(Projection) mapping the brain: a critical cartographic approach to the artist's use of fMRI to study the contemplation of death.

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Abstract

This paper discusses the author's artwork, Neuro Memento Mori, a self-portrait comprising digital animations and live action video projection-mapped onto a 3D print. The life-sized sculpture of the head and neck, dissected to reveal the artist's brain, was produced from MRI data gathered as the artist viewed memento mori paintings and meditated on death. The production of the artwork, made with neuroscientists, explores the relationship between the so-called frontier of neuroscience, data and the map. The use of computation to produce neuroimages, 3D prints and projected video is discussed from the perspective of critical cartography.

Keywords: 3D print, MRI, projection mapping, critical cartography

Figure 1: *Wax model of a Female head depicting life and death (Unknown 1701-1800. Image courtesy Wellcome Trust.*

Introduction

Neuro Memento Mori is inspired by an object in the Wellcome Trust Permanent Collection, "Wax model of a Female head depicting life and death" (Unknown 1701-1800). It shows a woman's bisected head, the left half apparently a detailed portrait of a living woman, open-eyed, with painted lips and blond hair arranged in ringlets. Her left hand frames her face while the right half of her head is shown in post mortem decay. Resting on her skeletonised right hand, her skull crawls with insects, maggots and worms. A snake emerges from her empty eye socket. As we look at memento mori artworks such as this compelling object, I questioned whether we 'remember, we must die'? What parts of our brain are active when we look at these artworks, and, when we contemplate death by meditation, without looking at memento mori art?

The project discussed here has been made in collaboration with neuroscientists Zoran Josipovic from NYU who has been conducting experiments into non-dual awareness (Josipovic 2010; Josipovic et al. 2011), anthropologist turned neuroscientist, Andreas Roepstorff, director of the Interacting Minds Lab at Aarhus University, whose commitment to working collaboratively with people from many fields is also the subject of some of his research (Bahrami et al. 2010) and psychologist turned neuroscientist, Joshua Skewes, also from Aarhus University, who, with Roepstorff and others, has opened up the black-box of "critique" within critical neuroscience (Fitzgerald et al. 2014). Together we designed experiments that included me looking at representations of memento mori while in a Magnetic Resonance Imaging (MRI) scanner to record my brain activity via functional MRI (fMRI). In a second experiment, with tutoring and instruction from Josipovic, I learned to meditate, to contemplate death, and repeated that meditation in the scanner. Neuroimages from these experiments and structural MRIs produced when I was not doing any particular task were processed to produce datasets of my brain in order to make a 3D printed sculptural object. The form of the resulting, life-sized portrait sculpture refers to the Wellcome Trust object, shown in Figure 1. 3D scans of the artist's head were combined into one model that was dissected, then recombined with a 3D skull and a brain model made from the aforementioned MRI scans. Video and computer animations are then projection-mapped onto the sculpture to create a contemporary memento mori. These included animations derived from the fMRI data showing brain activity whilst looking at memento mori images. In creating this artwork, the intention was not to produce a Turing Test-related artwork that interacts with the viewer, nor to make robotic artwork (Kroos et al. 2012) but to use neuroscience techniques to make a contemporary memento mori, an object that brings together a sense of the living and the dead.

Background

As new neuroscientific instruments such as MRI and EEG have made it possible to safely image living human brains, there has been a concurrent significant increase in data from neuroscientific research, in particular neuroimaging, and a proliferation of the use of neuroimages in the popular press. Scholars of rhetoric have problematised the 'seductive allure' of both neuroscientific explanations (Weisberg et al. 2008) and of the neuroscientific

Figure 2: *Neuro Memento Mori: video projection mapped onto 3D print.*
Left to right: Procedural animations wireframe, cracked stone; live action video; artist faces 3D print.

images (Gruber et al. 2011) that are often used in conjunction with such explanations.Against this background, a better understanding of neuroimages, which are referred to repeatedly in the debates and practices of neuroscience, became important for the realisation of the artwork as neuroimages are central to the way the work is produced.

