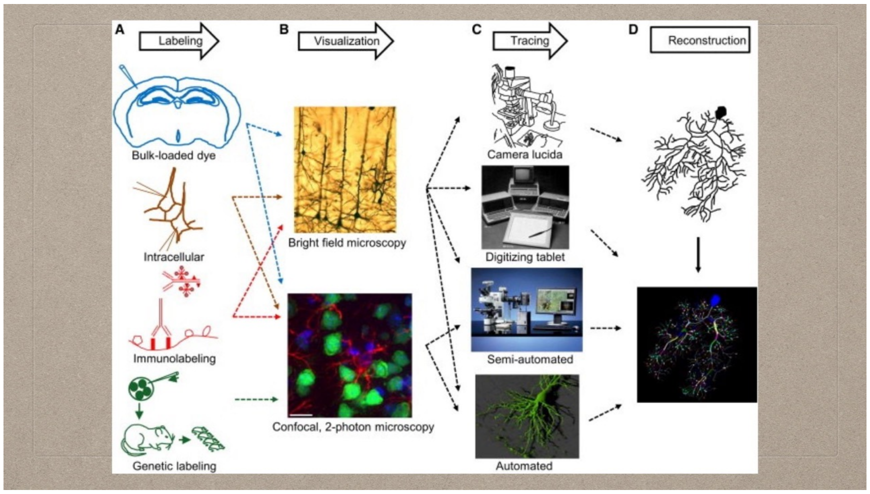

Figure 5[vii]

The research of Professor Ascoli and his colleagues "aims to understand how the brain relates to the mind at the level of neuronal morphology – the "shape" of nerve cells"[viii] — and its effect on neuronal electrophysiology.[ix] Although the 100 billion neurons in our brains share a basic structure, they "are not exactly similar, and in fact have an astonishing diversity that leaves scientists with much to discover."[x] By way of contrast to the relatively simple and uniform models of so-called "neural networks" that are typically used in today's computer simulations, "over the past ten years, [Ascoli's] group has [developed] 3D digital reconstructions of over 35,000 neurons from dozens of species and brain regions and [the number of different models] continues to grow."[xi] And, of course, a better understanding of brain structure will require much further study, not only at the neuronal level at which Ascoli's team is working, but also at the level of larger, hierarchically organized structures within the brain.

As thrilling as are the many current attempts to implement massively parallel computing architectures capable of packing the requisite number of "neurons" into a small, low-power package,[xii] building a brain is much more than scaling up the number of processors while scaling down their size and power requirements — as credible mainstream scientists are well aware.[xiii]

The Challenge of Modeling the Functions of the Brain

Although the focus of many researchers to date has been on replicating the detailed *structure* of the human brain, we should not forget the equally or perhaps more daunting challenge of understanding how the brain *works*: reproducing the complex details of its *functions* and *processes*.

There are many popular, persistent myths about the way the brain works — for example the erroneous idea that we only use a small percentage of the brain[xiv] or exaggerated notions about people being right-brained or left-brained.[xv] Here, I will touch briefly on only two of these: 1) the myth that the human visual system works like a simple camera; and 2) the myth that human memory works like today's computer "memory."

Figure 6[xvi]

The first thing to know about such human sensory and cognitive processes is that they are active, not passive. Visual data is not simply taken in passively as in a simple camera that focuses the light from an entire scene through the lens and onto a sensor; memory is not laid down in the brain as simple traces of experience that, in principle, could be retrieved intact at a later time, like fixed configurations of bits in computer memory. Instead, the brain relies not only on complex feedback mechanisms that shape learning based on *past* experience, but also on feedforward mechanisms that direct cognitive processes by *anticipating future experience*. As a rough analogy you can think of these feedforward mechanisms as if they were part of an automatic railroad track laying system like the one shown above that first lays out the track ahead of itself, and then follows the track it has made in order to control its forward movement.[xvii]

