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Image and Evidence: The Study of Attention through the Combined Lenses of Neuroscience and Art

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Image and Evidence:
The Study of Attention through the Combined Lenses of Neuroscience and Art

by

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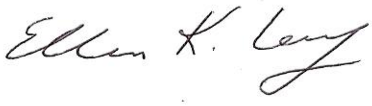

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ABSTRACT

Image and Evidence:
The Study of Attention through the Combined Lenses of Neuroscience and Art
Ellen K. Levy

This study proposed that new insights about *attention*[i], including its phenomenon and pathology, would be provided by combining perspectives of the neurobiological discourse about *attention* with analyses of artworks that exploit the constraints of the *attentional* system. To advance the central argument that art offers a training ground for the *attentional* system, a wide range of contemporary art was analysed in light of specific tasks invoked. The kinds of cognitive tasks these works initiate with respect to the *attentional* system have been particularly critical to this research. The implicit tasks of artworks and explicit tasks used by neuroscience to assess and train *attentional* performance activate the neural circuits used in alerting, orientation, and executive control function. As a result, the kinds of informal learning that take place during engagement with art can provide training for real-world tasks (e.g., categorisation, conflict-resolution).

Attention was explored within the context of transdisciplinary art practices, varied circumstances of viewing, new neuroscientific findings, and new approaches towards learning. Research for this dissertation required practical investigations in a gallery setting, and this original work was contextualised and correlated with pertinent neuroscientific approaches. It was also concluded that art can enhance public awareness of *attention* disorders and assist the public in discriminating between medical and social factors through questioning how norms of behaviour are defined and measured. This territory was examined through the comparative analysis of several diagnostic tests for attention deficit hyperactivity disorder (ADHD), through the adaptation of a methodology from economics involving patent citation in order to show market incentives, and through examples of data visualisation. The construction of an installation and collaborative animation allowed participants to experience first-hand the constraints on the *attentional* system, provoking awareness of our own "normal" physiological limitations. The embodied knowledge of images, emotion, and social context that are deeply embedded in art practices appeared to be capable of supplementing neuroscience's understanding of *attention* and its disorders.

Keywords: *attentional* system, constraints, taxonomy, *attention* training, norms

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i The word "attention" is generally italicized in this thesis to designate its scientific meaning

EXECUTIVE SUMMARY

This thesis proposes that art offers a training ground for the *attentional* system and can stimulate public and scientific debate about *attentional* disorders. The dissertation analyses a wide range of contemporary artworks in light of specific tasks they may invoke. My impetus to undertake research into the neurobiology of *attention* was fostered by the realisation that some of the expertise acquired in art can be transferred to the study of *attention* as understood by neuroscientists. -- --------------- ------------------- ----------- ------------------------ ------------------------------------.---

I propose that a taxonomy of these correlations might be of value to those conducting *attention* research. It may broaden the resources of art historians by categorising selected artists according to the tasks of *attention* elicited by their art (e.g., tasks resolving conflict and categorisation) rather than restricting the classification to traditional art historical categories alone; it provides artists with examples of how their art may relate to neurological tests of *attention*; it provides medical health professionals with examples of alternative approaches to testing, some of potential therapeutic value; and it offers neuropsychologists a broader range of images and experimental staging than generally used in their tests. This information may be useful to those involved in the growing field of neuroaesthetics who are themselves contributing to these correlations. As a whole, there are potential benefits of a taxonomy for neuroscientists wishing to expand their visual approaches in their research and publications.

The context for my research is a long history of both practical and theoretical interests, including a zoology major at Mount Holyoke College and drawing from a cadaver while taking a course in anatomy and gross dissection at Columbia University College of Physicians and Surgeons (1964). My interests in neuroscience were initially sparked by a job in the pharmacology department of Harvard Medical School where I worked as a laboratory assistant and illustrator during and following my art studies at the Museum School of Fine Arts in Boston in the late 1960s. The laboratory was adjacent to the neurophysiology department, in which David Hubel and Torsten Wiesel (1968) had together determined the pathways of the primary visual cortex. I was fortunate to have had the opportunity on occasion to engage Hubel and other scientists in casual conversations about neuroscience, perception, and visual art. These discussions reinforced my own developing interests in their interrelationships.

This dissertation is informed by four years of research, past laboratory work in pharmacology and microbiology departments of major hospitals, past work in art therapy and illustration, work as an educator, exposure to a large range of art, art historical, and educational practices as past president of the College Art Association, and lifelong work as an artist. Since beginning this PhD research (2007), I have reflected upon the many years of my own practice and context within the discourse of art and neuroscience. This has resulted in a deep analysis of my own illustrational history (resulting recently in cover designs for articles in *Nature*

Neuroscience and *Neuron*)[i]. I also reflected upon an earlier article for the *Journal of the History of Neuroscience* (2004) co-authored with neurologist David E. Levy and neurophysiologist Michael E. Goldberg on the work of Roger Shepard[ii] dealing with mental rotation and the parallel investigations of art and science during the 1960s. This focus is included in my dissertation.

This thesis explores how art fosters informal *attentional* learning. I analyse the kinds of *attentional* learning that can take place during the creation of art and while attending art exhibitions. The training that artists have undergone offers insights about *attention* that can be valuable to others, and exhibitions offer opportunities to be exposed to these benefits. Technology has extended the parameters of *attentional* testing and opened up new possibilities for learning. To demonstrate these opportunities I gathered examples of artistic explorations of the body that utilise techniques of biofeedback, augmented reality, virtual reality, and eye-tracking. Increasing numbers of artists now share experimental processes with scientists, enabling comparisons with respect to the testing and training of *attention*. My analysis discriminates among resources and processes shared by artists and neuroscientists (e.g., databases and imaging technology) and their different aims.

I propose that fostering visual literacy can help the public distinguish real *attentional* pathology from that which is socially-constructed. Much controversy has been generated because of various putative causes of *attentional* disorders and by the social and economic motivations involved in categorisations of disease, particularly ADHD. The interpretation of drawn images and medical imaging constitute part of its diagnostics. Genetic and neurochemical factors play a large role in ADHD. However, the greatly increased number of diagnoses in the US in the absence of no single clear diagnostic determinant also raises the question of contributing social and environmental factors and may point to a dilemma in the balance of categorical versus dimensional factors in medical classification.

A related issue is how a culture decides what is normal and how it tolerates deviant behaviour. Images can question society's values, goals, methods, and public policies. These issues frame the context in which medical discoveries are made and commercialised. Excessive diagnoses also raise issues of drug overuse and unintended use, exacerbated by aggressive advertising that often includes promotional images. Artists who are trained to understand and delineate the complexity of images and who can portray the relevant cultural contexts can be instrumental in communicating the various factors that play a role in adjudicating wellness or pathology with respect to *attention*.

The fact that art and cognitive neuroscience encompass an expanding range of intellectual and technical concerns necessitates looking at and integrating information from several fields. A need for research follows from the reasons stated above; no single field provides the answers. My research draws on approaches

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i Cover for *Nat Neurosci* in conjunction with Wang et al. 2007, *Nat Neurosci*, vol. 10, no. 5, pp. 640-6; cover for *Neuron* in conjunction with Belova et al. 2007, 'Expectation modulates neural responses to pleasant and aversive stimuli in primate amygdala', *Neuron*, vol. 55, no. 6, pp. 970-84 (see supplemental CD).

ii Levy, EK, Levy, DE & Goldberg, ME 2004, 'Art and the Human Brain: The Importance of Art on Roger Shepard's Studies of Mental Rotation', *J Hist Neurosci*, vol.13, 79-90.

from art history and visual studies, but is also transdisciplinary as it involves neuroscience and cognitive psychology. It includes some social analysis of educational systems, economic analysis of market incentives affecting the production of medications that treat ADHD, extensive analysis of institutions that determine *attentional* pathology, and observations based on original artwork.

My methods included interviews, observations, and comparative analysis. More specifically, they included a comparative literature review, data visualisation, comparative analysis of diagnostic drawings, an examination and comparison of *attention* tasks initiated by artworks versus those of neuropsychological testing, an analysis of neuroimaging, and examination of the behavioural and social bases on which categorical judgments are made. In addition, I adapted a methodology from the field of economics involving patent citations to shed light on the relationships between medical technological innovations (e.g., isomeric separation) and the marketing of medicine (e.g., methylphenidate as treatment for ADHD). The use of citations requires access to database records of pertinent medical innovation generally unavailable and unmanageable as large datasets until advances in computer technology eliminated difficulties during the late 1980s and enabled this kind of approach. I gathered data from the US Patent and Trademark Office (USPTO) and used it to visualise the economic indicators of methylphenidate production along with more common epidemiological factors.

