ARTIST'S ARTICLE

Virtual Reality—Virtual Brain

Questioning Reality

TERESA WENNBERG

ABSTRACT

The author's multimedia art is inspired by memory and cognitive processes. This paper discusses certain human brain functions, including a reflection on the evolution from individual human memory to collective computer memory and the role of the artist in this vital change.

In 1997, invited to participate in the installation of VR at the Royal Institute of Technology KTH Stockholm, I produced my first 3D virtual reality work. This new way of experiencing "reality" had indeed already been introduced in the USA [1,2], but my *VR-Cube* at KTH was the biggest in Europe at the time, offering a complete six-sided virtual experience for up to eight visitors at a time (Fig. 1). Unfortunately, however, its performance didn't last very long. It was perhaps too exclusive, too costly to maintain, too new for the mainstream public.

However, the interest in and focus on Virtual Reality as such and its possibilities didn't end with the disappearance of the cave system; it merely took another turn. VR is still a highly dynamic field. From a very enthralling, fully immersive space involving the entire body and sharing the experience physically with other people—such as with the *VR-Cube*—we have moved on to HMDs (head-mounted displays): an integrated pair of glasses and a sound system, all concentrated on the head and involving one single person [3]. But that is still a way of experiencing a fictitious reality.

My VR piece *The Parallel Dimension* (1997–1998) presents an imaginary human body with six "worlds," each of which is a virtual interpretation of a certain part, readily described by its name—the Brain Chamber, the Heart & Blood Room, the Breathing Cathedral, the Thought Cabinet, the Flesh Labyrinth, the Dream Cavern—some vast and open, other small and claustrophobic like a dwindling vein (Fig. 2). The work was presented at the inauguration of the *VR-Cube* at KTH Stockholm in 1998 [4], provoking sensations like

Fig. 1. View from the first *VR-Cube* at KTH Stockholm, built 1997–1998. (© Teresa Wennberg)

Fig. 2. Entrance room: Detail from *The Parallel Dimension*, VR, 1998. (© Teresa Wennberg)

Teresa Wennberg (artist), Royal Institute of Technology, Stockholm, Sweden 113 50. Email: <teresaw@kth.se>. Web: <www.people.kth.se/~teresaw>.

See <mitpressjournals.org/toc/leon/51/5> for supplemental files associated with this issue.

 doi:10.1162/LEON_a_01554

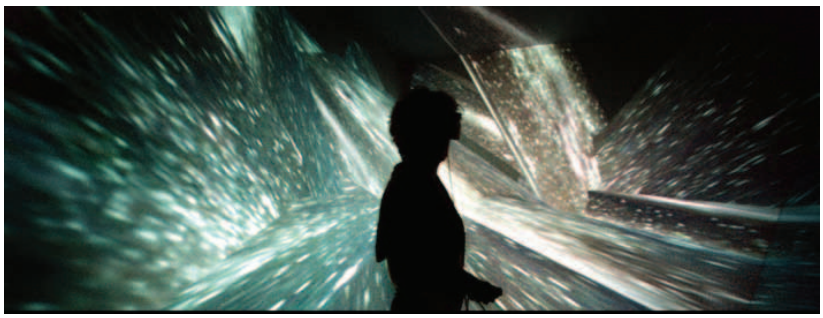


Fig. 3. View from *Brainsongs—Welcome to My Brain*, VR, 2002. Standing inside the cube, inside the brain. (© Teresa Wennberg)

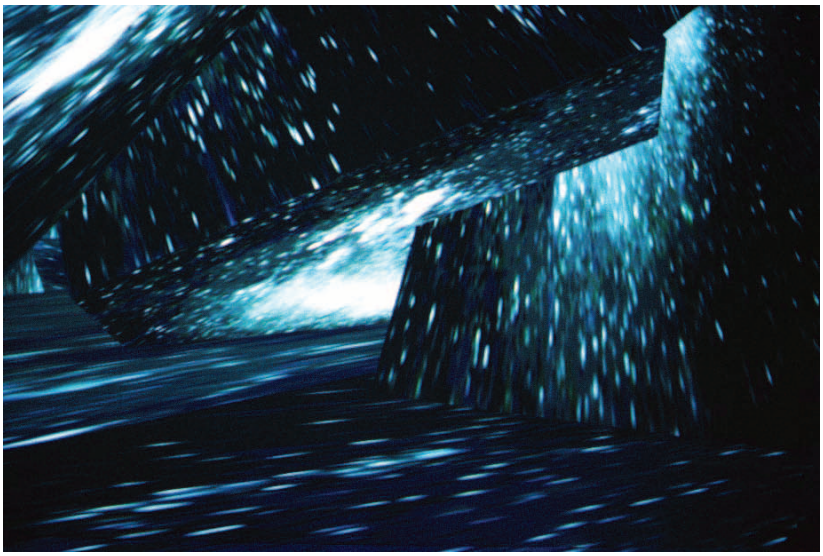


Fig. 4. Still photo from *Brainsongs*. A view from "Space World" (posterior parietal region). (© Teresa Wennberg)

claustrophobia in some and agoraphobia in others. Interestingly, although people knew it was virtual, they reacted as if it was real. Their conscience could not overrule the learned reactions of their brains.

