THE CONCEPT OF NOISE IN MEDICAL VISUALISATIONS PERCEIVED THROUGH A CONTEMPORARY DRAWING PRACTICE

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THE CONCEPT OF NOISE IN MEDICAL VISUALISATIONS PERCEIVED THROUGH A CONTEMPORARY DRAWING PRACTICE

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Abstract

This research project explores how the concept of noise in medical visualisations is perceived through an analogue visual arts practice. Noise – which is the informational opposite to signal in science – is an unknown and visually ambiguous aspect of medical visualisations.

A residency in a medical imaging institution was undertaken to investigate scientists' perceptions of noise and to identify its key attributes. Conversations with contemporary artists and an examination of their work, explored how noise attributes are used as a strategy in their practices. Theories from art history and the neuropsychology of vision were used to interrogate how noise is implicated in visual perception. Critically, my on-going drawing exploration using instruments of vision, biosensor technologies and responding to unknown stimuli was a primary method of investigation used to understand how an analogue drawing practice perceives noise.

My research identified that unknown movements and interactions are deeply implicated in the generation of noise and that the distinction between signal and noise is unstable. My practice-based investigations revealed that all my sensory perceptions become heightened in response to noise, so that vision becomes inseparable from them. This was an important difference between scientists' and artists' perceptions of noise, for scientists do not recognise the full sensorium in their practice. The writings of Jean-Luc Nancy and Michel Serres were used to elucidate this process.

This research demonstrates the differences between artistic and scientific perceptual responses to ambiguity, the unknown and to noise. It evidences that artistic responses to noise can be a catalyst for change, generating new ways of perceiving, working and making. It contributes to an under-represented area of research: how an analogue arts practice perceives the digital concept of noise. Furthermore, my project indicates that analogue drawing could be used as a method in scientific training to explore visual ambiguity.

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Lastly, I am hugely thankful to my family for their continued support and love. This thesis is dedicated to my children Amita and Kiran.

Declaration

I declare that the work contained in this thesis has not been submitted for any other award and that it is all my own work. I also confirm that this work fully acknowledges opinions, ideas and contributions from the work of others.

Ethical clearance was not required for this research by the Schools Ethics Committee.

I declare that the Word Count of this Thesis is 38,651 Words

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Introduction

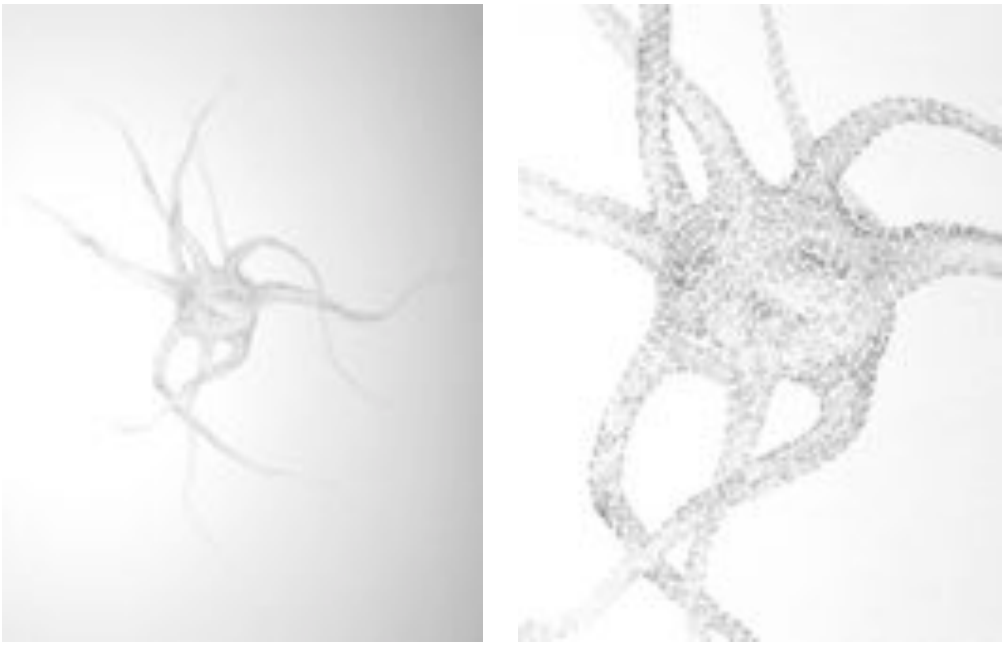


Figure 0.1 (Left) *Untitled*, 2006, graphite on paper, 42 x 59cm, work by the author.
Figure 0.2 (Right) Detail of *Untitled*, 2006.

My drawings have engaged with medical visualisations for a number of years exploring the ways in which they map, measure and represent the human body. My on-going interest is underpinned by a desire to understand how an artist looks at scientific documents that visualise internal living bodies. The drawing of a neuron above (Figure 0.1 and 0.2) is produced by repeating the numerical symbols of binary code (0 and 1) to refer to its provenance – a visualisation that is constructed from data. I use systems of grids and lines to draw the organic forms of the internal body to explore ideas of what can and cannot be measured. Medical visualisations can be perceived and looked at in very distinctive ways. To a radiographer, they are scientific documents that are decoded by an expert eye searching for signs of abnormality. Patients undergoing treatment are likely to have a highly charged visual response to their own scan. And they are intriguing images that powerfully capture the changing relationship between technology and the human body. Furthermore, their absorption into contemporary visual culture generates a multitude of meanings that are unrelated to their original purpose. These diverse ways of seeing coexist as I look at medical visualisations through eyes that cannot decode or read them as scientific documents. They are, in a sense, unknown to me. Questions concerning the ways in which I perceive

medical visualisations as I draw underpin this research. Drawing is therefore a fundamental method of investigation for this research.

Figure 0.3 Author undergoing an EEG brain scan in the Psychology Department, Northumbria University, Newcastle 2012.

A critical moment that defined the focus of this doctoral project, was my experience of participating in a brain study *EEG Investigations of Creativity and the Wandering Mind* conducted at Northumbria University during the first year of my research. EEG (electroencephalogram) measures the electrical activity emanating from the surface of the brain using small electrodes attached to the scalp. I took part in order to experience being the subject of a medical visualisation investigation into the artistic mind. Furthermore, medical visualisations are images that have informed my practice for a number of years. The study explored the phenomenon of 'Mind wandering'[1] in people working in the creative industries and consisted of a series of text based and listening tasks. At one point during the process, I was asked to draw for approximately ten minutes whilst the electrodes were attached to my scalp. I was of course very interested in what the EEG patterns of my drawing activity might reveal, but was surprised to learn later that the data was discarded and unavailable because my body movements had caused

[1] Mind wandering is a growing area of study in cognitive science and neuroscience that is widely defined as 'task unrelated thought' and was described to me simply as 'day dreaming'. Please see: Baird, B. et al (2012) 'Inspired by Distraction' *Psychological Science*. Vol. 23, Issue 10, pp. 1117-1122.

too much interference or ‘noise’ in the signal. The concept of noise immediately intrigued and raised questions for me, which I will explore in the following chapters. Noise was described to me in terms of random and unknown information, which manifests itself as ambiguous visual traces during medical scanning processes. This resonated with my own interests in looking at medical visualisations as images that are unknown to me.

Noise is expressed as patterns of visual interference in medical visualisations, and is widely defined as unintentional, unverifiable or unknown signals generated by the human body or technologies during the process of data transmission.[2] Noise is always present to a larger or lesser extent; imaging practice and theory agrees that it cannot be fully eradicated. The binary signal-to-noise is a cornerstone of science, and medical visualisation practices largely (although not uniquely), focus on the signal and aim to reduce noise. However when I look at medical visualisations, I cannot distinguish between them. Consequently, they have an equal status as sources of visual ideas and meanings in my work. Nevertheless noise breaks down distinctions between scientist and artist, for it remains outside of knowledge to both disciplines. Given the close relationship between vision and the generation of knowledge in medical practice, noise has potential to provide an interesting interface between scientific and artistic practice. Furthermore, it allows me to understand and to negotiate the differences between artists and scientists through the ways in which they respond to it.

Remarkably, scientists use a term that essentially refers to sonic qualities – noise – to describe ambiguous visual information. Their use of a non-visual term renders noise as metaphorically invisible and raises questions about the status of noise in medical visualisation practice. How do scientists look at noise when it resists legibility? And how can a visual artist respond to its symbolically non-visual status? Noise is an aspect of medical visualisations

[2] Definitions of noise in medical visualisations can vary and some are highly technical. The definition used here was provided to me during a residency in medical imaging at the University of Manchester – which I describe in the subsequent chapter – is widely accepted in imaging practice and theory.

that is ambiguous and unknown to both scientist and artist. Ambiguity and uncertainty are understood differently in artistic practice,[3] as is the relationship between sight and knowledge. This difference provides a lens through which to interrogate noise from other perspectives. My research project explores what a drawing practice and a theoretical investigation into artistic and scientific practices of looking (and not looking) can reveal about noise in medical visualisations.

It is important to address the term 'noise' at the beginning of this enquiry because it has multiple meanings and associations, many of which are not directly relevant to my project. Noise is a slippery word that resists definition. Its etymology is visceral and harsh, deriving from the Latin *nausea* meaning disgust, discomfort or sea-sickness: an intense rejection from the body (OED, 2017, s.v. *noise* n). Noise in this sense is abject; it is something that cannot be contained.[4] In recent history, noise has become widely integrated into technical language. The term *white noise* is used across disciplines such as statistical forecasting, acoustic engineering, physics, information theory and telecommunications, albeit with slightly different meanings, but nevertheless connected to ideas of random or meaningless information, and to denote information overload.[5] In the field of electronics, a bewildering number of noises are defined. They include *Gaussian noise, pink noise, popcorn noise, shot noise, poisson noise, avalanche noise* and *thermal*

[3] William Empson's *Seven Types of Ambiguity* (1949) is a key text that explores the use of ambiguity in poetry. It is ubiquitous in English studies, although less widely read in the visual arts. The TRACEY publication *Drawing Ambiguity* (Sawdon and Marshall, 2015) contains papers by contemporary artists exploring ambiguity in drawing practice. TRACEY is a drawing research network and site hosted by Loughborough University (School of Arts). It publishes and disseminates material concerned with drawing.

[4] Its later meanings are associated with discord, from the Old French *noise*, meaning din, disturbance, uproar, or brawl, again evoking a bodily response through sound or physicality. Its Middle English meanings include a loud outcry, clamour and shouting, whilst *chercher noise* is a modern French expression meaning to pick a quarrel. Noise is therefore associated with conflict. Contemporary English usage of the word includes phrases such as: *to make a noise about something* (to complain a lot about something) and *empty vessels make the most noise (sound)*. There is an underlying sense in both phrases that noise is meaningless or of little value.

[5] In medical practice, white noise is a particular type of sound that is used to treat patients with tinnitus and sleep disorders.

noise[6]. A central premise of all the above usages is the idea of noise as unwanted or undesired interference in the information that is transmitted. Claude Shannon, widely understood as the founder of information theory, first theorised about noise in the 1940s, and presence of noise in information has since become an established focus of study. Whilst I acknowledge that noise is very closely connected to the notion of information and to digital technology in general, my project is not concerned with information theory. I am interested in uncovering what an artistic response to noise might reveal.

Medical visualisations are part of a long history in medical science that link sight to the generation of knowledge. This relationship can be traced back to practices of anatomy in the sixteenth century[7] which connected the disciplines of art and science in the examination of non-living bodies using the human eye. The development of instruments of vision such as different types of microscope, and, over time, the use of complex digital technologies, has intensified and strengthened the relationship between sight and the generation of medical knowledge. This in turn, has enabled increasingly new ways of visualising internal living bodies. The relationship between vision and medical knowledge has been theorised extensively, particularly within the philosophy of science. Michel Foucault and a large number of socio-politically oriented thinkers agree that a medical gaze emerged in the late eighteenth century out of the clinical practices of teaching hospitals. In *The Birth of the Clinic* (1973), Foucault argues that the medical gaze is bound up in complex systems of power, surveillance and the objectification of the body. Clinical practices produce relationships of power that circulate and define bodies through discourses.[8] The medical gaze renders the body into a locus of disease, which is isolated, classified, regulated and ordered. In the process, the patient becomes a signifier of disease. According to Foucault, the medical gaze is presented as 'silent and gestureless', for 'over all these

[6] For definitions of these various electronic noises see Vasilescu (2005).

[7] The publication of '*De Humani Corporis Fabrica*' (On the Workings of the Human Body), by Andreas Vesailius in 1543 is a key point in the development of anatomy.

[8] For Foucault, discourse denotes a group of statements that form a system of knowledge and produce meanings, often making use of specialist terminologies and rules.

endeavours on the part of clinical thought to define its methods and scientific norms hovers the great myth of a pure Gaze that would be pure Language: a speaking eye' (1973, p.141). Foucault's critique of a seemingly 'pure' and objective medical gaze has been the subject of extensive academic enquiry. This enquiry does not take this well-worn pathway, but follows a more diverse theoretical route.

This research is trans-disciplinary[9] and encompasses literature from diverse fields of knowledge that are pertinent to this enquiry. My theoretical framework encompasses well-known academic sources such as James Elkins, W J T Mitchell and Bruno Latour, as well as the writings of new media theorist and artist Joseph Nechvatal. The diverse nature of this research reflects its subject matter (noise), which escapes from fitting neatly into one subject discipline. Throughout my thesis I shall rely on the notion of 'cognitively closed' information (my own formulation) in order to describe the interpretive consequences of medical visualisation practices and, in turn, break down the well-established relationship between vision and the generation of knowledge. Firstly, key texts from the medical humanities, social studies of science and the philosophy of science are used to analyse the relationship between medical visualisation practices, vision and the construction of medical knowledge within cultural and social frameworks. Secondly, cultural and new media theorists interrogate how medical technologies of vision change how the human body is understood, and how noise affects these perceptions. Thirdly, theories about vision from art history and the psychology of visual perception that explore how the acts of looking and seeing can be understood as interactive, multiple and ambiguous are examined, to show that they are implicated in key characteristics of noise. Writings (and conversations) of artists, particularly concerning drawing practice and its relationship to vision are also an important strand of investigation. Lastly, the thought of the philosophers Jean-Luc Nancy and Michel Serres provides a theoretical framework for analysing how artists

[9] I use the term trans-disciplinary following the definitions and discussions in McGregor (2004) and Buntaine (2014).

perceive ambiguous visual information (noise). Their ideas are furthermore used as a way to conceptualise noise in order to elucidate the practice-led research of this project. Paradoxically, both philosophers draw on sound and the act of listening which provides an analogy for how I look when I respond to noise.

My methodology reflects the trans-disciplinary nature of the research project. I placed myself in different environments during this enquiry to investigate noise from the positions of art and science. These environments included a residency within a medical visualisation research institution, the artist's studio (mine and others artists) and bio-medical laboratories to explore how they engendered different acts of looking at and conceptualising noise. I looked through microscopes in scientific laboratories and constructed devices for looking in my studio to explore different methods of looking and to investigate visual ambiguity. I experimented with technologies such as biosensors, by working with a creative coder to develop new ways of visualising biomedical data. This aspect of the research enabled me to engage directly with medical visualisation technologies that are relatively simple and accessible, since large-scale technologies precluded artistic experimentation. Face-to-face conversations with scientists and other artists, along with email correspondence, provided opportunities for primary research into day-to-day scientific and artistic practices that engaged with concepts of noise. The records I kept of this first-hand contact allows me to support my discussion with direct quotes rather than rely entirely on secondary literature. Primary research was also undertaken in my studio, where I experimented with artistic methods and processes to test ideas about noise through drawing practice. This provided a counterpoint to scientific methodologies for investigating noise, and offered a space to reflect upon, explore and demonstrate ideas through my own practice. Secondary research was undertaken through an examination of other artists' work and through a literature review.

Chapter 1 reflects upon my residency in medical imaging at the University of Manchester, which enabled me to converse with scientists about their

practical and theoretical engagement with noise. This central experience of my research provided opportunities for me to view a variety of scans of the human body produced from different imaging modalities, and to learn about the ways in which noise is generated in medical visualisations. My dialogue with different scientists leads me to assert that noise is cognitively closed to scientists, and diagnostically irrelevant in their practice. As I negotiate scientific ideas and practices from my artistic perspective, I identify key attributes and characteristics of noise. They are concerned with movement, indirect methods of measurement and unknown interactions within and without the environments of the human body. Throughout the residency, I reflect upon these ideas and explore how noise changes acts of looking through drawing activities in the studio.

The second chapter considers the diverse ways in which contemporary artistic practice engages with the characteristics of noise that I identified in the preceding chapter. It examines the methods and processes that artists employ to complicate acts of seeing and looking, often in ways that involve movement, interaction with their environment and slippages in their visual perception. Perception is a complex and largely unconscious fusion of sensory information and its assimilation into cognitive processes. In this project, I focus upon theories of visual perception because of its centrality in medical visualisation practice, and in order to question how noise can be visually perceived. I consider theories concerning the psychology and neurophysiology of visual perception to examine the relationship between noise and human vision. Elkins' and Mitchell's ideas about multiple and interactive ways of looking and seeing provide a theoretical framework to investigate whether noise can be perceived through active and dynamic styles of looking.

The subsequent chapter reflects on phases of activity in my studio that make use of scopic instruments to explore how they frame my vision. I experiment with different acts of looking, such as looking into a microscope, looking at projections and looking through a magnifying lens. I test a box construction to explore how visual perception changes in response to Latour's concept of a

‘black box’. I experiment with drawing materials such as clay and oil, and unusual drawing grounds such as seaweed and latex. These methods enable me to immerse my drawing process in unpredictable changes and movements, or unknown interactions between the drawing and its environment as I draw. Through this, I test how my drawings respond to unknown movements and interactions: the conditions that generate noise. Lastly, I work with a creative coder and biosensors to develop a drawing performance in response to bio-data that is deliberately noisy. I reflect upon how unknown, unpredictable and ambiguous interactions with the environment change my visual perceptions.

In Chapter 4, my wish to understand and contextualise the changes in my perceptions in response to the attributes of noise, lead me to examine Jean-Luc Nancy’s text *Listening* (2007). Although Nancy is theorising about the sense of sound and ‘being as resonance’ (p. 21), I assert that my experiences are analogous to Nancy’s concept of listening. His writing provides a theoretical framework to contextualise my contention that my visual perceptions change in response to (the characteristics of) noise. Scientific theories about noise cannot account for its impact upon my perceptions as I respond through drawing. However philosopher Michel Serres’ text *Genesis* provides phenomenological insights into noise that elucidate my experiences. He theorises about noise as the environment of the universe and asserts that it is multiple and contains the possible. For Serres noise is ‘the trace of the observer’ (1995, p. 61). These ideas resonate with my experience. Lastly, I refer to recent scientific studies investigating levels of tolerance of ambiguity in medical students. These studies make use of artistic methodologies to explore how they might be used to build tolerance of visual ambiguity and consequently change perceptions of noise in scientific practice.

Chapter 1. Noisy Bodies (A residency in medical imaging)

This thesis begins with my reflections on an artist residency in medical imaging at the University of Manchester (cf. University of Manchester, n.d.). The initial call-out in 2014 was an open brief for collaborative projects between scientists and artists, and after making contact with Rebecca Elliott, who is professor of Neuroscience and Psychiatry to discuss my interests, a proposal that focused upon my research into the concept of noise was accepted. The reader will note that the residency was undertaken approximately halfway through my project, but it is positioned at the beginning of this thesis. This is because the questions and issues it raises are central to my enquiry and structure my process of reflection upon earlier stages of this research project.

The residency was set up as a series of conversations with imaging scientists. They took place in their respective offices, at their desks and in front of a monitor to enable us to look at (anonymised) scans as we talked. I asked each scientist to describe noise in medical visualisations, both as a theoretical concept and phenomenon encountered in their day-to-day practice. This provided a counterpoint to the widely accepted definition I refer to earlier in the introduction. The scientists I engaged with were from a wide variety of backgrounds and disciplines, and reflect the multi-disciplinary nature of medical visualisation research. They included physicists, mathematicians, electrical engineers, neuroscientists and radiologists. In general, they avoided too much specialist terminology in their accounts to acknowledge the trans-disciplinary nature of our dialogue. Inevitably, I negotiated a delicate balance between gaining a good enough level of knowledge and understanding of core scientific processes and concepts, without becoming immersed in unnecessary technical information for my project. This negotiation also involved making sense of scientific concepts from an artistic perspective. Nevertheless, my first conversations with scientists left me feeling quite overwhelmed by the complexity of information that was being conveyed to me. It was almost as if I was attempting to

understand something which was continually shifting and changing its shape; it refused to form a legible picture.

Noise is unknown, unverifiable and ambiguous information that is entangled in a signal, i.e. the useful and available information. It is important to make a distinction here between ‘cognitively closed off’ and ‘cognitively closed down’. The latter can be thought about as information that is completely unavailable, whilst the former refers to information that has the *potential to be available to knowledge*. In this thesis, when I state ‘cognitively closed’ I refer to it in the former sense, as potentially available information. For, as I discuss later, noise can change into signal as perceptions and knowledge change. Despite advances in technologies, noise or unknown information cannot be eradicated from medical visualisations and is continually minimised or filtered. However, the distinction between signal and noise is not always clear and ambiguity remains. Noise is widely defined as random information, yet I learn during the residency that visualisation processes also involve measurement methods that are inherently random. This inherent contradiction destabilises the signal/noise dichotomy and raises questions about the distinctions between them. If the methods used for ‘seeing’ (visualising) the body and the nature of what is being seen are both to some extent unknown and random, in what ways does this change the status of signal as the informational opposite to noise? The distinction between signal and noise is perhaps more closely connected to perception – cognitive and visual – than a sharp division between them.

The interactions and movements of the internal body caused by the circulatory, digestive or respiratory systems for instance, are known to generate noise. Similarly, noise can also be generated by interactions between scanning technologies and their environment, which is manifested as visual ambiguity in the scan. How then do scientists look at noise when it breaks down the relationship between sight and the generation of knowledge? It is noteworthy that noise is a non-visual term that is used to describe a visual phenomenon in medical practice.

The residency provided opportunities for dialogue with scientists working across different imaging modalities such as MRI (magnetic resonance imaging) and PET (positron emission tomography), to develop my understanding of different processes. Magnetic resonance imaging utilises magnetic fields and radio waves to generate images of the internal body, whilst positron emission tomography utilises radioactive drugs that are inhaled, swallowed or injected to generate images. A more detailed description is provided later in this chapter. The medical visualisations I saw were from large studies involving volunteers at the University of Manchester, and not from diagnostic scans of individual patients. They comprised of lung, brain, liver and heart imaging. Throughout the residency, I continued to make drawings in the studio. I reflected on my conversations with scientists and the questions that they raised for me, as my understanding of noise in scientific practice developed, through practice and through notes I made during the residency. Consequently this chapter is divided into four sections, each of which begins with my dialogue with scientists about different aspects of noise and is followed by my reflections upon those conversations in my studio.

Figure 1.1 Shane McKie, senior research fellow, Institute of Brain, Behaviour and Mental Health, University of Manchester and the author, 2015

1.1 Dynamic imaging, movement and noise

*'*Noise is something without structure. There is not much information in it, you can't actually measure it; it is randomly moving around.'
(McKie, 2015)

My first conversations with scientists, particularly when speaking with Shane McKie, were quite intense and overwhelming. He is a physicist and his responses to my questions often involved making diagrams to elucidate a

particular point. It was like learning a new language and required intense concentration from me. I found myself continually trying to uncover what lay beneath the scientific explanations, to reveal how scientists perceived (visually and cognitively) the ambiguity of noise. Yet somehow the conversations remained within a scientific framework, and crucially, answers to my questions described scientific processes that were largely structured to minimise noise. Thinking about noise directly was circumvented, even side-stepped. As Shane (McKie, 2015) stated '*you can't actually measure it*'. Perhaps this is why it is thought about indirectly and circumvented. However, noise is always present in the background: sifting through the noise to get to the signal is what imaging scientists do on a daily basis. It is embedded in their structures and processes of looking. But to me, noise is intriguing in itself. What is it, why is it there, what does it look like and why is it so elusive? These questions continue to hold my imagination.

I began by exploring the relationship between noise and movement, because movement is one of the chief causes of noise in medical visualisations as evidenced by my own experience of taking part in an EEG brain study. Shane confirmed that the physiological functions of the human body, such as breathing, heartbeat, circulatory and digestive systems, produce noise as a result of their intrinsic movement. All imaging modalities require the body to be as still as possible during the scanning process. Whilst external body movement can be controlled to some extent, internal body movement cannot, and calls for faster scanning speeds. Medical visualisations fall largely into two main groups: static imaging and functional or dynamic imaging. Static imaging visualises the structures of the body (e.g. X-ray of bones or the structure of the brain); it involves slower scanning speeds with relatively high image resolution. Dynamic imaging looks at function rather than structure, for instance by visualising the volume of oxygen inhaled into the lungs, or the blood flow in parts of the body. Consequently, dynamic imaging involves a faster scanning speed that can last just a few seconds. It produces images that are of a lower resolution and typically contain higher levels of noise. There is a continual tension between movement (noise) reduction and image quality.

This is further complicated when patients are asked to perform tasks inside scanners, such as pressing a button – a common task in brain imaging: 'When they press the button they move, and that movement creates noise, but it's completely correlated with the signal you are interested in. We tend to assume we know where about in the brain the motor signal is, and we'll try to take that out. But there may be a motor component in memory. So exactly what you keep and throw away can be very tricky*'* (Elliott, 2015). She continues: 'The difficulty is [that] you don't know what's noise and what's not. If you knew what was noise, it might be much easier to get rid of. You see this signal, and you have to decide what's noise and what's real.' I am interested in the use of the word 'real' here, because the implication is that noise is of a different ontological order than signal; as if it is unreal and does not exist in some sense. And yet noise is enmeshed in the signal, in the 'real'. Shane (McKie, 2015) states 'Noise is inherent in all data, its what's in the background. You can't get rid of it - it is always there. What you have to maximise is the signal using your probabilities'. Noise then has an ambiguous status, it is both present (in the signal) and absent (cannot be measured and is not 'real'). A similar dichotomy is evident when one considers movement in the physical body and emotional change. Rebecca points out:

> We are interested in emotional response; we'll show people emotionally salient images. But when you see an emotionally salient image, you'll move, you'll jump. Your heart rate will have a little blip. And if you then try and throw away anything that's to do with heart rate, or startle, you're actually throwing out what you are potentially interested in. But if you let too much of that come through, you are looking at a startly, jumpy thing. (Elliott, 2015)

Noise is therefore part of systems of knowledge development in medical visualisation technologies and is intrinsic to data generation. Yet it sits outside diagnostic relevance because it is cognitively closed and cannot generate knowledge. I learn that certain interfaces, such as the border between air and tissue (inside the lungs for instance), are known to generate very high levels of noise: lung imaging is particularly noisy. This type of noise is manifested visually as cloudy, indistinct areas with low definition. However, cloudy areas in medical visualisations can also define different types of

tissue. A trained eye is essential in recognising noise from signal. A trained eye is, nevertheless, a human eye: interpretations can vary. It is pointed out to me that two radiologists looking at the same scan can read them – see them – differently. Consensus and collaboration through discussions between different specialists plays an important role in diagnosis and is a process that acknowledges the inherent ambiguity in imaging practice.[1]

The bodies of technologies also generate noise. Hardware noise cannot be fully eliminated, as the new-media theorist Sue Ballard points out:

> In every model of information there is noise. This is because information travels through technology. Technology cannot exist without movement, and without movement there is no information. Movement no matter how imperceptible introduces noise. As soon as something moves it picks up traces of dust and dirt, glitches, mistakes, and error. Without movement there is no information, and without noise there is nothing to hear. One seizes the other. (2011, p. 60)

A scanner heats up and uses more energy when scanning speeds are high; in the process it produces more noise. However slower scanning speeds can lead to higher levels of noise produced by the human body. There is a continual balancing act between generating visualisations with the best definition and relatively low levels of noise. Furthermore, the more sensitive the scanning technology, the more it will pick up noise as well as signal. The flows and ebbs of systems within the body, and the flow of data in non-living systems can both generate random interferences that are cognitively closed. Scientists are familiar with seeing high levels of visual ambiguity in medical visualisations, as well as uncertainty about the underlying data. Artists, too, are familiar with looking at (and generating) ambiguous marks in a drawing. However, there is no equivalent for decoding or reading visualisations in the artistic drawing. Interpreting a drawing is always fluid: there is no fixed outcome. To apply scientific ways of thinking to the artistic: a drawing can be cognitively open (for all interpretations are valid), but not cognitively closed

[1] Bleakely (2015, p.338) states: 'pondering ambiguity and uncertainty may prevent premature closure in diagnostic reading … in radiology, where a high level of ambiguity is often present in reading images, uncertainty can be used as a resource to encourage collaborative readings dependent upon generating dialogue rather than competitive debate'.