As a result, the methods used enabled me

- to explore how variable objectivity and interpretations related to images and imaging technologies may have created unsupported perceptions of what constitutes the norms of behaviour in children and adults;
- to show how a methodology from economics could be adapted to artistic visualisation of some of the financial motivations surrounding ADHD; and
- to determine that images and artists can promote reflection on the neurobiology of *attention* and its consequences by encouraging considerations of social context and habit in the determination of disease.

In recent years considerable literature has been published on *attention* by art historians and historians of science. In addition to Jonathan Crary (1999) who extensively explored developments in philosophy, science, and art and art history pertinent to the study of *attention* from the 1870s to the 1910s, Michael Fried, David Freedberg, Barbara Stafford, Michael Baxandall, and Michael Hagner have made important contributions that specifically highlight *attention*, and their insights along with many others have informed mine. Work as an artist and researcher has allowed me to make new connections and add them to this detailed historical research.

The new view developed in my thesis that art, when engaged, serves as an *attentional* training ground emerges from the analysis of the often complementary achievements of neuroscience and some pertinent contemporary art. I claim that this broader perspective is actually essential to practitioners in either field since the phenomenon and pathology of *attention* can be more fully rendered through uniting insights from multiple disciplines.

I also conclude that the holistic approach offered by art expands the resources available for diagnostics and treatments. If we better understand the components that surround adjudication of illness and normality, we can approach treatments with more confidence. The results indicate a great need for continued monitoring of the facts surrounding *attention* disorders. As new economic and legal ramifications stemming from the overuse of stimulants unfold and as demand increases for new clinics and treatments of ADHD, art may increasingly assume the position of interlocutor between science and public.

I claim that the general public will gain a deeper insight into the subject of *attention* by being better informed about image modalities and the extent to which imaging offers evidence and objectivity. I conclude that since these influence the determination of medical classifications, deeper knowledge will help the public discriminate between medical and social factors. This thesis thus becomes a model of art/science interaction in which the art frames some of the diagnostic practices of science in order to pose questions of context and evidence.

By the end the thesis, groundwork will have been laid for considering the contribution of art to understanding the cognitive and behavioural manifestations of our *attentional* system and for attempting to make the fields of art and neuroscience more mutually intelligible. Although the examples of art selected for the thesis differ from more common notions of activism, they may succeed in challenging the status quo in essential ways – through provoking consideration of the limitations of the categories we too automatically consign and knowledge of how our *attentional* systems might underlie the operations of categorisation and awareness, itself.

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INTRODUCTION

1 Premise

The overall premise of my thesis is that new insights about attention, including its phenomenon and pathology, can be provided by combining perspectives of the neurobiological discourse about attention with analyses of artworks that exploit the constraints of the *attentional* system. Specifically, I suggest that some art offers a training ground for the attentional system. "Attention" is a word used both in everyday life and in scientific usage; its scientific use in this research is generally assumed or signified by the term, "attentional system" or, henceforth in this thesis, *attention* placed in italics. The fact that art, itself, is constitutive of *attentional* phenomena suggests why it should hold special interest for neuroscientific research on *attention*. Furthermore, although most art manipulates the viewers' *attention*, a subset of contemporary art has taken *attention*, including its phenomena and/or pathology as a main subject of inquiry. The kinds of cognitive tasks these works initiate with respect to the *attentional* system have been particularly critical to my research. ------- -- -- Some art may call *attention* (1) to "habits of mind"; (2) to the boundaries that separate interior and exterior perceptions; (3) to the task of parsing categories from each other; or (4) to the act of processing conflicting information. A climate of developing interest in these areas reinforces my belief that the communities studying perceptual and cognitive issues may benefit from the analyses provided in the body of this dissertation and its associated taxonomy. Some artists discussed in the body of the thesis are hyperlinked to the taxonomy, which is placed in the supplement at the end of the dissertation. The taxonomy is comprised of artworks with which I have greatest familiarity that activate a range of *attentional* responses. --- -- -- It is my hope that neuropsychologists might find it useful to adapt aspects of those artworks (e.g., the images and their staging) to their own experimental designs. I also suggest that the specifics of context that are imparted by the artwork may hold import for scientific studies and the construction of future experiments.

This thesis examines the evidence as to whether the kinds of learning that take place in public settings can provide training for real-world tasks of discrimination. It explores *attention* within the context of transdisciplinary art practices, varied circumstances of viewing, and new neuroscientific findings. My premise is that the artworks analysed can help viewers consciously acknowledge routine issues of viewing and can thereby establish a framework for learning. *Attention* training programs today are comprised of a variety of methods, including biofeedback, virtual reality, and augmented reality, and these have their counterparts in many of the artworks I have examined.

In addition, visualisations of the boundary between health and illness are examined in several ways in this thesis through the creation and analysis of original art. I suggest that the public "airing" of *attentional* issues such as attention deficit and hyperactivity disorder (ADHD) through critical analysis of its associated images and imaging technologies can help illustrate the value of visual literacy and raise awareness of some of the bases of categorical judgments, themselves. My redirecting a focus to the issues just mentioned through data, documentation, and historical and visual analysis will lay the groundwork necessary for my demonstrating that art can complement scientific studies about the neurobiology of *attention* and stimulate public debate about its disorders.

2 Aims

One of my goals was to help provide a framework for understanding the *attentional* system that encompassed artistic and neuroscientific research. To accomplish this aim, I attempted to supplement art historical categories (e.g., modern, post-modern) by categorising selected artworks -- and by providing examples of neuroscientific experiments to which they may relate. My intention was to reconceive our view of certain artworks in light of this knowledge, thereby attempting to create a bridge between the disciplines of art and neuroscience. A related goal was to resolve how and under what circumstances art might help test and train the *attentional* system. It was also hoped that this thesis might help to clarify what has been largely unnoticed, namely the role of images and medical imaging in determining the norms of the *attentional* system.

The impetus to explore images in relation to the pathology of *attention* was spurred in part by models of activism, which intimated the power of images to question society's values, goals, methods, and public policies. Past examples of such activism include the "demedicalisation" of homosexuality (1973) in the American Psychiatric Association's Diagnostic and Statistical Manual (DSM). Another example is the impact of art activism on the perception of AIDS during the 1980s, when the activist group Act-Up applied scientific knowledge to pre-empt negative images of targeted groups (Gilman, 1989; Goldstein, 1990). These activities support my premise that art and images can help foster social change.

A related challenge was to analyse artworks that allow us to experience first-hand the constraints on the *attentional* system, provoking awareness of our own "normal" physiological limitations. These constraints involve more than physiology; some involve habits of mind. A pertinent example is the unquestioning acceptance of diagnoses in the US of attention deficit and hyperactivity disorder (ADHD) as reflecting its actual prevalence. It is likely that ADHD involves the cumulative effects of several genes alongside interaction with the environment. The absence of a clear path to diagnosis raises the question of contributing social and economic factors. In addition, medical classification has fluctuated, reflecting diagnostic uncertainty, and may point to a dilemma in medical classification regarding the norms of behaviour. If genetics is accepted as the underlying cause of ADHD, it becomes more likely that ADHD will be viewed as a disorder that is manifested as adult ADHD, requiring life-long medication (Conrad & Potter, 2000: 572). In fact this process is well underway. How, then, can a mind-set be changed to consider factors not readily perceived? I raise this question in this dissertation with the aim of showing how artworks in a range of media and genre can encourage considerations of social context and habit in the adjudication of "norms of behaviour".

My research is positioned to show great changes in the conceptualisation of *attention* from the following transdisciplinary analysis: psychology, neuroscience, social and cognitive science, and art.

3 Basic concepts of "attention"

Attaining a conceptual understanding about *attention* was necessary to pursue my research. The *attentional* system comprises mechanisms that are used by the brain to select and modulate relevant information for further processing (Chun and Wolfe, 2001). Figure 1 shows a simplified diagram of the projections from the retina to the visual areas of the thalamus (lateral geniculate nucleus) and midbrain (pretectum and superior colliculus).

Figure 1: Visual pathways (Wurtz & Kandel, 2000) has been removed due to Copyright restrictions.