In 2001, when the InterCommunication Center (ICC) Tokyo invited me to present a new work (which I showed there in 2002), I spent a year collecting medical, psychological and neurological information concerning the brain and its cognitive faculties. I then created a metaphorical model of certain vital parts, focusing on three of the major and most active functions. The human brain has long been considered a static organ with a fixed set of neurons that are used up without ever being replaced again. Now research claims that our brain is quite dynamic and continuously renewing itself, in a neurogenesis and synaptogenesis, throughout our entire lifetime (although it tends to slow down a bit after age eighty) [5]. The parts that are particularly active and in a constant mode of creative action are the prefrontal region, which controls executive decision making and short-term memory; the inferior temporal region, which plays a crucial role in the visual recognition of patterns (objects, faces); and the posterior parietal region, which is important for spatial orientation [6]. These parts are also particularly affected when we experience virtual reality. *Brainsongs—Welcome to My Brain* (2001–2002) presents a model of seven different "worlds" corresponding to the abovementioned parts, where each world challenges the visitor with a spatial, visual or cognitive provocation [7] (Figs 3 and 4).

From a technical and scientific point of view, a dramatic evolution has taken place in visual computer science in only 20 years. We advance with giant steps, moving away from the Gutenberg paper galaxy to a digital one. Computer science has augmented and changed the lives of all of us. Society is becoming electronic and portable, with a new set of values and codes of behavior. Even if the evolution of the human brain hasn't gone through any major shift in such a short time, our digital brain—the computer—has begun its race toward . . . becoming human? Surpassing humanity?

We still know surprisingly little about how the human brain functions. Physically speaking, it mainly consists of vibrantly active neurons operating in a gelatinous mass placed inside our skull. It is fluid, electric, chemical, sensitive to magnetic forces and possibly more directed by emotion than by reason. The adult brain is composed of more than 100 billion neurons and is said to be fully grown at the age of twenty [8]. A one-year-old child can produce about one million synapses per second, processing an enormous amount of information per day, but needs to live at least to the age of two before beginning to speak a language [9]. A human brain programs itself bit by bit, which takes a little longer—the computer is instantly programmed by a programmer writing a code.

Not until the age of four is the child aware of and able to reflect on itself. A twelve-year-old brain is said to function at top speed. Perhaps the brain is at the height of its creative intelligence just before the sex hormones set in [10]. This is generally speaking how the brain evolves, but a human brain is not stable. One goes through various phases during a lifetime. In this selfie-obsessed world, an interesting parenthesis is that our facial features seem to be formed before our brain cells. We seem to have a practical memory guiding the functions of our body, and a historical memory capable of remembering the past and planning for the future. The right side of the brain, directed by the hippocampus, which in turn is sensitive to the female hormone estrogen, apparently matures quicker; it comprises intuition, spatial recognition and short-term memory [11]. The left side, dealing more with logic and putting our ideas into action, is potentially steered

by the amygdala, which is connected to the feeling of fear and pleasure; it is supposed to be more developed in male brains, whereas a female brain seems to have a more pronounced faculty for learning in general and languages [12].

The most important brain function is our memory [13]. We can see it as a pond full of images, in which we can fish more or less at will (Fig. 5). One single image, but also a smell or a sound, can wake up the past.

The capacity to remember, our storing capacity, is the main cognitive function of our brain. Our faculty to remember is also what makes us more or less "intelligent," a word that is by no means synonymous with "having a brain." This memory "chalice" is handled by the neurons, the information processing cells that connect to each other through synapses, in charge of the multiple networks that are responsible for all our thoughts, feelings and actions. Since each neuron can make connections with more than 1,000 other neurons, the adult brain is estimated to have more than 60 trillion neuronal connections, and we construct our personal memory by accumulating them.