(for it disallows the information contained within it to be used for complete closure or fixed meaning). Nevertheless artists and scientists share – albeit through different methods and systems of knowledge – practices of looking at visual traces in images that are ambiguous. But once a visual trace is identified as ‘noise’, scientists move away from seeing ambiguity and create a sense of closure. Noise can become invisible when it is designated as noise. Yet ambiguity remains in the visualisation and practices of collaborative diagnosis acknowledge this as they work towards a consensus (and closure) in meaning. How do artists respond to visual ambiguity in their practice? And can artistic approaches towards ambiguity suggest other ways of looking at noise?

1.2 Drawing on interaction

Figure 1.2 (Left) *Untitled*, 2015, graphite on paper, 84 x 59 cm, work by the author.
Figure 1.3 (Right) Detail of *Untitled,* 2015.

In my studio, I reflect on the relationship between movement and the phenomenon of noise by exploring ideas through drawing. I am looking at a scan of a torso. It is comprised of cloudy ephemeral forms that suggest organs within the body, which are however indistinct and difficult to separate. I imagine that I am immersed in the space of a moving, pulsing, changing body and that each mark I make is a living thing that interacts with the next mark. Looking at a drawing involves looking at relationships between

different areas of tone, form, texture etc. The act of imagining the interaction between marks does not feel strange to me. I look at the drawing as if it is continually shifting. Keeping my gaze slightly off-focus helps me to do this. I start making marks from the inside of the image, and by thinking of each mark as a unit of information or as a cell, which is repeated with subtle shifts in pressure, time taken and density. The drawing grows slowly without a clear sense of direction. I try not to 'see' the finished drawing in my imagination, but instead keep my gaze fixed upon close details and relationships between different areas in the composition. I am attempting to not know the drawing; to lose control of where it is going. This process evolves out of relationships and perceived interactions between marks. Nevertheless, I make choices at each step of the way, which is not dissimilar to making a distinction between signal and noise. Is it possible to let go of the choices I instinctively make, and to allow the movement and energy of the drawing itself to dictate the mark making? It seems to me that I am continually looking at the drawing to direct me. Yet, I am also looking into my imagination to dictate the next step.

Is there a similar process when the scientist looks at noise – a process of allowing the visualisation to direct which area of the image to focus upon? The social scientist Nicolas Rose (2012), theorises about two opposing styles of thought in the life sciences: reductionist and dynamic. He argues that a reductionist style typically visualises parts of the body in isolation[2] and not immersed in their living environment. He calls this environment a 'milieu' and states that 'an organism develops through constant transactions with its environment – its cellular, organic, biographical, ecological milieu' (Rose, 2012, p 12). The milieu is the context of living things, and consists of movement and change. Reductionist styles of visualisation typically suggest static forms. In the drawing above (Figure 1.2), I imagine that I am immersed in the milieu of the body being represented, as well as inhabiting my own body through the movements it makes whilst I draw. This implicates the

[2] For instance, highly magnified images of cells, viruses or bacteria, are typically presented in isolation, resembling abstract and static objects.

environment of my studio as changes in light and sounds around me influence how I feel, think and respond.

Dynamic styles of thought, according to Rose, conceptualise the body as 'located in a dimension of temporality and development, and constitutively open to their milieu – a milieu that ranges in scale from the intracellular, to the psychological, biographical, social and cultural' (2012, p. 3). He is proposing movement and change at a scale that moves beyond the body and into the social and cultural world. Dynamic styles of thought are unquestionably highly complex and difficult to measure with certainty. They are unverifiable and unknowable; noise is intrinsic to them. A dynamic style, I would like to suggest, includes the noise. It includes extraneous contextual information that is diagnostically irrelevant. A reductionist style suggests a completely transparent and noise-free view into the body.

What is at stake if one represents the internal body using a dynamic as opposed to a reductionist approach? Images are key tools in the dissemination of scientific knowledge, as many theorists have pointed out (Kemp, 2006; Latour, 2010; Sturken and Cartwight, 2001; Zwijnenberg et Vall, 2009). Dijck (1998, p. 11) observes that science is not only a 'fact-producing process', but is also an 'image-producing process'. Images enable scientists to communicate complex abstract information in a simplified form and, as such, are implicated in scientific insights and the scientist's ability to 'see', understand and generate knowledge.[3] My conversations with Shane affirm this. His work involves processing and analysing data from large numbers of brain scans taken of many participants. The results of his studies cannot be presented as numerical data or diagrammatically because of the volume and complexity of information involved. They are presented as a composite scan. He states (McKie, 2015): 'We have to get across our findings in a meaningful way, and most if the time that means using an

[3] On the importance of images in scientific practices, see for example Rheinberger (2002, p. 520), who argues that 'The decisive phase in scientific insight happens only by means of images, for images allow a reduction in complexity, a condensation in representation, and they produce visual clarity'.

image. The visual gives meaning and location to the data.'

The medical visualisation is, however, more than a scientific document in terms of the meanings it can generate. It is important to note that it can also simply generate visual pleasure as an aesthetic image. But there is one meaning that can become lost or hidden, particularly outside of scientific contexts: the understanding that all medical visualisations contain elements of noise. Although the non-expert may be aware of concepts of signal and noise, the ways in which medical visualisations can be presented – for instance on the covers of magazines, or prominently on the websites of scientific institutions and in sci-art exhibitions – has the effect of concealing the presence of unknown and cognitively closed information – noise – within them. Perhaps this is partly due to the fact that images produced by imaging technologies are understood as being unmediated and considered objective depictions in public perceptions.[4]

Conversely, the artist's drawing is perceived as full of noise because it is profoundly subjective; it cannot be decoded or interpreted in fixed ways. The knowledge within it is ambiguous and contingent, it demands the participation of the viewer in making meaning. My process of drawing evolves out of relationships and interactions between marks. I allow the dynamic energy of the mark-making to direct the drawing. Ambiguity becomes a resource for generating work, and is valued (rather than tolerated) in my methods. Both artistic and scientific practices involve engaging with uncertainty and ambiguity, which at times cannot be cognitively processed and consciously understood. However, ambiguity has a different status in artistic practice, as artist and curator Derek Horton points out in his introduction to the TRACEY publication *Drawing Ambiguity*:

> Without ambiguity, art lacks depth, subtlety and richness. Ambiguous artworks, in our case in the field of drawing (recognising of course that

[4] These perceptions mask the relationship between medical visualisations and an 'objective reality': 'Scientific images refer to data and to algorithms by means of which they are generated. Their level of reference is indeed a reality – not the reality of phenomenal reality, as is usually assumed, but of their medial construction' (Rheinberger, 2002, p 522).

> the correlation of drawing and art is ambiguous territory in itself), offer a potentially complex cognitive experience in which we have to navigate multiple meanings and cope with indeterminacy. (2015, p. 3).

1.3 The indirect gaze

‘What we actually measure is an indirect measurement of what we want to know. Often it's a projection.’
(Matthews, 2015)

I have established that the movement of the human body – particularly in dynamic imaging modalities – is highly implicated in the generation of noise. Furthermore, the movements of the bodies of technologies, both the hardware and data, can also generate noise. Ambiguous visual information that is cognitively closed is therefore part of the structures of medical visualisation systems of knowledge development. However, ambiguity has a different status in arts practice, it can be used as a method to generate artwork.

During the residency, I was surprised to learn that the processes by which visualisation technologies capture data were remarkably indirect and also involved unknown movements and ambiguity. Data was not captured as a result of direct measurements from the body, but rather generated from the side-lines and off-centre. I would like to clarify by giving a short account of the MRI process. The MRI scanner consists of an extremely powerful magnet that can be 10,000 times more powerful than the earth’s magnetic field (Pope, 1999). When the human body is placed within it, the magnetic field stimulates protons in the nucleus of hydrogen molecules present in the body. The average human body mass consists of approximately 10% hydrogen, largely within water molecules (Pope, 1999). The protons, which are positively charged, spin along an axis within the nucleus and are ordinarily randomly aligned. The magnetic field aligns all their spin states so that their axes line up. A radio frequency pulse is applied next. When it is switched off the protons return to their original spin states or resting state. In short, (a part of) the body is stimulated to produce a response, and the time that it takes for it to return to its original ‘resting state’ is measured. An image is

constructed out of the difference between two states: the percentage of signal change is fundamental to the process. Although this account is an over-simplification of a complex process, I am nevertheless struck by the indirectness of the measurement and the obliqueness of the process, as well as the necessity for movement and change in the measurement process itself. Furthermore, the movement of individual protons is random and not measureable. Therefore, unknown movements and interactions play a significant role in the ways in which signal is collected. This indicates that the dichotomy between noise and signal is unstable, and arguably a false one. I would like to suggest that the term 'signal/noise' more accurately reflects the status of signal.

I learn that fMRI (functional magnetic resonance imaging measures brain activity through oxygen uptake in blood flow) and PET, which are both dynamic imaging processes, involve stochastic measurement. In a stochastic system, the outcome of repeated experiments or scans, under the same conditions can be variable.[5] Within a deterministic system on the other hand, repeated experiments or scans will produce exactly the same results given the same starting conditions. Therefore, not only is noise random, but random processes are implicated in dynamic imaging measurement. These processes are described to me as 'random variables' (Epstein, 2008). When I probe further about the meaning of 'random variable' the definitions and explanations are framed as mathematical formulae.[6] I am conscious that my way of making sense of this is to translate the numbers into words (and questions), and ultimately into images – drawings. But it is also the case that scientists too cannot make sense of vast amounts of numerical information without putting it into images. I am reminded of another conversation during my residency with Alex Morgan, an imaging physicist, who describes her frustration at clients who request the outcomes of large imaging studies to be

[5] I refer to the *Handbook of Medical Imaging: Physics and Psychophysics,* which states: 'a stochastic system, when presented with two identical inputs, may produce similar outputs but they will not be exactly the same' (Beutel et al, 2000, p. 109).

[6] For a more detailed account and definition of random variables, see the '*Probability theory and random variables*' chapter in Epstein (2008, pp 525 – 574).

presented to them as numerical information instead of as (composite) visualisations: ‘But you are losing all that spatially interesting stuff. There are more interesting ways of doing that then calculating a mean number. We have fought quite hard to keep those images, considering there is so much noise in them’ (Morgan, 2015). Scientists as well as artists, can value the presence of ambiguous visual information, because it reflects a reality.

Similarly, PET (a functional imaging modality) utilises small amounts of radioactive substances called radioisotopes, which are introduced into the human body (injected, swallowed or inhaled). They ‘attach’ to different molecules in the body and undergo radioactive decay (half-life[7]) whilst in the body. As they decay, they release positrons, and this process is measured[8]. However the radioisotope’s rate of decay is not fixed and can vary. The half-life of large numbers of radioisotopes is predictable, but for the smaller numbers that are typically introduced into the body during PET the half-life is variable and the decay process is random. Consequently, a sequence of stochastic events that are intrinsically random and noisy is used to map the location and timing of radioactive decay within the body. ‘If you look at a population of such isotopes it looks to us as if the decay is exponential, but each one is random.’ (Matthews, 2015). This data is in turn used to construct images. It is a process that demands a certain style of looking: a looking for patterns to emerge.

The tension between fixed and stable measurements, and fluid, unstable and variable measurement processes are important to this enquiry because they change how one looks. If the scientist is looking at a visualisation that is produced using methods that involve indirect and random elements, it is, I

[7] A half-life is the amount of time required for a radioactive substance to lose fifty percent of its activity through decay.

[8] As a positron moves through the body it loses energy until it comes into contact with an electron. When electron and positron encounter each other, they release energy in the form of two photons moving in opposite directions. Photons travel with kinetic energy through the body, moving in different directions and through different angles of deflection as they interact with the body. This phenomenon is called Compton Scattering and this is also a random process. Although patterns do emerge and can be analysed and mapped, the behaviour of photons (these are the basic units of measurement in MRI, PET, SPECT and CT) is, I am told, stochastic (Pope, 1999).

would like to suggest, an inherently fluid and open process. Shane McKie often uses the phrase ‘a close fit’ when speaking to me about medical imaging processes. He (and others I speak to) acknowledges that measurements are not exact but *close enough*: probability and estimation are key factors. It is important to point out that random variables are not only implicated in dynamic (functional imaging) processes, but to a lesser extent also in static imaging such as X-ray too (cf. Epstein, 2008, pp. 543-565). How the body is visualized is therefore contingent and variable. The same scan repeated twice would vary, however slightly: ‘Every time you do an experiment the data isn't the same’ (McKie, 2015). Being able to predict – with some accuracy but without absolute certainty – is a cornerstone of this style of scientific looking. Perhaps it is a style of looking that has something in common with artistic styles of looking. Scientists are looking for something that may be hidden or not apparent; they are searching for patterns to emerge by looking through the noise to some extent. Perhaps in the same way that an artist looks for something hidden to emerge from a multitude of visual stimuli by looking into their imagination.

Olaf Breidbach, writing about the scientific representation of dynamic systems, calls for new ways of visualising an ‘imaginative science’: ‘If we take them not as representations of something else but as their own reality, as some hypotheses about the world that is described by them, that would be the first step toward an extended use of imaginative sciences’ (2011, p. 117). Whilst ‘imaginative’ is too far a leap to describe the contingent nature of medical visualisations, I would like to suggest that an element of intuition is involved when the scientists looks at and ‘reads’ a scan. Many times during my residency, scientists seem to respond instinctively to certain scans as being particularly noisy; they immediately know something is not quite right. They are after all, highly visual people who spend long periods of time examining images. It is an intuitive response, which is immediately felt and largely unconscious in a way that is very similar to the artist’s intuition. Intuition is not explicit knowledge; it is an embodied way of knowing what is diagnostically irrelevant in scientific contexts. However, it also plays a part in imaging practice. The artist makes aesthetic decisions, whilst the scientist is

making decisions about the underlying data that is visually portrayed. In this way, the scientist looks *through images to perceive the data*, in a perceptual leap between numerical and visual information. This suggests an 'imaginative' leap that is not dissimilar to Breidbach's 'imaginative science'. It is an indirect method of looking, which moves between data and image, from visual representation to measurement.

Scientific systems of measurement are, in general, perceived as fixed and stable, as precise and objective. I am surprised to learn about the indirectness of the methods of visualisation technologies used to capture data about the body, as well as their intrinsically stochastic nature. This is perhaps a necessity when measuring living systems, but nevertheless, there is an inherent conflict between the aims of measurement – to produce an accurate rendition of the internal body – and the methods employed. How does one reconcile indirectness with the idea of measurement? It complicates the process of diagnosis and the visual perception of medical visualisations. Fluid rather than fixed measurement processes blur boundaries between signal and noise, creating visual and cognitive ambiguity. Medical education theorist Alan Bleakely (2015) calls for practices that develop a higher tolerance of ambiguity in medicine.[9] Such practices could change perceptions of diagnostically irrelevant visual material in scientific practice, potentially by rendering it more visible and open to new readings.

[9] Chapter 4 contains a more detailed account of recent studies exploring tolerance of ambiguity in medical students.

1.4 The indirect drawing

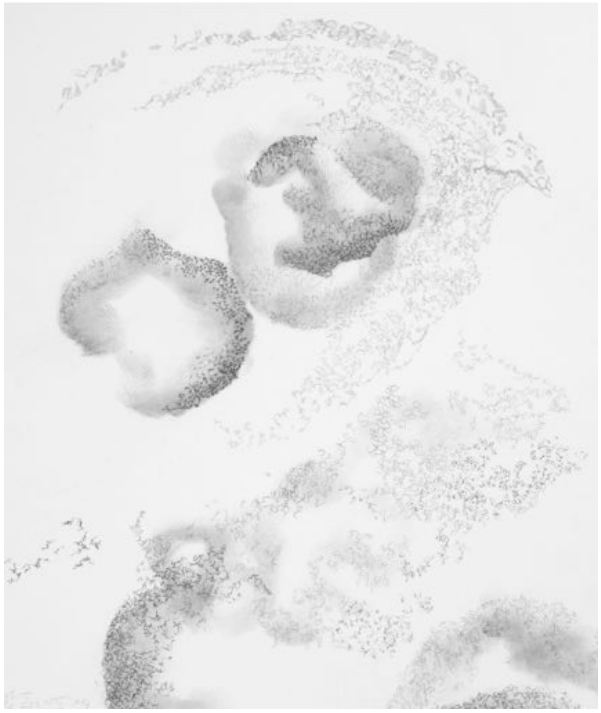



Figure 1.4 (Left) *Untitled*, 2015, graphite on paper, 84 x 59 cm, work by the author.
Figure 1.5 (Right) Detail of *Untitled,* 2015.

To reflect on medical visualisation methods that are stochastic, ideas about indirect measurement and indirect looking are next explored in the studio. I experiment with glancing sideways at my source material whilst drawing. Selections of images of the same scan at different magnification levels are placed upon the wall next to my drawing board. I need to turn my head to look at them and glance up at different ones as I draw. Looking sideways and indirectly at them is quite an uncomfortable method of drawing. As I move between them, I am layering different glimpses upon each other in the drawing. The different registers of images require different types of response through the drawing and it feels necessary to make use of a variety of drawing materials. Pencil is combined with graphite powder, which is used with a dry brush. This allows a more fluid and rapid response to my indirect glances. As I draw, I am thinking about Martin Kemp's concept of the 'fuzzy picture' as I draw, a term he uses to describe the visualisation of dynamic and chaotic systems:

> Much modern science may be uncomfortable with the 'fuzzier' pictures arising from chaos and self-organised criticality, but they seem to represent something that is real. There is no indication that the fuzzy

> shapes of such a system at, say, the larger scale of an ecosystem are less significant than the neat geometrical pattern woven by DNA at the molecular level. (2006, p. 161)

Inevitably patterns begin to emerge from my initial apparently chaotic marks, and I find myself building upon them by creating abstract shapes and forms. It is difficult to completely avoid this process, which directs my looking and the drawing. Perhaps it can only be avoided by not looking at the drawing. However, my intention is to explore indirect looking and my responses tell me that I make connections between marks to build up patterns of forms. Pattern recognition is profoundly connected to human visual perception and is an important element of the drawing process. It is also connected to how medical imaging scientists look at scans. Siân Ede observes:

> We take in signals and interpret them. And so too with the discipline of science itself. Concepts are tested through pattern recognition – visual, behavioural, mathematical. In turn patterns suggest new concepts. Reason and logic, the detective work implied in 'the scientific method' play an important part but it comes as a surprise to learn how much scientists need to see or visualise ideas in order to understand. (2000, p 21)

According to Kemp (2000, p. 2), pattern recognition is closely connected to an 'aesthetic impulse', which he claims is part of a 'feedback mechanism' that is designed to gratify and reward us for the continual effort involved in making sense of the visual world. Whether this can be proved is unclear, nevertheless, pattern recognition is a selective method of looking that inevitably filters visual elements that do not fit within the overall pattern. Noise, I would like to suggest, is particularly likely *not* to fit into an overall pattern, and consequently, remains unseen. When scientists identify traces of noise in medical visualisations, it may become necessary to focus upon the larger visual patterns at the expense of the noise in order to make coherent sense of the whole image. Perhaps inevitably, an unconscious blindness[10] to visual signs that do not make sense and do not fit into a pattern may also be involved as scientists look. After all, if visual (and numerical) information refuses to make sense, if it is cognitively closed and

[10] An interesting counter-point here is offered through Derrida's conceptualisation of the act of drawing (and of the drawing itself) as blind. (1993).

diagnostically irrelevant, it has to be disregarded. This motivation drives how the scientist looks.

However, there are not always clear-cut definitions between the noise and the signal, but rather many shades of grey exist. Negotiating the grey areas involves looking through uncertainty. One way in which scientists negotiate this uncertainty is by changing how they look. The manipulation of data and modes of seeing the data through the use of different algorithms is an important part of medical visualisation practice. Complex interactions between scientist and data determine what scientists see: the medical visualisation is not a fixed image. The next series of conversations is concerned with the relationship between algorithms and scientific acts of looking.

Figure 1.6 Professor Rebecca Elliott, Neuroscience and Experimental Psychology, University of Manchester and the author, 2015.

1.5 Looking through algorithms

The use of algorithms (sets of rules that are followed in problem-solving operations and calculations by a computer) is fundamental to the processing of medical visualisation data. By manipulating the numerical information, algorithms change the image. They are typically utilised to make adjustments to data linked to body movement and as such are implicated in the reduction of noise. I outline some key processes below to emphasise how data manipulation is central to how the scientist looks. It is important to note however, that algorithms can only detect what they are designed to do:

> The measurement equipment you use will only measure what it has been programmed to do. This is why we have to keep testing... There are so many parameters that you can change, and many unknown parameters. We make all these assumptions, but we don't know if we've got the equations right. If you don't know if it's meant to be there, then it won't be in the equation to start with. (McKie, 2015).

The inexorable growth and innovation of imaging technologies indicates that the scientific community is continually addressing this issue. During my conversations, scientists refer repeatedly to algorithmic processes that are used to reduce noise. They are largely concerned with adjustments for body movement. I will briefly give an account of one such process – Normalisation – to outline the relationship between data manipulation and the image that is seen. Normalisation is an algorithm that co-registers a functional scan and a structural scan, and is concerned with spatial resolution. It is described to me as: 'basically it is averaging out; placing the functional brain on top of the structural brain, in the same space' (McKie, 2015). Normalisation combines interpolations from a structural scan with a mean[11] of the realigned images. The use of interpolation is interesting to explore a little further here, as it is a method that underpins many of the mathematical calculations involved in medical visualisations. It plays an important role in defining what is seen. Interpolation is the mathematical method of constructing new intermediate data points between sets of known values. It is based upon probability and 'an informed estimate of the unknown' (Thevenaz, 2000, p.393). Thevenaz perfectly sums up the tensions involved in capturing data (and generating images) from living bodies by describing interpolation as: 'the link between the discrete world and the continuous one' (2000, p. 394).

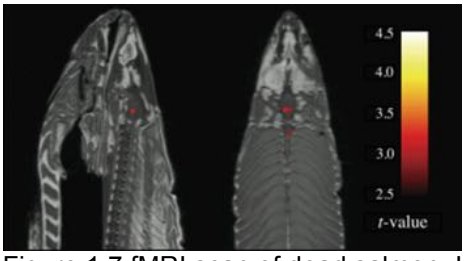


Figure 1.7 fMRI scan of dead salmon. Image is taken from poster (2012) Bennet, C. et. al.

[11] 'Interpolation' is defined as: 'The process of determining a value of a function between two known values without using the equation of the function itself' and 'Mean' as 'A measure of location or central value for a continuous variable.' (Everitt & Skrondal, 2010)

However the use of algorithms can be controversial, as the following intriguing study demonstrates. In a recent paper concerning the process of 'phantom imaging', which is a procedure for checking whether a scanner is calibrated correctly'[12], neuroscientists devised a unique test to check a scanner prior to a study measuring changes in blood-oxygenation levels in the brains (of humans) during tasks involving looking at different images inside a scanner. In a much-publicised study (Bennett, et. al. 2012), a dead salmon was placed in the scanner and projected a series of images whilst it was being scanned. To their surprise, the fMRI scan registered brain activity in the (dead) salmon, despite no evidence of malfunction in the scanner and the use of noise removing algorithms. This incidence has sparked much debate in the neuroscience and brain-imaging community about the use of 'multiple comparisons'[13] algorithms in fMRI processes. Advocates point out that it is essential to reduce false positives, such as in the case of the dead fish. Opponents, on the other hand, argue that it is a conservative tool that can generate 'false negatives' and mask valuable information. Debates about which algorithms are best placed to enhance signal and reduce noise are not of significance to my project. What is of interest however, is the persistence of noise despite the use of algorithms.

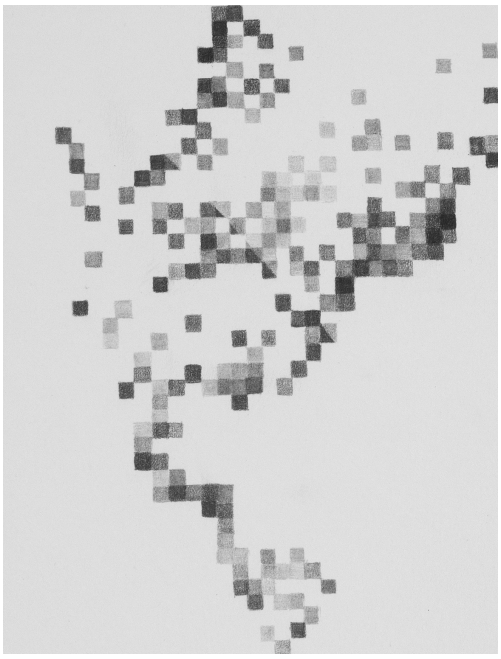
Medical visualisations 'picture' the body through many acts of filtering, masking or re-organising numerical information. This can perhaps be compared to the way in which human visual perception functions by making choices about what it focuses upon and what it discounts or filters from the visual field. Looking is like hunting, James Elkins (1996) asserts. It is a process of actively searching as one looks for patterns and meanings to emerge. But searching is highly selective; it also involves filtering visual information that is not the object of the search. 'Each act of vision mingles seeing with not seeing, so that vision can become less a way of gathering

[12] This typically involves the use of vials filled with agar gel, which contain measured amounts of different contrast agents with pre-set values that have been prepared under laboratory conditions. These vials are placed in the scanner to check their values and to test and calibrate the scanner.

[13] The use of multiple comparisons correction in medical imaging is, for example, discussed in Bennett et. al. (2012).

information than avoiding it' (Elkins, 1996, p. 201). The human eye and visualisation technologies are both actively making sense of the visual field. 'Ideas about control and lack of control are played out differently in artistic and scientific practice. Crucially, scientists look at 'pictures' of data, which they have set parameters for using mathematical methods and rules designed to reduce noise and to enable them to see clearly. Nevertheless, the images still contain some noise. The push and pull in this way of looking, and of producing images is in a sense creative, although it may not be perceived as such by scientists. They are searching for something to reveal itself by manipulating data. Is there a similar process as I manipulate my analogue drawing materials and search for images to be revealed? I reflect upon the idea of looking though algorithms and through the human eye in the studio.

1.6 Drawing algorithms



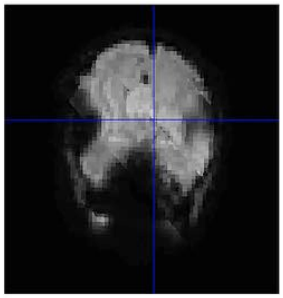


Figure 1.8 (Top Left) Untitled, 2015, graphite on paper, 84 x 59 cm. Work by the author.
Figure 1.9 (Top Right) Detail of *Untitled,* 2015.
Figure 1.10 (Below left) Image of original scan.

The starting point for the drawing above (see Figure 1.8) is a particularly 'noisy' brain scan (see Figure 1.10) in which high levels of body movement were involved. Despite the use of algorithms for motion correction, it was considered to be unusable for the study. The 'noisy' areas of the scan were pointed out to me; they consist of misalignments that resemble fault lines in the image. It is a visually arresting image; its abstract composition and formal qualities are far removed from a living brain. I find myself responding to the variations of tone – its subtle shifts in density and powdery greyness. I render the different tones of grey in the pixelated image by using a variety of pencils from 6H to 6B. It is slow, meticulous work, requiring control of hand movements and an awareness of how breath and slight tremors of the body can disturb the process. Small areas of tone are worked over again and again, until the graphite has a slight sheen. I am giving a material presence to the abstracted digital image: it is a way of reaching into the data back to a body. The drawing becomes a bridge between the body that is scanned and data. Its material presence demands a different style of looking. It invites one to take time in its viewing and requires a close look (literally moving close to the paper) which is quite different to looking at the original scan. This style of looking feels more like loosing oneself in the marks (in the body of the drawing), rather than picking out overall patterns and meanings, and through this, I would like to suggest, invites an engagement with not knowing (noise) is opened.