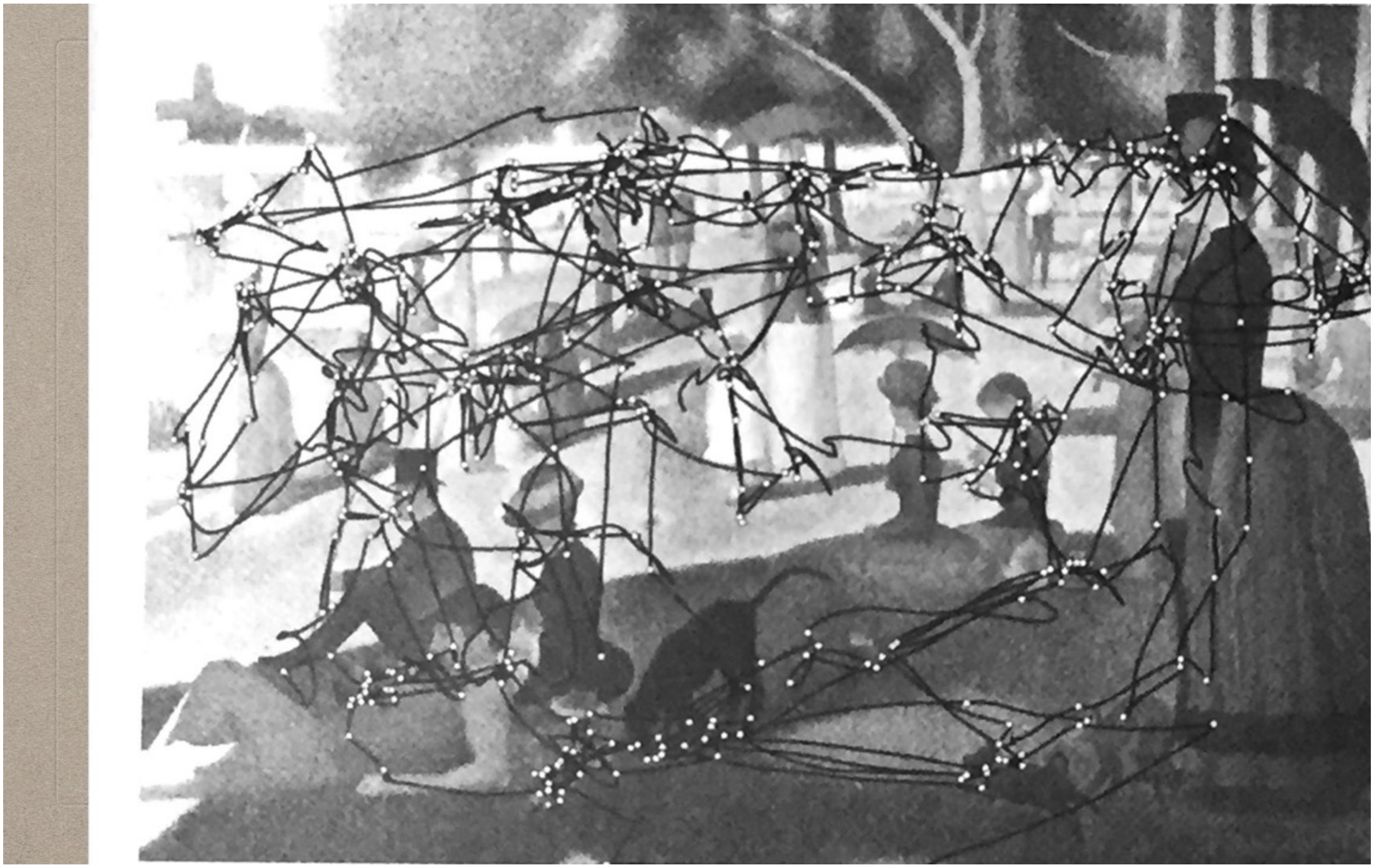

Figure 7[xviii]

Active vision: The eye is not a simple camera. As a first example of the active, feedforward nature of human cognition, consider this figure, from an overview of brain mechanisms for active vision written by Robert H. Wurtz, a National Institutes of Health Distinguished Investigator at the National Eye Institute. The image is a record of eye gaze for a human viewer looking at Georges Seurat's famous painting *Sunday on the Island of La Grande Jatte* for three minutes. "Saccades[, rapid eye movements that occur two or three times each second,] are represented by black lines, and intervening periods when the eyes are stationary (fixations) are represented by white circles. … Note that the fixations are not to random locations, but rather to points of likely interest"[xix] which, of course, may change, even for the same person at different times and in different contexts. "Why bother with all these saccades? Why not just hold the eye steady and inspect the painting?"[xx] To answer these questions, one must know something about the varying resolution of the retina, the surface at the back of the eye that receives light:[xxi]

> The retina is equipped with receptors that respond to light, dark, and color, but it does not have uniform resolution across its surface. The highest receptor density is found in the central region of the retina, called the fovea, which gives us the highest visual resolution and enables us to see small details. Retinal areas outside this central region, responding to light from the periphery, have a lower density of receptors and therefore lower resolution. Thus, the viewer enjoying the Seurat painting is essentially using the fovea to examine the rich detail, jumping from one part of the painting to another. In the three minutes of saccades shown in [the figure], the viewer examines the details in a substantial fraction of the painting, but never sees the whole scene at once.
>
> How do subjects pick the next object to examine? Using their peripheral retina, subjects can see objects in the field at a relatively low resolution and select ones of potential interest to examine next. This shift of attention from one item to the next accompanies each saccade. This selection is not random: if we look at the saccades superimposed on the Seurat painting, we can see that the trees at the top of the painting and the grass at the bottom are largely ignored; in contrast, faces, dresses, and other significant objects are frequently inspected. …
>
> The goal of … saccades is to bring images to the fovea for detailed analysis. Even though these saccades displace the image of the whole visual field on the retina, the system operates so perfectly that we regard the scene as serenely stable.

In short, the eye and brain work together much differently than does a simple camera. And, as complex as what we have described above may seem, Wurtz points out that the many components that underlie active vision are "only a small part of the larger brain systems involved with sensation and motor control. In turn, the puzzle of how these systems operate to produce action is just one of many global questions about how the brain produces all behavior, including learning, memory, and emotion; and even how consciousness arises from brain activity."[xxii] But since the state of the art in current research on these topics still leaves many important questions unanswered, Wurtz admits that he has no choice but to rely on "the classic approach of reducing the overwhelming complexities of the brain to more easily understood fragments" by considering active vision in isolation.[xxiii]