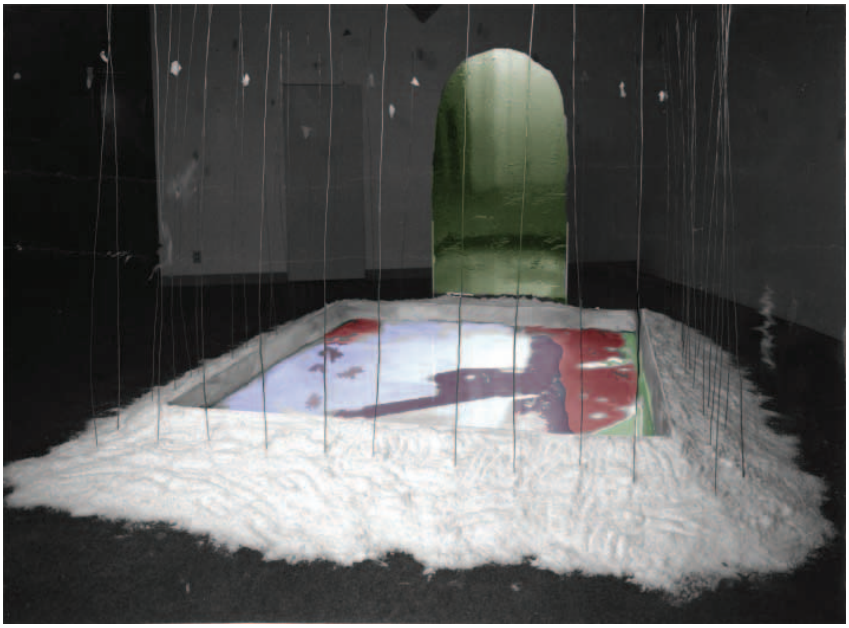


Fig. 5. *Oblivion Pond*, multimedia installation, Hara Museum of Contemporary Art, Tokyo 1987. Water surrounded by a bed of salt, lightning rods, a semitransparent mirror in front and small mirrors hanging in the room, video projection. Song by Lenaïc Gicquel. (© Teresa Wennberg)

Are we born with a genetic memory, transmitted by DNA, or is the brain like an empty pad to begin with? The answer is probably a bit of both. In any case, from our very first day on Earth, we begin to train the brain and fill it with recognition patterns and basic instructions for body behavior and actions in order to live and function as a human being. Once we have learned the basic mechanical skills that make us somewhat independent, such as grabbing things, standing up and walking, these skills are integrated in a subconscious memory bank as an automatic behavior, thus allowing us to think about other things while performing these actions. Multitask.

The ancient way of preserving rules of behavior, traditions and memories was to share them by recital to one another, or to sing them like the native tribes of Australia, thereby also creating a collective awareness, albeit subjective. However, as in the metaphor of the feather that became a hen, the way we tell a story varies. In order to preserve our history, accumulating knowledge digitally is the synthetic substitute solution that we can depend on, as long as the computer battery works—but a battery exchange is nothing complicated compared to brain surgery.

As we all know, the brain depends a great deal on visual information (Color Plate A). In fact, we can see every thought as an undefined image in our head, until it is given a name or code—which is the beginning of the conscious cognitive process. (In the beginning was the word.) Then, in order to understand the code, we must visualize it (again). Thinking is a way of seeing, one might say. However, there are many steps to understanding something, and the most important part is definition—to name the phenomenon. Words that we use to describe things around us, like mother, apple, chair, are the primary and symbolic references in a very complex language interpretation system.

At first, even if we don't define it more precisely, the word *apple* is an accepted and functioning reference, and this is basically how we communicate superficially speaking. We use key words to describe the surrounding world and can get pretty far with that.

The individual human memory bank has a capacity peak around the age of 20 and from that point begins a slow decline, even if we keep learning during our entire lifetimes. People can learn new words and expressions throughout their lives.

Another interesting fact is that although we have this coordinating cerebral center in our heads, it doesn't help us to define either who we are or where we live. The exterior reality we refer to is difficult to understand and describe. We define it according to our sensorial information, our degree of consciousness and our memory, but there is no common reality; it is personal for each one of us, just like our individual brains, and we must update the concept of a surrounding reality through a constant ongoing analysis. Neurons guide our mental activity—or should we say that the neurons are our thoughts? Is an idea something that comes from the outside of our body or does it already potentially exist in the brain, coming to life by some kind of external stimulation? In other words, are we living a life where information enters our body from the exterior, or is it a product of our interior fantasy/chemistry?