The hand-made image is inevitably associated with subjective and open readings, and conversely, the scientific visualisation carries with it associations with objectivity and knowledge making. But as Briedbach (2011) argues, an emphasis upon advances in computation capacities, technical performance and the production of life-like images of the body (from data) is not always the same as advances in the underlying analysis. An emphasis upon visualisations has a tendency to conceal the very close relationship between human decision-making, visual perception and the production and analysis of the technological image. Raw data files require 'extensive processing, analysis, and interpretation as well as massive reduction in size to become meaningful at all' (Burri & Dumit, 2008, p. 303). Thus, medical

visualisations are images that are ‘part of making data meaningful’ (ibid). However they can also have other relationships with data. Images can communicate in ways that data cannot as Elkins points out: ‘An image is not a piece of data in an information system. It is a corrosive, something that has the power to tunnel into me, to melt part of what I am and re-form it in another shape’ (1996, p. 42). Elkins is referring to our unconscious responses to images, which art historians (and psychologists) have theorised about extensively. Although medical visualisations have not been studied in this way, they are nevertheless images of the human body, and unconscious – cognitively closed – responses to images of the body have been theorised:

> We tend to look first at bodies and only afterwards let our eyes take in whatever else is there. It may be that the unthinking search for bodies is the most fundamental operation of vision, and that, even when there are no bodies present, we continue to understand the world in terms of bodily forms, textures, or metaphors. (1996, p. 13)

The material presence of a drawing demands different styles of looking to the digital scan displayed on a monitor. In my experience, a close observation of its surface qualities leads to a heightened sense of my own body as I look. An interesting comparison between two linear images, an EEG scan and a Hokusai drawing, in David Griffin's paper ‘On not defining drawing’ (2012) is noteworthy. Griffin observes that both images contain lines that oscillate as they move across the image, but the weight, density and texture of the Hokusai lines – material presence – are integral to its reading. The lines of the EEG on the other hand, are read solely for the path they travel through a data field and any other information, such as the weight of the line, is cognitively irrelevant. This information is central to the drawing's meaning. However, the logical structure and rational environment of data-field pathways in the EEG scan do not reflect the ambiguity (and noise) that is an integral part of medical visualisations. The environment of the drawing allows for a wider interpretive field and, I would like to suggest, more complex ways of communicating ambiguity. My next conversations with scientists explore how noise is part of the environments of scanners.

1.7 The environments of noise

'As you lose noise you also lose image resolution. It's a balance.'
(Matthews, 2015)

A central characteristic of noise is that it is random; its behaviour cannot be predicted. Perhaps one of the most random and unpredictable manifestations of noise is concerned with the interactions between scanning technologies and their environments. It is a well-established fact that MRI technology detects not only radiation from protons in the body, but also from the CMB (cosmic microwave background).[14] This is a diffuse electromagnetic radiation that is the after-glow from the 'big bang' of cosmology, and which fills the universe. CMB signals 'contaminate' the scan; they can be filtered using algorithms, but cannot be entirely eliminated. CMB is perhaps the ultimate expression of Rose's concept of a 'milieu'; it is the environment from which life itself emerged. A similar process takes place in other image modalities such as X ray, which can detect radiation signals from their geological environment. As Ede points out:

> Current scientific research, and simultaneously the most recent expression in contemporary art, both depend on an increasing conviction that nothing can be fixed in time or place or isolated from its environment… Activity within the individual living cell, neurons firing in the brain, the inter-relationships between subatomic particles … are all dynamic systems in a perpetual state of flux. (2000, p. 22)

Flux suggests an environment of interactions (milieu) that is constantly changing and unstable. They extend from the immediate to the cosmic. The actions of cells, organs and systems within the body, as well as interactions between radiation in the external environment and the scanner generate noise. Noise is a trace of the 'perpetual state of flux' that Ede refers to. It is contextual information about the milieu of medical visualisations.

The artistic image is understood as contextual, as being fundamentally connected to the social, geographical, political and cultural environment of its making. The scientific image is less likely to be understood in this way in

[14] Cosmic microwave background (CMB), also called cosmic background radiation, is electromagnetic radiation filling the universe that is a residual effect of the big bang of cosmology. The background radiation is in the microwave region of the electromagnetic spectrum. (Shu, 2017).

public perceptions, despite widespread agreement amongst social scientists, historians and philosophers of science that it is embedded in the social world. Perhaps the use of complex technologies is one of the main reasons that medical visualisations are not perceived as contextual images. And yet the sensitivity of these technologies is precisely why they can pick up signals from their contextual environments. I am reminded of previous conversations with scientists: the more sensitive the technology, the more likely it is to pick up noise as well as signal. Perhaps this is inescapable. But more importantly, as Matthews (2015) points out, when you reduce noise, you also lose valuable information. It is always a balance. Throwing away information that is perceived as cognitively irrelevant information can be problematic.

Why then do scientists use the term 'noise' – which is at heart a sonic term – to describe ambiguous visual information? Why do scientists, who have historically connected knowledge to vision, choose a non-visual term? Is there a quality in sound – as opposed to vision – that is more closely aligned to information that is not available to cognition? Or is it more to do with not looking at (seeing) diagnostically irrelevant information? In the studio, I reflect upon these questions as I draw in response to the idea of an environment of noise.

1.8 Drawing the milieu

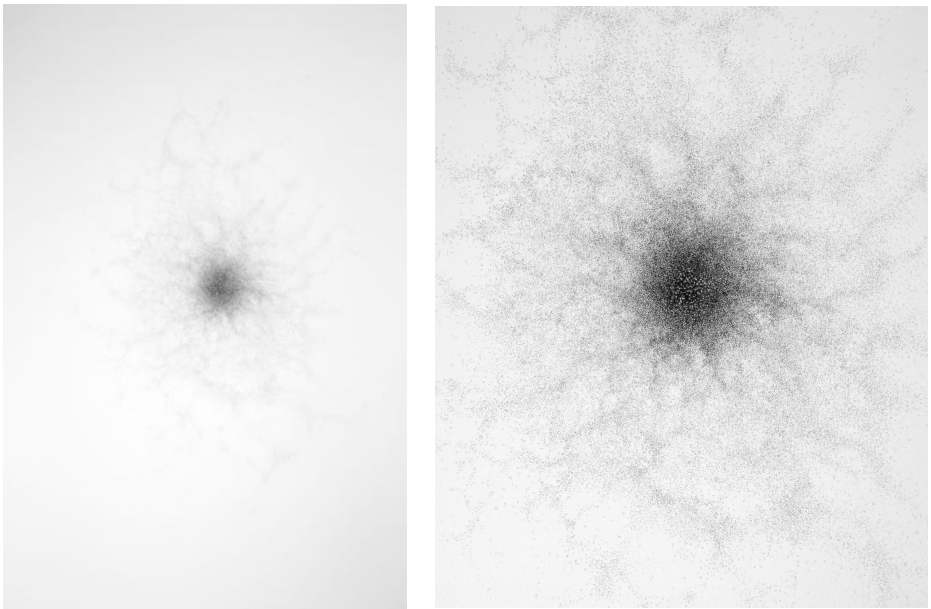


Figure 1.11 (Left) *Untitled*, 2015, graphite on paper, 84 x 59 cm, work by the author.
Figure 1.12 (Right) Detail of *Untitled,* 2015.

How does the artist imagine a milieu or environment of flux and change? Flux is essentially a temporal phenomenon; it is rooted in change over time. How do I suggest the temporal in a still image? I explore time-based media in the form of a hand-drawn animation later in this thesis, but it also seems important to work with static drawings to uncover what they can do. Medical visualisations are largely still images. I begin by imagining that I am immersed in an environment that is continually moving and changing. Particles of dust caught in the sunlight, changes in temperature and the sounds around me in the studio become heightened as I draw. Although my focus is upon looking at the drawing, my alertness to the environment of the studio informs my drawing.

I do not look at images of scans as I draw, there is no external image as stimulus for this drawing. It is built up very slowly over time, allowing each mark to connect with another. The idea of networks of interactions drives it forward, without a clear idea of its form or shape. I avoid thinking about the drawing as a whole and try to stay in the moment of making each mark. I also avoid gestural responses, and attempt to stay continually receptive and alert. Drawing in this way is strangely arduous, for I am continually blocking out internal images of how the drawing might proceed. It is difficult to know when the drawing is finished, because I could in a sense build upon it indefinitely (until the paper disintegrates) by continually making connections between marks. The choices I make are rooted in momentary perceptions that are visual and also material, because this drawing pulls me in very close. My marks are small enough to allow me to feel minute variations on the surface of the paper. The delicacy of individual marks reflects the unknown quality of my looking.

As discussed previously, scientists use a sonic term – noise – to describe visually (and numerically) ambiguous information. Perhaps this is connected to its unknown visual status and its position outside of scientific knowledge. It may also be connected to the invisibility of noise within signal, and to the somewhat false dichotomy between them. The collection of signal from the human body involves unknown interactions and random movements. Noise

is, arguably, part of the process by which scientists gather data that they call signal.

Conclusion

This chapter explored how noise is generated by and deeply implicated in complex movements and exchanges within the milieu of the human body and by interactions between visualisation technologies and their environment. Despite the use of algorithms to reduce noise, it cannot be fully eradicated from medical visualisations. Thus, noise is embedded in the structures and processes of looking developed by science and can neither be excluded from the concept of a medical visualisation, nor the interpretive practices associated with the technologies involved.

I investigated how scientists create the informational category of noise when they look at medical visualisations. Noise always sits outside diagnostic relevance. It is therefore cognitively closed but still part of the system of knowledge developed in the technologies of science. However, the boundaries between noise and its informational opposite, signal, are not always clear-cut, and some ambiguity remains. The collaborative practice between different scientists during diagnosis and their statements in conversations with me demonstrated this. Later in this thesis, I refer to examples of scientific enquiry where noise changes into signal over time.

My negotiation of noise in medical visualisation practices led me to observe that noise is implicated in the generation of signal. The positive and negative values attached to signal and noise in medical science can mask the grey areas between them. Random movements and interactions within and without the environment of the body not only generate noise, but are also embedded in the production of signal. Therefore, I assert that signal/noise more accurately describes the nature of signal, for it destabilises the dichotomy.

The instability and visual ambiguity of noise was explored in my studio through drawing processes that engaged with different acts of looking.

Artistic practice, I assert, responds to visual ambiguity in different ways to scientific practice and can provide different perspectives upon noise. Thus the aim of this first chapter has been to argue that noise-signal ambiguities in science constitute an interesting interface with creative practices.

Chapter 2. Noise On Vision (Talking about artists)

The previous chapter focused on noise from the environment of a medical visualisation research institution, and considered how imaging scientists conceptualise and respond to it in their practice. Building on this information, this chapter interrogates how contemporary artists conceptualise and engage with noise to investigate how their approaches may offer different insights into its workings. The residency raised some key questions about how noise is perceived, recognised and seen by scientists; I argue that it complicates perception because it is difficult to separate it from the signal. The historical link between medical science, visual perception and the acquisition of knowledge suggests that vision is the primary sense in scientific enquiry. How does noise, which is unknown and unknowable, change this relationship in medical science? And how does the contemporary artist visually perceive noise? I consider the interactions within the human body,[1] and between the bodies of technologies and their environments (milieu) that are understood to generate noise in scientific practice, and explore how they also change how noise is perceived. Theories about an ecological approach to visual perception by James J. Gibson (2015) contextualise my ideas about the relationship between the milieu, noise and vision. Furthermore, I explore James Elkins' (1996) and W. J. T. Mitchell's (2005, 2015) ideas about active and multi-directional ways of seeing, to interrogate how they can provide models for considering how vision can be thought about in the context of noise. Their ideas are from the discipline of art history, which has historically prioritised vision over the other senses. This approach is shared by many imaging scientists, who also do not privilege multi-sensual methods when analysing medical visualisations.

[1] I would like to clarify my use of the terms ‘human body’ and ‘body’. In art history, the term ‘body’ is associated with ideas about the human body as a contested site of identity, particularly representations that construct identity (gender, race, class etc). Signs of identity are primarily seen and performed upon the surface of the body. Notions of ‘the body’, which carry with them the weight of art history, are less relevant to my project. I use the terms ‘human body’ and ‘body’ interchangeably to refer to the internal body as it is represented in medical science.

How do contemporary artists engage with acts of looking and seeing through practice and theory? What kinds of methods do artists employ to perceive unknown, ambiguous or unpredictable visual material? If looking is understood as the anatomical function of the eyes, and seeing as that which is seen or perceived when one looks, it is impossible to distinguish between them.[2] However, in general, I use the term 'looking' to describe acts of observation such as looking through an instrument of vision, and 'seeing' as that, which is cognitively perceived. Nevertheless, this is not a fixed distinction, but fluid and variable, much as the eye itself is in continual movement. Marilène Oliver's installations problematise a transparent view into the body (Dijck, 2005) by creating ambiguous visual environments. Artist Claude Heath's drawing practice complicates vision by using indirect methods of looking and (not) seeing, as well as slippages in his perceptions. His use of visual instruments such as stereoscopic glasses disrupts the functions they were originally designed for, leading him to perceive his subject matter in unknown ways. He actively generates drawings that break down the relationship between vision and knowledge. Beatriz Olabarrieta's video *Bolas* sets up a process whereby acts of drawing and looking become entangled in unexpected and difficult to control movements and interactions. Whilst the scientist's own body movements are not explicitly acknowledged and implicated when looking at noise in visualisations, I consider whether artistic processes that respond through unknown or unpredictable body movements whilst drawing can generate new ways of connecting with noise. Noise is an emerging theme within new media art, particularly in the work of Joseph Nechvatal who directly engages with key themes in my project. He theorises and produces artwork about the concept of noise, using algorithms that interact with his artworks in unexpected ways. Through this process, he actively generates noise to change how his artwork is seen. Imaging scientists also manipulate algorithms to determine how medical visualisations are seen. How could artistic strategies and methods involving the manipulation of data change perceptions of noise? This chapter interrogates

[2] James Elkins states that 'the more neurological evidence is taken into account, the harder it is to separate anatomy from history, manners, or psychology' (1996, p. 19).

what kinds of knowledge artistic processes that engage with the concept of noise (both directly and indirectly) can reveal. The writings of artists, art historians, new-media and visual-culture theorists, who interrogate vision and perception and explore the concept of noise provide a framework for this chapter.

2.1 Noise as error

At the heart of all attempts to reduce noise is the attempt to reduce error. But is noise merely error? Is it simply a glitch in the system? Glitch is theorised as an 'aesthetics of error' in new media art, one that 'mines what was once the erroneous' (Nechvatal, 2011, p. 18). This process transforms what was once valueless into something valuable, thus changing perceptions. Whilst the incorporation of error (noise) has produced new forms of art, it is difficult to reconcile the use of error in scientific practice. Certainly, it would appear that error is inimical to scientific enquiry. However we also learn through errors (and failure). Finding a solution to a problem involves finding out what does *not* work, and trial and error is a cornerstone of laboratory experiments. In this sense, error is central to learning and the acquisition of knowledge. Moreover, error (noise) is inseparable from information (signal), and is embedded within the methods that scientists use to gather data, as I point out in Chapter 1. Noise can generate signal and therefore, is not simply an interference in signals. The media theorist Mako Hill points out that error and noise in systems can reveal their invisible workings: 'errors can reveal the affordances and constraints of technology that are often invisible to users' (2011, p. 29). He compares this to looking through a lens: 'When technology works smoothly, its nature and effects are invisible. But technologies do not always work smoothly. A tiny fracture or smudge on a lens renders glasses quite visible to the wearer' (2011, p. 27). Noise can therefore, reveal the limitations of visualisation technologies.

An interesting example of this is an account by the artist Marilène Oliver in her thesis, which is concerned with MRI (2008, pp. 26-34). She recalls looking at scans of her own body and noticing what she describes as 'blobs' around the heart. Upon asking the radiographer about them, she was told

that they are ‘noise’ - cardiac motion artefacts (a type of noise) - caused by the movement of her heart. She is intrigued and attempts to find out more:

> This phenomenon caught my imagination and I was keen to return and try and develop this work further ... but struggled to find a research partner willing to work with me. At one meeting I found myself in a very bizarre situation where I was showing a radiographer one of my heartbeat scans pointing out the very pronounced blobs but he kept insisting that ‘there is *nothing there* to see*’,* that it was *‘*displacement. Just displacement. Nothing.’ Sensing his frustration I moved on to a different topic of conversation. In another meeting the radiographer explained that for him it would be a complete waste of time to embark on a project that scanned for artefact and that ‘besides, I am such a good radiographer I never get artefact’. (Oliver, 2008, p. 33, italics in original)

The statement by the radiologist, that ‘there is *nothing there* to see’ is revealing. His use of language – notwithstanding that he is using the phrase metaphorically – is telling. One can simply deny the existence of and not see something in front of ones eyes if prior knowledge tells us it is erroneous. By labelling a part of the scan as ‘noise’, *it disappears from view*. It is cognitively irrelevant and therefore the radiologist can deny his visual perception. There is of course a considerable difference between a radiologist working in a hospital diagnostic unit and one working in a research institution. In research environments, radiologists are more likely to examine noise or to retain it in the visual field; in diagnostic radiology, the pressure to remove traces of noise is high. Nevertheless both environments are focused upon generating knowledge, whether it is about an individual scan or a large research study involving numerous scans. Oliver states that as an artist, she is attracted to the ‘faults’ in the image (2008, p.34), and this is perhaps a luxury afforded to an artist who can look without the pressure of diagnosis. Nevertheless it is common practice in hospitals for a group of specialists to discuss potential readings of a scan prior to diagnosis. Consensus is arrived at by acknowledging multiple ways of looking at and seeing the scan, and the possibility of uncertainty and ambiguity between signal and noise that I have drawn attention to in Chapter 1 as a signal/noise dichotomy. They are closely bound together. Noise is not so much error but *ambiguous* information. How does one look when there is uncertainty about what is being seen?


Figure 2.1 (Left), Marilène Oliver, *Family Portrait*, 2003, ink on acrylic sheets.
Figure 2.2 (Right) Detail of *Family Portrait*, 2003.

Oliver's work *Family Portraits* is a manifestation of the ambiguous and uncertain nature of looking into the body through medical visualisations. The work is produced from MRI scans of the artist and her immediate family, which are printed in sections upon transparent acrylic sheets to reconstruct to form the whole body at actual size. The use of transparent materials such as glass, acrylic and architectural film is a recurring theme in the work of many artists whose work responds to medical visualisations. They evoke a dematerialised and technological body which is further emphasised by the use of complex technologies to construct artworks based upon visualisations.[3] As one walks around the figures in the installation, slight changes in the viewer's position seem to trigger shifts inside the bodies. A trick of the light caused by reflections upon transparent surfaces creates the illusion of movements. The body emerges from connections between cross-sections that are not seen individually and facing the eye, but are angled away from the direct gaze causing patterns of interference. Bodies appear out of an environment of shifting planes and positions, clouding vision.

The new-media theorist José van Dijck (2005) investigating how medical visualisations can generate perceptions about a fully visible and transparent body, argues that peering into the body is not an innocent activity. She

[3] Examples of artists working with transparent materials and images of visualisations include Katherine Dowson, *My Soul,* 2005; Annie Cattrell, *Capacity,* 2008; Angela Palmer, *Self Portrait Crouching*, 2007; and Justine Cooper, *Rapt 11*, 1998.

asserts that the transparent body is ‘a cultural construct mediated by medical instruments’, which ‘feeds into a desire for a manipulative body [that] perfectly fits a material, technological culture in which imitation has been replaced by modification’ (2005, p. 42). According to van Dijck, this apparent transparency is a contradictory and layered concept, which transforms the interior body into technologically complex visual information, which can confront people with agonising dilemmas and ethical choices. The notion of transparency in this context complicates understanding and renders the body more opaque.

2.2 Tracing noise

Artist Claude Heath’s practice continually experiments with visualisation technologies such as laser range-finding instruments, stereoscopes, aerial photography and stereo glasses to destabilise and create uncertainty about what is seen. His methods foreground lack of control and the tension between looking and not looking, for instance by using both hands to draw an object upon different planes that are hidden from view. Touch and body movement, particularly proprioception – the sense of the body in space – are important elements in his methods. Heath moves between seeing and not seeing, knowing and not knowing. In the process, he produces drawings that are difficult to read because of the ways in which he disrupts the relationship between sight and knowledge:

> Heath's work resists clear sense. It never fully translates. It seems to carry with it the groping darkness in which it was made, as if what was intelligible there can never emerge into the light of visibility... The knowledge embodied in these images is knowledge that we're just not up to using. (Lubbock, 2002)

Figure 2.3 (Top Left) Claude Heath drawing eucalyptus plant without looking at paper.
(Top Right) Claude Heath, *Eucalyptus*, 2001, acrylic ink on paper, mounted on board, two panels, each 45.8 x 56cmm.
Figure 2.4 (Below) Stereoscopic glasses with map of Ben Nevis, 2003.

Heath's drawings are difficult to decode because he breaks down the relationship between sight and representation. His methods are deliberately indirect. I am reminded of the indirect ways in which medical visualisations both measure and produce images of the internal body during my residency. Whilst indirect methods are perhaps understandably required when imaging technologies interact with living bodies, their ultimate aim is to accurately depict their subject matter. Heath's methods, on the other hand, ensure the experimentation with error and invite slippages between vision, touch and representation. He points out that these slippages allow him to 'see' what the eye cannot:

> When drawing blindfold, one thing that strikes you is that it is possible to draw the far side of an object, which is ordinarily out of sight, or 'behind', simply by reaching around with your hand. By drawing it in this way, the hidden surfaces are made visible. This also brings things into view in such a way that they might compete with those up front which are normally visible to sight. So making something visible does not always make it easily available. (Heath, 2016)

His drawings demand new ways of looking; it is difficult to recognise the object that is being represented. They are traces of not knowing and, as such, can be thought about as cognitively closed. As the unseen pencil in his hand follows his perceptions, it produces a material trace of slippages between sight and representation. He takes the emphasis away from the

representation and into a response to the object that is from the imagination – a looking inward. However looking inwards is not inseparable from looking outwards. Human vision is fraught with contradictions and is impossible to reconcile with ideas about 'objectivity' as many theorists have observed (Elkins, 1996,1998; Kemp, 1996, 2006; Latour, 1986; Mitchell 2005).

2.3 Noise and human vision

Noise, I would like to suggest, is implicated in everyday vision. The physiological function of the eyes generates images that are full of noise in the form of highly ambiguous visual information. Simple forms can become 'distorted' in a multitude of ways. The angle of vision, light conditions, texture and tonal contrast are just some of the factors that can change the appearance of a spherical form in dramatic ways, as Martin Kemp observes:

> It is remarkable how many variations can be introduced without destroying our ability to compute the basic sphericity of the form. Depending on our cognitive interest at any particular time …we can selectively pick out one or more of the 'interferences' which affect the basic 'signal'. We can, for instance, mentally filter the image to concentrate on variations in surface colour or tone. (Kemp, 2006, p. 68)

The act of looking is a continuous process of interpretation and meaning-making, while the appearance of objects may change dramatically when viewed under different conditions. Movement complicates everyday vision. The 'interferences' that Kemp refers to are analogous to noise; they are 'signals' that cannot be clearly read or understood. We are continually filtering such signals – visual information – in order to function in the world. This is largely an unconscious process that allows us to disavow the noise in our visual perception. Looking is deeply connected to recognition, prior knowledge and processes of filtering and not seeing.

How does one see something (recognise something) that is completely unknown and outside our frame of visual reference? It becomes perceived as noise I would like to argue. For noise is a relational phenomenon: it is perceived in relation to signal. If we take the example of looking at something that is unknown, this process is revealed more clearly. Kemp gives the

example of looking at the moon through the early telescope at a time when the earth was understood to be the centre of the universe, and where 'strange things were becoming visible for which no ready frame of interpretative seeing existed' (2006, p. 45). The dark patches on the surface of the moon were initially understood as patterns of discolouration, and not as patterns of light and shade across a spherical object, as Galileo asserted.[4] Consequently, the telescope became 'vulnerable to the charge that what was seen through it was in whole or in part produced by the instrument itself … rather than showing in an accurate manner what was out there' (ibid). Technologies of vision are ultimately mediated by the human eye and brain, and in this sense, what they reveal is filtered through existing knowledge and cultural attitudes. The idea that vision is principally mediated by social and cultural attitudes is however contested by ecological theories of visual perception.

It is well established in neurophysiological study that visual perception is comprised of two systems, the ventral and the dorsal, which are located in the cortex (Norman, 2002).[5] The dorsal is more sensitive to motion and is speedier in its responses, but is not as efficient at storing long-term (visual) memory. We are more conscious of the ventral system in everyday life, whilst the dorsal system is implicated in unconscious visual perceptions (Norman, 2002). I outline this highly simplified account of the two systems to provide a context for two opposing theories in the psychology of visual perception: the constructivist and the ecological. Constructivist theories of visual perception emphasise the role of prior knowledge in making meaning. They assert that the information reaching the eye is insufficient to make sense of the world, and that many stages of cognitive processes, which involve hypothesising, are necessary prior to making sense. Ecological theory asserts that the

[4] For another account of Galileo's encounters with the telescope, see Umberto Eco's (2000) description of his drawings of the rings around Saturn. Eco emphasises that the process of drawing becomes Galileo's method of conceptualising and structuring something that is outside his prior knowledge.

[5] The function of the ventral system is 'the recognition and identification of the visual input' whilst the dorsal system is concerned with 'the analysis of the visual input in order to allow visually guided behaviour vis-à-vis the environment and objects within it' (Norman, 2002, p. 74).

information from the environment is largely sufficient. It proposes a more immediate and direct response to the environment that does not require high levels of cognitive processing (McLeod, 2008). This is an interesting distinction with regard to noise, for if one wants to visually perceive it, prior knowledge is not helpful. Each visual encounter with noise is in a sense new. However it is also problematic to assume that no prior knowledge is implicated in visual perception, as critics of ecological theories of visual perception argue. Nevertheless it is a matter of emphasis, for ecological theory does encompass perceptions of memory and expectation.

There are many resonances in Gibson's (2015) influential *The Ecological Approach to Visual Perception* with the phenomenon of noise. He emphasises the flows of light and the key role of body interaction within environments as central components of visual perception. For Gibson, the movement of the head upon the body, and the body supported by the ground are all implicated in visual perception. Furthermore he refutes theories of vision as perspectival, for as the body moves there is no fixed point of observation. He argues that paths of observation are generated by ambulatory vision. As we move through the environment changes in the flows of light – what he terms as the optic array – provide a rich source of information about textures, distances of objects, the edges of things and our bodily relationship to them. Gibson proposes that light itself can 'convey information about the world and hence, the phenomenal world does not have to be constructed by the mind' (2015, p. 44). Recent studies suggest that there are limitations to both constructivist and ecological theories, and that a combination of both can explain visual perception more accurately (Norman, 2002). My aim here is not to get caught up in these debates, but to explore the relationship between bodies moving and interacting in space and visual perception. Bruno Latour suggests: 'What is needed to fathom scientific image making is probably the equivalent of what Gibson started to study for ordinary vision: an ecological interpretation that manages to focus not on vision per se but on the deambulation of active bodies registering features of a landscape by judging the relative proportion of what changes and what is transformed' (2014, p.349).

2.4 Movement and noise

There is a further sense in which the act of looking is understood in terms of movement, if one considers the constant saccadic movement of the eye. As the eye scans and maps the visual field, it makes a series of involuntary rapid eye movements known as saccadic (Bach, 2012). Human vision consists of a continual series of rapid and involuntary eye movements; it is not a fixed and static stare. Visual perception is accordingly, inseparable from movement. Furthermore, the brain processes two sets of information, one from each eye, by moving between them to generate an image with a sense of depth. But what do we actually see when the eye is actively darting around between different points? According to neuroscientist Jan Lauwereyns, a process of saccadic suppression takes place: 'visual perception shuts down during eye movements … as no useful sensory information can be registered while the eyes are in mid-flight; we would get nothing but senseless streaks of light on the retina' (2012, p. 139). Saccadic suppression has been researched widely since the 1970s and there is a general consensus that a process of active suppression as well as a desensitising to stimuli (not seeing) is involved during rapid eye movement. Lauwereyns argues that active suppression involves too high a price in terms of the energy required through biological processes, and that human vision has adapted to filter the noise and simply not see it: 'Instead of expending precious molecular resources on suppression, the visual system can simply let the noise be' (2012, p. 138).

To 'let noise be' is perhaps not so simple, a Kemp-like 'fuzzy' image or noisy data can be problematic in the disciplinary frameworks of science. But artistic practice and disciplines can 'simply let noise be'. Olabarrieta's video *Bolas* captures the dynamic interplay between unpredictable movement and its representation through drawing. She holds two pens, one in each hand, and attempts to keep two marbles rolling upon a sheet of paper as she draws. The marks that she makes are traces of missed connections between hand and eye, sudden changes and interrupted lines. They are a record of her not knowing the direction of the drawing from moment to moment. She describes

the work as extending the body and as ‘losing authorship, when the subject becomes the object and visa versa’ (Olabarrieta, 2013).