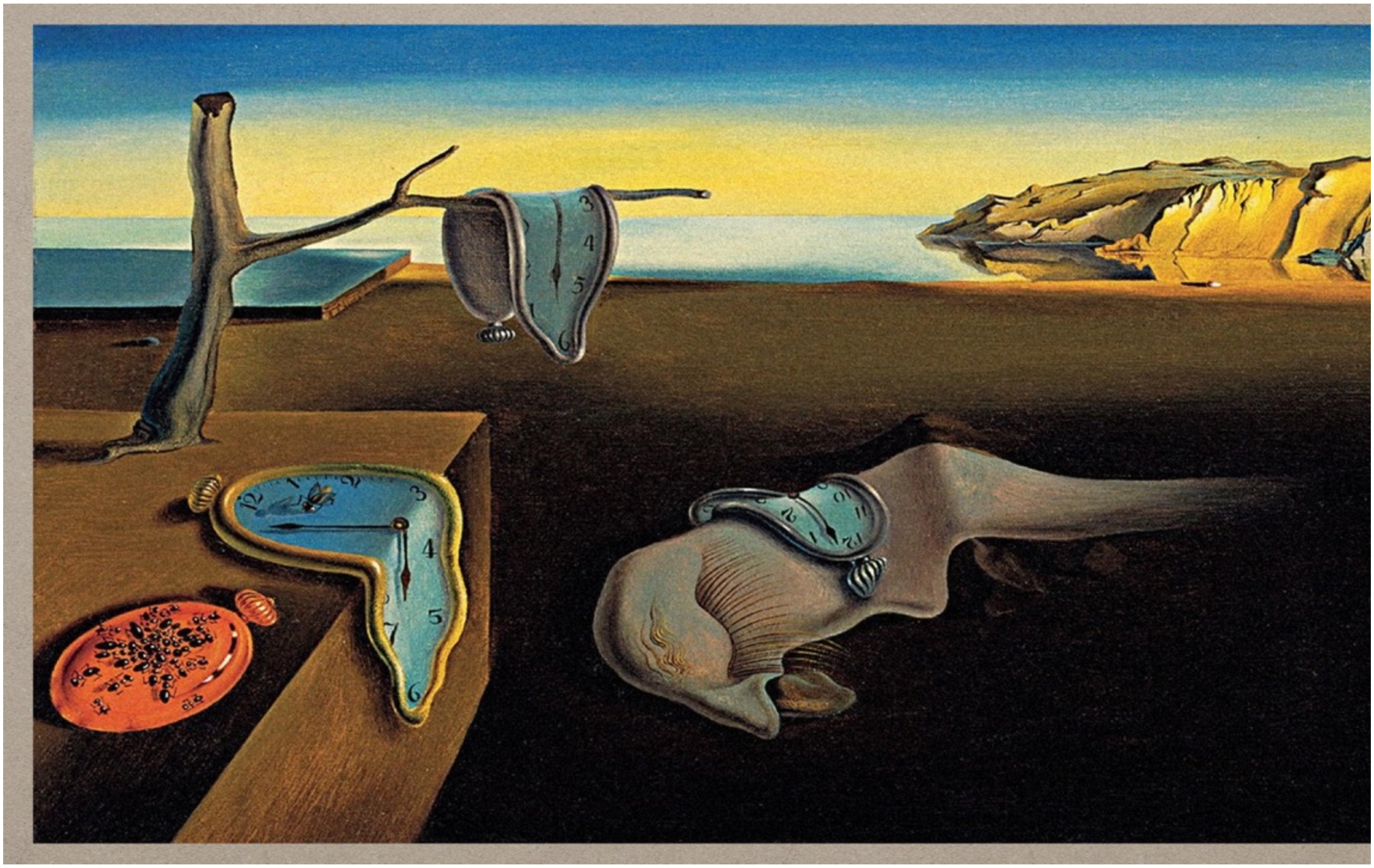

Figure 8[xxiv]

Reconstructive memory: The brain is not a simple canvas. As a second example of the active, feedforward nature of human cognition, consider the complex and still somewhat mysterious phenomenon of memory. Salvador Dali's famous images of the pliable, melting pocket watches make a fitting representation of the contrast between a naïve, static perception of time and events and the actual fluid and dynamic nature of memory.

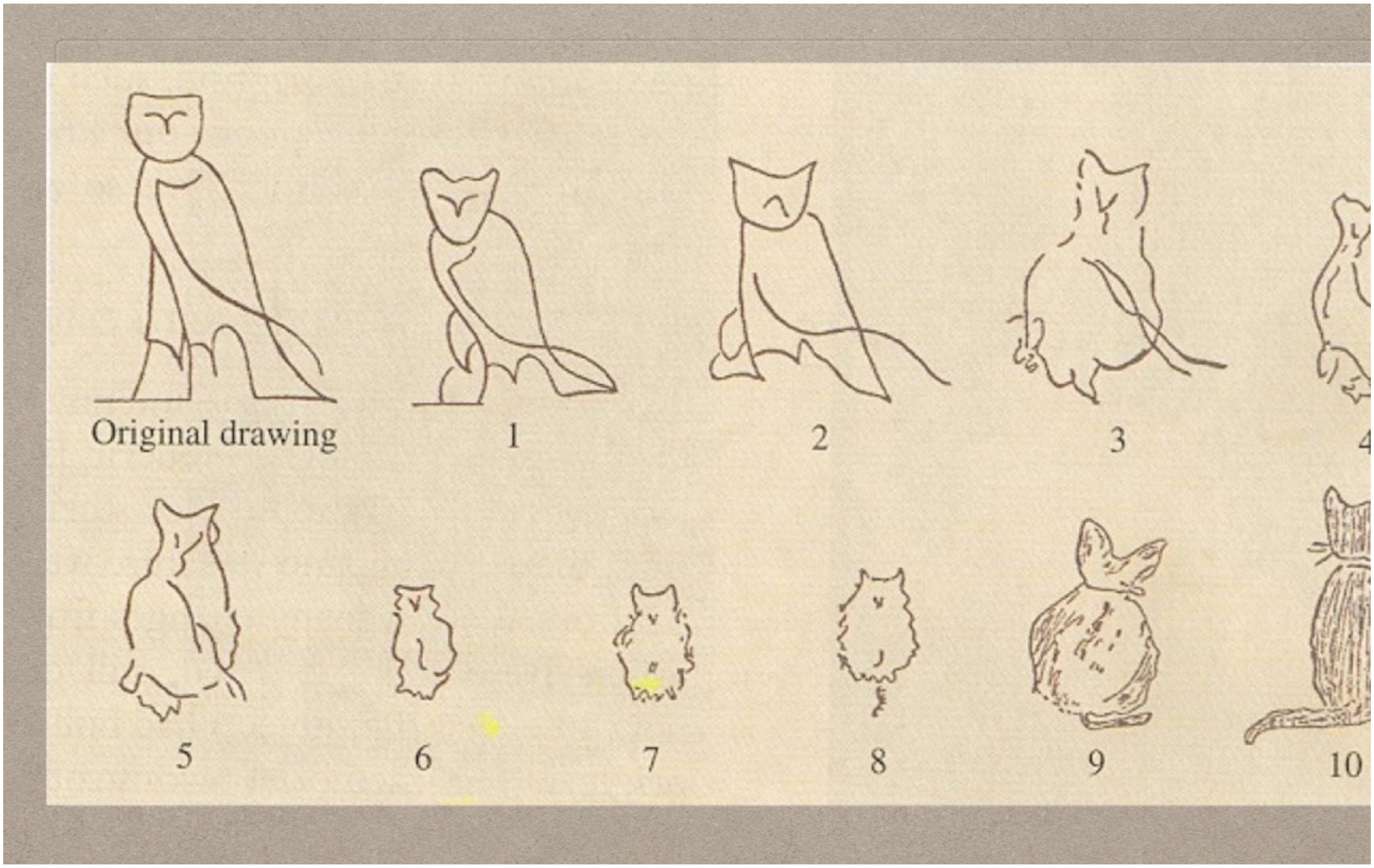

Figure 9[xxv]