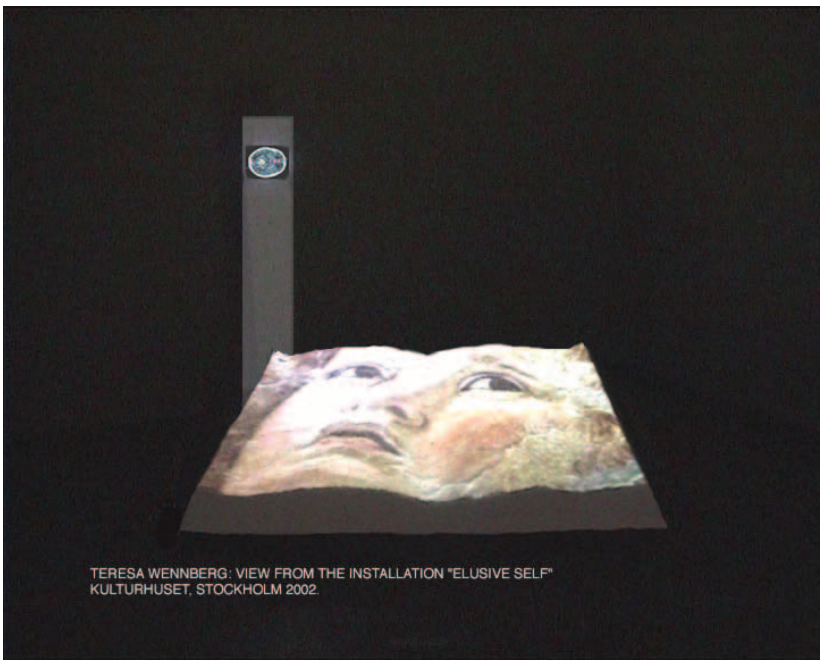


Fig. 6. In the multimedia installation *Elusive Self*, a huge open "book" made of salt and placed on the floor shows a multitude of images (video projection from the ceiling). Beside it, a high pillar presents a sequence from a brain scan, with the word *memory* dancing over it. Exhibition "Tanken Flyger," Kulturhuset, 2002–. (© Teresa Wennberg)

In good company with Plato and Kant, the Swedish philosopher Gunnar Svensson takes this one step further:

> Is there really an external world? The question may seem rather silly at first. The sceptic, however, asks for a justification of something we are all *sometimes* deceived by, viz. our sense experience. What guarantees that it is not *always* delusory? Common sense? Logic? God? Clearly, there is no obvious answer. Doubting the existence of an external world does not seem so silly after all. Why, indeed, accept that there is one? [14]

Likewise George Moore:

> In order to prove my premises, I should need to prove one thing, as Descartes pointed out, that I am not now dreaming. But how can I prove I am not? I have, no doubt, conclusive reasons for asserting that I am not now dreaming; I have conclusive evidence that I am awake, but this is a very different thing from being able to prove it [15].

Obviously, in order to define the reality we think we're in, we need to be "conscious"; this is also a complicated definition. There is no point +–0 of awareness—we are constantly under the influence of different substances, making our consciousness flutter and affecting our perspective of time and space as well as our mnemonic capacity. The way we relate to the surrounding world as a whole also varies depending on individual education, culture, moral codex, even the genetic structure. In fact, we do not know much about the reality that we constantly refer to as ours or that which other people define as theirs. But we somehow manage to live in it. Even these great philosophers are insecure as to what is real and what is not. This is what I call a "metareality," a term that has arisen out of VR experience. People tend to believe the information given by computers—more on that below.

So, how do we react when confronted with an unknown (virtual) reality?

Those who have experienced VR are no doubt familiar with the sensation of "reality" conveyed to our senses. Actually, in VR we find ourselves in a state that more resembles that of a dream: We fall but we don't hit the ground; we can advance at great speed and yet we stand still. How can we define this spatial confusion? Which reality is the true one, that which depends on physical laws or the one produced by this substantially visual experience? The people who visited my VR works accepted what they saw as "true" when they moved around the virtual zones. If we see a steep canyon in VR, we experience vertigo although we know it to be a fake. If we see an object coming toward us at high speed, we tend to duck, although we know it is virtual, and so on. Rather than asking for a correct analysis of the world and what is happening, the brain instinctively reacts according to its training and its ancient, inherent fight for survival.

In *Brainsongs*, one of the "worlds" had walls that moved, a little like an imaginary heart chamber. In this room were a number of strange objects, moving, seemingly breathing. They looked alive. Were they? People came out quite affected, with interesting comments about how we perceive life. If something moves, the brain thinks it is alive. Our brain is in fact quite easy to influence and so to manipulate. VR is a perfect tool for making people think in new ways concerning how we define the surrounding world. If you let heavily burned patients travel through a landscape of ice, they will feel soothed and their pain will diminish. I was able to provoke claustrophobia as well as vertigo with my VR work—or a feeling of absolute calm when floating through what seemed a star-filled space. A doctor suggested that it would be beneficial for traumatized patients, like a sort of meditation. Such a VR room could be considered for inclusion in hospitals [16].

Our visual perception, how we "see," is also a complex experience. The eyes transmit light waves and frequencies that the brain has little by little learned to analyze. Exactly how we manage to interpret these signals and translate them into our consciousness is still to be explained. Obviously, nerves don't think—they only transmit. At first, the conclusions of the brain are based on interpretations of light and movement [17]. Somewhere on the way, the signals turn into ideas, thanks to our inner language. The idea can be seen as a mental projection of a real or invented image. Schrödinger's cat.

In VR, we can see an apple and recognize it as an apple although we can't touch it or smell it. Where is the cognitive frontier in our heads between the image of an apple and the idea of an apple? In which "reality" does it have to exist to be "real"? How do we interpret the idea of reality? We have virtual money that we accept as real money. Apple = apple. We just need to agree on the name of the entity and its value on an etymological and factual basis. Avatar money. Manipulating reality—these cognitive somersaults [18].