Pioneers and map-makers: towards a critical cartography of brain maps

Neuroscientific research is one of a series of scientific endeavors, including stem cell research and space exploration, that have been described as 'pioneering'. Scholars of rhetoric have argued that the use of pioneer metaphors is key to the funding of this scientific research (Ceccarelli 2013) and have drawn attention to the relationship between the popular interest in contemporary neuroscience and the excitement and power associated with any research that is marketed by nation states as 'pioneering' (Prophet In Press). The use of terms like 'conquest' and 'land grab' in discussions of so-called pioneering science points to the relationship between the pioneer, the frontier and the map. Historically, geographic-pioneers needed cartographers in order to map out, and lay claim to, newly discovered territories, to define boundaries, to demarcate, divide and classify. This mapping rhetoric is played out in the use of metaphor in pioneering neuroscience where neuroimaging is an essential part of making what is termed 'brain-maps' and related computational 'brain atlases'.

Critical mapping starts by questioning "a scientific epistemology of the map as an objective form of knowledge […] to begin from the premise that cartography is seldom what cartographers say it is." (Harley 1989). I will not revisit the well-known arguments against the 'God's eye view' and the impossibility for truly objective forms of knowledge. However, in detailed academic discussions about Geographical Information Systems (GIS) and 3D mapping, attention has been drawn to the fact that "uncertainty about 3D data (as relief or subsoil data) is greater than about 2D data" (de Cambray 1993). This further undermines our sense that there is an objective form of the earth that is fixed, proposing that the earth's perceived formal stability is relative, as its three-dimensional structure constantly alters as a result of changes that might only visible at specific scales, or made visible and sensed via instruments. Maps and atlases of the brain are further indexically removed from that which they seek to define. If, as critical cartographers show us, mapping the relatively fixed structure of the earth is problematic, then developing a brain atlas is even more fraught with problems. Firstly, there are as many brains as people, secondly, there is no single representation of the brain and, finally, there is no easy way to create an average brain. Neuroimaging experts (Thompson et al. 2000) have noted the "Striking variations in brain structure, especially in the gyral patterns of the human cortex, [that] present fundamental challenges in human brain mapping." Because of this variation some brain maps and atlases are created using population-based averaging that takes anatomical data from a large number of subjects.

The historian J. B. Harley argues for a redefinition of geographic maps as representations of power (Harley 1988) and with other scholars from the field of 'critical cartography' suggests that critical mapping "calls things into question" (Crampton 2011). Insights from scholars of pioneer rhetoric also call things into question, suggesting that it is fruitful to pay attention to the knowledge and power at play in neuroscientific mapping processes and to position these processes as political. A new materialist view of frontier metaphors sees them as interwoven and entangled with basic scientific research, and a new materialist intra-active understanding of entanglement would claim that neuroscience cannot be adequately dealt with other than as co-constituted with these metaphors of the frontier. Sceptics of both geographic and brain mapping are asking, "[w]hat are the underpinning assumptions that help to govern knowledge? That is, what rationalities are in play? […] because these rationalities shape and form the subject of the map, that is, how the map helps oppress, subjugate, or subjectify individuals and populations (Wood and Krygier 2009)." In this spirit, the academic psychologist and feminist critic of the neurosciences, Cordelia Fine, questions the creation of normative and potentially oppressive models of brain activity (Fine 2010). Fine's recent re-evaluation of fMRI investigations of sex differences, and her systematic examination of citation practices, support claims of neurosexism "that enable the proliferation of untested, stereotype-consistent functional interpretations [of MRI]" (Fine 2013).