Pioneering studies of the fluid and dynamic nature of memory were made early in the 20th century by the British experimental psychologist, Frederic C. Bartlett (1886-1969).[xxvi] His experiments on how people remembered stories and pictures over time showed that the "accuracy" of memory was not simply a function of some original, pristine trace gradually fading away, similar to what happens when a photographic print is continuously exposed to sunlight. Rather, Bartlett showed that the reason our recall of complex scenes, narratives, or situations becomes confused is because every perception and every memory is made in the context of our knowledge, emotions, motivations, and expectations at the time of the experience. Moreover, our memories of the past are unconsciously associated and colored with later attitudes and memories laid down *after the fact* in a way that sometimes makes it nearly impossible to tease them out:[xxvii]

> Bartlett's participants were asked to reproduce stories taken from the folklore of other cultures; thus, their content and structure were rather strange to Western ears. The reproductions showed many changes from the original. Some parts were subtracted, others were overelaborated, and still others were additions that were completely new. In effect, the participants had built a new story upon the memorial ruins of the original. This memorial reconstruction was generally more in line with the cultural conceptions of the subjects than with the story they had actually heard. For example, certain supernatural plot elements were interpreted along more familiar lines. In a variant of the same experiment, Bartlett used the method of serial reproduction. A drawing was presented to one participant, who reproduced it from memory for the benefit of a second, whose reproduction was shown to a third, and so on for a chain of up to ten participants [as shown above].[xxviii] With this technique (an experimental analogue of rumor transmission), each participant's memorial distortion became part of the stimulus for the next one down the line; the effect was to grossly amplify the reconstructive alteration.

The important takeaway is not the obvious fact that memory distortions occurred, but rather that the *kinds* of distortions were predictably in the direction of what people expect to see rather than simply a fading away of what they saw.[xxix] Hence, the final drawing of the cat eliminates the unusual, foreign aspects of the original drawing in favor of a conventional rendering that would be recognized by most people in a Western culture today.

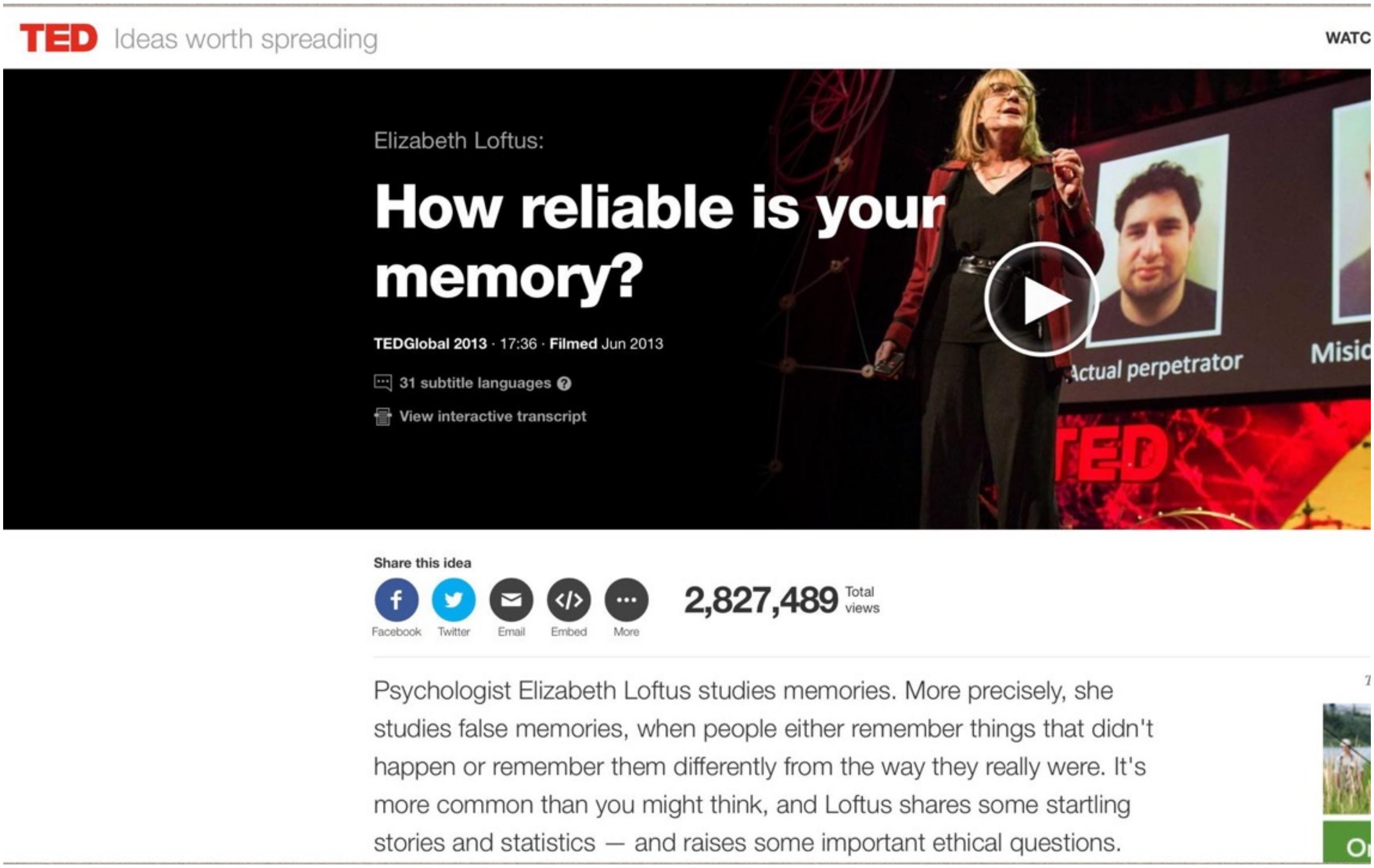

Figure 10[xxx]