In the visual system, input is needed from *attention* and memory to perceive and guide eye movements. The flow of visual information is initially from the retina to the midbrain and thalamus, then from the thalamus to the primary visual cortex. In addition to the afferent pathways (incoming visual information), there are multiple efferent pathways (the outflow of information to the visual organs). Information flows systematically from one cortical layer to another once afferents from the lateral geniculate nucleus enter the primary visual cortex. The retinal projection to the pretectal area is important for pupillary reflexes, and the projection to the superior colliculus contributes to visually guided eye movements. The projection to the lateral geniculate nucleus and from there to the visual cortex processes the visual information needed for perception.

The psychologist and philosopher William James (1890) anticipated many current theories of *attention* and remains a basic source of important information. The late nineteenth century approaches of physiologist Wilhelm Wundt and his student Edward Bradford Titchener were based on a subjective, introspectionist methodology that lasted into the first part of the twentieth century. In the mid twentieth century a protest movement developed called behaviourism which is generally identified with B. F. Skinner (1953). Behaviourists largely avoided consideration of affective responses, metacognition (thinking about thinking), and cultural influences (Gardner, 1985). By the 1970s, considerations about mental phenomena that behaviourism had minimised became opened to scientific scrutiny (Baron-Cohen, 1991). The re-establishment of interest in *attention*, memory, images, language processing, thinking and consciousness became known as the Cognitive Revolution. Howard Gardner pointed out (1995) that cognitivism still lacks a cultural interpretation of the mind despite efforts by Jerome Bruner to develop a cultural psychology.

Structuralists posited the existence of innate structures to explain cognitive development (Piaget, 1971), language (Noam Chomsky, 1968; Claude Lévi-Strauss, 1958), and levels of consciousness (Jacques Marie Émile Lacan, 1949). Nativism (the belief in innate encoding) took place in neuroscience as findings demonstrated a high level of cognitive sophistication in young infants (Mehler & Dupoux, 1994). Jerry Fodor (1983) and Steven Pinker (1997) are associated with nativism, proposing the existence of cognitive modules within the developing brain that processed stimuli. According to Fodor (1983), high level visual systems could not affect lower level modular units. He pointed to persistence of the Müller-Lyer illusion despite understanding its cause as evidence of the impenetrability of modules (McCauley & Henrich, 2006). Initial ideas of modularity have been questioned (Solso, 1994; McMahon, 2003), and some have tried to qualify these claims (Karmiloff -Smith, 1992). The argument relies on the likelihood of communication paths that are reciprocal in the brain by which early vision might be affected by higher order cognition. Cognitive neuroscience stresses the importance of constraints and timing in brain development and a developmental perspective has led to the consideration of approaches beyond modularity (Karmiloff-Smith, 1992). According to “neural constructivism”, a dynamic interaction takes place between neural growth mechanisms and environmentally derived neural activity that impacts the cortex. Jean-Pierre Changeux (1973) and Gerald Edelman (1987, 1993) have updated these models through ideas respectively of synaptic reinforcement and "neural Darwinism". Such ideas including neural plasticity are central to my thesis because they suggest how learning takes place and how it might be informally enhanced by art.

This dissertation will show that some artists have generated new findings about *attention* and continue to do so, some building on recent neuroscientific knowledge. Concepts in at least three areas of cognitive neuroscience matured during the latter part of the twentieth century, including social, cognitive, and affective discoveries that impact *attentional* studies. Some artists and art historians have examined *attention*'s links with emotion and memory from a humanist standpoint. Doing so has helped to highlight the nature of the creative process.

3.1 Recent social concepts

Examples of social interaction suggest that culture should be viewed as more than a by-product of brain evolution. Attracting *attention* from others is often concomitant with creative activity (Dutton, 2009) and can be linked to both reproductive success and survival (New et al., 2007). Cognitive psychologist Merlin Donald stated (2006) that, as the prefrontal and parts of premotor cortex expanded, increased motor control created metacognition or the ability to self-reflect on one's own cognitive processes. Archaeologist Lambros Malafouris posited that the artistic use of occluding contours and canonical perspectives in cave paintings enabled human perception to attend not only to what was depicted but to the mechanisms that produced it (Malafouris, 2007). Philosopher Dennis Dutton (2009) conceptualised art as a surrogate life action without the costs and risks of real-world activity. He proposed that the executive function of the *attentional* system can evaluate imagined situations while using the same neural circuits that evaluate reality, itself. Terrence Deacon explored (2006) how art offers a transfigured experience by implementing new forms into relationship with each other that had not been present in the component elements alone. In agreement with these ideas, evolutionary scholar Francis Steen has viewed artistic representations as optimising conditions of self-realisation (Steen, 2006). Many of the artworks considered in this dissertation fit this description, and the way the artists utilise emotion, context, and memory may hold particular import for scientific *attentional* studies.

3.2 Recent cognitive concepts

Concepts of shared *attention* are basic to intuiting the mental states of others. The cognitive basis for such understanding is known as a "theory of mind" and figures prominently into discussions of *attentional* processes. Michael Tomasello (2005; 2007), a comparative psychologist, claimed that it was the use of eye gaze and visual gestures that enabled humans to coordinate their activities. The work of Colwyn Trevarthen (1977; 1978) has similarly demonstrated how "primary intersubjectivity" is achieved between caretakers and infants through mechanisms promoting joint *attention*. The reason this is significant is that the inherent ability to understand other people's minds underlies concepts of empathy in both developmental psychology and cognitive neuroscience (Carruthers & Smith, 1996). It also suggests why a lack of intersubjectivity might be manifested in either autism or an *attention* disorder.

J.J. Gibson (1979) viewed the organism and environment as dynamically reciprocal in order to eliminate dualities. Behavior became considered to emerge from interaction of mind, brain, body, information, and environment. In recent years, cognitive science has developed new views of perception and action that have modified theories of "conventionalism" by Nelson Goodman (1968) and Roland Barthes (1977) (Bal & Bryson, 1991). Theories such as Wollheim's ideas of pictorial representation (2001) have also benefited by input from cognitive science. Just as cognition is considered to be central to understanding perception, it is important to reflect upon philosopher Marx Wartofsky's inverse assumption (1984) that our modes of pictorial representation impact our modes of theorizing visual cognition. Mark Rollins (1994a, b) has described and critiqued varied accounts of vision and representation. Analyses of pictorial representation are informed today by connectionist models and mental imagery, and new theories of perception have found ways to unite elements of "representationalism" with an emphasis on *attention*. Some of these theories offer support for how one might transfer *attentional* skills to new domains, which I maintain is a training that art can informally provide.

The idea of "enactive signification" derives from cognitive scientists Gilles Fauconnier and Mark Turner (2002), who referred to a notion of "embodied conceptual integration" that results from active engagement with the world (i.e., when manipulating an object). O'Regan et al. (2005) proposed that the way in which we engage with objects gives us access to bodily experience through vision. Sensorimotor experience has also been theorised as a dominant consideration in making and experiencing art and is discussed in the thesis (O'Regan & Noë, 2001a, 2001b).

3.3 Recent concepts of emotion and memory

Recent understandings of the *attentional* system involve how neuronal pathways have been linked to systems of emotion and memory. For example, it is now generally accepted that the brain regulates its allocation of *attention* in accordance with the emotional significance of sensory stimuli. Art historian David Freedberg and neuroscientist Vittorio Gallese investigated the role of sensorimotor activity in empathy and emotion, arguing that it has been overlooked in current writing about art and its history (Freedberg & Gallese, 2007, p. 199). The most current manifestation of this theory is mirror neurons (Gallese et al., 1996).

3.4 Art historical concepts

In 1990 and 1999, art historian Jonathan Crary examined perception and how the understanding of *attention* changed as the environment became filled with apparatuses and spectacles. Like historian of science Michael Hagner (2003), Crary showed that, by 1900, *attention* was re-conceived as being susceptible to manipulation. Crary contextualised several nineteenth century works within modernity, within the scientific and philosophic studies of the time, and within the effects of new technologies that permitted testing of the *attentional* system or provided new distracting entertainments. Although, like Crary, my study involves *attention* within the context of new technologies and art forms, it not only applies to a very different time period, but it includes the very different vantage points of practicing artists involved with neurobiology.

Art historians Michael Baxandall (1995), David Freedberg (1989, 2006), Stafford (2007), and John Onians (2008) have delineated how art can perform cognitive work. There is by now a growing literature dealing with “the cognitive work of images”. Individuals involved in areas of *attention* research (e.g., neurologist Richard Restack, Stafford) have pointed out that much work of the brain involves automatic processes and that selective *attention* is but a small percent of our vision. I agree with recent scholarship in this area but my emphasis is different and concerns the possibilities for the arts to direct viewers outward.