Despite using the examples above, a critical cartographic questioning of brain maps is not undertaken here as part of any project to denigrate such mapping processes, but rather to draw attention to how relational and entangled the mapping processes are, in order to be better able to articulate the contingency of such maps. The critical cartography theorist Jeremy W. Crampton asserts that "[a] critique is not a project of finding fault, but an examination of the assumptions of a field of knowledge. Its purpose is to understand and suggest alternatives to the categories of knowledge that we use. These categories (i.e., assumptions and familiar notions) shape knowledge even as they enable it." (Crampton 2011). A critical cartographic approach to brain-mapping enables a better understanding of the relationship between knowledge and power in the production, interpretation and dissemination of neuroimages and their amalgamation into brain maps and brain atlases. The aim is to better understand the way that brain mapping shapes our knowledge of the brain, how understandings of brain function emerge through the entanglement of MRI images and cartography.

Using examples of the shift from techniques such as handlettering through to software, Crampton notes that it not the changing technologies that cause discomfort to geographers. Rather it is that with them has come the need for ever more specialised skills that have in turn been used to argue for cartography to be moved from within geography departments, with their critical theoretical framework, to independent departments that are supposedly a-political and internalist. With this post-war shift, he asks us to consider, "What kind of concepts and theories were excluded?" (Crampton et al. 2006). The idea that any map can be a-political and offer a 'view from nowhere' is clearly at odds with social constructivist arguments about scientific knowledge. Cartographers like Harley "sought to situate maps as social documents that needed to be understood in their historical contexts. Harley went on to argue that mapmakers were ethically responsible for the effects of these maps (Harley 1990a). In this way he could explain the dominance of seemingly neutral scientific mapping as in fact a highly partisan intervention, often for state interests" (Crampton et al. 2006). Taken to its extreme, social constructivism sees science only as rhetoric. While the scholarship of rhetoric and social constructivism both offer useful insights into brain mapping, Donna Haraway points to the problems of seeing science as "a series of efforts to persuade relevant social actors that one's manufactured knowledge is a route to a desired form of very objective power" (Haraway 1988).

Truth, uncertainty and embodiment

Feminist technoscience suggests we view objects of knowledge (like our brains) not as passive and inert things to be subjected to a God's eye view, but rather as active agents in the production of knowledge that emerges through intra-actions with human and nonhuman agents and their environment. In keeping with this, Haraway proposes that maps are "embodiments of multifaceted historical practice [… that] constitute spatiotemporal worlds […] maps are models of worlds crafted through and for specific practices of intervening and particular ways of life". These maps become fetishes only when seen as non-tropic and metaphor-free (Haraway 1997). Haraway calls for what she terms "an embodied objectivity". Critical cartographers, like Amy D. Propen have taken up Haraway's project of moving beyond positivist critiques, claiming there "appears to be a shift in how we have come to conceptualise visualization practices - a shift that has allowed us to arrive at a point where we might utilize the "remote viewing platforms" once critiqued by Gregory and Haraway for their lack of accountability, for purposes that ostensibly work toward the creation of more sustainable environments by invoking specific local or cultural contexts." (Propen 2011) Propen goes on to suggest that we engage with a map "as both socially constructed and as purporting to represent a "correct" model of the physical world by understanding cartographic practice as embodied knowledge." This is especially relevant when engaging in neuro cartography, as this practice – the production of neuroimages - depends on living, embodied, brains. However, the body and brain need to remain very still for the 5-10 minutes that a functional MRI scan takes to complete. This need for stillness creates a self-consciousness that accentuates ones's sense of being embodied, as one tries to control (and becomes hyper aware of) what are usually unconscious and small bodily movements associated with breathing or swallowing. To move while being scanned adds noise to the data and therefore the most scientifically useful MRI image emerges through intra-actions that partially erase the trace

Figure 3: *Neuro Memento Mori: fMRI images projection-mapped onto 3D printed head.*

of the embodied human via post-scan automatic data manipulation. Ironically, given the experiments we performed, I needed to still my body, to 'play dead' in order to prevent the micro movements "due to swallowing, fidgeting, overt speech, or transmitted motion as a result of finger pressing on a keypad [… which] are a major cause of inconclusive or uninterpretable fMRI results in the clinical setting". (Desmond et al. 2002).