This leads us to another question: that of the concept of Self—who is the interpreter of the constant image flow? Another riddle. According to Marvin Minsky [19], there is no principal executive or *me* surveying everything—brain functions are parallel. He describes our brain as a society of mind with a fluid communication by a whole system, where different parts contribute with different functions, in a multitude of interactions.

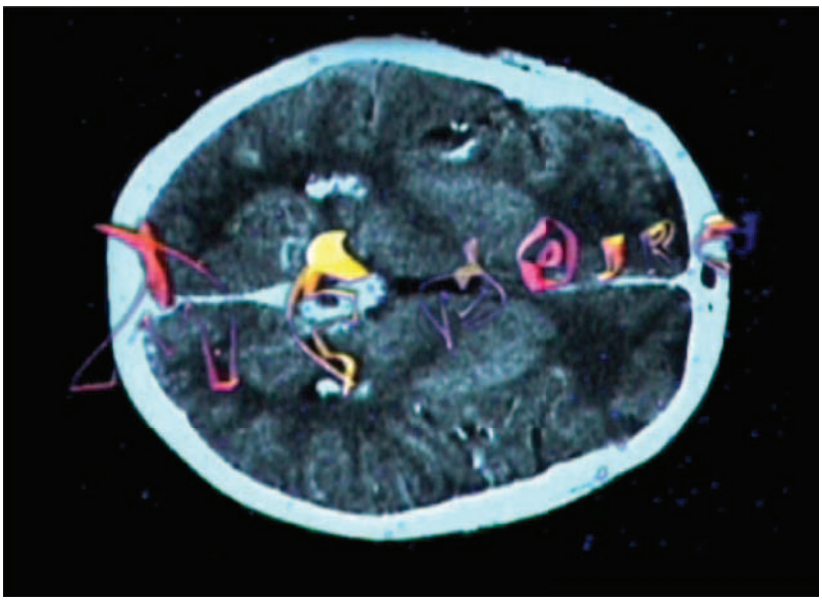


Fig. 7. Scan of my brain, done in 1992, with an overlay from the 3D animation *Amnesie*). From the installation *Elusive Self*, Kulturhuset Stockholm, 2001. (© Teresa Wennberg)

The controversial philosopher Ludwig Wittgenstein asked: "How would it be if somebody seriously told me that he (really) doesn't know if he is dreaming or he is awake. Is a person lying if he says to me: 'I am not conscious'? (And is he telling the truth if he says this being unconscious?)" [20].

David Hume [21] compares the "I" to a long string of experiences of different apprehensions following one another and continuously changing, even when we sleep. This concept of the self is as an ongoing living experience—like a theater with impressions appearing and disappearing in an endless multitude of situations (Figs 6 and 7). We are only movement—our consciousness a series of moments and reality the interpretation our brain makes of these moments at every given time. If we adopt this explanation, we can live simultaneously in several realities without a problem. Our body is constantly changing. The cells in our brain and thus our memory change, clone, divide, die in a never-ending dance of birth and death, transferring DNA to the new cell (Fig. 8). The only exception is the DNA of the female mitochondria that are passed from mother to child without recombination, thus transmitting part of a very ancient memory through an incalculable number of generations [22]—as close as we can come to an indestructible memory chain.

In many ways, the brain and the computer have a similar way of processing information. Doors open and close, portals permit and deny access; both systems hum with orders and counterorders to carry out a specific action. But because our brain is constituted of relatively slow human tissue and at times doesn't know how to react correctly, it can have a problem in terms of speed, which is one of the reasons why the computer suits our calculative needs, since speed is an important argument in the contemporary society.

Not only is our brain comparatively slow but it is also lazy. We have always looked for servants and machines to do