4 Attention and learning

Many theories regarding the functioning of higher attributes like *attention* have emphasised the frontal cortex, which is considered highly related to concepts of creativity (Crick & Koch, 1998; Dehaene & Naccache, 2001; Dietrich, 2004). In general this thesis explores the value of embodied artistic approaches to the study of perception. In its early theorisations, biologists Humberto Maturana and Francisco Varela (1980) proposed that knowledge (learning) results from interactive engagement and motor skills, stressing the self-referential, living (autopoietic) nature of these processes. Artificial intelligence research and human computer interaction (HCI) now carry this research in new directions, and many artists are contributing to it.

By the 1970s a change of attitude took place among educational psychologists that paralleled those taking place in cognitive science (Jones, 1991). Those in education reconsidered the value of self-reflective questioning, metacognition, aesthetics, and context. Finke, Ward, and Smith (1992) explored the cognitive forces underlying creativity and its roots in “associationism”, while Root-Bernstein (1989) explored how creativity might be fostered. Gardner (1985, 1995) and Ellen Winner (2006) addressed some of the concerns of this dissertation with regard to the arts and learning.

5 Methods and methodologies

My methods and methodologies were informed by a consideration of art historical and new transdisciplinary approaches as explored in the following sections.

5.1 Art historical approaches

Art historical approaches throughout the thesis included analyses stemming from semiotics, visual culture, and critical theory along with consideration of the ideological constructs embedded in each methodology. The images analysed included those from artworks, diagnostic tests, and from medical imaging. I examined the interpretations embedded in adjudicating health or illness by conducting an analysis of varied medical techniques and through interviews. Categorical judgments were examined to explore how images might influence certain judgments by study of the cognitive processes involved in decision-making. Augmented reality (AR), virtual reality (VR), human computer interaction (HCI), gaze, biofeedback, and robotic interactions were examined. Artists’ reactions were contrasted with those of scientists with respect to these technologies and by gathering data from each group through published experiments, interviews, and literature. A large number of artworks were examined through catalogue essays, documentation, and direct communication with some of the viewers and artists through interviews.

5.2 New methodologies

My own artwork in chapter two was used as a case study to generate new data and to try to determine whether experiential knowledge can shift perceptual patterns. The results were assessed through interviews with viewers. My animation presented viewers with the phenomenon of “inattention blindness” (the inability to see something directly in the line of vision). My experiment was to determine whether the “mindset” of viewers could be “re-set” by the contextualisation of images. To determine this, I conducted interviews and then discussed and disseminated information about my findings.

Another experimental method described in chapter five involved adapting a patent citation method used in economics to art. I created a data visualisation about ADHD and a conceptual, annotated chart. To do so, I tracked and correlated the pace of pertinent technological development data with the increase of diagnosed ADHD cases and sociological trends by comparing the criticisms, shortcomings, and revelations of the United States Patent and Trademark Office (USPTO) data visualisation from roughly 1960 to 2010.

Comparative methods involved the correlation of specific contemporary artworks -------------------------------- with neuroscientific tests of *attentional* functioning that assign explicit *attention* tasks. This involved analysis, theoretical assumptions, conducting interviews, and a taxonomy to render the information in an accessible form. The correlations are discussed throughout the thesis and in a taxonomy placed after the body of the dissertation. --

I critiqued the standard way of adjudicating norms of *attentional* health in chapters four and five. To do so I analysed the Diagnostic and Statistical Manual of Mental Disorders (DSM) to investigate if categorical versus dimensional measures can better determine the diagnosis. Case studies involving the diagnosis of ADHD were compared to critically assess the basis of such judgments.

5.3 Transdisciplinary approaches

My topic is a transdisciplinary undertaking, spanning neuroscience, scientific medical imaging, artistic rendering, art history, and data visualisation. I analysed concepts of evidence and their change over time in these fields. This analysis suggested the impact of social trends by comparing what constituted “hard facts” over different historical time spans. I analysed some of the theoretical assumptions of each discipline regarding images to determine if the visualisation of data as generated by artists revealed cultural trends as opposed to biological patterns by contrasting how artists and neuroscientists viewed their results.

The interviews tended to run between 20 minutes and one hour, recorded on either a tape recorder or in writing. In asking scientists and artists about their relevant work, the goal was generally to learn about important aspects of the research and/or learn about the perspective each individual holds. My research included methods of practice-based research, as detailed by the founder of the Planetary Collegium Roy Ascott and Z-Node Director and media artist Jill Scott in which artworks can serve as case studies because they are subject to critical analysis. My art projects (practice-based) and those of other artists served as case studies exploring how art can complement the scientific research of *attention*.

6 Chapter content

In chapter one, “Towards a Taxonomy of Art and Attention”, through classifying the effects of artworks on the basis of their influence on the three major *attentional* networks and the tasks they share with neuroscientific research, I set the framework for relating particular artworks to neuroscientific studies. In chapter one I provided examples of artworks that may promote training in classification. In addition, I analysed how some art links *attention*, memory, and emotion.

In the second chapter, “An Artistic Exploration of Inattention Blindness”, I explored how an animation caused viewers to directly experience the phenomenon of inattention blindness. Then, through re-contextualising the viewing experience, I drew conclusions about the potential of art to train the *attentional* system. My art project allowed me to find my point of entry into the subject, enabling me to contribute my own artistic expertise to the neuroscience of *attention*. Chapter two confirmed that the kind of training that artists undergo is highly pertinent to *attention* training.

Chapter three, “Embodied Art and Perceptual Recalibration”, advanced the argument that art in conjunction with neuroscience is leading to new approaches in *attention* training. The chapter’s main goals were to see how art experiments focused on the body can help train *attention*, how technology can extend the parameters of such testing, and how designers can build new interfaces responsive to the therapeutic needs of users. I examined artistic explorations of the body’s boundaries, thresholds, and spatial orientation and analysed how the design of new interfaces has expanded the quality of life for the disabled. Up until this point, most of the thesis dealt with the phenomenon of *attention*. The next two chapters addressed issues of *attentional* pathology.

In chapter four, “Imaging the Norm”, I compared several case studies involving adjudications of *attentional* health or pathology through the interpretation of drawings in diagnostic tests of ADHD. I considered how images and imaging technologies can embody different degrees of objectivity related to the available technology at a particular time in order to examine how this variance of objectivity has played a role in creating perceptions of what constitutes the norms of behaviour in children and adults. In this chapter I demonstrated how art can question certain practices of science.

I then addressed visualisation tools in chapter five and how principles of design can foster the viewer’s perception of patterns of health and disease. “Visual Inscriptions of Health and Disease” demonstrated how artistic visualisations can make use of preattentive processes and selective *attention* to direct viewers. This chapter suggested why insights from many fields are needed to understand the social and economic factors involved in the diagnosis of ADHD. The goal was to illustrate new ways in which art can raise issues of broad public concern with regard to *attentional* pathology.

Chapter six, “The Evolution of Attention”, discussed *attention* within the context of the larger art/science discourse and traced the convergences of contemporary art and neuroscience. The chapter included some of the implications of neuroplasticity, rehabilitation, and the development of neuroaesthetics and looks to the future in terms of new ideas about learning and the arts. Today *attention* is regarded as a valuable and scarce currency as established and exacerbated by the conditions of information technology and media. These ramifications have implications for the fostering of learning.

The conclusions of the thesis summarised the findings presented in each chapter of the dissertation. The combined goals of each chapter support the original premise that art can complement scientific studies about the neurobiology of *attention* and stimulate public debate about its disorders.

7 Controversies and conclusions

Several of the chapters attempted to reflect upon the ongoing nature/nurture debate. Others reflected upon the nature of “evidence” with respect to diagnosis. As historians of science Peter Galison and Lorraine Daston (2007) observed, assumptions of objectivity are built into every technology. Sociologists Michael Lynch and Steve Woolgar (1991) offered thoughtful critiques of image production in science along with a later critique by Lynch (1991), both of which informed my thinking. One assumption that I pursued that has not generally been explored is how images and medical imaging shape our ideas of the *attentional* norm.

7.1 Can attention be trained? Can art train attention?

The traditional view of ADHD has assumed a biological cause with the corollary that pharmacological intervention with stimulant medications is necessary lifelong. Others have hypothesised that ADHD symptoms may be due to inefficient neural networks that could be strengthened during early development by specific experiences delivered by adaptive training (Tamm et al., 2007). At issue in this dissertation is the hypothesis that art can informally assist *attention* training.

7.2 Has ADHD been overdiagnosed? Can visual analysis inform this controversy?

There is no definitive correlation currently accepted between an imaging technology and proof of ADHD. Partly as a result, images and imaging play active roles in ADHD research, diagnosis, and treatment. Some ADHD diagnoses are certainly accurate, but their excessive numbers raise social and economic issues.