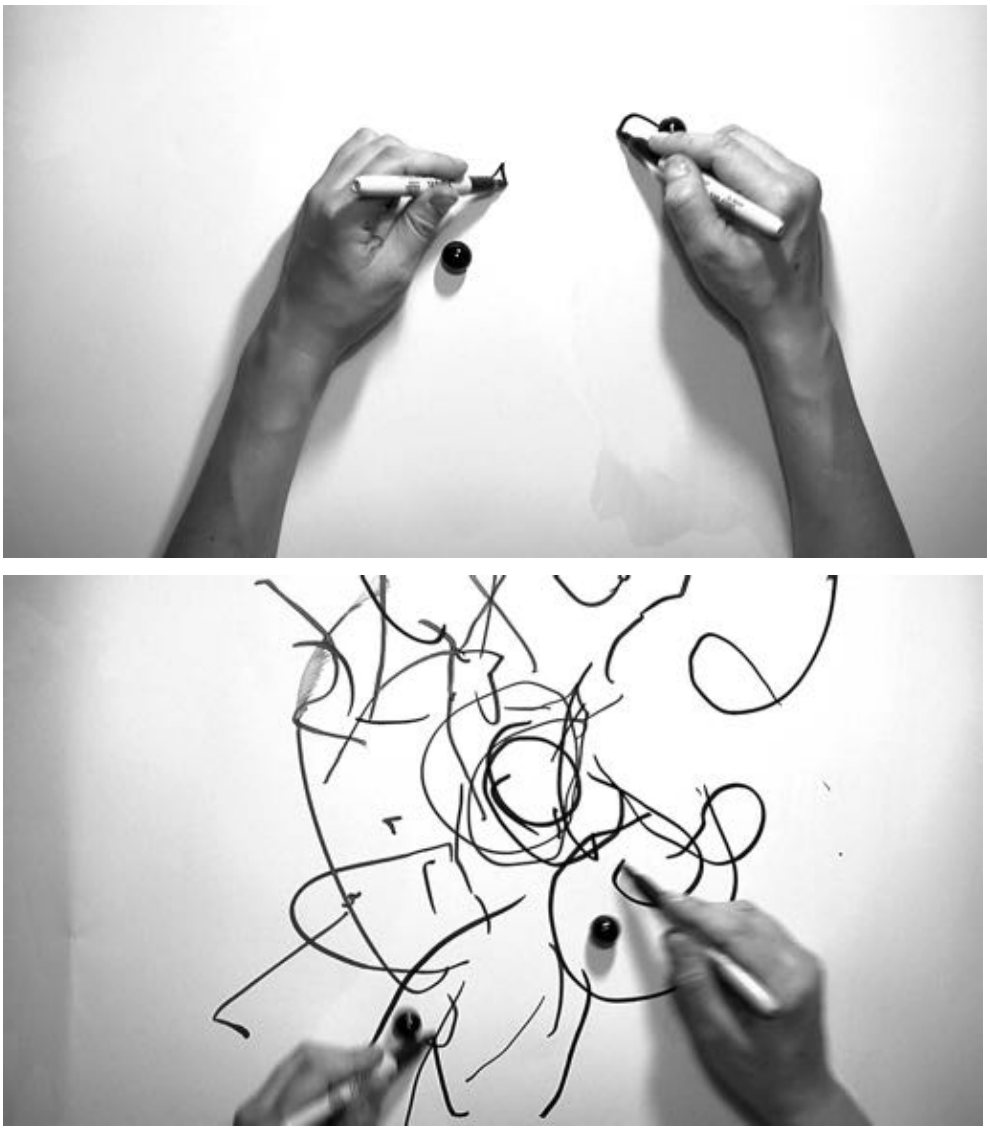


Figure 2.5 (Top and Below) Beatriz Olabarrieta*, Bolas*, 2012, two stills from video.

In *Bolas*, drawing, looking and touching are held in a tight relationship that is performative. Mitchell extends this idea to the image itself:

> An image is a relationship and an appearance: it might be better, in fact, to think of images as events or happenings rather than as objects, in order to register their often fleeting temporality (appearing and disappearing, going in and out of focus, or, in Galison's lovely metaphor, scattering and gathering). (2015, p. 30)

The video is both an event and its representation. Olabarrieta’s pens trace the movement of her hands and eyes across the paper; the drawn marks are

a trace of her visual perception and her body's active response in time. She is, I would like to suggest, looking through her whole body and not just her eyes. As the viewer's eyes follow the lines, they retrace the drawing activity. This brings to mind a process that Steve Garner calls spectatorship: 'drawing as a means of tracing that act of spectatorship and recognition' (2012, p. 17). For him, trace is understood in terms of what remains of the original act of looking by the artist. Her marks can also be thought about as traces of an 'ecological' visual perception, for the speed and immediacy of her process suggests Gibson's theory about the directness of vision. She has no time to think. Whether or not Gibson's ideas accurately describe visual perception, Olabarrieta chooses to immerse herself in a highly interactive and ecological form of looking and drawing that is very evocative of the milieu.

The act of drawing is, perhaps, one of the most immediate ways of tracing the act of looking, particularly when one considers the example above. The act of tracing becomes a reaching into the unknown, as if the hand is trying to feel something through the pencil that is not apparent. Mitchell speaks about the artist 'breathing life' back into the lines: 'Desire just is, quite literally, drawing, or a drawing – a pulling or attracting force, and the trace of this force in a picture' and points out 'the double meaning of drawing as an act of tracing or inscribing lines, on the one hand, and an act of pulling, dragging, or attracting, on the other' (2005, p. 59). The activity of tracing can enable the artist to focus upon re-animating an unseen aspect of the image or extracting a different kind of meaning from it.

Furthermore, drawing is closely associated with thinking as Deanna Petherbridge points out: 'since Classical times in the West, drawing has been understood by artists, philosophers and theorists to be linked to *idea* and contrasted with the sensational aspects of paint/colour that work more immediately upon the physical responses of the onlooker through value, hue and saturation' (2010, p. 88). Drawing's ability to respond directly to ideas, using simple means, such as a pencil (a tool that scientists and artists use to make sense of and understand the world around them), allows me to engage with the concept of noise without distractions, such as colour or associations

with the histories of painting for instance. It is a medium that has historically connected art and medical science through practices of measuring and mapping the internal body such as anatomical drawing. I do not claim that drawing has unique properties for this project, although I refer to its immediacy and directness, watercolour or video can also be very immediate and responsive media. My reasons for focusing upon drawing are primarily because it is a process that enables me to work with ideas about looking and seeing fluidly and directly.[6] Thinking-through-drawing is a primary methodology in this research, one that is manifested through a number of strategies that are demonstrated in the next chapter. I create structures for looking as I draw, and set up rules and methods that shape what I see. At times, I introduce unexpected movements and interactions into the drawing process, creating a sense of loss of control. My methods involve a conscious working out of drawing processes, as well as more intuitive responses that are an embodied form of thinking. In this, my strategies can be described at times as cognitively open and as cognitively closed in that they are not consciously available to me. There is a certain quality about drawing which artists and theorists recognise and that lends itself to my project. In the introduction to *Drawing Now*, the editors of TRACEY observe: 'Unencumbered by more sophisticated or "finished" processes such as painting or more "advanced" technological methods, drawing's simplicity seems more able to demonstrate the complexity of conceptual possibilities. It can be remarkably and peculiarly potent' (Downs et. al, 2007, p. x). Nevertheless, these qualities are not unique to drawing and can be experienced in other creative practices.

Olabarrieta's lines fluidly respond to the dynamic nature of her looking. She sets up an environment where she is compelled to look and draw in a highly interactive way. Unexpected movements set up certain styles of looking. Theories about looking, seeing and representation in visual studies are numerous and diverse. Some are interconnected and share a framework,

[6] The artist Michael Craig-Martin states: 'There is a cultural as well as a physical density that characterises painting and sculpture that is in contrast to the fluidity of drawing' (Craig-Martin, 1995, p. 9).

whilst others take different positions and can be somewhat contradictory. Definitions and terminologies compete or coexist with each other.[7] They are concerned with power relationships and with how bodies become objectified. However, noise sits outside theories such as the medical gaze (Foucault, 1973), because it cannot be assimilated into scientific knowledge or, consequently, into relationships of power. As I consider the diverse range of theories connected to vision, I am conscious of critiques of ocularcentric approaches that do not acknowledge the other senses and the material presence of the body in visual perception. I wish to argue that my project is exploring a phenomenon – noise – that is perceived visually (without acknowledging the other senses) in medical visualisation practice and theory. I am interested in exploring the differences between how scientists and artists visually perceive noise, particularly by considering how noise complicates vision.

To examine this further, I would like to refer to Bruno Latour's ideas about how scientists work with visual material. Latour (1986) examines the ways in which scientists work with images and argues that science builds visual knowledge through a system of signs, symbols and diagrams, which taken together he calls 'inscriptions'.[8] He argues that inscriptions are images that are used in specific ways to construct 'harder facts' (p.17). They have an: 'optical consistency' (p. 7) which allows them to be combined with each other and with text. Most importantly, inscriptions 'have the properties of being mobile but also immutable, presentable, readable and combinable with one another' (p.7). Thus, they can be mobilised to 'win an agonistic encounter between two authors' and to build 'statements' (p. 4) over time. These properties, he argues, create very favourable conditions for the construction

[7] One example is the concept of the 'gaze', which is theorised in a multiplicity of ways. They include the clinical/medical gaze (Foucault, 1973), the male gaze (Mulvey, 1975), the post-colonial gaze (Said, 1978), the panoptic gaze (Foucault, 1977), the virtual gaze (Friedberg, 1998), the haptic gaze (Marks, 2002) and the molecular gaze (Rose, 2006). For an extensive analysis and history of theories about 'the gaze', see Elkins (2002-present).

[8] The term 'inscription' has been extensively used in post-structural theory. However my use of it in this thesis is confined to Latour's conceptualization (1986) which is linked to how scientific images accrue knowledge as described.

of scientific knowledge. Networks[9] and associations of immutable inscriptions allow knowledge to be built cumulatively, and for Latour, they are the key differences between scientific and non-scientific images. It can be argued that scientific visualisations are today increasingly mutable, particularly when they are projecting change over time in such network systems as the spread of diseases for instance. However, this can also be thought of in terms of the incremental changes in visual units – signs and symbols in a statistical model for instance – that are reused or adapted by building upon previous versions. Optical consistency allows one to build upon previous knowledge. Latour gives the example of the early printing press which he argues, generated a sense of accuracy simply by being optically consistent and immutable. The hand-made copy or drawing is not consistent. It does not accrue knowledge in the same way. In contemporary drawing practice, multiplicity and mutability are more likely to be a valued than consistency. Symbols and signs can be reused to reference former artworks, but they are more likely to destabilise previous meanings and contexts; they do not function as inscriptions. Noise too does not function within a system of inscriptions, and in this, it is more closely aligned to the artistic image.

In contrast to the above account, art historians Elkins and Mitchell, have both written extensively about looking and seeing as active, interactive and multiple. Their ideas are of particular interest because they suggest that vision is itself enmeshed in unknown and multiple interactions (a milieu) that could shed light upon how noise can be visually perceived by the artist. Although I acknowledge that multi-sensory approaches are important to contemporary arts practice, I would like to first examine how far ocular approaches can elucidate how noise functions in relation to acts of looking and seeing. I am also conscious that Latour contests the validity of applying art-historical theories about visual perception to the scientific image, which is

[9] According to Latour (1996), networks are central to the acquisition of knowledge and can include human and (somewhat controversially) non-human actors. Although it is interesting to consider the hardware of imaging technologies as 'actors' in a network that generates noise, the focus of this enquiry is how scientists and artists look at noise. Actor-network theory is not a methodology for this enquiry.

defined by its immutability, mobility and ability to be combined with other images. But I would like to assert that noise in scientific practice is a special case in point, because it does not function as an 'inscription' as defined by Latour. Its cognitively closed status and its elusiveness from the generation of scientific knowledge means that it does not function in the same way as scientific images.

2.5 The milieu and multiple looking: James Elkins and W J T Mitchell

Elkins and Mitchell propose models of looking and seeing[10] in which the object 'stares back' (Elkins, 1996) or has 'desires and wants' (Mitchell, 2005). Their ideas about multi-directional, unconscious and consequently cognitively closed visual processes are, I would like to suggest, particularly appropriate to my subject matter. Noise breaks down the subject-object relationship; it escapes from becoming the 'object' of sight by evading comprehension and measurement. It emerges out of the milieu of interactions between living systems and energies such as magnetic waves and radiation; it is a visual trace of unknown interactions. Elkins concept of multi-directional lines of sight, which can move between object to viewer in both directions in unpredictable and unknown ways evokes the movements of photons, electrical impulses and magnetic waves that are implicated in the generation of noise in medical visualisations. Furthermore, to think about acts of looking and seeing as multi-directional is to situate them in their environments, where the actions of bodies as well as the actions of photons are enmeshed in each other. To perceive noise, I would like to suggest, one needs to conceptualise acts of looking and seeing as within an environment of interactions – a milieu.[11]

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[10] Theorists use the terms 'looking' and 'seeing' differently. In general, Elkins and Mitchell conceptualise 'seeing' as socially and culturally constructed, and 'looking' as the anatomical function of the eyes. Sturken and Cartwright (2001) on the other hand, reverse meanings by describing 'seeing' as automatic and somewhat arbitrary, whilst 'looking' is defined as actively making meaning. For Hal Foster, visuality is the social function of sight, and vision is the physical operation of sight. Nevertheless, despite the differences between definitions, all theorists affirm that social and anatomical vision is inseparable and completely entangled. I therefore move between the two terms fluidly.

[11] As the reader will note, I am using the terms milieu and environment interchangeably. Whilst Rose's concept of the milieu is concerned with interactions in living systems, I

There is no such thing as 'just looking' according to Elkins. Looking is highly problematic and complex. He deconstructs the phrase – 'the observer looks at the object' – and argues that to look is also to be seen. It is a continual and multiple 'cat's cradle of crossing lines of sight' (1996, p. 70). He states:

> Looking is much too complex to be reduced to a formula that has a looking subject and a seen object. If I observe attentively enough, I find that my observations are tangled with the object, that the object is part of the world and therefore part of me, that looking is something I do but also something that happens to me – so that the neat architecture of the sentence becomes a morass. (Elkins, 1996, p. 35)

This complexity is not consciously experienced he asserts, and perhaps it would be impossible to function if one was aware of it. I am reminded of film theorist Laura Marks, who asks: 'What if our perceptions were so embodied that we could feel every step of our digestive process, the twitching of our neurons. We would be so attuned to the universe within that it would be impossible to focus upon the world around us' (2000, p. 132). Does focusing one's attention on a specific visual task, such as identifying a particular shape within an assortment of different forms, lead to less awareness of other senses such as the sounds or smell around us? Unquestionably, in scientific practice, there is nothing to be gained from the other senses, as the scientist looks at an image of the scan on a monitor. Scientific enquiry does neither acknowledge wider sensual perceptions such as touch, smell or sounds in this specific context, nor the understanding that *looking is something that happens to me*. Other senses are diagnostically irrelevant for the scientist. When scrutinising a scan to identify noise from signal, visual perception is understood as moving in one direction – from scientist to scan. However, measurement systems in medical visualisation practices and the actions of noise itself are multi-directional and highly interactive. Perhaps an acknowledgement of the multi-directional and interactive environments (both inside and outside the body), with which scientists are engaging with through acts of looking can change what is perceived?

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would like to suggest that the interactions of photons or magnetic waves in the environment is analogous to the milieu.

Mitchell's ideas suggest another way of thinking about how noise could be perceived as a visual phenomenon. He argues that images are not static fixed things, but have agency and can interact with the viewer:

> The philosophical argument … is simple in its outline: images are like living organisms; living organisms are best described as things that have desires (for example, appetites, needs, demands, drives); therefore, the question of what images want is inevitable. (2005, p. 11)

Mitchell is proposing images have special powers and can affect us in extraordinary ways,[12] but not that they literally have desires and wants:

> Art historians may "know" that the pictures they study are only material objects that have been marked with colours and shapes, but they frequently talk and act as if pictures had feeling, will, consciousness, agency and desire. (ibid, p. 31)

Artists and art historians can look at an image in heightened ways, *as if it is a living thing*. This is not to literally assign agency and life to non-living objects, but to look at them *as if* they have agency, which is an important distinction. I am conscious that Mitchell's ideas, and particularly Latour's theories about the agency of non-human actors in actor-network theory can be understood as advocating living properties to inanimate objects. However, this enquiry does not propose that images are living things with agency. I am speculating whether noise in images – ambiguous visual material that is cognitively closed, and which consequently, it could be argued, escapes from the multitude of associations that images carry with them – could be looked at in terms of Mitchell's ideas about the desires and wants of images. Carl

[12] It is necessary here, to address the idea of images as having magical properties, particularly questions about animism and vitalism. Vitalism is the philosophy that all living things contains a life force that is separate from their physiochemical properties; it is this vital force, that it claims, distinguishes living beings from inanimate matter: (Merriam-Webster, n.d., s.v. *vitalism* n.). Whilst vitalism has long been discredited as a hypothesis in biomedical science, it still influences thinking in holistic medical practices. Similarly, animism is an ancient philosophy that attributes special powers to non-human entities; it is a belief that plants, animals and inanimate objects have spirits that are separate from their physical properties (ibid, s.v. *animism* n.). Mitchell acknowledges that his theory does advance magical properties for images and pictures, but he does so by arguing that this is based upon 'a deep and abiding feature of human responses to representation' (2005, p. 31). Furthermore, he also asserts that this idea is not a novel idea (Mitchell in Grønstad and Vågnes, 2017).

Knappett (2005) problematises the boundary between the animate and the inanimate by questioning whether self-organising systems[13] are indeed animate, for they clearly display signs of agency and structural organisation. Nevertheless, when considering inanimate objects, Knappett argues that they cannot have agency but that humans can imbue them with the attributes of agency when they trigger psychological responses. Noise, I would like to suggest, is likely to generate such responses, whether it is through frustration or curiosity. If one considers the desires and wants of noise, they appear to be to evade knowledge. It raises questions rather than provides answers. What if noise was looked at as if it had agency? To look at something as if it is alive is to acknowledge that it can look back and has the potential to interact and change in unexpected ways. It gives an equal status to image, and the one who looks. And a curiosity about the image that is centred upon not knowing how it may change. As previously noted, scientists can stop seeing something once it is called 'noise'. What if they perceived noise as something with agency? This approach would deny the 'unconscious blindness' that I suggest in Chapter 1 may be a response by scientists to visual marks that do not fit into the overall pattern of information. However the implication of thinking about noise as if it has agency is to overlook that it is simply a back-formation of signal, it is random data that cannot be decoded. Noise is not a different category of order to signal: the difference is between information that is available or closed.

Looking at images as if they have agency is arguably more common in artistic practice.[14] If our perceptions are modified to avoid an over-sensitivity to stimuli in our visual field, then the artists I refer to appear to do the opposite: they emphasise the multi-directional nature of looking and seeing. The viewer of the artwork is in turn invited to participate in similar styles of

[13] Examples of self-organising systems in nature include the flocking behaviour of birds, the social behaviour of insects and schoaling of fish.

[14] Michael Craig-Martin comments that 'for artists, a work of art is alive, a living reality, or it is only of marginal interest. To be truly experienced, the work of art needs to be felt, more than understood' (1995, p. 9).

looking. Or perhaps, it is more accurate to state that the artwork activates certain styles of looking.

2.6 Looking for rhythms

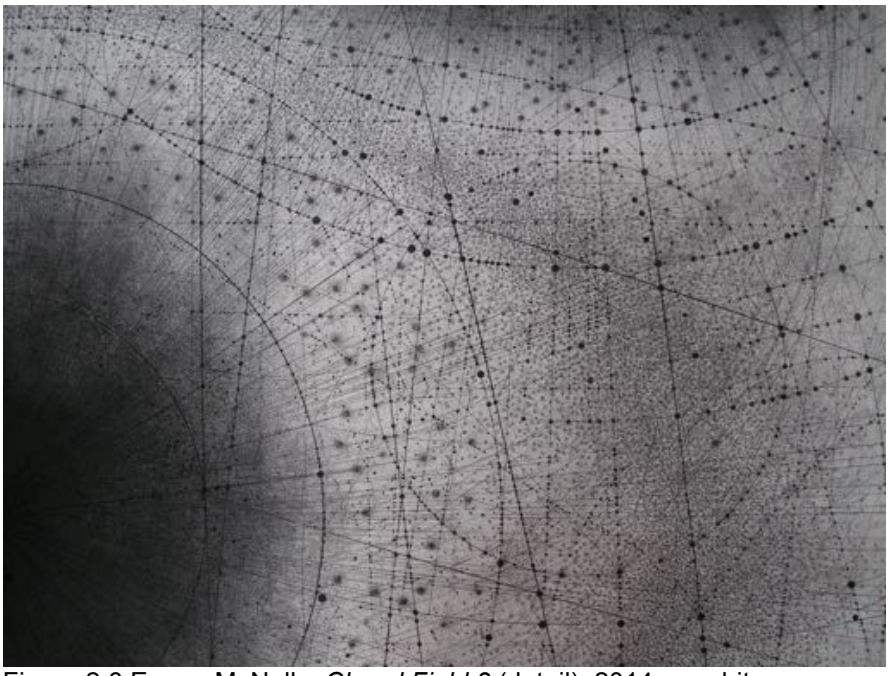


Figure 2.6 Emma McNally, *Choral Field 2* (detail), 2014, graphite on paper, 215 x 304cm.

The artist Emma McNally's practice is an interesting example to consider in relation to Elkins' ideas about multiple looking. Her densely layered, large-scale drawings evoke diagrams of constellations, digital networks or circuit boards but are constructed out of the artist's imagination (an inner looking) using the most basic of materials – a graphite pencil or chalk on a blackboard. They seem to be measurements of something yet it is unclear of what. Marks merge, emerge and disappear; some are hard edged, precise and crisp, others soft and cloudy. Looking at McNally's drawings induces a sense of being immersed in an environment of signs that cannot be decoded but which nevertheless*, insistently communicate*. She describes her drawing process in terms of: 'rhythms of making and unmaking… always being in the middle… disrupting hierarchy… a restless space' (McNally, 2017).

Lines criss-cross the surface constantly forming new relationships with each other. The apparent infinite possibilities for connection seduces the eye into restless movement across the surface. McNally returns again and again to the idea of rhythm: 'When you make rhythmic marks you start inhabiting a

certain space… as fast as you're receiving you are transmitting. Everything becomes a feedback loop of reception and transmission. You become circuitry' (McNally, 2017). She calls her lines 'pulses', as if they are living things or transmissions of energy, and this seems a very fitting way to describe them. Her drawings resemble maps of energies, models of potential interactions between unknown forces. In an interview for *Artforum*, she talks about her drawings in terms of 'turbulence' and complex inter-relationship and contradictions between noise and signal:

> I think of these drawings as fugitive, heterogeneous grey areas. They are the turbulence between noise and signal. They are a space of difference and deferral, a weather system of graphite. They are also broadband realms where signals at multiple frequencies are being transmitted and received—including those not usually within our 'range': sonar, ultraviolet, the very fast and the very slow. I'm constantly trying to disrupt the figure-ground relationship to make blurred areas where the conditions of focusing are undone. (McNally in McNally and Soin, 2014)

Figure 2.7 Emma McNally, 2012, Residency at Maths House, University of Warwick.

The photograph Figure 2.7 is from a residency she undertook in the Institute of Mathematics at the University of Warwick in 2012. She is drawing upon extended curved blackboards that line the walls of one of the Maths Houses. McNally attended lectures and seminars in the Institute as part of her residency, and she has stated that the drawings are influenced by the mathematical concepts she encountered during this time. However she asserts that they do not illustrate mathematical concepts but were produced from a purely intuitive process. The blackboards are large and the work

encompasses her field of vision. She immerses herself in a complex system of lines and dots, activating the surface of the board by looking for – and seeing – connections and pathways between each mark. However she does not proceed from a position of (consciously) knowing, but rather through the way in which she looks at the drawing. The drawing emerges out of the interplay between marks, the materiality of the chalk and black board, as well as McNally's own response to these elements. Here I would like to propose that the artist looks at the drawing in a particular way – as if it has agency – and that she visualises this sense of agency through the marks she makes. She is immersed in a milieu of movements and flux by looking within herself. Whilst Heath and Olabarrieta actively engage their bodily perceptions as they draw (here the sense of touch and of the body in space is important, and not accounted for in Elkins' and Mitchell's theories), McNally looks within herself to produce drawings that seem to be manifestations of multi-directional ways of looking.

2.7 Noise as productive: noise as destructive

The media artist Joseph Nechvatal explores the idea of the artwork as a living thing in a unique way. He makes use of algorithms that are based upon living systems to degrade his digital artworks in unexpected and uncontrollable ways, thus choosing to incorporate cognitively closed and cognitively irrelevant information in his artworks. He gives up control of his artworks to noise and allows it to act upon them. Nechvatal writes extensively about noise as a cultural, spatial and visual phenomenon, using diverse examples such as the stone-age artworks in the Lascaux caves and Antoni Gaudí's Casa Batlló in Barcelona. His central concern is a state of consciousness that occurs when one is immersed in 'noise art'[15] which he defines as the '*conditions and orders of conscious awareness in which perception-cognition (i.e. awareness linked to the process of forming intelligence) is found to consist of more than everyday (non-conceptual) vision or hearing typically reveals, by merging with some manifestation suggestive of a magnificent more* (2011, p. 59, italics in original). According

[15] Nechvatal (2011) uses the terms 'art noise', noise art' and 'art in noise' inter changeably.

to Nechvatal, the '*magnificent more'* is a transformational experience that immerses the viewer in an intense and confusing environment of cultural meanings and signifiers. He argues that the experience of immersion into an art of noise creates a 'vacuole of non-communication' (p. 15), (as opposed to the excessive communication of digital technology) that induces self-reflection and transformation in the 'immersant' (p. 59), it is not clear whether this is the viewer of the artwork, the artist, or both. Noise art, according to Nechvatal, is both disruptive and productive. It moves between subject/object as well as internal/external positions, and privileges art processes that are unpredictable.

Figure 2.8 Joseph Nechtaval, 2002, *Computer Virus Project 2.0*, video still

His series of '*Computer Virus Project'* artworks are formed by computer viruses based upon artificial life[16] interacting with his work. A virus is not unlike noise in that it is information without meaning that is random and difficult to control. Nechtaval's original image files are therefore degraded by diagnostically irrelevant information (noise), which is given the role and status of cultural creator. It acts upon his artworks in real time, and this seems fitting, for by its refusal to be contained within knowledge, noise

[16] Stéphane Sikora's paper 'Balancing art and complexity: Joseph Nechvatal's *Computer Virus Project*' (n.d.), provides a good description of this process: 'Artificial life is a field that studies artificial objects that exhibit properties of life... Here, viruses are modelled as autonomous agents inhabiting an image (the host) and try to survive by consuming or 'eating' the colours contained in the image.'

demands that one remains in the present (for there is no prior knowledge to fall back on). Artistic practice can therefore have very different attitudes towards noise, which seem in opposition to scientific approaches. However it could be argued that both approaches – artistic and scientific – perpetuate a binary opposition: noise is made invisible or made visible. Yet noise, through its refusal to communicate, remains beyond dualism; it simply is.

Nechvatal argues that an 'art of noise' produces new meanings by transforming the viewer's (immersant) state of consciousness. In scientific practice, noise typically destroys meaning and is framed in opposition to signal (meaning), as in 'signal-to-noise ratio'. However, it is important to acknowledge that although noise reduction is generally the overall aim in medical science [17], there is an implicit understanding within medical imaging practice that reducing noise inevitably reduces information (and meaning). And it is the perception that there may be some potential *(*information) embedded within noise, which I would like to argue, refuses dualism. The relational and contingent nature of noise is central to this; noise refutes dualism by refusing a fixed definition. The cultural theorists Greg Hainge (2013) and Paul Hegarty (2007) assert that the ontology of noise is profoundly relational: '[noise] does not exist independently, as it exists only in relation to what it is not' (Hegarty, 2007, p. 5).

The science writer Sandra Blakeslee provides a good example of its relational status. She points out that there are many instances in the recent histories of science, where data that was initially considered to be noise, is later reassessed as signal after changes in scientific knowledge. In the 1970s data about the ozone layer that was captured by NASA was initially dismissed as noise (Blakeslee, 1990). This data was reassessed in the 1980s after scientists recognised – and could see patterns of – the thinning of the ozone layer: 'what is noise now will not necessarily remain so' (Hegarty, p. 17). Information that does not fit within existing knowledge

[17] Medical scientists are increasingly studying noise to understand how biological systems can vary. The study of noise is more established in the disciplines of physics and is an emerging area of interest in medical science.

systems is not recognised and cannot be seen; it becomes signal once it is recognised within a framework of knowledge and can be seen. Sandra Blakeslee (1990) observes: '[the original data's] greatest value, researchers say, may lie in the light it can shed on scientific questions that have not yet been posed.'

The final statement is revealing – for not only does noise raise questions, but more importantly, it can point to questions as yet unframed. And it resolutely *does not* provide answers. This is perhaps why an artistic approach is valuable when considering noise, because questioning without looking for answers, through materials, methods and processes is embedded into artistic practice. Artists are more likely to remain with the questioning and to accept multiple answers rather than one, in what McNally describes as 'a restless space'.

Nechvatal's ideas about an 'immersion into noise' can be linked to Gibson's theories about environmental perception, which describes visual perception in terms of immersion in an environment of signals (flows). However his methods separate the body of the artist from the viewer and also, I would like to suggest, distance the viewer from experiencing a sense of immersion when looking into the monitor at the work. This is unlike Olabarieta's video, which evidences the movements of her hands and, in my experience, pulls the viewer into the environment she creates. In the next chapter, I test ideas and experiment with methods of engaging with noise using different drawing strategies in the environment of the studio, to investigate how they change my perceptions.