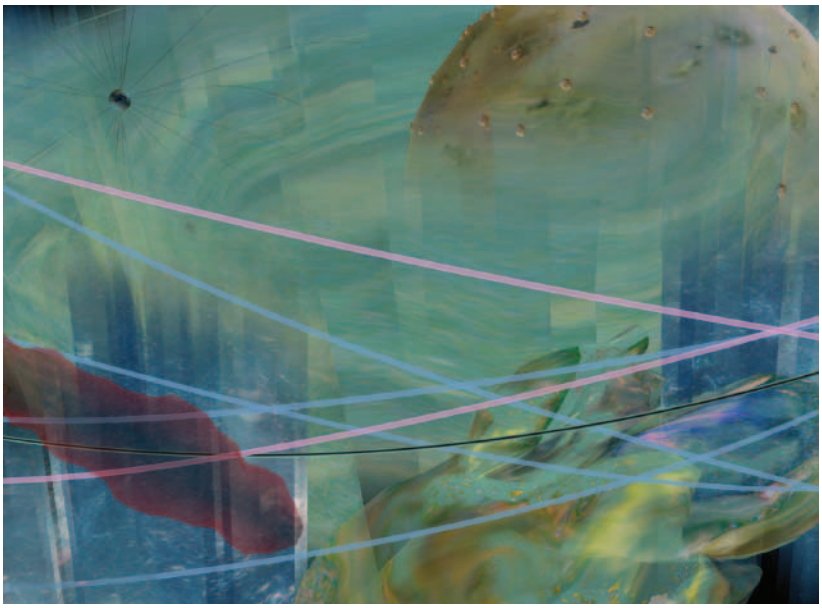


Fig. 8. Detail from *Soft Factory*, VR, 2010, Aalborg University Media Lab, Denmark. A voyage inside a human eukaryotic cell. (© Teresa Wennberg)

tedious calculations or physical work for us. The computer has made us totally dependent in a very short period of time. We rely on the computer for all information, and the portable computer, our phone, is our daily assistant, small, wafer thin and weighing less than our own brain. We use it to transmit voices and as well as texts, we photograph and film with it, it's a two-sided mirror and even a toy. But, in fact, it doesn't make us smarter, rather lazier (slower) and less analytical. What has this led to so far? Is the human brain quicker? No, rather it is a bit hebetated. Do we think more? No. Do we work better, more effectively? Not on a personal level, but computer-steered mass production has certainly increased. Is contact between people easier? Not really, nor more profound. It's just different, or as Sherry Turkle puts it, we are "alone together" [23].

The (personal) computer is also a very powerful control tool. There is an army of programmers pouring out new instructions for us to constantly update our toolboxes, making us more and more dependent—very commercially lucrative but not helping to enhance our intelligence or vital memory; quite the contrary.

From the portable computer it is a short step to the moving computer, a so-called robot. We already have some, equipped with artificial "intelligence," ubiquitous household robots like the autonomous vacuum cleaner, the washing machine, the thinking fridge. Soon we will have a car where the driver is a computer. Next in line is Chihira Aico, the singing Japanese doll-robot designed to welcome the visitors of the next Tokyo Olympics. This is a very hot field. Thanks to current neuroscience it has been possible to give this robot humanlike behavior and features. It can mimic human facial movements to a certain extent (which is psychologically very important). There is a veritable AI race between countries all over the world to create humanoid computers [24]. Is it in the name of progress? A common hang-up, transmitted through the words of astronomer Stephen Hawking, is that robots soon will take over the world. "Computers will overtake humans with AI within the next 100 years. When that happens, we need to make sure the computers have goals aligned with ours" [25].

This has already happened. Our computers already enslave us—with the Internet. The Web is the veritable revolution, the invisible net that binds us all together, opening the door to a worldwide forum where everybody can navigate but nobody can really steer.

A click and we are in yet another reality, a cyber-society with all its deputy personas and avatars. The Internet has created a live online metaculture. A digital enclosure with invisible borders but with enormous influence, a reality within a reality—perhaps more powerful than VR—where we are mentally captivated, not in a global village but in a global prison.

However, the autonomous robot with an evil mind does not exist and will not for long. Here is a responsibility that must not be neglected: As long as we cannot correctly define the reality we live in, as long as we can't describe what consciousness means—how can we transfer and program this vital knowledge to a machine? How do we make a machine feel "human"? [26] An important task where a lucid sensitivity is vital! The role of contemporary artists should be to ask all these questions, incorporate them in their work to try to make people think and be aware, using their creativity to enlighten their fellow humans. The artist of today is not only a skilled technician but also something of a philosopher. "Neuroplasticity" is the word. The mission for contemporary artists should be to improve the human cognitive capacity. I do not mean traditional education, but rather creative games, noncommercial educational games, where the player, young or old, is constantly positively challenged—not with killing—and so improving brain capacities.

When you live in the realm of virtual reality, you soon become aware of how powerful visual input is, be it a painting, a movie, a virtual reality or an ordinary sunset. We are just at the beginning of enhanced visual analysis and of understanding reality, with ensuing augmented communication. This is where artists can fill a gap, working with researchers on all levels, using their imaginations to develop and improve the unavoidable usage of technology in every part of the postmodern techno-society.

Virtual reality offers a powerful exploration of the human mind and a way to discover what a great tool our brain can be(come). Instead of creating cute robots, we should try to enhance the capacity of the human brain and human memory, using computer science and technology, be it VR or AI or the World Wide Web, to focus on how to develop the human brain and human intelligence. How about learning to spin a spider's web? If the intelligent robot is standing on the doorstep, better if it is an artist and not a killer.