Different perspectives on maps

After hundreds of years during which powerful elites controlled cartography, geographical mapping has also recently undergone a rapid and significant shift. The development of affordable GPS tools and applications such as Google Earth has made it relatively easy to access, collect, display and share spatial data. Processes that have historically been controlled by government and academic experts have become available to large numbers of people with a wide range of views and goals. "Cartography's latest "technological transition" (Monmonier 1985; Perkins 2003) is not only a technological question but a mixture of "open source" collaborative tools, mobile mapping applications, and the geospatial web." (Crampton 2006) The quantity of geographical data and the way it is made easily accessible via Google maps is informing the development of brain atlases, as evidenced by a team developing an atlas of the rodent brain using a spatial framework that integrates neuroscience data with an associated Digital Atlasing Infrastructure (DAI) which is a Swedish-based online portal. During the discussion of their prototype implementation of this infrastructure they state, "Tools like Google Maps are appealing because they serve as gateways to enormous amounts of spatially-registered information. This type of functionality, if available in the realm of neuroscience, would appeal to researchers, as everything is tied to "where in the brain" and relating different data by brain location would greatly facilitate our ability to do rigorous, and unique quantitative analyses." (Zaslavsky et al. 2014)

In their discussion of the application of augmented reality for environmental geoscience, Westhead et al highlight not access to big data, but rather the significance of mobile technologies' enabling of "two-way sharing of information, through twinned display of digital maps and live 'crowdsourced' collection of point observations." (Westhead et al. 2013) Westhead is alluding to the fact that maps are "no longer imparted to us by a trained cadre of experts, but along with most other information we create them as needed ourselves" (Crampton et al. 2006) We cannot say the same, yet, for so-called maps of the brain which are in the early stages of production. However, neuro cartography is already open to the expert crowd. Arguably, a shift in control away from very a small elite is underway, prompted by the developers of brain atlases who want to harness the labour of the expert crowd, to create cartographic tools that enable those users to add data in order to more widely disseminate research and support scientific research. For example, the development of rodent brain atlases, initially based on paper atlases (Hof et al, 2005), have been re-organized using digital data to produce 3D atlases that are available on the desktop and online (Zaslavsky et al. 2014). The technical challenge remains to agree protocols for the representation of brain data so that independently-produced and individually coherent datasets can be merged and new data marked up and added by a wider range of brain mappers. The DAI has brought together people from many disciplines to create a kind of leap-frogging technology that will jump over some of the development stages that geographic atlases went through, much in the same way that some countries telephone networks have leapt over the landline phase and jumped to widespread mobile phone use.

Most of these existing brain atlases still depend on expert brain mappers to use MRI, fMRI and other expensive and potentially dangerous imaging apparatuses. Whilst they are an elite, they are working at a time when neuroimaging technology is in a state of transition with the potential to become available to non-expert brain mappers. Much as the development of GPS had an impact on non-expert geographical mapping, so as EEG becomes more widely available to non-experts, including artists, 3D brain data can be gathered relatively safely and more affordably.

Artists' maps

In geographical mapping, "the infusion of [geo]mapping technology in the late 1980s […] set the stage for an explosion in "locative art" and psychogeographical mapping. […] These map events question the commensurability of Euclidean space, a basic assumption of much GIS." (Crampton et al. 2006). Euclidean space is combined with time in the production of fMRI and EEG to produce what has been termed 'multidimensional data' (Baumgartner 2001) a spatiotemporal dynamic image of brain activity. Artists have a history of bringing together data relating to space and time to create maps or scores of performances. Yolande Harris describes her *Score Spaces* and their scores not as notational but rather as "contextual and communicative" (Harris 2014) and the performance artist Alessandro Carboni has referred to critical cartography in the development of his mapping *EM toolkit* for performers that enables actions based on walking experiences to be mapped and repeated (Carboni 2014) in what theorists like Amy D. Propen might describe as "embodied cartographic knowledge" (Propen 2011).