7.3 Do artists need to consider neuroscientific data? Do neuroscientists need to consider art?

Knowledge of neuroscientific research on *attention* will help insure that the arts will look more knowledgably not only inward at brain processes but also outward, enabling the fostering of learning and public debate on critical issues involving *attention*.

CHAPTER 1: Towards a Taxonomy of Art and Attention

1 Introduction

This first chapter lays the groundwork for exploring how art can complement scientific studies about the neurobiology of *attention*. It is generally understood that perception consists of acquiring information through the senses, that *attention* singles out what is important, and that cognition processes it. However, not only is there difficulty in separating these entwined processes but the vexing question is raised of what is not attended to and therefore not perceived. I observed the difficulties while sitting on a bench in the Frick Museum in NYC over two decades ago when I overheard a strange conversation. Two men were moving very slowly from painting to painting, and one was describing what was to be seen in each artwork as they moved through the Museum's central court. Apparently the silent man was blind, and his companion was trying to substitute for his lack of sight. I then closed my own eyes to "see" these paintings through the descriptions I overheard. The images that I saw in my mind's eye had now gone through several phases. The images formed from descriptions of the blind man's companion were under constant revision by my own memory of what was most salient in the art that I had actually seen. My thesis elaborates on the critical component of *attention* in such experiences.

Some of the practices of contemporary art and their staging of acts of perception and cognition share approaches with neurophysiological studies. --
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Furthermore, those additional qualities frequently found in art (e.g., emotional and social content, issues of agency and context), which until recently were not routinely addressed during the neuroscientific testing of these networks, may also suggest new ways to explore *attention*. ---
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Furthermore, because they activate the *attention* system in similar ways, certain artworks can informally serve as an *attentional* training ground.

2 The need for art

Psychophysical tasks involving visual search constitute a mainstay of *attention* research; subjects have to look for a particular target among a varied number of non-targets and determine its presence or absence as fast as possible. Some artworks similarly present tasks to participants although they are rarely made explicit. A taxonomy comprised of these correlated tasks (placed at the end of the thesis) should constitute a resource for neuroscientists, artists, art historians, and those involved in the growing field of neuroaesthetics. It will, ideally, facilitate communication between the fields of art and neuroscience, and representative examples have been provided throughout this chapter and thesis. ---
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--. The taxonomy fills another role as well – that of providing neuropsychologists with a supply of pertinent images and approaches to consider adapting to their tests and research.

There may be a need to reconsider the role images play in the published articles of psychological journals. They are seldom all reproduced in the hard copy of journals, and many of the reasons involve cost. Electronic capabilities now provide the ability to publish images online. Such publication would provide readers a chance to view the stimuli and evaluate the findings influenced by the visual stimuli used in research. For example, an excellent source of information for tasks of visual discrimination is Gregory Ashby and Todd Maddox's publication (2005) in the *Annual Review of Psychology*, which itemised the theories and tasks involved in human category learning. The article included two figures in 20 pages, and, although it covered the discriminations delineated in the text, it might also have provided readers with an experiential sense of the itemized tasks described by including more images. This was again true of another excellent article about object recognition (Humphreys & Forde, 2001). Ashby and Maddox then cited an earlier publication relating semantic categories to visual complexity (Cree & McRae, 2003); their Appendix C refers to features for 541 concepts. Unless the pictures are known widely among image psychologists (e.g., IAPS Pictures used in the 2004 study by Mathews and Mackintosh), such articles might benefit from making images available online that embody as well as describe visual concepts.

Authors of journal studies that explore the visual effects of emotional salience might also profit by providing readers an opportunity to view more of the images used. This is especially true for those lay readers who are less familiar with psychological conventions. Distinctiveness affects perception as well as memory (Schyns, 1999), and it may be important for the reader to see what images are actually denoted by the descriptions used in psychological publications.

In most publications reporting the testing of ambiguous figures that evoke perceptual alternations, minimal standard images are presented (e.g., Necker cube, Rubin's face-vase, the duck-rabbit). Perhaps some of them need to be re-considered as privileged images in light of new cultural associations. For example, art historian W. J. T. Mitchell (1994, pp. 56-57) pointed out that a "metapicture" like the duck-rabbit ". . . involves discursive or contextual self-reference: its reflexivity depends upon its insertion into a reflection on the nature of visual representation . . . . Pictorial self-reference is, in other words, not exclusively a formal, internal feature that distinguishes some pictures, but a pragmatic, functional feature, a matter of use and context". The question is whether the duck-rabbit's use in certain psychological testing can affect the outcome of the test in light of its changed cultural status.

The "pictorial turn" identified by Mitchell adds a significant dimension to our lives and suggests to me that a taxonomy of artworks related to particular psychological tests might offer some value to neuroscientists. The examples in this chapter and supplement will hopefully demonstrate the utility of this construct. I suggest that many of the artworks discussed throughout this thesis can foster the viewer's empathetic understanding and self-realisation and can open up social, political, and metaphoric dimensions. As Alan Kingstone's team stated, ". . . in visual search, *attentional* orienting can be triggered not only by primitive features but also by complex object properties like social significance. For instance, we have shown that *attention* can be oriented by the emotional expressions of faces" (Kingstone et al., 2003, p. 179). Art objects or performances seldom draw *attention* to purely informational data but set in motion simulated events that may involve a qualitative transformation in viewers. The qualia involved are increasingly amenable to measurement and thus to scientific knowledge, bridging the presumed objectivity of science and the subjectivity of art. I suggest that additional knowledge related to *attentional* learning may be gained in understanding how art enables insights to occur.

2.1 Art and neuroscience

Neuroscience has a history of using art to demonstrate its principles but has not tended to view art as an *attentional* training ground. In the nineteenth century, Gustav Theodor Fechner (1997) helped to re-orient the study of aesthetics towards psychology. Sheehy et al. (1997, p. 188) related how Fechner investigated the bases for aesthetic judgments. Fechner undertook a methodical study to determine how viewers decided which of two different versions of a Holbein painting (madonnas from Dresden or from Darmstadt) were genuine. Psychologists like Fechner used artworks because they recognised that they could learn much about the visual system based on the features that were and were not analogous to looking at objects in real life. One clear difference is that the paintings froze an instant in time (permitting the investigator to assign different tasks to viewing the same visual stimulus), something that rarely happens in real life. Such differences could be used to generate knowledge about the cognitive functions involved in perception. An important difference in viewing objects that are designated as artworks is that seasoned viewers can often intuit the intentions of the artists, generating a grasp of the salient characteristics of the artwork. The evaluation can take the form of categorisation and the reconstruction of images and/or processes of fabrication; contemplation and comparisons are generally involved. In a broad sense, the overall task of *attention* in art is to create meaning.

Many of Yarbus's investigations, like Fechner's, also involved paintings: he analysed how subjects viewed Ilya Yefimovich Repin's history painting, <u>They Did Not Expect Him</u>, while they were given different tasks (Yarbus, 1965). Tasks were assigned such as estimating the material circumstances of the person or noting differences in clothing (Figure 2). To record eye movements accurately and stabilise the image, Yarbus used suction cups on the eyes and monitored the scan patterns of viewers.

Figure 2: Eye movements (Yarbus, 1965: 109) has been removed due to Copyright restrictions. One participant viewing the same image seven times, each with a different set of instructions: (1) Free examination of the picture. (2) Estimate the material circumstances of the person. (3) Give the age of the person in the picture. (4) Estimate what the person had been doing immediately before the photograph was taken. (5) Remember the clothes worn by the person. (6) Remember the positions and details of everything in the picture. (7) Estimate how long the person had been away from home.

Few works of art prior to the twentieth century evoked behavioural responses; Fechner's and Yarbus's studies were based on paintings. The kinds of tasks involved identifying the mood of the work, the feelings it evoked, and its haptic and formal qualities, including colours, tones, composition, and shapes. As art has branched into performance, simulations, video, interactive new media, gaming, and augmented and virtual reality, some of it has also elicited behavioural responses, including motor actions. In addition, viewers may be presented with phenomena closer to those found in real life as opposed to representations. This chapter analyses how this changed situation has created new opportunities for understanding and training some of the *attentional* functions through art.