My own introduction to this subject came through exposure to the research of Elizabeth Loftus, who recognized and demonstrated the implications of the workings of human memory for situations such as eyewitness testimony or hypnosis, where false presuppositions and suggestions planted after the fact often came to be remembered as if they had been part of the original experience. The following summary of Loftus' accomplishments accompanied a 2013 TED talk that I highly recommend to anyone interested in this subject:[xxxi]

> Elizabeth Loftus altered the course of legal history by revealing that memory is not only unreliable, but also mutable. Since the 1970s, Loftus has created an impressive body of scholarly work and has appeared as an expert witness in hundreds of courtrooms, bolstering the cases of defendants facing criminal charges based on eyewitness testimony, and debunking "recovered memory" theories popular at the time, as in her book *The Myth of Repressed Memory: False Memories and Allegations of Sexual Abuse* (with Katherine Ketcham).

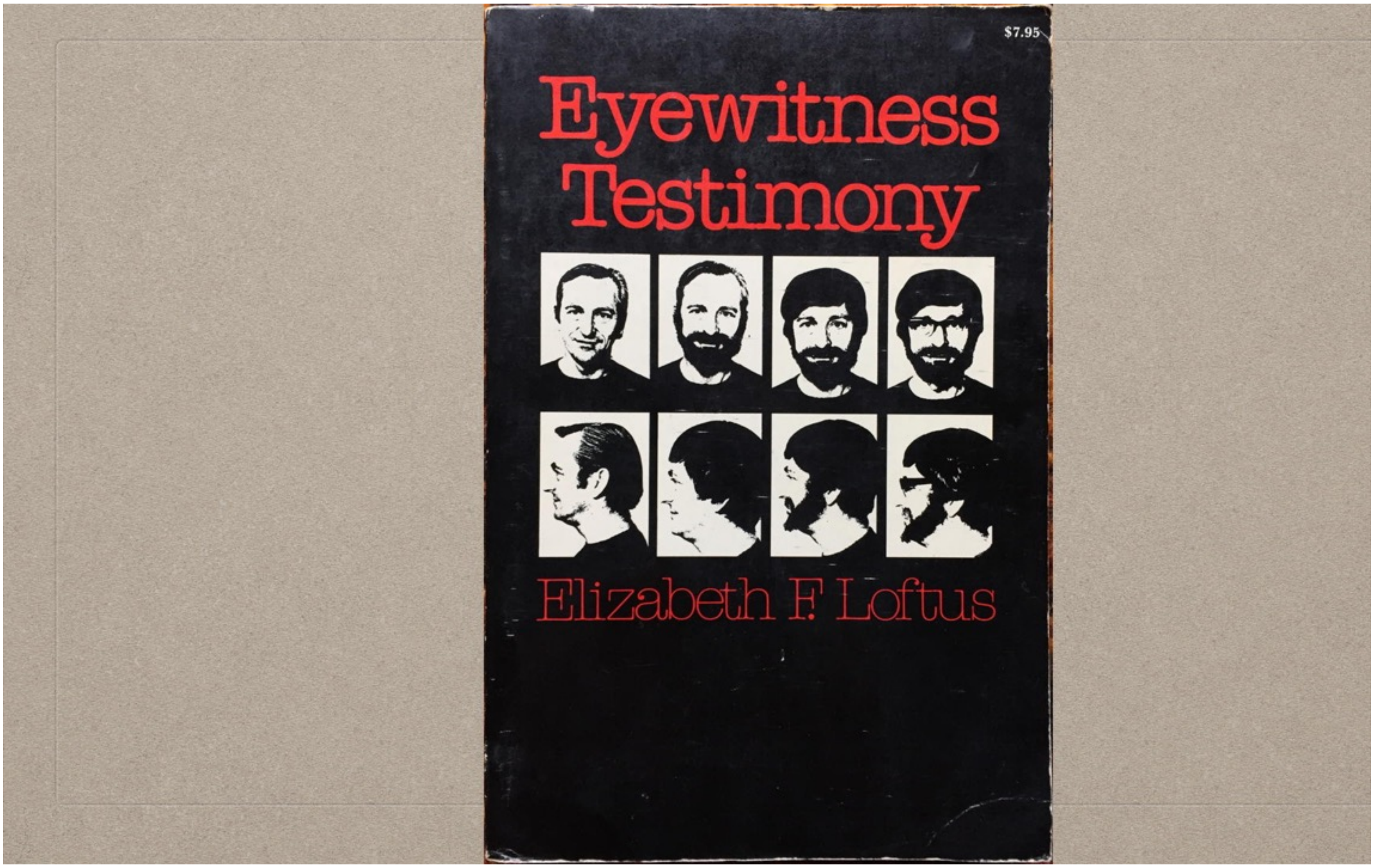

Figure 11[xxxii]

Loftus' early experiments on eyewitness testimony showed:[xxxiii]

> that when people who witness an event are later exposed to new and misleading information about it, their recollections often become distorted. In one example, participants viewed a simulated automobile accident at an intersection with a stop sign. After the viewing, half the participants received a suggestion that the traffic sign was a yield sign. When asked later what traffic sign they remembered seeing at the intersection, those who had been given the suggestion tended to claim that they had seen a yield sign. Those who had not received the phony information were much more accurate in their recollection of the traffic sign.

As an undergraduate at the University of Utah, I was invited by David Dodd to help carry out a variant of this experiment where we showed that Loftus' results sometimes may have been exaggerated by the way misleading information was introduced to her subjects.[xxxiv] A few years later, after beginning graduate school at the University of Washington, I was fortunate to serve as a teaching assistant for one of her courses, one of the most engaging I have ever attended.