Conclusion

The previous chapter investigated the concept of noise in medical visualisation practice. This chapter explores whether artistic practice has an equivalent to noise. Do artists perceive certain kinds of visual information as cognitively closed and diagnostically irrelevant?

My survey suggested that while many artists do not address or acknowledge

noise specifically as a subject, their practices do engage continually with the key characteristics of noise as defined in the first chapter. They experiment with slippages in visual and cognitive perceptions, as well as with movements and interactions in the environments of the drawing that precipitate a lack of control. Thus diagnostic irrelevance and cognitive closures seem to be as embedded in aesthetic structures of looking as they are in science.

An important discovery has been that noise in the visual arts involves the interaction of the artist's sensory body with the material environment. As a result, this chapter considered theories of interactive and dynamic styles of looking in order to propose that noise is a perceptual tool with trans-disciplinary potential. Scientists, nevertheless, do not recognize the full sensorium of human perception when examining medical visualisations. This is a key difference to even the most visual of visual-arts practice.

Chapter 3. Phases of Activity (Thinking through practice)

This chapter investigates the concept of noise through phases of artistic activity. It explores acts of looking and seeing[1] through different optical instruments, and responds to unintentional, unexpected or unknown movements and interactions through drawing. I test methods that emphasise interactions between my drawing ground and drawing materials, and involve unexpected movements that are difficult to control. The animation *Mind Wandering 3*, is produced by looking through a macro lens and drawing with graphite powder upon a ground that is continually moving. The resulting animated drawing takes on a peculiar quality; it resembles a living thing such as a bacterial growth. I draw upon vellum, an organic material that is very responsive to the temperature and humidity of its environment. It changes shape as it expands and contracts in response to the heat of the light box. Looking through a macro lens accentuates this phenomenon. The interrelationship between a drawing and the environment of the paper is explored by drawing with animal fat. These methods demonstrate how drawing can be used as a tool for thinking, as Petherbridge and others have observed, and for testing ideas connected to my research into the phenomenon of noise.

My use of instruments of vision, such as a microscope, macro lens and light box in this chapter, acknowledges the mediation of technologies of vision in medical visualisations. I respond to the notion of the transparent body (Dijck, 2005) through the materials I use and the ways in which I look. Magnification and scale are similarly explored through my use of macro lens or microscope, and through large-scale drawings. The ways in which visualisation technologies frame and determine how the body is seen are investigated by using a hand made construction: a cardboard box that I look through. This simple device, which stands in for the 'black boxing'[2] of

[1] See my previous discussion of looking and seeing in Chapter 2 page 39. The next chapter explores ideas about looking and seeing from a theoretical perspective in more detail.

[2] See my notes about Latour's (1987, 1999) concept of black boxes later in this chapter on page 55.

technology, enables me to look through the space between instrument of vision and the object being looked at. To explore how the environment changes the ways in which I look, my drawing activities take place in different environments such as the studio, the laboratory and the public spaces of a university and arts organisations. Finally, I test drawing methods that investigate the relationship between data manipulation and noise. During my residency at the University of Manchester, I observed that there is a close relationship between the use of algorithms in medical visualisation practice and acts of looking. They determine what is seen and are a key tool used to filter and reduce noise. The phenomenon of noise is implicated in the manipulation of data and in its movement through technology. New-media artist Joseph Nechvatal utilises algorithm processes in his artworks to generate rather than to reduce noise. In this chapter, I test methods that not only generate noise in data, but also explicitly implicate my body in the drawing process. This is achieved by using live data from body sensors, such as skin galvanometers, whilst drawing and through a performative drawing process that involves my whole body in an active response to unpredictable and unknown signals as I draw. Throughout this chapter, I interrogate what constitutes cognitively closed and diagnostically irrelevant information in my methods, and explore what a contemporary drawing practice can reveal about noise in medical visualisations.

3.1 Drawing in the laboratory: looking through the microscope

Figure 3.1 (Left) Author drawing while looking through microscope in laboratory, Manchester Metropolitan University, Manchester, 2014.
Figure 3.2 (Right) Sketchbook drawing produced by looking through microscope in laboratory at King's College, London, 2012, work by the author.

The laboratory, with its focus upon close observation, is the environment for a series of drawings which are made by looking through confocal and light microscopes at Kings College and at Manchester Metropolitan University. Confocal microscopes provide sharper and more detailed images than a conventional light microscope, but focus upon smaller points (Bisen & Sharma, 2013). Drawing in the laboratory is, of course, a very different context to being in the studio. I am wearing a lab coat and conscious that this is a space where other disciplines are intensively focused on the act of looking. There is a shared process of selecting, isolating and framing areas of visual interest, albeit with the aid of technologies that are not typically found in an artist's studio. Scientists work with coloured dyes to stain samples and can choose between various visual styles to look at samples on the computer screen. In both laboratories, I am first given a detailed description of each slide – which part of the body, which type of tissue, its function etc. It is evident that this knowledge – cognitively relevant information – is considered to be vital before one looks. It is a style of looking – building upon existing knowledge – that defines this environment.

Consequently, the sketchbook I am using includes notes and information about each slide; it begins to resemble a journal, possibly changing the perceived function of the drawings. Nevertheless the drawings I produce are not scientific illustrations; I am responding to the slides as images rather than elucidating their function as specimens from the human body (although this may happen indirectly). However, when scientists see the drawings I produce, they speak about them in terms of how they illustrate scientific knowledge. They see things into them that I simply don't see; they read them differently. It is clear that the function of the drawing changes radically depending on its upon context, with the consequence that its meaning also changes. However, this is part of a scientific process of making images meaningful. Latour and Woolgar observe that laboratory 'practices widely regarded by outsiders as well organised, logical, and coherent, in fact consist of a disordered array of observations with which scientists struggle to produce order' (1979, p. 36). They argue that scientists work with visual information in specific ways to construct knowledge. Latour describes this as a process by which they move from looking at 'confusing three-dimensional objects' to looking at 'inscriptions', which are 'two-dimensional images that have been made less confusing' (1986, p.16). This approach towards images is perhaps in opposition to artistic methods, which often retain the 'confusion' or ambiguity, and emphasise multiple meanings. Artistic methods can nevertheless be highly conceptual ways of looking as Siân Ede observes:

> Visual information in laboratories is conveyed by technological media – through microscopes, telescopes, various scanning instruments – and how you set up the instruments and how you interpret the results may well be open to opinion. Artists are used not only to perceiving shapes and structures quickly, a skill which, after all, anyone might acquire with training and experience, but they are accustomed to see more than meets the eye, to see beyond a focused or perspectival viewpoint, to look 'off screen', on the edges or even in the imagination. They are used to recognising that 'pictures' have depth, layers and multiple meanings because conceptual thinking plays as much, or more, of a part in seeing as simple visualising – as experts in experimental psychology and consciousness studies know. Suggesting alternative interpretations is the artist's natural way of working. (2000, p. 61)

The light microscope I am looking through contains four different lens, each set at a different magnification (x4, x10, x40, x100). I move between the

different magnifications, keeping the slide in the same position, and layer drawings upon each other. The change in the image as it is magnified is quite startling: unexpected details appear and come into focus. I try not to look at the drawing except for a quick glance and locate the edges of the sketchbook through touch to orient myself around the paper. The confocal microscope produces a sharper image in three dimensions, however it seems to have a shallower depth of field. The edges of the image seem out of focus, but when I readjust the focus it seems to change the image profoundly, as if I am looking at a different slide. It is quite disconcerting how a slight movement of my hand can produce an enormous change in what I see; it is as if my hand is disconnected from the eye. I explore this further by continually changing the focus as I draw, and am surprised by how much this disorients me. Moreover, when I look into the eyepiece of a microscope for an extended length of time, I experience a sense of detachment from the physical space of the laboratory, and a curious sensation of being in the space of the microscope develops. It is as if the body falls into and occupies the space that I am intently looking at. When I look up, it takes a moment for my senses to adjust back to being in the laboratory. Upon describing this experience to a microbiologist, I realise that it is not uncommon: ‘What I always find when I’m looking down a microscope, [is that I feel] I’m not a big person looking in, I’m a little person. I’m in there. It’s very seductive’ (Parry, 2015).

Looking through an instrument of vision by intensely focusing the eye appears to separate and distance the body from its environment. The process seems to desensitise the other senses – I am less conscious of the sounds around me. Although my body is quite still, I have a peculiar sensation of falling into the space of the image I am looking at. However, when I move images in and out of focus, I experience an uncomfortable sense of not knowing where my body is in relation to its environment. Proprioception is the largely unconscious sense of the body in space that is independent of vision and relies upon the physical sensations of body movements. It becomes disrupted when one is looking through an instrument of vision. Perceptual slippages between vision and proprioception are

cognitively irrelevant as the scientist makes sense of what is seen through the microscope: yet as I move between different magnifications, I allow them to inform my drawing process. I am attempting to access a process that Ede describes as seeing ‘more than meets the eye’ (2000, p. 61). It feels as if I am searching for something that is invisible by using slippages in my vision to trigger other ways of seeing. Perhaps everyday vision is full of these slippages, but we do not perceive them. Elkins states: ‘But vision, I think, is more like the moments of anxious squinting than the years of effortless seeing’ (1996, p. 18). Claude Heath’s drawing experiments similarly explore this phenomenon through disjunction between sight and the movements of his hands in the previous chapter.

I am also interested in how being in this laboratory environment changes how I look. Strategies of drawing without looking at the paper are quite familiar to me, and they consequently do not feel strange. I make some drawings without looking at my sketchbook while keeping my eyes focused upon the microscope. I make others by using a drawing tube microscope (Hodges, 2003, p. 47) that projects the image onto my sketchbook. But drawing without looking in this environment does feel strange; it is a place that is designed for objective acts of looking. Although I have set out to test these methods, I feel uncomfortable and less able to connect to more experimental – and less logical – drawing processes in this environment. If I think about my residency and the environment of medical imaging research institution, I imagine a similar sense of unease would occur. Both spaces seem to have a protocol, a set of practices and procedures for looking. The laboratory is a highly structured (and hierarchical) environment with rules and regulations (printed upon posters as one enters the laboratory) about how one works with materials and visualisation equipment. I feel constrained in my ability to take risks here, for instance, by drawing with unusual materials such as animal fat, which I explore in my studio. This is not only to do with health-and-safety constraints, but perhaps more to do with working with processes that would be considered cognitively closed and meaningless in this environment.

Such environments place less emphasis upon creative experimentation in acts of looking, seeing and representation. ‘Happy accidents' – unexpected outcomes in arts practice whereby mistakes or accidental slippages can be recognised as valuable – are less likely to be recognised in scientific environments. And yet accidents, such as contaminated petri dishes, have led to significant breakthroughs in scientific knowledge.[3] Arguably, there is a close link between the phenomenon of noise and this type of looking and seeing. The ability to tolerate multiple ways of looking and seeing may be linked to the ability to perceive (visually and cognitively) potential (signal) in ambiguous visual material. This may also be linked to an environment that enables multiple ways of seeing to coexist (rather than dismissing visual ambiguity as error or noise). How then is an artistic environment different to the scientific; in what ways does it change how I look and draw?

3.2 Drawing in the studio: seeing through memory and imagination

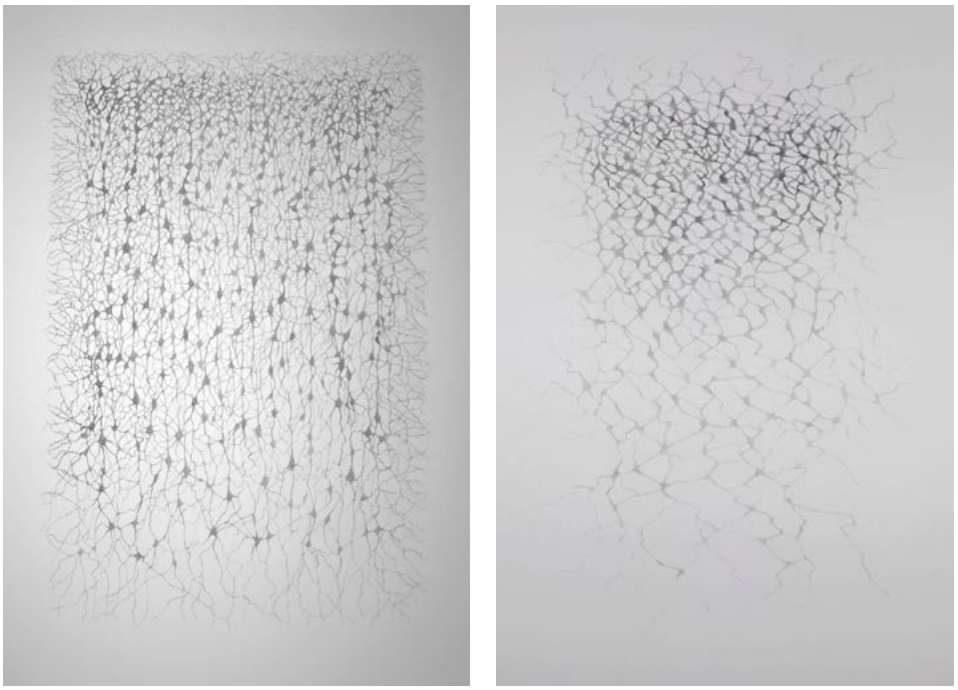


Figure 3.3 (Left) *Exemplar*, 2012, graphite on paper, 60 x 42cm, work by the author.
Figure 3.4 (Right) *Memoria 3*, 2012, graphite on paper, 60cm x 42cm, work by the author.

The environment of the studio feels very different; the quality of my looking feels more reflective. The studio space is a familiar space where I regularly practice this kind of looking and seeing. This familiarity and regular practice

[3] Alexander Fleming’s discovery of penicillin in 1928 is a notable example.

creates an environment that seems to activate a reflective and embodied style of looking. There is an intense sense of looking inwards as well as looking outwards, and I move fluidly between the external image of the drawing and an internal image that shifts and changes. There is a dialogue between the two which is unspoken but intensely felt. Crucially, this dialogue is manifested through the body, through subtle changes in pressure as I look and draw. I often pace around the studio between marks or walk away from the drawing to see it from different perspectives. The space around the drawing is an environment that becomes charged.

To explore this phenomenon I make a series of drawings that begin with a response to a computer-generated model of the internal body. The starting point for these drawings is an image from the *Blue Brain* project. It declares that its goal is 'to build biologically detailed digital reconstructions and simulations of the rodent, and ultimately the human brain' (Blue Brain Project, 2017).[4] The image is a computer-generated model of neural structures in the brain.[5] The contrast between the trailing dendrite forms, the entangled neurons and the visual formality of squared, straight edges highlights the constructed nature of the image. Practices of computer modelling and simulation in imaging research complicate the relationship between real bodies and medical visualisations. They can appear very organic and life-like to the non-expert eye (Rose, 2006). Peter Galison describes the opposition between image and data, abstraction and concrete bodies in science as 'that sudden, powerful opposition-attraction between wanting to know with eyes-open and wanting to know with eyes-closed' (2002, p. 301).

Simulations make use of data from real scans to develop models. They are constructed from vast amounts of data – a memory bank of information – accrued over time. To explore the ways in which technologies 'see' and an

[4] The Blue Brain Project is a large-scale European-funded research project that has received some criticism from the scientific community concerning the rigour of the research and its leadership. However, my aim is not to get caught up in these debates. I am rather particularly interested in the image because of its formal qualities and the questions it raises about how one looks at an abstract 'map' of the brain which is constructed from data.

[5] See the image at: http://www.visualcomplexity.com/vc/project.cfm?id=145

artist sees, the next series of drawings test strategies that 'simulate' drawings from an unpredictable and arguably 'noisy' source of information: my visual memory. The first drawing is highly detailed and made by projecting the *Blue Brain* image upon paper, transforming it into a screen as I trace the imagery. I choose to work in this way because it replicates the conditions in which simulations and digital reconstructions of the body are viewed. Looking at a computer screen is very different to looking at paper in natural light. My process is a slow and meticulous transferral of complex imagery onto paper; muscles tire, eyes become strained. As I work, the studio space is flooded with light from the projector, yet there is a strong sense of not being able to see clearly. The drawing disappears beneath the projection; it is competing with the simulation for the same space. My body blocks the light from the projector at the moment when I am making a mark, so that I am intuiting its position. I use a variety of hard (1H-6H) pencils for the tonal range, they give me greater control over the line and the hard graphite produces a glassy greyness, which evokes the cold greyness of the projected image.

Subsequent drawings are spaced approximately six weeks apart and made without looking at the first drawing and without a projection. They rely upon a memory image that is unstable and unpredictable, which is in a sense diagnostically irrelevant and not unlike noise in its attributes. Visual memory is comprised of multitude interactions over time in individual histories and bodies. They can be comprised of physical, psychological or social experiences, which influence each other and change visual (and other) perceptions in largely unconscious ways. James Elkins (1996) asserts that seeing is irrational, inconsistent and undependable. Perhaps looking into my visual memory as I draw is a way of experiencing noise.

There is a very different quality to the making of subsequent drawings, as I try to look at my memory image, there seems to be a stronger sense of myself being present in the act of drawing. I'm interested here not only in the loss of detail (a surprising amount of visual information is lost), but also in the changing shape and quality of the drawing. The memory drawings seem to have become more about the act of drawing rather than the act of

representation; the mark-making feels more assured. The edges are no longer contained and enclosed. There seems to be a relationship between looking into an unstable and unpredictable image, and the presence of the drawing. It is as if the drawing emerges from and through an acute awareness of the body, and not from something external.

I consider whether I could make this type of drawing in scientific institutions. Certainly the time and space needed for quiet reflection would be difficult to achieve in the busy working environment of a laboratory. But it is much more than that. I experience the studio as a place that supports reflective practice; it seems to facilitate the process of thinking through drawing. I am highly sensitised to my environment as I work, and register subtle changes in light, temperature and sound around me. This is quite different to the idea of focusing my attention as I look through a microscope, where there is a narrowing down of my attention and a desensitisation to the wider environment. Here my senses are widening, and despite my aim to focus upon vision as a primary sense, it becomes impossible to separate it from my other senses. This is a largely unconscious phenomenon over which I have no control. When this phenomenon changes I often stop drawing. I instinctively know that the quality of my looking has changed and that this will affect the drawing.

I begin thinking of the interactions between bodies and their milieu, which typically produce noise. It could be argued that drawing in the studio sensitises me to the conditions that generate noise, in that I become more attuned to interactions in my environment through my senses. Although these interactions are not directly connected to my drawing activity (and are therefore diagnostically irrelevant) they seem to be linked to my ability to respond to my memory images, which are continually changing and shifting. My alertness to the studio environment, without a point of focus or specific outcome in mind, seems connected to my imaginative looking. There seems to be a link between my sensitivity to my surroundings and my receptivity to ambiguous visual information that can at times be cognitively closed or not consciously available to me. In my experience, the environment of the studio

supports my process of looking inwards into my imagination as I draw, whilst the laboratory makes me more self-conscious and less likely to take creative risks. But scientific institutions are not the only environments that can determine how one looks. What of technologies of vision such as MRI scanners, how do they create environments for looking and how do they change what is visually perceived? My next experiments explore how technologies of vision can create environments for looking.

3.3 Black boxing: looking inside instruments of vision


Figure 3.5 (Left) Artist in studio with box construction, 2013.
Figure 3.6 (Right) Box construction in the studio, 2013.

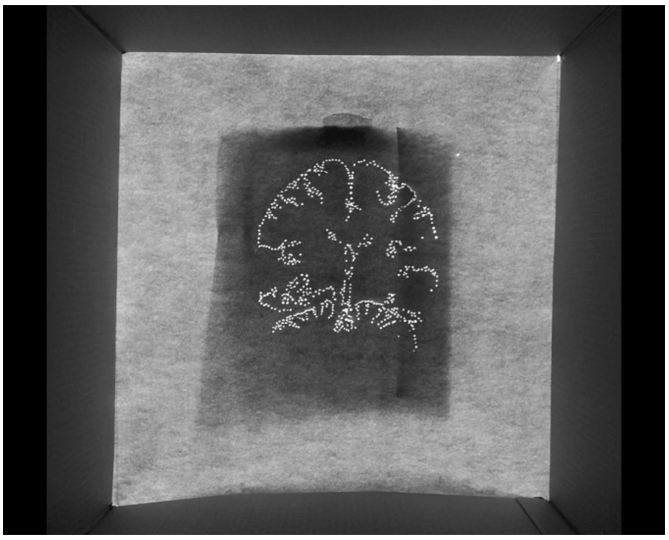
I would next like to consider how visualisation technologies frame the human body and determine how it is seen. My subject matter – noise – is inextricably linked to the technologies that are used to look into the body. They not only generate noise through their interactions with their environment, but also play a central role in the methods used to reduce noise. Throughout this phase of activity, I make use of instruments of vision that enable me to 'look through' or 'look into' my subject matter. Through these methods I wished to enact how medical visualisation technologies look at the body. However I am conscious that technologies such as MRI or PET are 'black boxes'[6] to me. Latour (1987, 1999) states that a black box stands for the unknown inner workings of technologies (hardware and software), which are normally only seen through their inputs and outputs. He argues that black boxes seal the exchanges between technology and the external

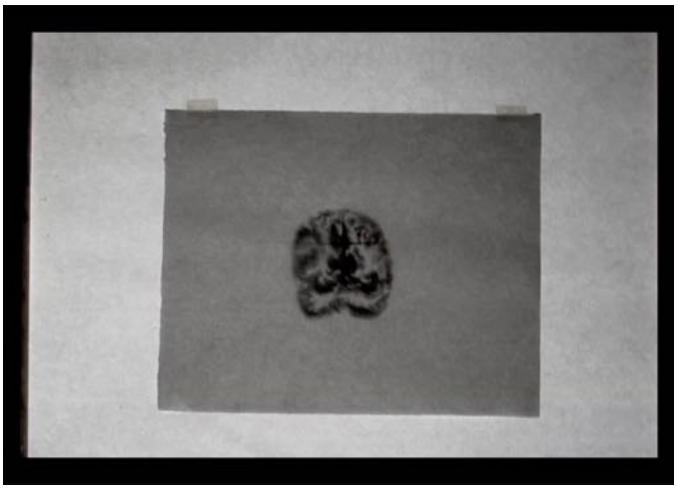
[6] I am using the term 'Black box' as Latour (1987, 1999; Latour and Woolgar, 1979) conceptualises it, rather than, for instance, how it is used in fine-art practice as a term for a video-installation space.

world once any form of knowledge becomes established. The closing of the box conceals the workings of knowledge (its successes and its failings) and stops it from evolving and changing. Through this process, which involves networks of associations that validate and strengthen the knowledge contained within the box, it becomes impossible to challenge its power. A black box, I would like to suggest, disavows the presence of noise in its workings, because its function is to conceal. In the next phase of activity, I symbolically open up the 'black box' of technology.

The use of a cardboard box is motivated by my desire to counter ideas about complex technologies and specialist knowledge by using an everyday material. It is constructed with a small hole on one side, into which a camera lens is inserted. The opposite side is cut out to allow paper to be taped across. A light source is placed beyond the paper, so that the view through the camera resembles a backlit screen. The fibrous structure of the paper suggests a membrane or skin tissue. A drawing is lightly taped on the paper stretched over the side of the box opposite the camera lens, so that it resembles a frame within a frame. Some drawings are made by creating small pinpricks in the paper, while others are executed with graphite. I take a photograph after making each new mark, and a series of still images is used to construct an animated sequence of drawings. To give my body a presence in the sequences, the shadow of my hand is at times seen. The taped drawings move slightly between sequential photographs, giving the animated sequence a fluttering movement that resembles a pulse. The box-construction strategy is primarily a way of thinking through drawing; it allows me to experiment with different ways of looking as I draw with materials or images that are continually moving and changing. Through this process, I explicitly acknowledge the context through which noise is generated in medical visualisations by bodies and body systems that constantly move and change. Furthermore, the fragility of the box alludes to the interactions between imaging technologies and their environments, which also generate noise.

As the camera looks *through* the body of the box to the backlit drawing of a visualisation, the enclosed space inside the box induces a strong sense of seeing a body from the *inside*. Although the construction is quite simple, its effect is quite powerful. Looking through the lens induces a peculiar sensation of my body being positioned inside the box. From there, it looks out to the drawing of a scan (another body) and the external environment. This is not unlike my experience of looking through a microscope, which also felt as though I was positioned inside the microscope. The ways in which I look can therefore, precipitate profound changes in my bodily perceptions.



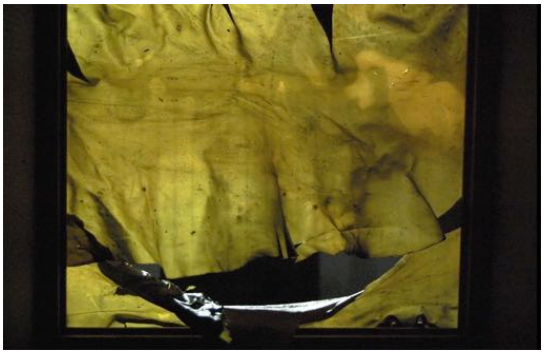


Figures 3.7 (Top) Still from test animations using box construction with pin prick drawings, 2012, work by the author.
Figures 3.8 (Below) Still from test animations using box construction with drawings upon paper taped on surface, 2012, work by author.

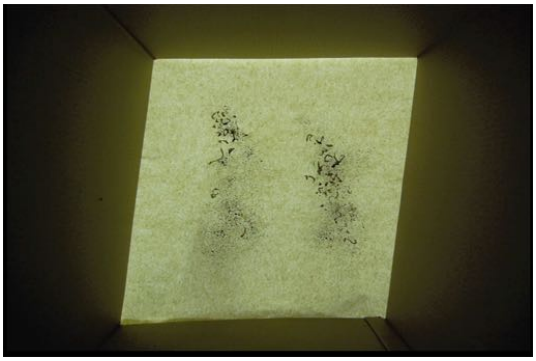
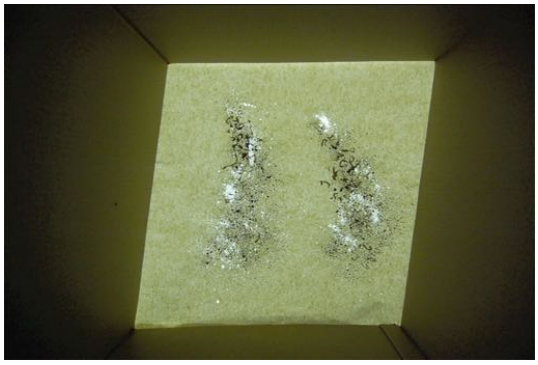
There is another sense in which my body in implicated in this drawing method. As I work, I am continually moving between different sides of the box – from the drawing on one side of the box to the camera on the opposite

side. As I walk, I am preoccupied with the next stage of the drawing: I am in transition between what I have just seen and what I can see in my imagination. The slight fluttering of the paper taped to its support resembles a pulse in the animated drawing.

I continue experimenting with different drawing grounds (seaweed, latex) and drawing materials (oil and water). My aim is to heighten the embodied quality of my materials, and a sense of looking through a body. Many of the materials I test have interesting visual properties but it is difficult to make marks upon them and drawing becomes restricted. The box construction is also tested, by placing a wooden frame inside it to stabilize it because after time the cardboard box becomes unstable. However the wooden frame gives a cinematic quality to the drawing ground and is excluded from my process. This series of tests are outlined below with footnotes (Figures 3.9 – 3.13) to give an indication of my process and to point to the role of trial and error as a method of finding out through doing.




Figures 3.9a and 3.9b (Above) Stills from test animations using box construction with seaweed chosen for its organic quality and resemblance to skin folds. The author 'draws' into this ground by cutting shapes out of it, 2012, work by author.

Figures 3.10a and 3.10b (Above) Stills from test animations using box construction with sugar paper and drawing with black ink and oil, 2012, work by author.


Figures 3.11a and 3.11b (Above) Stills from test animations using box construction with a wooden frame positioned inside the box frame. Drawing ground is tracing paper, and drawing materials are black ink and oil, 2012, work by author.


Figures 3.12a and 3.12b (Above) Stills from test animations using box construction with a wooden frame positioned inside the box frame. Drawing ground is latex, and drawing material is acrylic paint, 2012, work by author.