3 The attentional system

During the final decades of the twentieth century, much scientific knowledge was gained about *attention* and its division into distinct paths of communication within the brain. The team headed by D. R. Davies (1984, p. 434) delineated four main, overlapping categories of *attention* theories: structural theories, resource theories, state theories, and control theories. Donald Broadbent's 1958 model (a structural theory) proposed that *attention* should be conceived as forming a single-channel bottleneck that then requires the management of a filter. This contrasted with theorising *attention* as a matter of resource allocation within a limited-capacity channel, which both Daniel Kahneman and Christopher Wickens proposed. Kahneman's capacity model (1973) emphasised demand in the face of limited resources. David L. LaBerge pointed out that resource allocations were related to the "effort expended", inflecting the theory psychologically and suggesting ways to test it (Laberge, 1990, p. 159). Christopher Wickens's theory (2008) addressed how dual-task performance lead to decreases in time-sharing ability. In addition, his multiple-resource theory stressed how resources are differentiated both within and between cerebral hemispheres. The third *attentional* class comprised state theories. For example, Hockey's variable state model (1986) assumed that stress affects *attentional* performance, and he emphasised the demands of multi-tasking (Hockey et al., 1986, p. 292). The fourth approach to *attention* emphasised control aspects. For example, Michael I. Posner's approach (1994) involved a supervisory mechanism to preserve *attentional* priorities.

3.1 The three attentional networks

Over numerous studies Posner and Steven Petersen (1990) developed the theory that *attention* consists of three neurological networks, which are subserved by anatomically distinct systems. They proposed separate *attentional* networks and unique functions on the basis of numerous results from brain imaging studies and tests of spatial orienting. Figure 3`shows the various regions of the brain involved in *attention*, and it assigns them to one of three network functions: alerting, orienting, and executive control (Posner & Rothbart, 2007).

Figure 3: The attentional networks (Posner & Rothbart 2007) has been removed due to Copyright restrictions.
This diagram illustrates alerting, orienting, and executive *attention*.

Alerting was defined in relation to incoming stimuli that issue visual or auditory warning signals. Orienting involves guiding head and eye movements towards a new visual or auditory target. Executive control involves the mechanisms for resolving conflict among thoughts, feelings, and responses. Figure 3 indicates the frontal and posterior brain areas in relation to the three networks. Imaging has substantiated that the posterior area of the parietal cortex is associated with the disengagement of *attention* from its current location to another location. The anterior area is linked to the anterior cingulate gyrus and pre-frontal cortical areas and, since it became active in response to conflicts when imaged, was associated with conflict resolution. A distinct set of oscillations was confirmed for each of these networks (Fan et al., 2007).

Figure 4 provides a diagram of a connectionist model (also known as a neural network model) that represents a plausible explanation for the functional structure and interaction of the human *attentional* networks related to vision (Wang & Fan, 2007). Each box has bi-directional connections, reflecting multiple afferent and efferent pathways in the brain. The output network is connected with the object pathway, and the executive control network is connected only with the object pathway. The dotted line indicates that the executive control network and orienting network can be linked to resolve spatial conflicts.

Figure 4: Connectionist model of attention (Wang & Fan, 2007) has been removed due to Copyright restrictions..

3.2 Scientific attention tasks

Functional imaging during cognitive tasks has helped to sort out the networks involved in *attention*. Scientists have designed tasks that magnify the subtle interactions among the component systems to make predictions about *attentional* behaviour (Fan et al., 2002, 2009). Typical neurophysiological testing assigns tasks and measures the reaction time of the participants (the elapsed time between the presentation of a sensory stimulus and the subsequent behavioural response) needed to accomplish them. Different components of *attention* were localised to different brain regions by examining how reaction time was affected by brain damage in neurological patients. Posner and Fan (2007) described *attention* as an organ system, concluding that the *attention* system is like other sensory and motor systems in that it interacts with other parts of the brain but maintains its own identity. Even though their functions and neural substrates are different from each other, all three *attentional* networks act under the constant influence of each other (Callejas et al., 2004). The *attentional* functions and oculo-motor activities are also highly integrated (Corbetta et al., 1998).

Neurophysiological tests were designed to analyse the timing and sequence of activations within the *attentional* network. To do this a combination of *attention*-orienting trials and interpret-cue trials were implemented in conjunction with event-related potentials (ERPs) that measure electrical changes in the brain and functional magnetic resonance imaging (fMRI) recording. As the name suggests, interpret cues need to be interpreted for meaning in order for the subject to carry out particular behaviours (Woldorff et al., 2004; Grent-'t-Jong & Waldorff, 2007). Interpret-cues instructed the subject not to orient their *attention* and not to attend for targets. Active-attend (i.e., *attention*-directing) cues instructed the subject to attend to a location in the left or right lower visual field to detect a possible faint target that might occur in that location. Scientists detected effects at the behavioural level by designing tasks that magnified the interactions among the *attentional* networks through manipulations (Fan et al., 2009). Attention network tests were devised to study differences in the networks. Adult and childhood versions were developed, and a revised test was later designed. Results are based on comparing reaction-times among different experimental conditions. For example, if a subject is informed about the timing of a target but not the location where it will appear, by subtracting a "no-cue" reaction time from a cued reaction time, scientists can measure the advantage gained by correct orienting.

Figure 5 shows a schematic diagram of a compound event cued-*attention* trial (Woldorff et al., 2004). Single letter cues were presented at central fixation. These consisted of letters like "L" or "P", and the subjects were instructed to either covertly attend (i.e., without moving their eyes) to an area where a faint dot might (or might not) appear or to interpret the cue but not attend for a target. In some trials, no target was presented, so that the brain response would be due to the cue only. Participants were also sometimes instructed to delay their response to any detected target until the onset of a "report" signal toward the end of the trial, thereby helping to minimise motor-preparation activity during the cue-target interval. The report signal instructed the participants to press a button to report if they had seen a target. Thus, using different kinds of cues allowed scientists to compare patterns of activation that different tasks elicited (also see Grent-'t-Jong & Woldorff, 2007).

**Figure 5: A cued-attention trial has been removed due to Copyright restrictions.
SOA=stimulus onset asynchrony; ITI= intertrial interval, ISI= interstimulus interval.**

Scientists use the limitations of technology to derive information. ERPs are extracted from electroencephalography (EEG) recordings derived from surface electrodes on the scalp and provide information on brain activity triggered by sensory or cognitive events. ERPs have limitations because the detected electrical brain activations are hard to localise (especially in relation to depth) inside the brain. By contrast, fMRI localises event-triggered brain activations by measuring associated changes in local blood flow in three dimensions but only after a delay of several seconds. The two measures together provide additional information than either taken alone. Scientists claim that the different topographic areas underlying top-down (executive) *attentional* control can be isolated in studies combining the two (ERP and fMRI) by taking advantage of an increase in calculated regional blood flow following a recorded ERP (Woldorff et al., 2004).

Cueing with an arrow or a brightening of a peripheral cue box prior to the appearance of a target attracts visual *attention* automatically without involvement of directed *attentional* mechanisms. (In the co-created animation described in chapter three, a yellow circle served as a cueing device.) Other studies sometimes use a tone for testing the auditory presentation of stimuli. In the continuous performance task (CPT), human subjects monitor a sequence of visually or aurally presented stimuli over a period of 15-20 min and respond manually whenever a designated target or sequence of targets appears. The CPT has been a standard test of sustained *attention* or vigilance in varied populations for the last 40 years (Borgaro et al., 2003). There are multiple forms of this test with uncertain areas of overlap, and it is not clear exactly what scientific construct they measure (Borgaro, 2003). Connors's Test is the one most often associated with

ADHD testing and is used with the goal of revealing pathology where present (Conners & Jeff, 1999). It claims to provide information that enables the practitioner to better understand the type of deficits that might be present. Some response patterns suggest inattentiveness or impulsivity, while other response patterns may indicate activation/arousal problems or difficulties maintaining vigilance. I discuss this test again in chapter four since it plays an important role in diagnosing ADHD.

4 Correlating the attentional tasks of art with those of neuroscience

The general theory of *attention* training is that the repetitive practice of specific cognitive operations of *attention* produces adaptations in the underlying networks connected with these operations (Tamm et al., 2007). According to neuropsychologist Leanne Tamm and her group (2007) one reason why it has been difficult to prove that *attention* training is successful is because different kinds of *attentional* mechanisms have been used that resist correlation (e.g., tasks of divided *attention* as compared with sustained *attention*). A full description of the taxonomy and its functioning is available in the hard cound copy of this thesis.