On one occasion, a purse snatching occurred during the first few minutes of class. Unbeknownst to the students, this event had been staged deliberately. As the event was unfolding, stooges in the lecture hall shouted out misleading information, such as "Grab that guy with the moustache!" although the individual fleeing the room had no moustache. Later, when candidates for the "crime" were lined up in front of the class, people remembered having *seen* the moustache on the culprit, even though the misleading information had come through verbal rather than visual channels. The source of the false information had been forgotten and the verbal information had become inextricably associated with the visual memory.

The point of the preceding example is to illustrate a small part of the complexity and interrelatedness of higher cognitive functions such as learning, memory, emotion, and consciousness. The brain is not a simple canvas on which experience is passively written and recalled. Those who aspire to someday upload a fully functioning human mind to a computer inevitably will have to rely on complete, high-fidelity models of the structure and function of the human brain in general, and of an individual human brain in particular. Such models do not now exist.

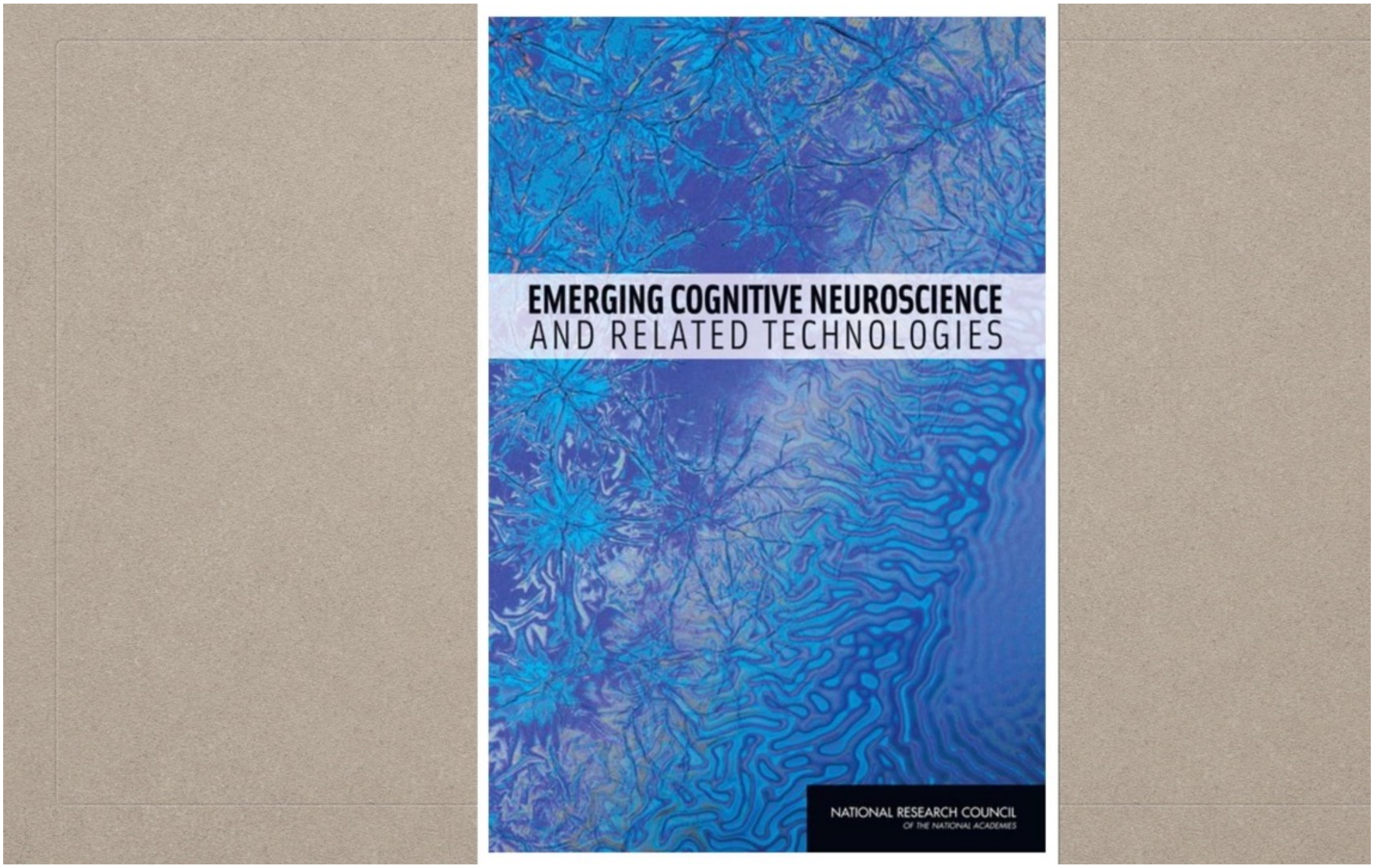

Figure 12[xxxv]

More than twenty years after my experience as a teaching assistant for Elizabeth Loftus, I served with her as part of a 2008 National Academies study of the future of cognitive neuroscience and related technologies. As part of our committee's summary on the topic of modeling and building the equivalent of a human brain, I wrote the following:[xxxvi]

> [Despite the impressive increases in high-end computing], there does not yet exist either an adequate and detailed understanding of *how* … modeling [of the human brain] can be done, or a complete model of how the brain interacts with complex regulatory and monitoring systems throughout the body. These and other difficulties make it highly unlikely that in the next two decades anyone could build a neurophysiologically plausible model of the whole brain and its array of specialized and general-purpose higher cognitive functions.[xxxvii]

Mark Changizi, an evolutionary neurobiologist, is even more cautious in his predictions. In his article entitled "Artificial Brains: Not In This Century" he writes:[xxxviii]

> Maybe I'm a buzz kill. But I prefer to say that it's important to kill the bad buzz, for it obscures all the justified buzz that's ahead of us in neuroscience and artificial intelligence. And there's a lot. Building artificial brains may be a part of our future — though I'm not convinced — but for the foreseeable, century-scale future, I see only fizzle.