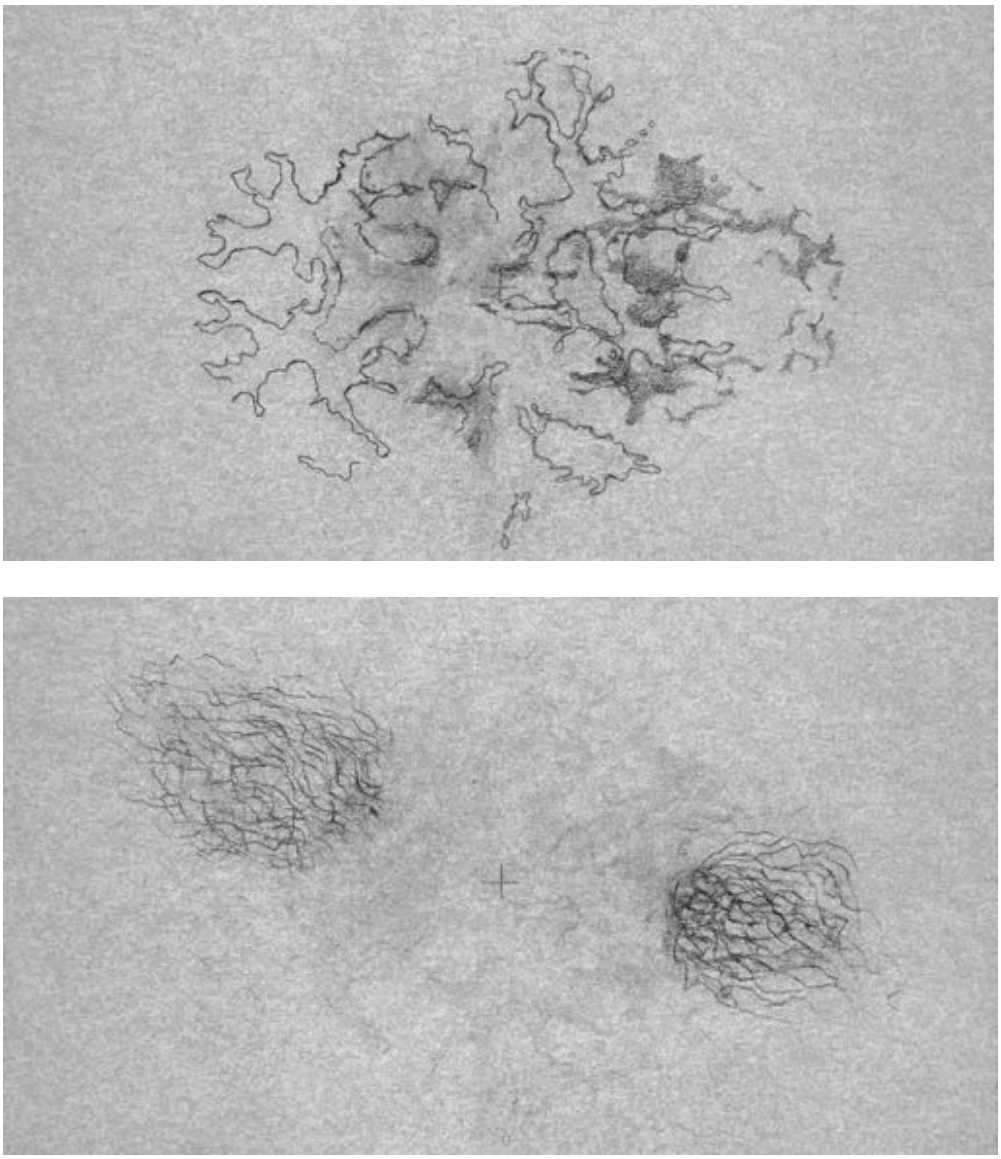

Figures 3.13a and 3.13b (Above) Stills from test animations using box construction drawing with black ink upon latex and plastic, 2012, work by author.

The tests lead me to identify vellum (calf and goat skin) as a material with great potential as a drawing ground. When examined closely, minute traces of hair follicles and pores can be seen on its surface; I particularly like the way this breaks down the distinction between the representation of a body and its reality. Furthermore, vellum is very responsive to its environment; it changes shape unexpectedly and curls into itself during variations in

temperature or humidity in the studio. This responsiveness makes it an unpredictable material to work with; it feels as if I am drawing upon a living material. The tests also lead to my recognition that the structure of a box creates a sense of distance between the drawing and me. I wish to heighten the sense of a moving, changing and pulsing drawing, to get closer to its movements. Is it possible to feel as though I am positioned *inside* the drawing being looked at? My aim is to activate a style of looking that is highly responsive to interactions and movements within the body of the drawing. The next animations bring me closer to my drawings, almost as if I am immersed in them.

3.4 Drawing on movement

In order to emphasise movement and interaction between the drawing, its environment and myself, a macro lens is used for the next series of animations. This enables me to magnify and get very close to the drawn mark: it feels as if I am in the drawing. I tape a sheet of thin cartridge paper on a lightbox and take a photograph each time I make a new mark. The drawing is backlit by the lightbox and its fibrous structure is accentuated. The macro lens has a shallower depth of field, and I am consequently working very close to the drawing with the lens just a few centimetres above its surface. The paper is purposefully taped lightly, so that it moves slightly between shots producing a faint vibration throughout the animated drawing. The ground of the drawing is therefore in continual movement. The macro lens encompasses my field of vision and creates a sense that I am looking at something much larger than its actual size. My body movements feel accentuated and slight movements of the pencil in my hand are magnified enormously. Consequently, my perceptions of my body in space becomes disoriented in a similar way to looking through a microscope.

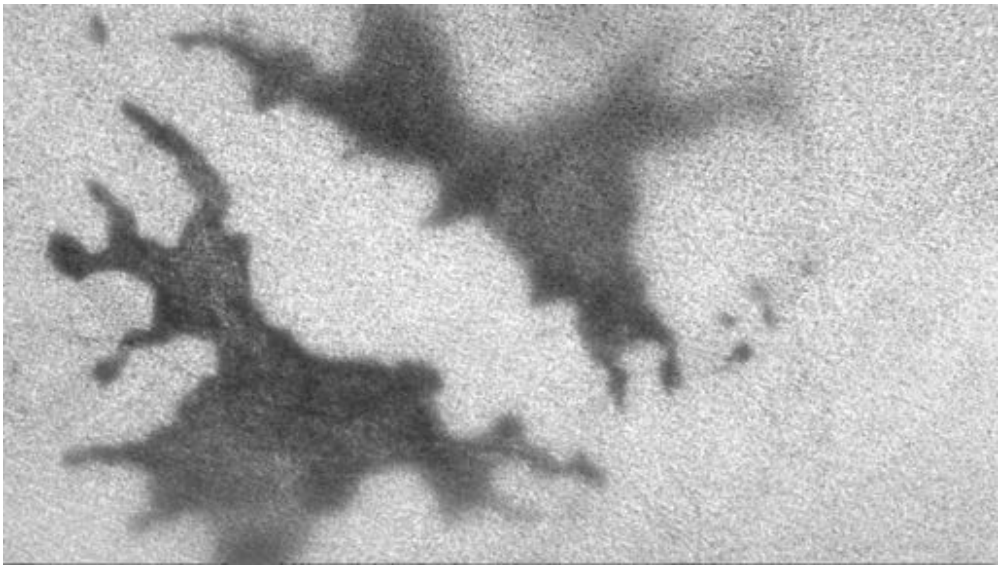


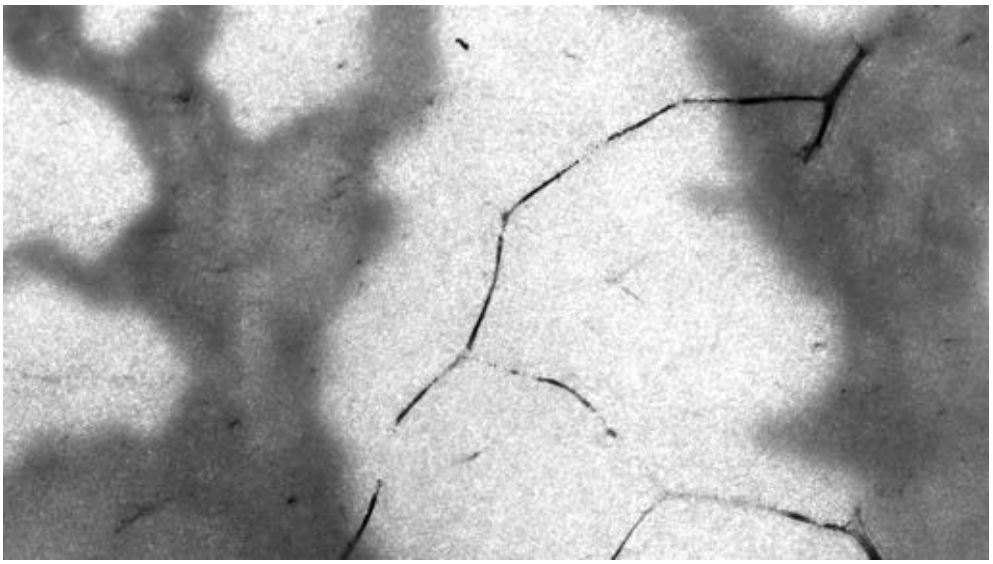
Figures 3.14a & 3.14b (Top and Below) Two stills from *Mind Wandering 1* animation, 2013, work by the author.

I complete a series of three animations (*Mind Wandering 1-3*), which are all based upon drawings of cross sections of the brain. At the centre of *Mind Wandering 1* is a small hand-drawn cross that remains in position throughout the animation as a still point. It refers to a computer tool which is used to navigate the coronal, horizontal and sagittal planes[7] of the brain in a linear 'journey'. It is taken from a three-dimensional computer-generated model of the brain, which is used for teaching purposes. I am interested in this model because it is an example of a visualisation that has its origins in real brain

[7] The coronal plane divides the brain from front to back, the horizontal plane is parallel to the ground and the sagittal plane divides the brain from left to right. Please see: http://accessmedicine.mhmedical.com/content.aspx?sectionid=45395988&bookid=673&jumpsectionID=45401969&Resultclick=2

scans. It is used to simplify, clarify and map the brain without the presence of noise (or living brains). Its function is to map a linear journey through the brain across different planes. My drawings appear from the central cross, they grow and change without logic or linearity. They jump between different planes, expand and contract, appear and disappear. I deliberately introduce cognitive irrelevance into the logical structure of the computer model that is my reference point. The charcoal and soft pencil is brought into sharp focus by the macro lens. By continually making and erasing marks, I can work upon the same drawing ground throughout. The marks of erasure remain on the surface. At the end of the clip, the image begins to break up, it dissolves into a ball of mark-making and appears to implode as it moves across the paper and disappears from view. It is as if the image can no longer hold together, and the drawing finally lets go of making any meaning. Noise returns and the drawn mark takes precedence over representation (of the brain). The abstractedness of the final marks holds more potential for meaning making to me. I am reminded of Mitchell's asserting that pictures want: 'to be seen as complex individuals occupying multiple subject positions and identities' (2005, p. 47).





Figures 3.15a & 3.15b (Top and Below) Two stills from *Mind Wandering 2* animation, 2013, work by the author.

In the next animation *Mind Wandering 2,* I foreground the movement and interactions of my materials. I work with vellum, which is made out of calfskin, and increase the magnification so that pores, follicles and traces of blood vessels on its skin can be clearly seen. It is impossible to keep the vellum flat, it curls and bends as it expands and contracts in response to the changing temperature of the lightbox. As it changes, it moves in and out of focus giving a sensual and haptic quality to the animation. I have placed drawings on tissue paper under the vellum, as it moves and shifts glimpses of the drawings can be seen. Movement and flux suggests interactions and exchanges between the materials, allowing partial looks and partial knowledge.[8] It is an intimate style of looking that evokes the sense of touch through the movements, textures and surfaces of the skin.

[8] Donna Harraway's influential paper '*Situated Knowledge: The Science Question in Feminism and the Privilege of Partial Perspective'* (1988), calls for scientific practice to acknowledge partial and situated knowledge.

Figures 3.16a & 3.16b (Top and Below) Two stills from *Mind Wandering 3* animation, 2013, work by the author.

In the final animation, *Mind Wandering 3*, a very fine tissue paper that is creased and crumpled, is used to take on a pronounced three-dimensional quality. As the sequence progresses, it folds and gathers into peaks and ridges, or gradually unfolds and opens out to reveal the drawing. There is a sense of interiority and exteriority, and the movement is suggests a rhythmic pulse, as if we are inside the body space (in the milieu). The movement has no clear beginning or end, and consequently the clip feels as if it has potential to continue indefinitely. I am drawing with powdered graphite using a dry brush with one hand, while I gently move the fine tissue paper with the other hand at the same time. The graphite powder is unfixed and is difficult to control. It gathers in folds and falls off edges, so that the image changes in

unpredictable ways as I move the paper. The drawing grows at the same time as the paper moves, and its folds conceal or reveal the image at different moments.

Of the three animations, this is the most visceral. The tissue-like paper and its pulsing movements powerfully evokes the interiority of the body. The graphite powder has a surprisingly organic quality: it suggests microorganisms growing and multiplying rather than a drawing material. This way of physically and conceptually working with drawing generates images that are strangely unlike drawings. If ‘science uses imagery … as an essential part of its quest for ever more accurate accounts of material reality’ (Mitchell, 2015, p. 23), than here the materials take precedence over the imagery in ways that are difficult to contain. They are perceived more immediately (as more first-hand) than the image ‘information’ they describe. The ‘image-as-organism is, of course, “only” a metaphor, an analogy that must have some limits’ Mitchell tells us (2005, p.10). But he asks: ‘what are the limits of this analogy? Where does it take us?’ (ibid). The power of images to have a ‘life’ of their own is interrogated in Mitchells (2005) text, and he asserts that we have a ‘double consciousness’ (ibid) surrounding images that both believes and disbelieves that they can have life-like qualities. But I would like to make a distinction here, for the animation is life-like in a particular way. It’s materiality gives it a specificity that demands a presentness in its viewing (and disallows it to be seen in a symbolic way). The drawing spills out of itself; it is unpredictable and random. Lack of control and 'interferences' that are analogous to noise are given precedence. If the aim of the drawing is to depict an image of a brain scan, my methods introduce diagnostically irrelevant visual material into the drawing. On the other hand, my method succeeds in evoking the interactions of living systems that generate noise. This emphasis is in opposition to the medical visualisation, which dematerialises living bodies and eclipses its movements to generate ‘accurate accounts of material reality’ (ibid). The animation creates an environment where both the ground and drawing materials are in continual flux. Its folds and pulse like movements are highly suggestive of living tissue. I find myself looking at the drawing almost as if it is a living

thing. My next experiment takes this a step further by drawing with materials that are more closely connected to the body.

3.5 Interactive materials

The brain is perceived as less fleshly than the rest of the body, perhaps because of its bloodless grey colouration.[9] It is nevertheless material and is largely composed of fat in the form of myelin – a fatty substance that surrounds nerve cells. The next drawing is instigated by a wish to break down the distinction between the representation (visualisation) and the materiality of the object (body) being represented.

Figure 3.17 (Left) *Fat Drawing*, 2017, fat on paper, 68cm x 48cm, work by the author

[9] The blood vessels of the brain are lined with endothelial cells which create a barrier between brain and bloodstream. Please see Sage and Wilson (1982).

The drawing Figure 3.12 is made using goose fat and a resist varnish. The fat is heated to change its state from solid to liquid, and a paintbrush is used to draw. It gives off a pungent smell as I draw which, in this environment, is strangely disconcerting. I am conscious that the brush will become congealed with fat if left over time in the studio, and that I am drawing with a biological material that once inhabited a body. The image is first traced on a lightbox using a transparent varnish. This is allowed to dry overnight. Next, I draw inside the negative spaces of the varnish image with the heated fat. Fat typically moves across paper in an osmotic process from highly concentrated to less concentrated areas. This process is normally quite fast and difficult to control. Here the varnish acts as a temporary barrier, slowing down the fat's movement. But over time, it seeps across the varnished areas and travels across the paper, changing the image in the process.

The drawing itself can be quite difficult to see. The position of lighting – whether the drawing is backlit or from the front – radically alters its visibility. In certain conditions, it is perceived as a slight sheen on the surface of the paper and is almost invisible. When placed on a light box, the contrast between the fat and varnish increases and it resembles an X-ray. *Fat Drawing* is carefully lit in the exhibition space and hung away from the wall with clips so that it moves slightly in air currents. Reflecting upon the finished work, the delicacy of the image and its transparent qualities are more evident than the materiality of the fat, which becomes a secondary presence. The changes in the fat drawing take place slowly and imperceptibly, and a trace of the original image remains. A visually abstract form may enable me to focus upon the interactions that generate noise more directly. With this in mind, my next tests explore methods that engage with abstraction and materiality. I choose to draw data – numerical information – to move away from representation and to acknowledge that medical visualisations are in fact images generated from numbers.

3.6 Drawing data

Figure 3.18 (Top) *Slip Drawing*, 2013, clay upon paper, 30cm x 42cm, work by the author.

Slip Drawing utilises a variety of different types of clay and water – a slip – as drawing material. Clay is an interesting material to use because it is a substance that is associated with the symbolic ground (earth) that bodies ultimately become after decomposition. It stands in for bodies and the organic. I'm interested in the way clay changes state from liquid to solid very quickly and its responsiveness to the levels of heat and humidity in its environment. When I first source the (unfired) clay it is in the form of solid lumps. When placed in pots of water for a few days, it changes to a grainy sludge that resembles a gritty paint. Over time, if left untouched in the studio, the slip transforms into a fine powder that clings to the sides of the pot. This transformation can also take place within the drawing. If left in a hot dry environment the slip can revert back to a powdered state and fall off the surface of the paper.

I collect a variety of different clays, such as fine white porcelain, deep red terracotta and a brown-grey grog (a material used in ceramics). By mixing different combinations of clays, I am able to create a palette of earthy colours. Drawing with slip is difficult: bits of gritty clay continually lodge into the brush. I try nevertheless to draw as precisely as I can, working against my medium. This brings to mind bodies trying to be as still as possible when

they are in a scanner, and visualisation processes that attempt to capture a fixed measurement of a moving living body (that generates noise). They are also working against their material; a completely motionless body would be far easier to measure.

My source material is a series of data sheets of brain scans. I place them on a lightbox and trace each number meticulously with a fine brush. However I move the data sheets continually, so that I disrupt its uniform structure by layering numbers upon each other. As I do so, they begin to suggest forms. The contrast between the numerical information and the earthy, gritty slip is curious; it gives the data a material presence. But perhaps equally importantly, the drawing gives the numbers a pictorial form – albeit an abstract one. Debates about the relative values of abstraction and pictorial representation in science, and the conflict between the 'abstract-concrete' are on-going, as Galison asserts:

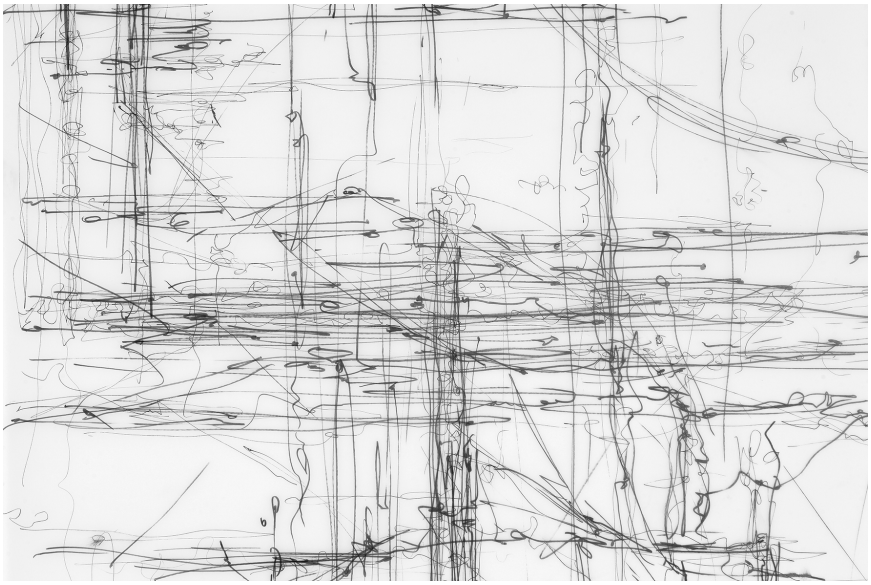
> At the heart of the scientific image is the search for rules; at the heart of the logical-algorithmic has been the hunt for the recognition that is the eternal promise of representation. Said another way: the impulse to draw the world in its particularity never seems to be able to shed itself of the impulse to abstract, and the search for abstraction is forever pulling back into the material-particular. (2002, p. 302)

By representing data in a pictorial form and emphasising its materiality, the drawing holds the abstract and the concrete together. This is not unlike the presence of noise in data, which, I would like to suggest, is like the presence of the body in abstracted information. Noise is the grit in the system that destabilises scientific knowledge.

My wish to destabilise the data further leads me to engage more closely with visualisation technologies in the final phase of activity. I work with bio-sensors: small wearable devices that are designed for the consumer market. They consist of an EEG headset that measures electrical activity on the surface of the (front) brain and a skin galvanometer (worn on the finger), which measures slight changes in skin conductivity. According to the manufacturers, the EEG measures attention levels and the galvanometer

reading is an indicator of emotional arousal. The accuracy of these claims is not of concern for this project. More importantly, the sensors are relatively simple devices that enable experimentation, which more complex visualisation technologies preclude. I work with a creative coder who applies my ideas and writes the code for this project. My aim is to deliberately maximise the amount of noise in the data and to reconfigure how the data is visualised. To increase unpredictability, two sensors are used at the same time. A feedback loop allows data from both sensors to interact generating noise. Bio-sensor data is typically visualised as a bar chart, a moving dial or a continuous oscillating line. Imaging technologies regularly make use of in-built algorithms to convert raw data into an image. The coder reprogrammes the visualisations to follow pathways dictated by my drawings, which have been previously scanned into the software. This radically changes the way in which the data is visualised, for it can no longer be read (decoded) for information about the data that is being transmitted.

Following tests in the studio, the drawing activities take place in public spaces such as a gallery (FACT, Liverpool), an art school (Manchester School of Art) and an arts venue (Cornerhouse, Manchester). To acknowledge the interaction between environment and visualisation, a series of diagrammatic line drawings of the spaces where the activity occurs are used as a basis for the visualisation. The biosensor visualisations are projected in real time during performances, and programmed to follow pathways determined by my drawings in the form of an animated line. This path, however, is easily disrupted. Data interactions between both sensors – the noise – can cause the projected line to move off its predetermined pathway and into unknown pathways. The interaction can also trigger changes in the direction, speed, movement and intensity of the visualisation, which is projected on a large sheet of paper upon which I draw by attempting to trace the lines. The size of the paper is designed to ensure my movement as I draw, for it is wider than the span of my arms.



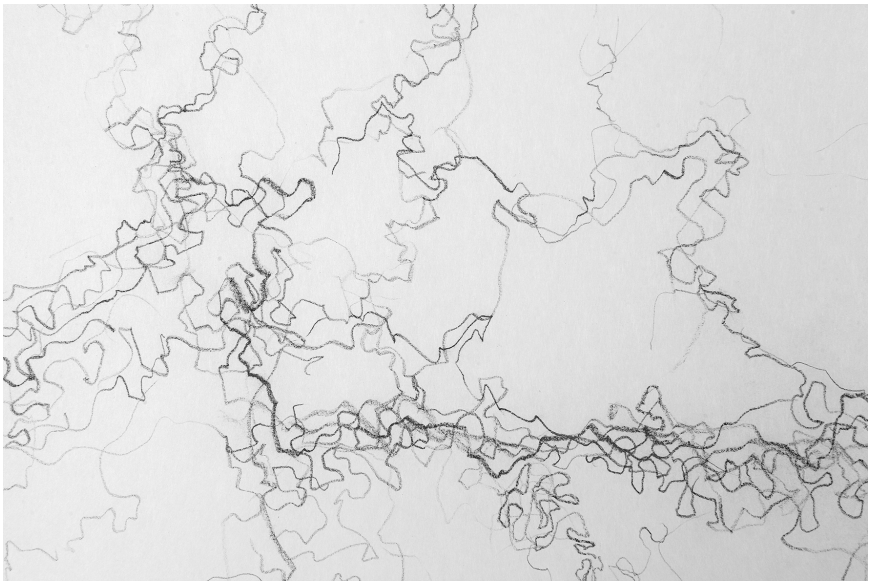


Figure 3.19 (Top Left) *Noise+Signal* drawing performance at Cornerhouse, Manchester, 2013. Author is wearing an EEG headset whilst drawing.
Figure 3.20 (Top Right) Detail of drawing produced at FACT, Liverpool. Work by the author.
Figure 3.21 (Below Left) Detail of drawing produced at Cornerhouse, Manchester, 2013. Work by the author.

I had not originally planned this phase as a drawing performance, but it seems fitting that tests in the studio lead to my making drawings in public spaces because they involve participants into the process. Observers are given the option to wear skin galvanometers during performances, and each new person changes the visualisation and drawing through the data generated by their bodies. This allows interactions between bodies, as well as the environment to generate noise. I am conscious that although this is an experimental process, participants nevertheless look for meanings in the visualisations, as if the drawing will reveal something to them. It is mesmerising to see the hidden functions of the body visualised, however indirectly and incomprehensibly. Nevertheless, there is a sense of perplexity and puzzlement in some participants for the drawings do not reveal knowledge about the sensor data, they are cognitively closed. There is minimal interpretive information about my process. My aim is to engage with noise and to make it visible through my drawing activity, rather than provide scientific explanations of the process. The drawing activity emphasises the role of my body in the process because of the scale of the paper, and through its inevitable focus upon my bodily response to the projected lines. This intensifies my experience, as I try to capture lines before they disappear, and respond to constant changes of direction and speed. It feels as if I am looking through my whole body rather than just the eyes, catching movements from the periphery of my vision. The body surface becomes highly sensitive to movements that cannot be seen directly, but are perceived indirectly. If ‘Nancy argues that thought possesses weight and movement; that it is lodged in the mass and motion of the thinking body’ (Maltz-Leca, 2013, p. 139), then this style of indirect looking is experienced as rooted in bodily mass and movement.

My mark-making often misses the exact point where the projected lines appears: it is less about precision and more about capturing patterns. I am in a sense *looking beyond* the data to draw. I am drawing from code, and as the drawings unfold, I find myself developing a code of marks for each performance. They resemble the signs and symbols of a map, but are without an agenda that clarifies their meanings. At times, I can decipher the

underlying drawing, which the projected line follows, but this drawing is something new and surprising. It compresses the time of the performance into one plane. Its map-like quality suggests space and movement, the repetition and multiplicity of the lines also suggest time. After the performances, I write a short text describing the experience:

All my senses are alert, listening out for the scent of the signal. I scan the surface of the paper trying to register movement at the edges of my perception. The body and hand responds in their own time; a different speed to the data. I anticipate and almost capture the projected signal, organising the lines into a new structure.

I am always out of step; the drawing evolves from off the side-lines, off centre. It is a trace of the almost captured. The live data has its own rhythm and structure. My hands learn how to connect with this unpredictable and fleeting line. Neurons reconfigure as I process the signals from alpha, beta, and theta waves...

A new visual code evolves, as one system generates another. Its symbols are the enclosed line, the open trailing line and the repeated line. I allow the collision between the speed of the data and the pace of my body to manifest itself through the pencil. Pressure and movement become my tools. Hesitations become a series of dots punctuating quick, darting lines that speed off out of control. Slower marks hint at my uncertainty and my unknowing. These lines retrace missed signals, following pathways by memory. Smudges, creases, the marks of my hand upon the paper evidence the encounter between signal and body.

Some drawings resemble electrical circuitry and diagrams. Others suggest an organic, pulsing, meandering trail. They are maps of the unknown: maps of losing my way through the data[10]*.*

The text above describes a style of looking where all my senses are highly alert and seep into each other. I experience an acute sensitivity to my immediate environment (my milieu) *through the body*. It transforms the locus of looking from the eye to the whole body, as if the surface of the body sees. There is an intermingling of the senses, which seems to be a result of being immersed in an environment of unexpected, unintentional and unknown movements. The experience of not knowing where the next mark will go or

[10] The feminist theorist Patti Lather (2007) theorises about getting lost as a methodology in scientific practice.

where the next ‘signal’ will be triggers a different quality in my looking, and, consequently, in the drawing. The drawing process becomes a dialogue with the unknown.

Thinking of of Nechvatal's viral works, I am conscious of similarities to *Noise+Signal*. We both use code to generate noise and allow interferences in signals to change the visualisation. The divergences between them, however, provide a counterpoint for me to reflect upon my own process. I respond to noise through the act of drawing; the movement of my body and changes in my perception are highly implicated in my response. Consequently, the drawing retains traces of my felt, embodied and experiential response to noise, which is quite dissimilar to viewing the disintegration of a digital image on a screen. Nechvatal's use of language nevertheless, points to the importance of the felt and the experiential in his work. He emphasises the idea of ‘immersion’ in relation to noise (as do other artists).[11] Although I describe my own drawing process differently (in terms of the environment or milieu for instance), there is a sense of immersion during my drawing performance. This is linked to my very conscious perception of the drawing’s environment. Noise is connected to perception; it exists (or does not exist) in relation to how it is perceived. Altering ones perceptual responses can therefore change whether one can see the potential (of signal) coiled within it.