4.1 Alerting

The artwork Pull (2005) demonstrated how sound artist Jane Philbrick simulated an alerting situation by creating an interactive performance that revolved around the issue of setting off a fire alarm.[1] In Pull, the viewer entered a space replete with drum rolls and flashing lights. The staging tempted the viewer to approach and then pull the lever on the alarm. Upon doing so, a shatteringly loud, abrasive noise instantly commanded *attention* of all present. Although the alerting function of the *attentional* system is often discussed primarily in relation to sound, in Philbrick's artwork, vision was also affected. The artist's immersive spectacle was staged in a room equipped with 430 fire alarm strobes, 312 smoke detectors, 6 speakers, and 84 fire alarm control panels. Figure 6 records a visitor approaching the red alarm, surrounded on both sides by lights and equipment, and Figure 7 shows the installation.

**Figure 6: Jane Philbrick, Pull (2005) has been removed due to Copyright restrictions.
Photo credit: Tony Cenicola (The New York Times), 2005 (Artspace
New Haven installation for "Factory Direct" exhibition)**

**Figure 7: Philbrick's installation has been removed due to Copyright restrictions.
Photo credit: Wanås Konst, Sweden, 2006 (Wanås Foundation ,
Sweden, installation for "Insight Out" exhibition)**

Once the participant pulled the handle, in addition to responding to the abrupt and piercing sound, he or she attempted to orient to the source(s) of light and sound. Similar orienting responses to an alert have been analysed by Driver and Spence (1998). The voluntary pulling of the alarm set off a painful sensory, physiological assault in the form of a cacophony of sound and strobe lighting, which visitors in the vicinity could not ignore. Almost all present covered their ears, and some left the immediate area in distress. Furthermore, Pull challenged each visitor to assume sole responsibility for setting off this ear-shattering spectacle. Philbrick described how she set in motion the inevitability of a "ready/aim/fire" command (analogous to a signal) accompanied by a field march recorded by a drummer. The sound of the drum roll was the signal to pull the alarm, with its resulting cacophony.

Philbrick's artwork is included in the taxonomy that supplements this thesis. In addition to listing (from left to right) her name, medium, artwork and date of creation, the "Task" column lists the task shared by the artwork and neuroscientific test and provides an example of a related psychological test and its goal. For example, the task listed for Philbrick is "Alerting network; relates to CPT used to assess vigilance". Several neuroscientific approaches to testing *attention* relate to Philbrick's eliciting of an alerting response, particularly the continuous performance task (CPT). In one particular version of the CPT, the response to a signal is probed; subjects are asked to respond to a predetermined target stimulus but only when it is immediately preceded by a signal stimulus. Consider Philbrick's drum march keeping the CPT in mind; her artwork led people through a pattern of activity that turned into a simulated performance. While the drum roll (the signal) pulled viewers into the space, a processional walk was created within the space that led to a motor act (the pulling of the alarm). The correlation between the art task and the CPT breaks down at the point of the relationship of signal to motor action. The participants of the artwork would have likely pulled the alarm even had there been no drum roll or flashing lights; by contrast, the participants of at least one version of the CPT would have been specifically instructed not to execute a response except when preceded by a signal. Another column follows the "Task" column and is labelled "Attention Network" (in Philbrick's entry, the alerting network is listed). The last two columns provide a brief description of her art, an online reference, a reference to chapter one since her work is analysed in this chapter, and an image.

Philbrick's simulation of a threatening event can be compared to such events in real life. In most life situations, a single event provides information both on the "when and where" of a target, and that is also true of Philbrick's installation. Normal vigilance tasks would generally allot *attentional* resources (e.g., visual resolution, use of working memory, speed processing) until the threat level is determined and the goal is reached. But in Pull, this aim was frustrated because the artist's goal was initially ambiguous to the participant (and for some viewers, remained so) and because the assault to the senses was much greater than anticipated. Philbrick's approach, like that of many other performance artists, was physiological rather than purely cognitive. It caused the participants to hold their hands to their ears and shut their eyes. The combination of jarring auditory and visual components in Philbrick's installation, while not substitutes for the fear instilled in dire situations, nevertheless provoked strong responses among the participants. As Philbrick herself noted in our interview (2009), the volume level alone can "make you sick to your stomach", a somatic response that she deliberately sought. In this way she succeeded in conveying some of the physiological qualities of fear.

Neuropsychologist Joseph LeDoux pointed out during an online interview with John Brockman (1997) that “The developmental psychologists are interested [in fear responses] because of the early development of the amygdala before conscious memories kick into play. Social psychologists are interested because the amygdala seems to do its work unconsciously. Emotional reactions that occur in this quick and dirty way are really reactions that are important in survival situations. The advantage is that by allowing evolution to do the thinking for you at first, you basically buy the time that you need to think about the situation and do the most reasonable thing. For example, freezing is often the first thing people and other animals do when sudden danger appears” (Brockman, 1997). The fact that Philbrick’s work was a simulation allowed participants a way to reflect upon the experience.

Attentional alerts are accompanied by substantial changes in the physiological state of the participant. The system immediately prepares for a rapid response, and within the central nervous system a negative shift in a scalp-recorded EEG occurs (Posner, 2008). A warning signal is accompanied by activity in the thalamic and frontal and parietal areas of the right hemisphere and is modulated by neurons from the locus coeruleus that release norepinephrine (NE), which typically increases in response to threat (Posner & Petersen, 1990). The alert state that follows a warning signal changes the heart rate and brain oscillatory activity, inhibiting competing activities. The inhibition of executive control during alerting makes intuitive sense because, in an alert situation, you want to promote a fast reaction by orienting the system and then having executive control execute a response (Fernandez-Duque, 1997; Fan et al., 2009).

Philbrick’s staging of an alert differed in obvious ways from the way traditional science typically tests the alerting function. The neuroscientific account of alerting is based on observation of highly controlled conditions, strict measurement of reaction times, and prediction. While her work, like that of psychologists did involve cues (the flashing lights and drum roll), she made no measurements of reaction times or responses in general apart from observation. Philbrick’s work also had features that neuroscience does not take into account such as agency. Her stated ambition was to create “an experiential revelation and a wish to expose fear politics” (Philbrick, 2009). <u>Pull</u> was intended to re-enact the moment of individual choice. Through staging the aural and visual circumstances of a danger alert and its painful sensory ramifications, she made participants complicit in enacting a decision to pull or not pull the alarm. For her this interaction was a metaphor for waging the US war in Iraq (Philbrick, 2009). It dealt with the agency, authority, and the influence of each witness (participant) since, once a gallery visitor made the decision to pull the alarm handle, the cacophony affected not only the participant but other visitors.

4.1.1 Philosophy on the subject of alerting

Given some of the differences between the artistic and scientific approaches to sensory tasks of alerting, I sought a reconciliation of these different approaches in philosophy. O’Regan et al. (2003, p. 59) noted that “Vision, touch, hearing, and smell are the prototypical sensory states and indeed have high corporality and high alerting capacity. . . . High alerting capacity is provided by the fact that sudden changes in visual, tactile, auditory or olfactory stimulation provoke immediate orienting behaviours that peremptorily modify cognitive processing". The same team later pointed out that *attention* is "grabbed" from another activity. They described the relationship between the body's corporeality and the alerting capacity as forming complementary aspects of an observer's interaction with the environment (O'Regan et al., 2004; O'Regan et al., 2005). Their approach is defined as "enactive" and as a "sensorimotor" way of thinking about perceptual sensations (O'Regan & Noë, 2001a, 2001b; Noë, 2002a; Noë, 2004) (Figure 8). Myin, one of the team (O'Regan et al., 2003), provided the example of how "implicit sensory knowledge' is involved in handling a sponge. (Philbrick similarly made evident within a performance context the range of usages that accrue to a military march and fire alarm in Pull.)

Noë has stated that "A phenomenological study of experience is not an exercise in introspection – it is an act of attentiveness to what one does in exploring the world. To reflect on the character of experience, one must direct one's *attention* to the temporally extended, fully embodied, environmentally situated activity of exploration of the environment. Experiential art enables us to do this" (Noë, 2000, p. 134). This will be further examined in the latter part of the thesis, during which I address the pathology of *attention* in relationship to issues like norms of behaviour. There I will ask how art, through its stress on agency can be effective in understanding some of the social aspects of *attentional* disorders, notably ADHD.

Figure 8: Sensory phenomena (O'Regan, Myin, & Noë, 2003) has been removed due to Copyright restrictions.
A chart of sensory phenomena and their interactions with corporeality.