(To be continued in Part 6)

References

Artificial Brains: The Quest to Build Sentient Machines. In *Artificial Brains*. http://www.artificialbrains.com. (accessed June 29, 2016).

Bansal, Sonia. 2016. Navigating the brain forest: Center for Neural Informatics, Structures, and Plasticity, Krasnow Institute for Advanced Study, George Mason University (28 March 2016). In *Showcasing DC Area Research, SfN, DC Metro Area Chapter*. https://sites.google.com/site/sfndcma/dc-area-research. (accessed June 1, 2016).

Bartlett, Frederic C. *Remembering: A Study in Experimental and Social Psychology*. Cambridge, England: Cambridge University Press, 1932. http://www.bartlett.psychol.cam.ac.uk/RememberingBook.htm.

Bostrom, Nick. *Superintelligence: Paths, Dangers, Strategies*. Oxford, England: Oxford University Press, 2014.

The BRAIN Initiative (Brain Research through Advancing Innovative Neurotechnologies). In *The BRAIN Initiative (Brain Research through Advancing Innovative Neurotechnologies)*. https://www.whitehouse.gov/BRAIN. (accessed June 29, 2016).

Changizi, Mark. 2012. Artificial brains: Not in this century. In *The Huffington Post*. http://www.huffingtonpost.com/mark-changizi-phd/artificial-brains-not-in-_b_1248948.html.

(accessed June 24, 2016).

Clarke, Arthur C. "The future isn't what it used to be." *Engineering and Science* 33, no. 7 (1970): 4-9. http://resolver.caltech.edu/CaltechES:33.7.clarke. (accessed September 18, 2015).

Dodd, D. H., and J. M. Bradshaw. "Leading questions and memory: Pragmatic constraints." *Journal of Verbal Learning and Verbal Behavior* 19 (1980): 695-704.

Ford, K.M., J.M. Bradshaw, J.R. Adams-Webber, and N.M. Agnew. "Knowledge acquisition as a constructive modeling activity." In *Knowledge Acquisition as Modeling,* edited by K.M. Ford and J.M. Bradshaw, 9-32. New York: John Wiley, 1993.

Furber, Steve. "To build a brain." *IEEE Spectrum* (August 2012): 45-49.

Gage, Fred H. *What is the brain good for? Special issue of Daedalus: Journal of the American Academy of Arts and Science* 144:1, 2015.

Green, Christopher C., Diane E. Griffin, James J. Blascovich, Jeffrey M. Bradshaw, Scott C. Bunch, John Gannon, Michael Gazzaniga, Elizabeth Loftus, Gregory J. Moore, Jonathan Moreno, John R. Rasure, Mark (Danny) Rintoul, Nathan D. Schwade, Ronald L. Smith, Karen S. Walch, and Alice M. Young. *Emerging Cognitive Neuroscience and Related Technologies. A Report of the Committee on Military and Intelligence Methodology for Emergent Neurophysiological and Cognitive/Neural Science Research in the Next Two Decades*. Washington, DC: The National Academies Press, 2008. http://www.nap.edu/catalog/12177/emerging-cognitive-neuroscience-and-related-technologies. (accessed March 5, 2016).

Human Brain Project. In *APT Advanced Processor Technologies Research Group*. http://apt.cs.manchester.ac.uk/projects/HBP/. (accessed June 29, 2016).

Jobs, Steve. 1983. The future isn't what it used to be (Presentation to the *International Design Conference in Aspen (IDCA)*, 15 June 1983). In *Soundcloud*. https://w.soundcloud.com/player/?url=http%3A%2F%2Fapi.soundcloud.com%2Ftracks%2F62010118&show_artwork=true. (accessed September 18, 2015).

Koene, Randal A. "Feasible mind uploading." In *Intelligence Unbound: The Future of Uploaded and Machine Minds,* edited by Russell Blackford and Damien Broderick, 90-101. Chichester, West Sussex, England: John Wiley, 2014.

Lewis, C. S. 1946. *The Great Divorce*. New York City, NY: Touchstone, 1996.

Loftus, Elizabeth. *Eyewitness Testimony*. Cambridge, MA: Harvard University Press, 1979.

———. "Creating false memories." *Scientific American* 277, no. 3 (September 1997): 70-75. http://faculty.washington.edu/eloftus/Articles/sciam.htm. (accessed June 24, 2016).

———. 2013. How reliable is your memory? In *TED Talks*. https://www.ted.com/speakers/elizabeth_loftus. (accessed June 11, 2016).

McDermott, Drew. "Artificial Intelligence meets natural stupidity." *SIGART Newsletter*, no. 57 (1976): 4-9.

The most influential experiments on memory. In *Memory Distortions*. http://socialscientist.us/nphs/psychIB/psychpdfs/MemoryDistortions.pdf. (accessed June 29, 2016).

Parekh, R., and Giorgio A. Ascoli. "Neuronal morphology goes digital: A research hub for cellular and system neuroscience." *Neuron* 77, no. 6 (2013): 1017-38.

Probst, Catherine. 2012. 'Mental Floss' project brings artists and scientists together (12 December 2012). In *Mason News*. http://tgillette.onair.cc/2013/08/11/mental-floss-project-brings-artists-and-scientists-together/. (accessed June 1, 2016).

Quatrochi, Alice M., and Giorgio A. Ascoli. "Mental Floss – 2012. Paper handout created to accompany the sculpture display." 2012.

Valéry, Paul. 1937. "Our destiny and literature." In *Reflections on the World Today*. Translated by Francis Scarfe, 131-55. New York City, NY: Pantheon Books, 1948.

Wellington, Naomi. "Whole brain emulation: Invasive vs. non-invasive methods." In *Intelligence Unbound: The Future of Uploaded and Machine Minds,* edited by Russell Blackford and Damien Broderick, 178-92. Chichester, West Sussex, England: John Wiley, 2014.

Wurtz, Robert H. "Brain mechanisms for active vision." *Daedalus: Journal of the American Academy of Arts & Sciences* 144, no. 1 (Winter 2015): 10-21.