Drawing in response to projected signals from technologies that are encrypted by cognitively closed information, leads me to experience my visual perceptions as highly embodied, as if the body surface becomes sensitised to movement and change in the visual field. The final drawings resemble open networks of connections, where each line has the possibility to connect with others. This brings to mind Latour’s ideas about networks where non-human, human, artistic and scientific 'signals' can connect with

[11] Immersion appears to be a recurring theme in noise music: the Japanese artist Merzbow immerses himself in a seemingly endless process of CD releases (over 400 to date). His harsh and discordant sounds and proliferation of output suggest the impossibility of meaning.

each other. However when noise is introduced, these connections break down, for knowledge cannot be generated. They are of diagnostic irrelevance in that they cannot be understood as direct manifestations of bio-sensor 'signals'.

Conclusion

In the second chapter I explored noise equivalents in the visual arts. As it turns out, these are primarily the cognitively closed aspects of bodily experience (awareness) when the body is immersed in its environmental setting. With this definition in place the next step in my research has been to compare my own perceptions working as an artist in a studio with those of scientists at work in visualisation laboratories. This has been the task of Chapter 3.

As a result, I have used this chapter to articulate a series of first-hand experiences of drawing processes that embrace cognitive closure and, I speculate, generate an artistic form of diagnostic irrelevance. Within this articulation, the key finding has been a recognition of my instinctive engagement with physical materials, a reaction that has enabled me to explore and extend dynamic ways of looking that are at one with the various environments which immerse me (my drawings, my studio, my body). These ways of looking heighten all my senses so that vision becomes perceived as intermingled with sound and touch and feels highly interactive.

In addition, the point of my practice-based research is to use first-hand creative experiences to reflect back on my earlier descriptive discussion of noise in Chapter 1 and Chapter 2. The consequence of these reflections has been that this third chapter concludes with the first sketch of the central hypothesis of my thesis: for an artist-in-residence immersed in the environment of a medical visualisation laboratory, scientific images contain traces of (noisy) interactions between living bodies and their environments that excite the same formal and interpretive interests I discovered in my studio.

Chapter 4. Listening to Noise (Nancy and Serres)

Chapters 1 and 2 of this thesis examined theories and practices connected to scientific and artistic acts of looking and seeing, to interrogate how noise – which is in my terms cognitively closed – can be understood. I focused on the sense of vision because it is the primary sense that is utilised in medical visualisation practice, and the one which does not typically recognise methods that involve the full array of senses, unlike artistic practice. James Elkin's ideas about looking as moving in multiple directions, and W.J.T. Mitchell's conceptualisation of vision as an interactive process of exchanges between images, objects and the viewer provide a framework for thinking about sight that shares many of the attributes of noise I identify during my residency. Noise is cognitively closed information that is diagnostically irrelevant in medical visualisation practice, and I investigate whether there is an equivalence in artistic practice. In Chapter 3, I tested artistic methods that engaged with key characteristics of noise such as unknown movements and interactions, and ambiguous visual material. My experience tells me that despite my focus on the sense of vision, the other senses are highly implicated in my response and become activated as I draw in response to the stimuli that characterise noise. The ambiguous and unknown nature of noise precipitated this.

My descriptions of noise in this thesis may, however, give it a status and meaning that are misleading. To elucidate I would like to cite the metaphor of a 'code' commonly employed by scientists when describing DNA. This term has become naturalised to such an extent that, over time, it functions as a figure of speech through a process that José van Dijck calls 'metaphorisation' (1998, p.20). Umberto Eco notes that a great number of disciplines practise semiotics unwittingly – 'it was not because biologists had been reading books on semiotics that they began talking about genetic "codes"' (2000, p. 3). Similarly, medical scientists may not be using the term noise solely because they have been reading information theory. My use of the term 'noise' may suggest that it is a natural phenomenon that exists in its own right and has an observable actuality. It is important to point out that noise is essentially a

scientific construction that is used to describe data or information that is not available to scientific knowledge. It is a back-formation[1] of signal, and as such is simply data that cannot be de-coded and which is expressed as a visual phenomenon in medical visualisations. Nevertheless, to describe something as cognitively closed is to define it as cognitive in some sense, if only as closure. But if one considers that noise has the potential to be re-assigned as signal, as I demonstrate earlier in this thesis, then it has the possibility to become cognitive. For its status is not fixed but is relational. The potential of noise to become signal suggests its instability as a concept and, consequently, the ambiguity that is inherent in my use of 'cognitively closed' is somehow fitting. I address this in more detail later in this chapter, by referring to scientific studies that investigate tolerance of ambiguity in medical students.

The phase of activity in the studio described in Chapter 3 highlighted the importance of my bodily perceptions and sensitivity to materials as I draw in response to stimuli that characterise noise. My artistic responses to visual and cognitive ambiguity employed the full sensorium and cannot be understood through scientific frameworks of theorising noise. The book *Listening* by Jean Luc Nancy (2007) provides a framework for understanding my artistic response in a somewhat paradoxical way. Nancy argues that the sense of vision is too closely linked to the generation of knowledge and that the act of listening is better placed to perceive *without knowing* in ways that vision cannot. He conceptualises listening as perceiving without explicitly knowing what is perceived. This resonates with my experiences during the phase of activity discussed in the previous chapter, and with the tension and implicit contradiction in the term ‘cognitively closed’. It is a contradiction that remains unresolved, and perhaps can only be experienced. Nancy’s ideas about listening and hearing provide a counterpoint to my investigation into looking and seeing, as I explore whether his text can elucidate the ways in which noise triggers changes in my visual perception.

[1] A back-formation in linguistics is a word formed by removing affixes from an exiting word. Although noise is not formed from the word signal, I am using the term backformation here to refer to its conceptual connection to signal.

In scientific discourse, noise is framed in terms of data, information and interferences in the signal being transmitted. How do I step outside this paradigm and conceptualise noise in artistic practice? The philosopher Michel Serres theorises about noise as the background sound of the universe. Similar to Nancy, his writing is poetic, fluid and open to interpretation. Noise is described in terms of multiplicity rather than fixed meanings. I would like to argue that this approach is closer to artistic responses and to the qualities of noise itself, which escapes from meaning and knowledge. When science conceptualises noise, it seems to have a limited vocabulary to describe its ambiguities, elusiveness and escape from knowledge. Just as an artistic practice can respond to noise from within an environment of ambiguity and uncertainty, so too can a poetic and philosophical investigation that offers a different perspective on noise.

4.1 Listening and noise

Nancy asks at the beginning of his text: 'hasn't philosophy superimposed upon listening, …or else substituted for listening, something else that might be more on the order of *understanding*?' (2007, p. 1, italics in original). In questioning whether philosophy can listen (perceive without generating knowledge), he makes a distinction between *entendre* (hearing or listening with the intention of making meaning) and *écouter* (listening as an acute and open state of perception which does not generate knowledge or understanding). Earlier in this thesis, I described how theorists use the terms looking and seeing in different ways. Elkins (1996) asserts that the distinction between looking as the anatomical functioning of the eyes, and seeing as that which is perceived (meaning making and cognition) is fluid. Similarly, Nancy's use of the term *écouter* cannot be completely separated from understanding; it is a question of emphasis and mode of listening as Brian Kane points out: 'For the meaning comes not with the term itself [écouter] – but acts as a guide, offering etymological constraints and evoking historical connotations – but with the definition and characterisation on the listening mode' (2013, p. 446). Nancy asks: 'Isn't the philosopher someone who always hears (and who hears everything), but who cannot listen, or who,

more precisely, neutralizes listening within himself, so that he can philosophize' (2007, p. 1). This question could also be addressed to scientists. The motivation and driving force of science is to generate knowledge and understanding – often by making use of technologies and data – to make sense of the world. Technologies enable scientists to 'hear' in Nancy's terminology, and they are directly implicated in the generation of scientific theory.

There are many layers of translation taking place as I respond to Nancy's and Serres' texts. Firstly, within French itself, from early meanings to contemporary usages of words, and secondly from French to English, with nuances in meanings do not translate from one language to the other.[2] My interpretation of Nancy's ideas about listening and hearing into ideas about looking and seeing[3], is another layer of translation and transformation. There is much scope for ambiguity in meanings. However, this indirect and oblique approach to understanding is in keeping with attributes of noise itself. Noise evades direct knowledge and understanding; it remains on the edges of perception.

Écouter is a state of perceptual attentiveness that is 'an intensification and a concern', and which Nancy describes as 'tendre l'oreille – literally, to stretch the ear' (2007, p. 5). He is evoking a heightened sense of perception that evades the accumulation of knowledge. *Écouter* in Nancy's terms is not dissimilar to scientific understanding of cognitively closed, for cognition is being bypassed. However, *écouter* is not cognitively closed to artists, for it is a state that offers other kinds of information that is considered of value in their practice. The artists I refer to in Chapter 2 draw on methods that can be thought of in terms of Nancy's concept of listening. They purposefully create strategies that circumvent cognition so that the felt knowledge of the body is relied upon. It is a different way of making meaning. My drawing activities in

[2] For this enquiry, I study the English translation of *Listening* by Geneviève James, but refer to key French terms.

[3] It is important to point out however, that Elkins (1996) uses looking and seeing interchangeably.

Chapter 3 emphasised that all my senses were acutely atune. Nancy's metaphor of stretching the ear alludes to this. The *intensification* and *concern* is, I would like to suggest, triggered by disallowing conscious knowledge-making. The other senses strain towards a different kind of meaning.

Nancy's ideas are very pertinent to my study for they can be applied to the question of how noise can be perceived. Noise poses a unique problem in relation to visual perception for the scientist because once something is defined as noise it is framed as cognitively closed and meaningless. There is nothing there to see, scientists tell Marilène Oliver (see Chapter 2 page 41). *Écouter* therefore becomes a closed-off state for scientists, where lack of meaning is a closing down rather than an opening up of opportunities to perceive differently. Perhaps for the artist, whose discipline is not commonly focused upon generating fixed knowledge, *écouter* (listening to noise) can provide an opportunity to explore ambiguous forms of visual perception that are 'straining towards a possible meaning, and consequently one that is not immediately accessible' (Nancy, 2007, p. 6). The *straining towards* and being 'on the edge of meaning', describes my experiences of drawing in response to noise characteristics.

Nevertheless, Nancy makes a clear distinction between the visual and the auditory, describing the visual as 'mimetic, and the sonorous as tendentially methexic (that is, as having to do with participation, sharing, or contagion)' (2007, p. 10). He asks 'Why, in the case of the ear, is there withdrawal and turning inward, a making *resonant*, but, in the case of the eye, there is manifestation and display, a making *evident*?' (p.3, italics in original). Resonance is an important concept for Nancy, and is connected to the idea of sound reverberating within and without the body. It is a deeply experiential form of knowing. Nancy asks why there is a closer affinity between 'spectacle and speculation' than the 'sonorous and the logical' (p. 2). In doing so he contributes to the vast body of literature that critiques vision which I refer to previously in this thesis (see Introduction page 4 and Chapter 2 pages 51-

52). My intention is not to contest this literature,[4] but to explore whether noise – because of its intrinsic unknown qualities – triggers changes in how the artist looks in ways that are similar to Nancy's conceptualisation of listening.

When I activate an ambiguous (unknown) way of looking, it is a participation in my environment, what Nancy calls a 'contagion' (2007, p. 10) that seeps into me. There is a sense that all stimuli have an equal weight, all possibilities are held in balance: 'to be listening is to be *at the same time* outside and inside, to be open *from* without and *from* within' (p. 14, italics in original). This is quite different from highly focused and controlled methods of looking as I draw. This is experienced as a distancing and losing touch with my environment. When I am responding to unknown – cognitively closed – stimuli it feels as if there is a circular movement between my looking, my environment, my materials and the drawing. This continually brings me back to myself. It is experienced, in Nancy's terms, as '*renvoi*' (p. 9). The translator's notes to *Listening* explain *renvoi* as a 'return to sender', a 'sending back' or a 'repetition (as in a phrase of music)'[5]. Kane suggests that renvoi is 'manifest in the limits and contiguity of modes of listening' (2013, p. 446). When the object is at the limits of perception, it brings me back to myself. He observes:

> Nancy's attention to the difference between *entendre* and *écouter* is ultimately a way of reformulating the question of the subject by encouraging a shift from the phenomenological subject – the subject of representation who constitutes the objectivity of things by its inherent yet unrepresentable power of representation – to a subject that is listening to the infinite *renvoi* of meaning, sound, and self. (2013, p. 446, italics in original)

Noise, that is drawing from a position of ambiguity and not knowing, changes the quality of my looking into something that resembles Nancy's conceptualisation of listening.

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[4] It is important to note that alongside critiques of scientific vision as objectifying, other theorists call for an embodied vision in science, see, for example Harraway (1988), Chemero (2009) and Plunkett (2013). Furthermore, the interaction between digital technologies of vision and scientists has generated new theories about embodied visual responses between technologies and humans.

[5] See Charlotte Mandell's Translator's Notes (Nancy, 2007, p. xi).

4.2 Looking as listening

Nevertheless, there is some fluidity in Nancy's statements about vision, for despite his clear delineations between listening and looking, he also asks 'Why, however, does each of these facets also touch the other, and by touching, put into play a whole system of the senses?' (2007, p. 3). Here he is acknowledging that the senses cannot be separated. Phenomenological insight recognises the interconnection between sight and the other senses and an embodied sense of vision. Nancy asks if there can be a visual sound: 'Although it seems simple enough to evoke a form – even a *vision* – that is *sonorous*, under what conditions, by contrast, can one talk about a *visual sound*?' (p.3, italics in original). He seems to suggest that vision could be sonorous more easily than sound can be visual. In Nancy's usage, sonorous implies an environment (of sound), one that seeps into the body and resounds both externally and internally: 'Sound is also made of referrals: it spreads into space, where it resounds while still resounding "in me"' (p. 7). Resonance is an important concept for Nancy, one that describes a different way of making meaning. It is a way of knowing that is *felt* and does not generate explicit knowledge. Resonance is where listening, sound and self resonate in unison. I recall Elkins' statement from Chapter 2: 'looking is something I do but also something that happens to me' (1996, p. 35). Bruno Latour on the other hand, describes a process that seems the opposite to resonance when he theorises about how science uses networks and inscriptions that fix knowledge by erasing noise-built knowledge systems (see Chapter 2 pages 52-53). This type of knowledge-making is external to self.

When I draw from a position of not knowing I am continually brought back to myself; my process of reflection grows from my synthesis of external and internal stimuli. It is a style of looking that privileges the 'touching' of vision with the other senses in a continual interaction: vision becomes inseparable from the touch of the paper through the pencil, the sounds in my studio and the light of the projector. It has an intensity that is, in Nancy's words, a 'feeling-oneself-feel' (p. 8). Perhaps this is a critical difference between the imaging scientist's and artist's response to noise. The scientist is more likely

to be focused on solving a problem that is perceived as external to the self, as a splitting of subject and object. My sense of 'feeling-oneself-feel' grows out of an instinctive understanding that the knowledge I need in order to produce a drawing comes from an experience that resonates within me, and not from a logical, cognitive working out of methods. Imaging scientists do not have a disciplinary framework that values their sensual responses as they look at noise in a visualisation on a screen.[6] For the artist this is familiar, as can be evidenced by (a long history of) the importance of touch, pressure, surface and responsiveness to materials in drawing practice (Garner, 2012; Maslen and Southern, 2011; Rawson, 1969). *Listening* elucidates a different way of perceiving noise. But how do I conceptualise noise? What does it mean to an artist? Scientific explanations cannot account for the ways in which I understand it. The book *Genesis* by Serres provides a different perspective that resonates with my experiences.

4.3 Noise as environment

Noise cannot be penetrated by language asserts Serres: 'Before language, before even the word, the noise' (1995, p. 54). His poetic text flows around the idea of noise, circulating around it without fixing it, employing language in fluid and open ways. His writing moves freely between diverse ranges of references from science to metaphysics, Greek mythology to information theory. For Serres, noise is always present (p. 65). It is 'limitless, continuous, unending, unchanging' and is part of 'the ground of our being' (p. 13). This way of thinking about noise feels both very far removed from scientific accounts, and yet is also strangely familiar. The cosmic background radiation described earlier in this thesis (see Chapter 1 page 33) also forms an environment of noise that is 'limitless' and 'continuous'. Serres could be describing a scientific phenomenon. But the way in which he communicates is entirely different; he moves freely between a diverse range of references from Greek mythology to information theory, science to metaphysics: 'It is the function of the scientist to be right and rational ... the philosopher does not

[6] However, medical practice does recognise other senses, for doctors do undertake physical examinations of patients; they palpitate skin or listen to the heartbeat for instance.

wrap himself up in truth as in breastplate or shield... he wants to let the possibilities roam free' (p. 23).

Possible meanings rather than fixed meanings run throughout the text. Serres emphasises partial knowledge: ‘a meagre amount, enough, quite a bit; there are various undulations, even in the hardest and most advanced sciences’ (1995, p. 5). Whereas scientific practice aims to fix meanings and to separate signal from the noise, Serres conceptualises noise as a unified whole and as the background to everything. In this paradigm, noise is larger than the information it contains. Underlying this is the difference between a (scientific) will to control and (artistic/philosophical) acceptance of lack of control. Similarly, ideas about transparency (complete knowledge) and opaqueness (the partially known) are at play.[7] These differences reveal attitudes towards what constitutes knowledge, for in artistic practice to be in control and have complete knowledge of the drawing process would disallow the unexpected, the intuitive and the unknown from which new ideas can spring. *Genesis* invokes this place:

> Background noise is the ground of our perception, absolutely uninterrupted; it is our perennial sustenance, the element of the software of all our logic. It is the residue and the cesspool of our messages. No life without heat, no matter, neither: no warmth without air, no logos without noise, either. Noise is the basic element of the software of all our logic, or it is to the logos what matter used to be to form. Noise is the background of information, the material of that form. (Serres, 1995, p. 7)

Serres brings together matter, life and heat with logos, information and messages. This clash of seemingly incompatible and incongruent things asserts the interdependence of the material and data. The background noise is elemental – heat and air – suggesting the ‘fury’ of thunderous storms whilst at the same time, it is ‘the element of the software of all our logic’. Here science, technology and data are taken out of the laboratories and placed in a different environment: one which is vital, chaotic and material. It more closely describes, I would like to suggest, the subjects of scientific enquiry.

[7] Haraway (1988) calls for the privileging of partial perspectives in science.

He emphasises the interdependence of matter, logos and noise.[8] No information without noise he asserts (no visualisations without noisy bodies). Information scientists and medical imaging scientists agree that noise is inseparable from the medium and pathways that signals travel through. The interactions between materials and heat (which is the energy of movement) are the ground from where noise springs. These are the same materials that carry signals. All this is recognised and acknowledged, albeit using very different language, in medical imaging textbooks. It is the emphasis that is different, for Serres describes noise as if it has agency and power. Crucially, it is a force that sits outside understanding and will and this is precisely why noise has such a different status in science.

Ideas about the unit and the multiple recur in Serres' text. The unit – the basic unit of information – is at the heart of scientific measurement. Once something can be measured systematically, it can be calculated and absorbed into knowledge systems. However, when Serres speaks about multiples he is not describing the grouping of things: 'it's neither flock, nor a school, nor a heap, nor a swarm, nor a herd, nor a pack' (1995, p. 5). It is not a unified collection of things, but rather an incalculable multiplicity. Elkins too evokes the multiple in terms of the immeasurable and the unknown: 'How can the observer look at the subject if it is multiplying and changing under his very eyes? The supposedly static object is a moving target, like the exit door in a hall of mirrors' (1996, p. 39). Elkins' word 'multiplying' evokes a growing living thing that cannot be contained or measured. Serres contrasts the desire to measure and to know with the way in which that other way of knowing – sensory perception – functions: 'We are fascinated by the unit; only a unit seems rational to us. We scorn the senses, because their information reaches us in bursts' (p. 2). The movement suggested by his use of 'bursts' is also uncontainable, unexpected and uncontrollable. Here sensory information is experienced in ways that are similar to noise itself. They are in flux and immeasurable. He describes sensual perception as if it

[8] The materiality of data has been theorised from a variety of perspectives, such as the interactions between bodies, software and hardware (Raessens, 2009), and through the generative potential of data (Rushkoff, 2009).

is an environment: 'Perceptions bursts, inner and outer, how can they be told apart? How am I to tell any environment I've entered in, become immersed in, that this wood I'm confronted with doesn't go on forever, that I'll get to the edge of the forest some day?' (p. 6).

Rather than complete knowledge, Serres is interested in the idea of the possible: 'The most common forgetting is that of the possible. It is so much forgotten that it is not visible' (p. 24). This statement illustrates how noise can be perceived in medical visualisation practice and theory. It becomes invisible once it is labelled as noise and the focus shifts towards signal (and a false dichotomy). But the invisibility of noise also conceals its possibility to become signal. For me, the potential of noise to transform into signal is a central concept. However, Serres contests the use of the word 'potential' and states that it is too closely associated with power, instead describing noise as 'capaciousness' (p. 22) or as an environment of possibilities.[9] Perhaps he is referring to power within the specific context of knowledge/power, or perhaps for Serres noise is a 'viscous' (p. 5) thing that refuses to become assimilated into any form of knowledge. More importantly, the possible is for Serres enmeshed in sensual perceptions: 'The raucous, anarchic, noisy, variegated, tiger-striped, zebra-streaked, jumbled-up, mixed-up multiple, criss-crossed by myriad colours and myriad shades, is possibility itself' (p. 22). He is describing possibility as an overwhelming sensual experience that cannot be contained within scientific knowledge; it cannot be divided into units of information. Noise is elusive; it cannot be measured and perhaps can only be experienced. Serres is suggesting that sensual experience opens up a way of knowing noise and the possibility contained within it, and in this my use of the word ‘potential’ is not dissimilar to his conceptualisation. My experience of drawing in response to noise resonates with Serres’ writing and points to ways of knowing noise that are closed to scientific methods. These ways of

[9] Ideas about the potential of noise (its possibilities) recur in music, new media and cultural theory. Noise is conceptualised as a catalyst that ‘has the potential to bring about a change in the system into which it is released’ (Hainge, 2013, p. 10) and as ‘a paradigm of innovation’ (Malsapina, 2012, p. 58) that ‘possesses the possibilities of liberation’ (Goddard et al, 2012, p. 9).

knowing are located in the subject who perceives: 'Noise, you see, is also a trace of the observer. There is noise in the subject, there is noise in the object' (p. 61). His ideas echo Nancy's evocation of the subject and emphasise the interaction between object and subject. It is through this interaction that knowledge is produced: 'Cognition is subtraction of the noise received and of the noise made by the subject' (p. 61). Something is lost – perhaps resisted – in the transference.

4.4 Resisting noise

Cécile Malsapina explores whether noise can be thought about as breaking down boundaries within disciplines to activate a 'strategic use of ambiguity' (2012, p. 59). She asserts that noise cannot remain 'self-same' (2012, p. 58); once it is assimilated into new genres or disciplines its status changes. This flux and ambiguity seems linked to its potential to trigger innovation. The strategic use of ambiguity is not uncommon in arts practice, as I explore earlier in this thesis (see Chapter 2). But what role does ambiguity play in science? The philosopher Miguel de Beistegui observes:

> Scientific thought is essentially interventionist and efficacious; it is a thought that measures and predicts. But science does *think*, and its thought is one that increasingly maps on to the phenomenality of phenomena, that is, to the reality of the world as we perceive it: it is a world of flux and becoming, and one that is often opaque. It would seem, therefore, that the distinction between the world of phenomena and the world of scientific objects no longer holds, at least no longer in the same rigid and absolute way.' (2005, p. 113)

'[A] world of flux and becoming' is full of noise; its opacity and ambiguities, its escape from absolute measurement are the conditions of noise. This paradigm is however not evident in scientific accounts of noise, as described to me in chapter one. They tend to focus upon technical procedures and mathematical approaches. Beistegui calls for philosophy to engage closely with science, for 'many of the questions and issues that traditionally fell under the authority of philosophy, and which helped clarify the fundamental meaning of that which is, now fall under science' (2005, p.109). The continuing evolution of science has radically transformed these questions in ways that increasingly destabilise fixed knowledge. Perhaps more than ever,

it is imperative that disciplines that have different approaches toward ambiguity such as art and philosophy engage with these questions. For science alone does not have the framework to utilise ambiguity and not knowing - cognitive closure - as methods. It does not recognise the potential of noise. If one considers the aims of science, tolerance of ambiguity is inimical to scientific practice. And yet, as the descriptions of noise in medical imaging in this thesis evidence, ambiguity is an inescapable aspect of scientific practice.

The medical education theorist Alan Bleakley (2015) calls for uncertainty and ambiguity to be used as resources rather than perceived as hindrances in medical education. Investigations into tolerance of ambiguity are a growing field of study in medical education, particularly in highly visual specialisms such as dermatology, pathology and radiology.[10] Studies indicate that art workshops can develop medical students' visual acuity, visual diagnostic skills, pattern recognition, communication skills, team working and empathy (Friedlaender and Friedlaender, 2013; Naghshineh et al., 2008; Shapiro et al., 2006). Bleakley identifies some key challenges in the growing trend of arts integration into medical curricula. He questions whether processes of evaluation constitute a defence against tolerance of ambiguity and points out that there is a danger that artists working with medical institutions may 'suspend the innovation and radical nature of their practices in the service of becoming "educationalists"' (2015, p. 352).[11] This chimes with my own

[10] Low tolerance of ambiguity in medical practice has been defined as the tendency to perceive ambiguous situations as 'sources of threat' and is associated with 'mental rigidity, conformity and ethnic prejudice' (Weissenstein et al., 2014). Visually examining an artwork can be a new experience to medical students; one which can be perceived as cognitively closed. This paradoxically can open up new ways of looking, for there is no visual distinction between areas of lesser or higher importance in an artwork - it is all relevant. As Bleakley points out: 'where visual material is complex, ambiguous, or novel [it] calls for close, detailed attention' (2003, p. 302). Habitual ways of (medical) looking that 'occlude fresh seeing' can become destabilised in gallery/museum contexts. A focus upon close observation over extended periods of time in not tied to one outcome, but is 'active looking – unbiased inspection' (Naghshineh et. al. 2008). This encourages students to continue looking after a meaning emerges, to allow other meanings to emerge.

[11] An overview of different studies reveals a variety of approaches to evaluation – from short tick-box questionnaires at the end of workshops, to detailed assessments pre- and post-workshop examining visual diagnostic skills, alongside detailed questionnaires.

experience of drawing in the laboratory. I became self-conscious and uncomfortable with taking risks, shying away from using unusual drawing materials or methods (health and safety notwithstanding). Perhaps workshops in the environment of an artist's studio could be investigated. There is potential to explore this further. But nevertheless, scientist's recourse to art in their medical training is an arguably belated and overdue recognition that their own discipline does not and cannot address the question of ambiguity. I am reminded of Latour and Woolgar's observations of scientists working in the laboratory:

> Despite participants' well-ordered reconstructions and rationalisations, actual scientific practice entails the confrontation and negotiation of utter confusion. The solution adopted by scientists is the imposition of various frameworks by which the extent of background noise can be reduced and against which an apparently coherent signal can be presented.
> (1979, p. 37)

In the twenty-first century, with the increasing capacity of visualisation technologies to 'see' what was previously invisible, their observations hold truer than ever. The visible world is becoming even more complex and confusing. The cognitively closed and diagnostically irrelevant aspects of medical visualisation practice may increase rather than decrease over time. New ways of looking, seeing, perceiving and thinking are needed. Artistic practice is well placed to respond to visual ambiguity and the cognitively closed aspects of noise in medical visualisations, as my investigation demonstrates.

4.5 Noise and generation

In the previous chapter I asserted that drawing is indeed a thinking practice, and yet thinking seems to be in contradiction to the notion of listening, feeling and intuiting through the senses. During the phases of activity described in Chapter 3, I knowingly formulated methods and strategies to explore aspects of noise through drawing by orchestrating unknown movements and interactions in my materials for instance. These methods were nevertheless, designed to precipitate a state of not knowing. Their aim was to place my body and perceptions into an environment of noise whilst drawing. Although

some of these strategies such as loss of control and the use of fugitive materials are not new to my practice, they were taken a step further. For instance, the use of bio-sensors or drawing on materials and grounds that are themselves moving are new ways of working for me. When my subject matter is cognitively closed, I cannot approach it directly. There is no clear way into my subject and, consequently, my methods and drawing strategies become more inventive and speculative. Cognitive closure as a starting point for a drawing (despite my knowledge of the characteristics of noise) is productive and generative in ways that I had not anticipated.

Figure 4.1 *Untitled*, (detail) 2017, slip on paper, 150 x 120cm, work by the author.