> "Well, it's no use *your* talking about waking him," said Tweedledum, "when you know you're only one of the things in his dream. You know very well you're not real."
>
> "I *am* real," said Alice and began to cry.
>
> "You won't make yourself a bit realer by crying," Tweedledee remarked. "There's nothing to cry about."
>
> "If I wasn't real," Alice said—half laughing through her tears, it all seemed so ridiculous—"I shouldn't be able to cry."
>
> "I hope you don't suppose those are real tears?" Tweedledum interrupted in a tone of great contempt. [27]

Acknowledgments

Martin Ingvar, professor, CEO, Karolinska Institutet, KI Stockholm; Gert Svensson, PDC deputy director, Royal Institute of Technology, KTH Stockholm; Bjorn Obrink, professor emeritus, Karolinska Institutet, KI Stockholm; Anders Zetterberg, professor emeritus, Karolinska Institutet, KI Stockholm; Pierre Lobstein, artist, professor, Université de Nancy; Anders Sandberg, research fellow, Future of Humanity Institute, Oxford; Ingrid Melinder, Dean of School of Computer Science and Communication, KTH Stockholm.

References and Notes

1 Tom de Fanti and Dan Sandin introduced the first "CAVE" in 1992 at the UIC, Chicago: <www.evl.uic.edu>.

2 Early VR contributors included Jeffrey Shaw, Char Davies and Maurice Benayoun. Yoichiro Kawaguchi also did some very inspiring 3D animations.

3 See <www.nada.kth.se/~teresa/PDVR.html>.

4 See Ref. [3].

5 Martin Ingvar, interview, 2010. M. Gazzaniga, R. Ivry and G. Mangun, *Cognitive Neuroscience: The Biology of the Mind* (Norton, 2013).

6 Gerard J. Tortora and Sandra Reynolds Grabowski, *Principles of Anatomy and Physiology,* 9th ed. (New York: John Wiley & Sons, Inc., 2000) pp. 446–474.

7 *Brainsongs—Welcome to My Brain* was presented at ICC Tokyo in 2002 and at KTH Stockholm in 2002 and 2004. See also <www.digitalartarchive.at/database/general/work/brainsongs.html>.

8 Tortora and Grabowski [6]; J. Stiles, "The Basics of Brain Development," *Neuropsychology Review* **20**, No. 4, 327–348 (December 2010).

9 Stiles [8].

10 Simon Baron-Cohen, "The Essential Difference: The male and female brain," Phi Kappa Phi Forum, Cambridge University, 2005.

11 Baron-Cohen [10].

12 Baron-Cohen [10].

13 Antonio Damasio, *Descartes' Error: Emotion, Reason, and the Human Brain* (New York: Avon Books, 1994) pp. 128–140.

14 Gunnar Svensson, *On Doubting the Reality of Reality* (Almquist & Wiksell International, 1981) p. 8.

15 G.E. Moore, "Proof of an External World," *Philosophical Papers* (London: George Allen and Unwin, 1953) p. 149.

16 See for instance M. Burgess, "Is VR Really the 'Magic Pill' We Need to Treat Mental Health Conditions?" 22 March 2017: <www.wired.co.uk/article/vr-mental-health-treatments> (accessed June 2018).

17 Although we can describe the visual pathway as a more-or-less single pathway, visual signals are thought to be processed by at least three separate systems in the cerebral cortex, each with its own function. One system processes information related to the shape of objects, another system processes information regarding color of objects and a third system processes information about movement, location and spatial organization. Tortora and Grabowski [6] p. 529.

18 Throughout human history, representational technologies have served two functions: to deceive the viewer and to enable action, i.e. to allow the viewer to manipulate reality through representations. Douglas Hofstadter, *Gödel, Escher, Bach* (Paris: InterEditions, 1985).

19 Marvin Minsky, *The Society of Mind* (New York: Simon and Schuster, 1988).

20 Ludwig Wittgenstein, *Zettel*, GEM Anscombe and G.H von Wright, eds. (Oxford: Blackwell, 1967) p. 85.

21 *David Hume: A Treatise of Human Nature*, Book I (Glasgow: William Collins Sons & Co. Ltd., 1962).

22 Tortora and Grabowski [6] pp. 84–85.

23 Sherry Turkle, *Alone Together* (Philadelphia: Basic Books, 2012).

24 *International Business Times*, UK Edition (9 June 2015).

25 <www.geek.com/news/stephen-hawking-predicts-robocalypse-in-next-century-1622734/>.

26 Alan Turing, "Computing Machinery and Intelligence," *Mind* **59**, No. 236 (1950) pp. 433–460.

27 Lewis Carroll, *Through the Looking Glass*, 1871.

Bibliography

Ascott, Roy. "Seeing Double," *Reframing consciousness*, 1999.

Baudrillard, Jean. *The Gulf War Did Not Take Place*, Paul Patton, trans. (Sydney: Power Publications, 1995).

Dawkins, Richard. *The Selfish Gene* (Oxford Press, 1989).

Diderot, Denis. "Lettre sur les aveugles à l'usage de ceux qui voient" (1749), Diderot (Editions Flammarion, 1972).