[i] N. Bostrom, *Superintelligence*, p. 31. For examples of some of the preliminary thinking going on in this arena, see R. A. Koene, Feasible Mind Uploading; N. Wellington, Whole Brain Emulation; N. Bostrom, *Superintelligence*, pp. 30-36.

[ii] Photograph by Jeffrey M. Bradshaw, DSC05961.JPG, 14 January 2014.

[iii] Photograph by Jeffrey M. Bradshaw, IMG_1808.JPG, 10 April 2014.

[iv] Photo by Evan Cantwell/Creative Services/George Mason University, 120618506E.jpg, 4 February 2015. http://gmu.smugmug.com/keyword/mental%20floss/i-XQrwdfs, accessed June 1, 2016.

[v] A. M. Quatrochi et al., Mental Floss – 2012. Paper handout created to accompany the sculpture display.

[vi] Photo by Evan Cantwell/Creative Services/George Mason University, 120607018.jpg, 4 February 2015. http://gmu.smugmug.com/keyword/mental%20floss/i-XQrwdfs (accessed June 1, 2016).

[vii] From R. Parekh et al., Neuronal Morphology, as reproduced in S. Bansal, Navigating the Brain Forest.

[viii] C. Probst, Mental Floss.

[ix] S. Bansal, Navigating the Brain Forest.

[x] Ibid.

[xi] Ibid.

[xii] E.g., S. Furber, To Build. In contrast to less-well-grounded researchers, Furber admits that developing a suitable computing architecture is only one of the many parts of the foundation that needs to be laid in order to "build a brain" (ibid., p. 49):

SpiNNaker won't get us all the way to full-scale simulations of the human brain. But the machine's communications architecture could help pave the way for better-networked analog chips that could get us there. It will also help show us what information we need to make good models. Then we can really put our brains to use.

[xiii] Significant large initiatives to understand and model the brain are currently underway. For example, the SpiNNaker computing platform described by Furber is part of a pan-European initiative called the Human Brain Project that began in October 2013 and is projected to last for ten years with a projected cost of one billion euros (Human Brain Project, Human Brain Project).

In April 2013, the US White House announced the Brain Research through Advancing Innovative Neurotechnologies (BRAIN) initiative, which was to be guided by a twelve-year research strategy. Participating federal agencies include the National Institutes of Health (NIH), the National Science Foundation (NSF), the Defense Advanced Research Projects Agency (DARPA), and the US Food and Drug Administration (FDA). Partners include private foundations, research institutes, universities, and industry (BRAIN Initiative). For pointers to additional efforts of a similar nature, see, e.g., Artificial Brains, Artificial Brains.

[xiv] For an entertaining TEDEd video debunking this myth, see https://www.youtube.com/watch?v=5NubJ2ThK_U.

[xv] For a brief overview on this topic, see https://www.youtube.com/watch?v=yE6VTvxkhFs.

[xvi] From https://www.youtube.com/watch?v=i6VYuw52z-0 (accessed June 22, 2016).

[xvii] See, e.g., K. M. Ford et al., Knowledge acquisition as a constructive modeling activity, pp. 11-17. For an impressive example of an automatic track-laying machine, see https://www.youtube.com/watch?v=i6VYuw52z-0, https://www.youtube.com/watch?v=_MKcTbYDP7w (accessed June 22, 2016).

[xviii] R. H. Wurtz, Brain Mechanisms, p. 11, Figure 1.

[xix] Ibid., p. 11, Figure 1 caption.

[xx] Ibid., p. 11.

[xxi] Ibid., p. 11.

[xxii] Ibid., p. 12.

[xxiii] Ibid., p. 12.

[xxiv] Salvador Dali (1904-1989): *The Persistence of Memory*, 1931. In http://artearth.ru/news/painting/v-ekaterinburge-otkroetsya-vystavka-syurrealizma-posvyaschennaya-tvorchestvu-salvadora-dali (accessed June 29, 2016).

[xxv] Memory Distortions, after F. C. Bartlett, *Remembering*.

[xxvi] See, e.g., F. C. Bartlett, *Remembering*.

[xxvii] Memory Distortions.

[xxviii] F. C. Bartlett, *Remembering*.

[xxix] C. S. Lewis, *Divorce*, pp. 67-68 brilliantly imagines how this phenomenon might color our perceptions of events if we were allowed to witness the scenes of our mortal lives being played out retrospectively in heaven:

[We] cannot in [our] present state understand eternity … [but we] can get some likeness of it if [we] say that both good and evil, when fully grown, become retrospective. Not only [the light of the spirit world] but all this earthly past will have been Heaven to those who are saved. Not only the twilight in [the spirit prison], but all their life on earth too, will be seen by the damned to have been Hell. That is what mortals misunderstand. They say of some temporal suffering, "No future bliss can make up for it," not knowing that Heaven, once attained, will work backwards and turn even that agony into a glory. And of some sinful pleasure they say, "Let me but have *this* and I'll take the consequences;" little dreaming how damnation will spread back and back into their past and contaminate the pleasure of the sin. Both processes begin even before death. The good man's past begins to change so that his forgiven sins and remembered sorrows take on the quality of Heaven; the bad man's past already conforms to his badness and is filled only with dreariness. And that is why, at the end of all things … the Blessed will say "We have never lived anywhere except in Heaven," and the Lost "We were always in Hell." And both will speak truly.

[xxx] E. Loftus, How Reliable.

[xxxi] Ibid..

[xxxii] E. Loftus, *Eyewitness Testimony*.

[xxxiii] E. Loftus, Creating False Memories.

[xxxiv] D. H. Dodd et al., Leading Questions

[xxxv] C. C. Green et al., *Emerging Cognitive Neuroscience*.

[xxxvi] Ibid., p. 80.

[xxxvii] For a readable summary of the state of the art in the study of the nervous system and its functions, see F. H. Gage, What Is the Brain Good For?.

[xxxviii] M. Changizi, Artificial Brains.