The drawing above (Figure 4.1) is a detail from a new drawing made in response to the earlier *Noise+Signal* work (see Figures 3.15 and 3.16) described in the previous chapter. I return to this work because of the ways in which it merged my senses. I experienced the act of looking as if through the surface of my body, not just the eyes, and my hands seemed to become tools for thought. The work, perhaps more than other experiments, triggered the most intensely felt changes in my perceptions. This was connected to the physicality of the process and the unexpected movements I responded to, which seemed to provoke a deep sensitivity to my environment. The *Noise+Signal* drawing events involved a relationship with viewer and space.

My bio-sensor data was interacting with the participants'/viewers' bio-data, and there was an audience for the drawing performance which inevitably changed my perceptions.

My wish to explore this further, leads me to test different drawing materials – slip not graphite – and a different environment – the studio – for a new drawing with bio-sensors. Being in the studio space feels more reflective and allows me to test whether the 'audience' aspect of the *Noise+Signal* drawing performances was essential, or whether my methods triggered my drawing experiences. I wear both sensors myself, and the code is modified to reflect the studio space. The slip, which is a gritty suspension of clay in water, drips on the floor as I work, and hardens upon the brush as it dries. It is as if its grittiness on the paper provides an additional haptic dimension that intensifies my sense of thinking through touch. Its earthy colours suggest the body and flesh. However, the drawing remains untitled because I do not want to disclose meanings, and because I approach it without knowing what it will be. The studio is quiet as no one else is present. I can hear the faint hum of the projector and am aware of changes in light in the space caused by the projections. As I move forward slight vibrations from my steps transfer to the plinth that the projector rests on, causing further unexpected movements. Returning to this drawing process in the studio with different materials intensifies my sense of looking through the body and the mingling of touch, sight and sound as I work. Although an audience and public performance could be thought about in terms of adding an extra dimension of unexpected change and movements into the process, working alone in the studio allows me to feel the resonance of all my senses more acutely.

Studios are nevertheless contested spaces that have been the subject of much debate. Daniel Buren's essay 'The function of the studio' (1979) argues that artwork needs to be seen in the context where it was made. In a recent talk, Rebecca Fortnum (2014) discusses debates about the studio as a barrier between artist and audience and as theoretically indefensible. Without entering into debates that are outside the remit of this study, I would like to refer to a video by Bruce Naumann (which Fortnum also refers to). *Mapping*

the studio (Fat chance John Cage) (2001) was filmed at night in the artist's studio. The only activity is the occasional appearance of a cat, insect or mouse. Here the studio is the central focus of the work, not a mythical artistic genius. Fortnum (2014) states: 'As the artist is not present to make the work, the film makes itself. It literally enacts the drive in the making of the artwork, making that which is unknown available to him'. When I am in the studio, it feels as if the activity of drawing is more present than I am, and the interaction between the drawing and myself becomes acutely felt. I am more self-conscious during public performances. In the studio, it is easier to lose myself in the drawing, and it is this experience that sensitises me to unknown and unexpected stimuli. It is an oddly vulnerable experience, and perhaps the reason I return to the studio is because it feels less exposed.

According to Elkins, everyday seeing (which he calls just looking) is accompanied by a blindness to things that we find too disturbing, puzzling or even too boring: 'things that fall through the cracks of vision, things so odd we never figure them out, blurs, confusions, smudges, and smears' (1996, p. 205). Vision is full of interferences (noise) that we daily filter. Elkins points out that just as the eye filters what it does not want to see and at the same time searches for what it desires to see,[12] so too do the ears actively search and ignore a range of sounds. He asserts that '[t]he same could be said about my tongue, or my fingertips, or the blind man's cane' (p. 34). The whole sensorium can be employed in evading unwanted stimuli: noise is the background to everything we perceive as Serres argues. When noise is my subject, I am attempting to prevent the blindness that Elkins describes. Perhaps this is why it is experienced so acutely (I am thinking here of Nancy's notion of listening), for in daily life I do not practise this way of seeing, feeling or listening. This is then another layer of noise that sits below the scientific concept of noise. I understand this in terms of Elkins' ideas about the 'immensely troubled' nature of visual perception, which he compares to 'a skein of changing relations with objects and people' (1995, p.

[12] I state earlier in this thesis (see page 22) that Elkins argues that vision is like hunting.

201). How can scientists see noise when they do not acknowledge the 'immensely troubled' nature of vision?

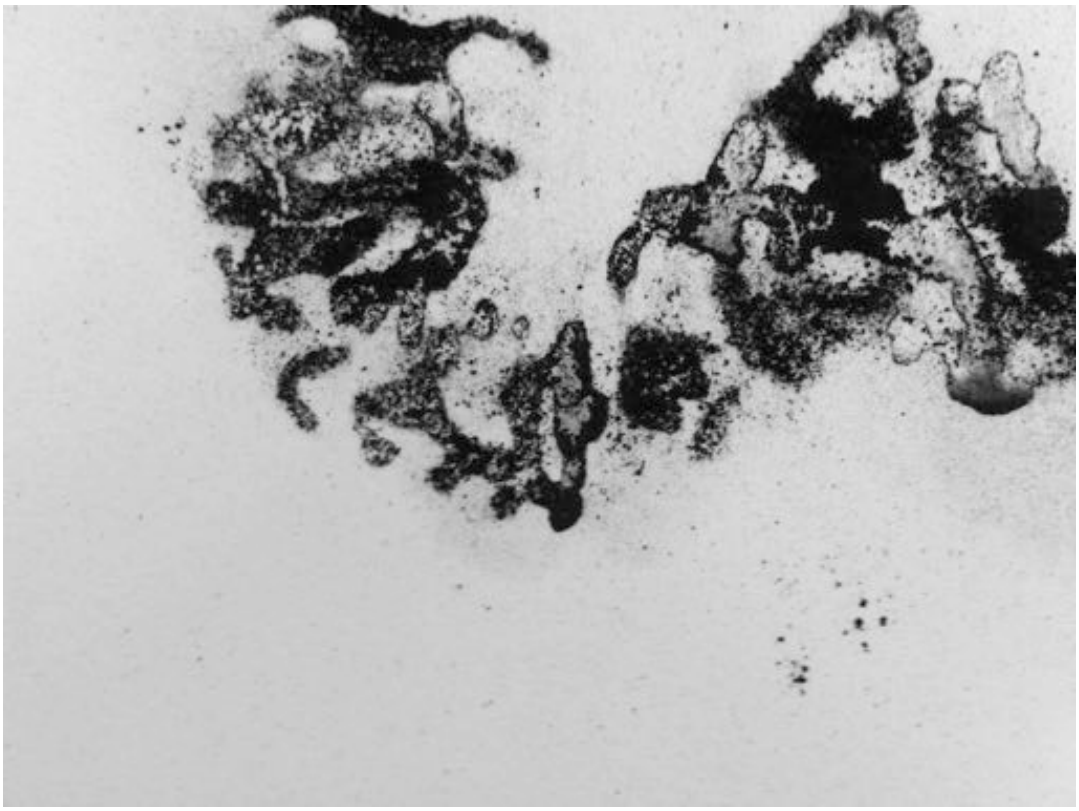

Figure 4.2 *Untitled*, (detail) 2017, graphite on paper, 42 x 30cm, work by the author.

In a final drawing experiment, I test a method that navigates Nancy's ideas about sound, the sonorous and resonance. I am interested in the idea of knowledge that resounds within and without the body. An exchange between the interiority of my body and the external environment – my breath as it is expelled from the body – becomes a tool to produce the drawing. It seems apt that although I use breath, no sound is produced but instead an image is revealed. Nancy states that 'visual presence is already there, available, before I see it, whereas sonorous presence *arrives'* (2007, p. 14, italics in original). I wish to explore how I can reverse this statement and make the visual arrive through the body. When I first consider this method, I question whether it is too literal a translation of Nancy's thought. But as I experiment with the materials, I am surprised by how immersive the process becomes. I become fully absorbed into this way of working, it demands my perceptual attention for there are elements of chance and the unexpected at every step.

I begin by drawing with a completely transparent material that is not unlike water – it is a diluted pigment binder. Using a brush, I draw quickly and without thinking beforehand, giving myself permission not to know before I start each drawing. It is a process of finding out through doing, and I produce many drawings in this way in quick succession. This is a method of thinking though materials and through making that is rooted in unexpected and unknown outcomes. Before the binder solution dries, I sprinkle natural pigments in the form of dry powders with a brush over the surface of the paper. They are made from organic materials: bone black is largely composed of burnt animal bones and burnt umber is a mineral compound mined from the earth. These materials are chosen because of their connection to bodies. Next I gently blow the pigment off the surface of the paper and where it adheres to the binder, a drawing is revealed. It is a very delicate image – a slight touch can dislodge the pigment. In some areas it adheres in clumps, whilst in others it leaves a fine powdery trace. As I look closely at the particles of pigment, my looking feels like a touching. This may be linked to its textural quality and the fact that I cannot touch the surface of the drawing. Perhaps my wish to do so becomes displaced into vision. It may also be connected to the drawing being revealed in a matter of seconds rather than growing over time. The speed of the revelation pulls me in close to the drawing. It holds not knowing and knowing together, for each time I do this the drawing is seen anew. The disjunction between my mark making (with the binder solution) and the final image also causes me to look with fresh eyes; each drawing is a surprise. Looking anew is important, for it is the only way of approaching noise. The drawing is revealed by breath, a life force that gives the drawing life.

Conclusion

In this chapter I have proposed an over-arching theoretical frame for the ideas developed in the first three chapters. Because these ideas associate noise with the embodied meanings experienced as a visual artist experiments in a productively noisy environment, Chapter 4 employed the phenomenological insights of Nancy's *Listening*, and Serres' *Genesis* to explain why terms such as 'closed cognition' and 'diagnostic irrelevance' are

useful to creative practitioners. Nancy's text interrogates how it is possible to perceive the world, without reducing perceptual experience into knowledge systems. He argues that by evading knowledge-making (cognitive closure), a heightened perception of the world is experienced. He describes this state as *listening*, and in my experience, it is analogous to my perceptions as I draw in response to stimuli that are characteristic of noise. For Serres, noise is the background to the universe; it is a constant presence that asserts itself through the senses. His conceptualisation encompasses scientific understanding, but more importantly, embodies an understanding of noise that elucidates artistic responses through creative practice.

Nancy and Serres provide a philosophical frame that equates body/world resonance with the most heightened forms of knowledge. Their ideas are negotiated and given substantial practical form through the final drawing experiments in this chapter. They evidence that noise can be a potent source of artistic ideas. Accordingly, this chapter builds intellectually on the hypothesis which I proposed in Chapter 3. The results demonstrate how artists can be open to ambiguity in their environment without needing to make sense of what is encountered.

Conclusion

As we have seen, noise is generated by unknown movements and interactions within and without the human body and the bodies of technologies. However, signal – the informational opposite of noise – can also be generated by unknown movements and interactions. Therefore noise is embedded in the structures and processes of medical visualisation practice and the distinction between signal and noise is unstable. Although scientists recognised the difficulty of separating noise from signal in medical visualisation practice, when they ascribed information as noise, they perceived it differently as my thesis demonstrates. Noise is manifested as ambiguous visual traces in medical visualisations – images that have informed my drawings for a number of years. The presence of noise within them raised interesting questions about how visual ambiguity is perceived by scientists and artists. Despite continued advances in technology, noise cannot be erased from medical visualisations. It can be minimised in a number of ways, but it cannot be excluded. Its continued presence meant that an element of the unknown remains at the heart of scientific practice.

Questions about perception – particularly how artists and scientists perceived noise – were central to this study and provided a framework for testing my ideas. Perception is a largely unconscious fusion of sensory information and its assimilation into cognitive processes. This research began by focusing on visual perception because vision is the dominant sense used by medical visualisation scientists. For instance, pattern recognition is an important component in the decoding of scans. However, noise complicates visual perception, for it is difficult to separate from signal. The ideas of art historians James Elkins and W.J.T. Mitchell about the ambiguous nature of visual perception were negotiated by a series of drawing experiments I carried out through the course of this research that explore the instability of vision (see Chapters 1, 3 and 4). Their ideas provide a method of thinking about how acts of looking and seeing are themselves interactive and full of unknown exchanges. As my study progressed, it became clear that vision is inseparable from other senses when artists responded to unknown or

ambiguous stimuli. They make use of wider sensory perceptions which are not recognised in medical visualisation practice. To resolve the on-going nature of my negotiation of the scientific concept of noise through artistic practice and to understand how artists perceive noise, I cited the works of philosophers Jean-Luc Nancy and Michel Serres. Their writing provides a way of conceptualising noise and my artistic responses to it, which could not be understood solely through my art historical readings. Nancy's text *Listening* analyses and elucidates the state of being immersed in not knowing whilst also remaining highly alert to perceptions of your environment. He questions what is at stake when one truly listens, 'that is, when one tries to capture or surprise the sonority rather than the message?' (2007, p. 5). In *Genesis*, Serres asserts that noise is the background to the universe: it is both outside and inside (part) of us. These two ideas interconnect and resonate when I consider my understanding of and responses to noise.

Throughout this thesis I used two terms – 'cognitively closed' and 'diagnostically irrelevant' – to understand, articulate and pinpoint the divergences between scientific and artistic responses to noise. They are perhaps strangely incongruous when used to describe art-making. However, I use these terms purposefully because they can be clearly understood in the context of medical visualisation practice, and to negotiate between scientific and artistic practices. They describe important conceptual approaches in artistic practice in response to noise. My aim is to bridge two separate and distinct disciplines, while, at the same time, allowing the differences between them to become apparent. My strategic use of these terms and recognition that noise could be a valuable source of new ideas evidences that artist residencies in scientific institutions are a viable methodological tool. Furthermore, the subject matter of noise creates a productive dynamic for art-science residencies, because it is unknown to both science and art and thereby, it diffuses the role of scientific expertise and technological knowledge.

My research demonstrates that a number of contemporary artists actively engage with noise characteristics and utilise its attributes as strategies in their practice. I cite examples of artists whose methods intentionally generate unexpected and unknown interactions in their materials and perceptions. Claude Heath instigates slippages between vision, touch and cognition to draw – a process that would be considered diagnostically irrelevant by scientists. Beatriz Olabarrieta allows unknown (and uncontrollable) physical interactions to interfere with her drawing process. Emma McNally engages with a continual 'feedback loop of exchanges and transmission' (2017) between artist and drawing as she looks and intuitively perceives. Artists often invite ambiguity, the unknown and consequently noise into their work rather than attempt to control it. This ambiguity can, in turn, be perceived by the viewer. Scientists also perceive ambiguity in their practice, but their disciplinary framework typically attempts to control and minimise it in the outcomes of their research. Public perceptions of scientific visualisations similarly do not recognise that ambiguity, the unknown and noise are an integral part of them, as many theorists have observed (Briedbach, 2011; Dijck, 1998, 2005; Galison, 2002; Rose, 2006). Artists place different (often higher) values upon the unknown and unexpected. Artist and academic Rebecca Fortnum observes: 'The search for the unknown outcome is not only welcome but actually provides the driving force within the creative process' (2014). Scientists, on the other hand, actively exclude or minimise noise in their practice, and furthermore, they may refuse to see it, as my thesis demonstrates (see Chapter 2 page 41). If artists do not evade noise (the unknown) but immerse themselves in it, they are in a position to better understand – through their experiences and perceptions – how noise functions and how to use it productively in their practice. This difference in approach to noise between artist and scientist is an important one. Serres contrasts the function of the scientist: 'to be right and rational' with that of the philosopher who: 'keeps watch over unforeseeable and fragile conditions' (1995, p. 23). The artist similarly functions to 'let the possibilities roam free' (ibid).

I observed during the residency (see Chapter 1) that signal is itself constructed from data that exhibits noise characteristics and that, in my view, 'signal/noise' more accurately describes its status. Through my practice-led investigations, I have learned that I do not seek to distinguish between noise and signal. The dichotomy is a false one in my artistic practice. Furthermore, when noise is my subject matter and impetus for making work, it leads me to become responsive to all kinds of information, known and unknown, conscious and intuitive, felt and seen. They co-exist as different ways of knowing and at different levels of ambiguity. For example, when I was drawing from my memory (see Figures 3.3 and 3.4), I moved between conscious memory images, which I could 'see' in my imagination, and intuitively felt imaginings, which were not consciously known or available to me. My propensity and ability to remain in-between knowing and not knowing – in the middle – is not unique among artists. McNally has stated that she tries to remain in the middle ground. However, the ability to remain between knowing and not knowing – or in scientific terms, between cognitively closed and cognitively open information – may be less familiar to scientists. Given the ambiguous nature of information and data, and the instability of the terms noise and signal as I point out in this thesis, it would be beneficial to scientists to develop their ability to remain in the 'middle ground' as tolerance of ambiguity studies demonstrate (see Chapter 4 page 107).
If noise is assumed to be open and not closed (as artists often perceive it to be), the 'possibility' contained within it – to use Serres' term – can become available. It is from this possibility that new knowledge (in art and science) can spring. Therefore noise is potentially more fertile ground for investigation than signal when the dichotomy between them is understood as unstable and in flux.

I was surprised at the interplay of a controlled planning of my drawing strategies and the unknown and unexpected outcomes they precipitated. The careful orchestration of drawing methods was designed to take me beyond thinking. Paradoxically, thinking through drawing was designed to take me to not thinking. Noise as subject matter triggered conceptual ways of working that were at the same time very embodied. The *Noise+Signal* work (see

Figures 3.15 and 3.16) is a good example. It entailed detailed and lengthy tests of base drawings, materials, scale of projections and code prior to events. My aim was to maximise unknown and unexpected outcomes during the drawing performances. Scale was an important consideration here. The drawings involved my whole body as it moved in response to projected signals that often registered on the edges of my visual field. This example is perhaps one of the more complex strategies I used in this study, but this holds for other much simpler approaches such as the pigment drawings (see Figure 4.2). Here the method was more direct, yet nevertheless, meticulous testing of different pigments and strengths of binders was undertaken to gauge the best combinations that would be most responsive to my breath as the pigment was blown across the paper.

Connected to this, I observed that when I made work in response to noise, where my subject matter was highly ambiguous, it generated ideas and methods that were unusual and new in my practice. An important outcome of this project was that I extended my use of drawing strategies. I explored the use of technologies such as bio-sensors, used new materials such as fat and clay, created a box construction for looking through, as well as working with animation and performance for the first time. This multiplicity of approaches in response to one subject matter over a long period of time is unusual in my practice. Noise as a starting point for making new work was surprisingly productive. It does not feel as if I have reached an end point towards the end of my thesis, rather that this process could continue indefinitely. For noise is more than a subject matter: it seems to have become embedded in my practice as a process that will continue to evolve.

The potential of noise to innovate and generate new meanings, as well as to function as a catalyst for change has been noted by many theorists in the humanities (Attali, 1985; Hainge, 2013; Hegarty, 2007). Noise triggers innovation in my (and other artists') practice by activating risk taking and experimentation. Its inherent lack of meaning frees my imagination and allows me to make new connections between things. Its function as a catalyst for change is connected to my thinking, my making and my

perceptions, for it changes my sense of what is possible. However, the potential of noise to do this is less readily recognised in scientific practice. If science did not perceive noise as cognitively closed – it could unlock its potential to become a catalyst for change. The possibility contained within noise is evident in the implicit understanding within medical imaging practice that reducing noise inevitably reduces information and meaning (see Chapter 1). The interplay of the unknown and the new knowledge it may potentially contain is central to the concept of noise in scientific practice. Nancy asks: 'What secret is at stake when one truly listens, that is, when one tries to capture or surprise the sonority rather than the message?' (2007, p. 5). He is suggesting that looking specifically for a 'message', which is what science does, cannot unlock the 'secret'. One needs to 'truly listen' and 'surprise' the secret.

Materials played a key role when I attempted to explore noise through not knowing. I intentionally chose difficult to control materials that displayed a kind of agency by moving or interacting with the drawing ground. Materials stood in for the body – they generated unknown movements much as the human body generates noise in medical visualisations. But more importantly, my own body interacted with materials, and it was this interaction that was most keenly felt as noise. The body knows noise in a way that the eyes alone cannot. Painting with fat was strangely unsettling and visceral. Its pungent smell evoked peculiar sensations and associations as I was drawing. When it interacted with the paper transforming it into a translucent material, it felt as if the drawing ground was changing into something more bodily. Similarly, the grittiness of clay was felt with each brush stroke, so that my body knew the drawing through the clay. Noise became a catalyst for me to work with non-usual materials that made drawings strange and unknown to me. This provoked a kind of noise in my own practice, enabling me to see with fresh eyes by activating an embodied and haptic style of vision. Elkins states: 'looking is something I do but also something that happens to me' (1996, p. 35).

Linked to this, and a central observation of this study was that when noise is my subject matter my sensory perceptions become very intensely felt. They change, and in the process so do I: 'When it comes to seeing, objects and observers alter one another, and meaning goes in both directions' (Elkins, 1996, p. 43). It becomes difficult to separate vision from touch, sound and smell; they become displaced through each other. During *Noise+Signal* performances, as I strained to catch each new signal and to move quickly, I experienced the act of looking as if it was located on the surface of my body and not solely in my eyes. At the time, I described this experience as *listening out for the scent of signals* (see Chapter 3 page 91) that I could not see. It was as if the other senses tried to compensate when sight was compromised. Interestingly, this text was written earlier in my study during the phase of activity (2013), prior to my contextualisation of my experiences through my readings of Serres and Nancy. It was an instinctive understanding that noise precipitated acute sensory responsiveness to my environment that seemed to be searching for other kinds of information. This demonstrates that practice-led research was leading this investigation, and that my experiences of drawing prior to my cognitive formulation of ideas were a driving force.

Nancy states that '[e]very sensory register thus bears with it both its simple nature and its tense, attentive, or anxious state' (2007, p. 5). Noise triggers the 'attentive and anxious state' my experience tells me. It is difficult to determine whether this is solely connected to unknown movements, or whether my focus on unknown interactions in my environment during this enquiry (both conscious and imagined) precipitates this. Nevertheless, a key observation during the phase of activity was that strategies of not knowing whilst drawing intensified the sensory perceptions of my environment. This experience – which is not always comfortable – is becoming something I increasingly recognise and value.

Being surprised by a drawing was another unexpected outcome of this enquiry. Looking at work anew is an important aspect of making, and artists often use strategies to look afresh at their work. In the past I have simply

covered up drawings and not looked at them for a while, or peered at them from different angles and positions. However, in this project the methods I used produced drawings that I could not anticipate, so the element of surprise was fundamentally connected to my process. The animation *Mind Wandering 3* (see Figures 3.11a and 3.11b) was a peculiarly embodied drawing that resembled living tissues or cultures growing and multiplying. I am reminded of Mitchell's observations about 'the peculiar tendency of images to absorb and be absorbed by human subjects in processes that look suspiciously like those of living things' (2005, p. 2). The strangeness of the drawing, its unknown quality precipitates a dynamic way of looking that gives it a kind of agency. As I was drawing on tissue paper with a brush and dry carbon powder, I made a decision not to fix or bind the medium, thereby allowing it to move freely. Consequently it was very difficult to control and whilst I was immersed in the drawings I could not perceive what the outcome would be. I was looking through a camera as I was drawing, with the paper just a few centimetres from the macro lens. This created a strong sense of dislocation in my perception of space for although the paper was quite small, it was perceived as very large. Slight movements were magnified, and my hand did not know where it was in space. Each mark I made seemed somehow disconnected from my body. Perceptual slippages such as these activated ways of drawing and with it imagery that was surprising to me. It is important to point out that this can be linked to quite small and subtle changes in my practice, such as the drawings discussed in Chapter 1 (see Figures 1.4 and 1.5) where I was simply turning my head to look at images behind me.

There are wider, philosophical reasons why artists should research noise. Scientific theory and practice cannot account for how noise – in the form of unknown movements and interactions – changes my perceptions as I draw. This is not surprising given that it does not recognise multi-sensory responses to visualisations. Furthermore, scientific discourse about noise is limited to discussions about data, algorithms, interference in signals and highly technical information. To resolve the on-going nature of my negotiation of the scientific concept of noise through artistic practice, I look to

philosophical texts. Nancy describes a process of perceiving which sidesteps cognition and does not generate knowledge as ‘an intensification and a concern, a curiosity or an anxiety’ (2007, p.5). This eloquently describes what perceiving unknown stimuli (noise) feels like when I respond as an artist. The ‘intensification’ that Nancy refers to is what I experience as the senses finding other ways of knowing and perceiving the unknown. This experience is my way of being in the world that Serres calls – a world full of noise. Both texts foreground the sense of hearing: sound, sonority and resonance are key concepts for Nancy. Sound is a very different metaphor for perceiving the environment compared to light and vision. It resounds without and within the body, suggesting other ways of knowing. The heightened sense of perception that is activated by noise is, I would like to assert, experienced as all the senses resounding together. This changes my vision so that it becomes enmeshed in the haptic and sonic. Consequently, the distancing and objectification that ocular-centric approaches have been associated with dissolve: 'Perceptions bursts, inner and outer, how can they be told apart' (Serres, 1995, p. 6).

My study determines that the concept of noise can function as a catalyst for developing new methods and strategies in arts and science collaborative projects. It deepens understanding of how the particularity of noise can be applicable to art and science research. More importantly, noise allows me to understand and negotiate the differences between scientists and artists through the ways in which they respond to ambiguity, the unpredictable and the unknown. This is elaborated through my practice-led investigations, which navigated noise by immersing myself in it. My immersion into noise (and into not-knowing) reflects my understanding that noise is part of signal (see Chapter 1) and that in Serres’ statement, noise: ‘moves through the means and the tools of observation, whether material or logical, hardware or software’ (1995, p. 13).

Furthermore, my project contributes to an under-represented area of research: the relationship between noise and analogue arts practice. Noise has been the subject of much investigation in new media and music theory.

New-media art is perhaps understandably interested in the scientific concept of noise because of its on-going experiments with glitch methods and processes. Similarly, noise music is an established genre in music theory and practice. Both new media and music engage with noise largely (although not solely) through digital interfaces of electronic music, electronic devices and code. Further research could be done into perceptions of noise in analogue art practices that involve a bodily engagement with materials. Noise has been theorised as having a profound effect on the body (Serres, 1995; Hainge 2013; Hegarty, 2004), therefore analogue practices could offer different insights into its workings. Bruno Latour discusses the relationship between embodied knowledge and scientific notions of objectivity. He uses the example of the hand-made image (as opposed to computer generated) to question: 'But what if hands were actually indispensable to reaching truth, to producing objectivity, to fabricating divinities? What would happen if, when saying that some image is human-made, you were *increasing* instead of decreasing its claim to truth?' (2002, p. 16, italics in original). The 'human-made' may also be the best way to understand noise, for it cannot be scientifically measured but can be known through the senses.

This enquiry draws attention to what appears to be two distinct ways of perceiving noise in medical visualisations: scientific and artistic. They are built around different attitudes to the cognitive element of perception. Noise is perceived by scientists as cognitively closed and meaningless; artists on the other hand can perceive noise as a stimulus for new ideas. The consequence of this investigation is that it extends the scope that scientists and artists have to perceive and understand their distinct visual practices through bodily and environmental experiences. Medical education recognises that artistic practice can have a positive impact upon scientists' tolerance of ambiguity. This is evidenced by recent scientific studies and the inclusion of arts workshops in medical curricula (see Chapter 4). Medical students' interactions with artworks involve multi-sensory perceptions and multiple ways of thinking, feeling and responding to unknown stimuli. What if tolerance of ambiguity studies focused on experimental art making where highly interactive processes and difficult to control materials were given a key

role instead of the more commonly used approach of discussions about narrative-based paintings? Moreover, what would be the impact of an artist researcher – instead of a scientist – leading a tolerance of ambiguity study with medical students? There is potential to explore this further.

In conclusion, this thesis and the body of practical work that accompanies it demonstrate that the concept of noise has the potential to profoundly transform practices in art. Although the accounts in Chapter 4 are of final drawing experiments, I am conscious that they do not represent a conclusive method for this enquiry. They are part of multiple experiments that are interconnected and explore different aspects of noise. There is a sense that I could continue to generate new methods and strategies in response to noise, for once a method becomes familiar and known to me, it cannot retain an element of surprise (the unexpected or unknown) in the same way. Noise as subject matter demands innovation and invention. Its resistance to knowledge calls for new ways of working. 'To be listening is to be *at the same time* outside and inside, to be open *from* without and *from* within, hence from one to the other and from one in the other' (Nancy, 2007, p. 14, italics in original). The fluidity of this process resists fixed knowledge.

This thesis demonstrates that noise functions as a catalyst for change in artistic thinking, making and perception. The foundation of this potency is the instability and ambiguity of noise as a concept (which is made evident in this enquiry) and the possibility contained within it to become signal. This possibility becomes a source of new ideas in artistic practice. Serres states: 'The most common forgetting is that of the possible. It is so much forgotten that it is not visible' (1995, p. 24).

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