Ingvar, Martin. "The Art of Perception," in Wennberg (2002) pp. 60–64.

Johansson, Linda. *Äkta Robotar* (Stockholm: United Press, 2014).

Lane, Nick. *Oxygen—The Molecule That Made the World* (Oxford Univ. Press, 2002).

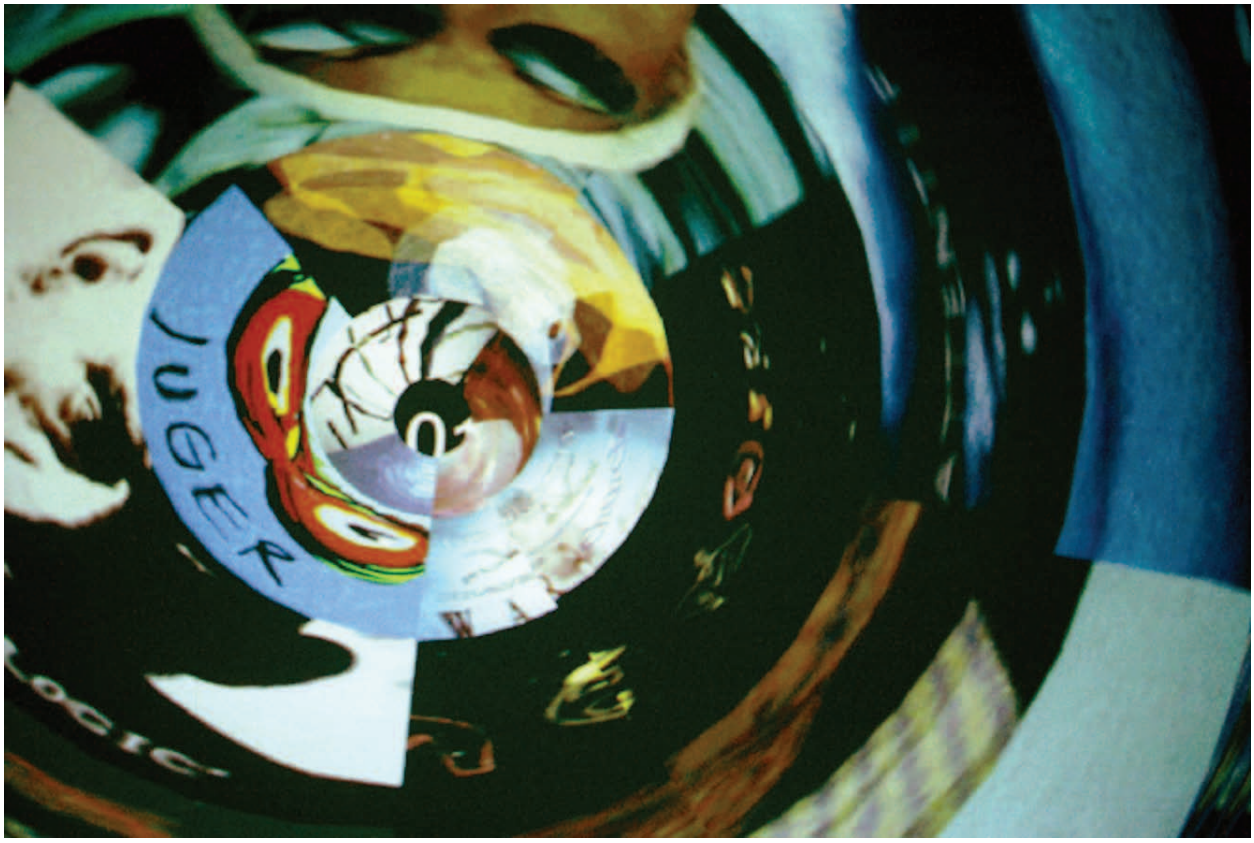
Manovich, Lev. "To Lie and to Act: Potemkin's Villages, Cinema and Telepresence" (ISEA, 1997).

Wennberg, Teresa. *Into the Brain* (Almlofs Forlag, 2002).

Manuscript received 28 March 2016.

TERESA WENNBERG *is a painter and multimedia artist based in Sweden and France. Her multidisciplinary background in law, economics, languages, painting, computer science and virtual reality has fueled an interest in cognitive functions and behavior that often provides a foundation for her work.*

COLOR PLATE A: **VIRTUAL REALITY—VIRTUAL BRAIN: QUESTIONING REALITY**



Still photo from *Brainsongs*. Inside the prefrontal region (short-term memory). (© Teresa Wennberg) (See article in this issue by Teresa Wennberg.)

a²ru

ALLIANCE
FOR THE ARTS
IN RESEARCH
UNIVERSITIES

6th Annual Conference

Arts Environments: Design, Resilience, and Sustainability

November 1-3, 2018 • Athens, GA

UNIVERSITY OF GEORGIA

*agenda and registration this summer at a2ru.org