Despite the difficulties of accessing MRI machines, a number of artists have been working collaboratively with neuroscientists. This is largely separate to research in the field of neuroaesthetics that uses neuroimaging to study the human brain as subjects experience art that seeks to answer questions such as, "What are the neural underpinnings of aesthetically moving experience?" (Vessel et al. 2012). In Neuro Memento Mori's experiment designs there are elements of neuroaesthetic research, in particular those experiments where we neuroimage the brain while the artist looks at memento mori artworks. However, this is only one aspect of the project, and is coupled with our second fMRI experiment that documents contemplation. Both fMRI experiments are inseparable from wider material-discursive practice, which is alluded to in the final sculptures that, for example, reference the computational structures of the 3D images by using wireframe rendering. The first exhibition of Neuro Memento Mori is in the Moesgaard Museum of Anthropology in Denmark, the procedural animations of cracking earth projected onto the model allude to anthropological skulls from death rituals that are currently displayed in the ethnographic display there. Lastly, the projection-mapped live video of the artist's face, eyes blinking, then closed as if in meditation, or drifting towards death, references the Wellcome Trust vanitas piece. Therefore the resulting works of art might better be described as 'neurocultural products'. Neuroscientist, Giovanni Frazzetto, and artist, Suzanne Anker, describe such products as "metaphors to describe and interpret neuroscience knowledge embedded in social values and competing cross-cultural norms within divergent societies. […] [It] does not seek to understand art neuroscientifically." (Frazzetto and Anker 2009) Similarly, the project discussed here is not focused on developing an understanding of memento mori art neuroscientifcally. Rather it explores the phenomena of contemplating and producing memento mori objects using neuroscience that draw attention to "individuality and history, which cannot be reduced to a single organ" (Frazzetto and Anker 2009, 816).

While MRI remains out of the reach of most non-scientists, EEG is being used more widely. Though EEG is in the early stages of adoption by non-experts, a new open source Brain Computer Interface (BCI), OpenBCI has been developed recently. The artist Ellen Pearlman is using Open BCI to create a brain opera, and she draws attention to the way that, unlike previous BCIs, it can be implemented and developed by anyone. It is significant in the way that it enables users to develop custom code and multi-modal interfaces that are especially attractive for artists, musicians, performers and makers. As Pearlman notes, "OpenBCI enables artists to reimagine the scenario though the use of these brain computer interface technologies." (Pearlman 2014). Tools such as OpenBCI offer the potential to open brain mapping much in the way that inexpensive and well-documented sensors have supported the development of citizen science. "The GPS and recording capabilities within modern mobile devices are becoming practical sources for citizen science data. This moves us towards a new era when the boundary between the scientific map maker and user will become increasingly blurred and dynamic." (Westhead et al. 2013).

The theoretical critique of cartography made space for alternative mappings by a wide range of practitioners, especially artists. As Crampton notes, "Perhaps the most noteworthy has been map experimentation by the artistic community, especially with representation and the map's role in creating a sense of geographical meaning (Casey 2002; kanarinka 2006a). For example, a number of artists have explored how maps are political and how mapping can be a political act." He calls these "subversive cartographies".

Conclusion

The Neuro Memento Mori sculpture is a response to Westhead's question, "what is a 'map'?" It is also part of a continuum of portraits made by artists to explore death. This contemporary memento mori experiment is presented in a time-based and spatial form, using moving images projection-mapped onto a figurative sculpture. The sculpture is, according to Anker and Frazzetto's definition, a neurocultural product. These neurocultural products "not only draw inspiration from the beauty and wonders of brain anatomy and mechanisms, but also have the power to critically address neuroscience findings."

Contact Information

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