O'Regan et al. (2005) maintain that their understanding of how something responds under different circumstances of handling (like the sponge) has allowed them to close the gap between the cause and effect of a sensation. In another publication they explained that ". . . the subject matter of phenomenological reflection is not an ephemeral, ineffable, sensation-like momentary occurrence in the mind, but, rather, the real-world, temporally extended activity of exploring the environment and the structure of sensorimotor contingencies" (O'Regan & Noë, 2001a, p. 962). For these philosophers, the sensorimotor approach analogously explains cross-modality as exemplified by Bach-y-Rita's demonstration of being able to "see" through stimulation of the tongue. The sensorimotor approach has also attracted criticism. Philosopher Ned Block has denied that anything outside the brain is part of it commenting "If there is a constitutive role for anything sensorimotor in perception, I think it is likely to be a matter of one's spatial sense—a sense that is shared by many perceptual systems, including vision and proprioception, and seems to be embodied in the dorsal system" (Block, 2005, p. 11).

4.2 The orienting network

Orienting has been described as a "what's that?" response (Rohrbaugh, 1984, p. 323). The orienting network guides head and eye movements towards a new visual target. It is associated with the frontal eye fields and subcortical areas such as the superior colliculus and the pulvinar, structures that guide *attention* to a new location (Posner, 1980; Posner et al., 1982). Orienting can be reflexive (exogenous), brought on by a sudden target, or it can be voluntary (endogenous), involving a deliberate search. Different sensory modalities can be involved; Posner and Petersen (1990) demonstrated that visual orienting involves systems separate but interconnected with those used for auditory processing. In 2007 Posner and Mary K. Rothbart confirmed that orienting is modulated by acetylcholine. The orienting network, like the *attention* network, itself, has three components. It involves disengaging *attention* from a current focus, moving *attention* to a new target or modality, and then engaging *attention* at the new target or modality (Fan et al., 2002).

In experiments on infant *attention*, the sudden presentation of a stimulus elicits an orienting response (Johnson et al., 1991). Its persisting presence then reinforces visual exploration. According to the team of Malcuit (1996), the complexity of the stimulus is a determining factor in orienting response habituation, in *attention* recovery, and in dishabituation under particular conditions and suggests the importance of taking into account the functional value of stimuli when analysing infant *attention*. The aim of orienting studies in psychology is to sort out these effects.

Artist Paul McCarthy, whose works are often characterised by aggressive infantile characteristics, used mirrors and banging to force the viewer to experience a highly charged and overloaded environment in an installation at the Whitney Museum of American Art in NYC (2008). In it, spatial *attention*-directing cues triggered activity from viewers. He employed jarring sounds and the spinning of objects; the sounds led the viewers to focus on new objects, and the spinning of those objects then re-oriented and captured the viewer's *attention*. His 2008 exhibition used architecture to create perceptual disorientation in the viewer through rotating walls, casting projections, and altering the viewer's space. Spatial orientation, relying on both vestibulo-proprioceptive and visual cues (Guerraz et al, 2001), was disrupted in McCarthy's exhibition. The exhibition included 22 spinning works that signified danger and threat through the employment of threatening motion and skewed perspectives along with heavy-duty machinery. Making one long wall into a mirror doubled the installation, causing further disorientation. Bang Bang Room (conceived in 1992) did not spin but had four hinged, motorised walls that opened and closed. Each wall had a door that kept slamming shut, eliciting an orienting response. McCarthy's Spinning Room (started in 1971 and re-created in 2009) (Figure 9) captured bright Venetian blinds flashing by and creating blurs by rotating a camera on a tripod in an empty room. The view went round as four video cameras revolved on a central machine within an enclosure. Images of viewers inside were dynamically projected onto four wall-size surrounding screens outside the enclosure. A perceptual and cognitive overload was created, also eliciting abrupt acts of orienting.

Figure 9: Paul McCarthy, Spinning Room (2009) has been removed due to Copyright restrictions. Photo: Sheldon C. Collins.

As New York Times reviewer Ken Johnson noted (2009), the rotating pictures on the screens were by turns live, delayed, upside down, reversed, or inverted while different image streams were shown one on top of each other amidst strobe lights. Scientific trials have shown that the effect of alerting upon orienting is to accelerate it (Callejas et al., 2004). The overload established by McCarthy also set up a situation akin to multitasking, resulting from conflicts between how sensory stimuli were processed. Bernard J. Baars (1998) pointed out that the behavioural view shows a brain that is slow, serial, deliberate, and with capacity limits in distinct contrast to the neurobiological view in which the brain is fast, parallel, largely unconscious, and with vast capacity. Baars further confirmed that both of these perspectives are accurate (Baars, 1998, p. 60). As a result, his conclusion was that, although it might have been adaptive to be able to do several conscious things at the same time, all tasks that require consciousness compete with each other, and, in general, only one can be done well at a time.

The orienting function is often tested alone by presenting a cue indicating where a subsequent target will (or will not) appear. As was noted in one example of the attention network test, scientists can separate information about where a target will occur (orienting) from when it will occur (alerting) by the use of cueing. It has been established that, although alerting and orienting are not correlated, they still tend to work together since a single warning typically provides information about both the timing and location of a target. Visual cues bring about auditory elevation discriminations once a saccade towards a flash is initiated, at which point the auditory localisation improves in the direction of the flash (Driver & Spence, 1998). Since Driver and

Spence determined that this occurs even before an overt eye movement, they concluded that the release of a saccade program is responsible for the impact of visual cues on hearing.

Posner and Fan (2007) described a rehabilitation study in which patients were trained to increase their self-alertness in an effort to improve deficits in their orienting system, manifested clinically as “neglect”. Exogenous alertness (in this case in response to a loud noise) was used as a basis for training patients to “attend” by generating a self-alerting signal (e.g., a knocking or vocal sound). Evidence showed that this rehabilitation training improved patients’ self-alertness and also reduced the extent of their spatial neglect (Posner & Fan, 2007, p. 18). The fact that people can train themselves in such a manner suggests to me that *attention* can be trained using other techniques, including artworks and installations. I elaborate on this kind of self-instruction throughout the thesis since the potential for art to train viewers in ways comparable to formal *attention*-training is a main premise of the dissertation. Paul McCarthy’s installation provides an experiential example of how our bodies in interaction with moving props can influence our *attention* and orient our actions, and it does this as a form of simulated “play”.

4.3 The executive control function

Art can elicit many kinds of responses involved with executive functioning. They include the ability to shift *attention* between competing stimuli (Zubin, 1975; Posner, 1980; Sohlberg & Mateer, 1987) and suppress unwanted responses (Drewe, 1975). Reliable planning, judgment, decision-making, anticipation, and reasoning are subsumed under the executive control network along with tasks that require sustained *attention*, selective *attention*, and dual task management (Fan et al., 2009). Executive *attention* also guides awareness; a self-aware system can attend to its own internal states, thus providing a means of generating introspection and self-modification (Bush et al., 2000).

The dorso-lateral prefrontal cortex plays a significant role in executive control as does the anterior cingulate cortex (ACC) and are active when conflict is present and overcoming habitual actions is required (Bush et al., 2000). The ACC is a part of a circuit involved in a form of *attention* that serves to regulate both cognitive and emotional processing; it is part of a larger network that might be involved in the early stages of learning where effort and flexibility are important control parameters. In sum, executive control (the third *attentional* network) is responsible for activities such as planning, cognitive flexibility, abstract thinking, target and error detection, conflict resolution, and inhibition of automatic responses (Posner & Rothbart, 1998). Selective *attention* typically does not function in isolation but nearly always also recruits vigilance and alertness (Posner & Fan, 2007). It calls for abilities in three different areas: selectivity, resistance to distraction, and switching or shifting to a new focus of *attention* (Davies et al., 1984, p. 433).

Selective *attention* can be examined using five different tasks, and I have identified the artistic equivalent of some of these tasks and included them in the taxonomy. The task categories include (1) selective and dichotic listening. Selective listening requires that one of two messages is attended to whereas in dichotic listening, the subject attends to both messages and is asked to recall them; (2) central-incidental learning, which involves subjects (usually children) carrying out tasks with cards showing two stimuli, one on top and one on the bottom, the central test being to accurately recall the location of items in a category; (3) speeded classification, during which subjects are asked to sort cards as quickly as possible into piles based on colour, size, or shape; (4) visual search during which subjects are asked to locate a target; and (5) time-sharing to perform multiple tasks (Davies et al., 1984, p. 396).

Conflict tasks include arrow cueing (known as Flanker tests) and the Stroop test. Flanker tests generally use arrows to guide *attention* and measure the delay in time when directional conflicts are posed (Leblanc & Jolicoeur, 2010). The cognitive system often adopts a default *attentional* set to orient in the direction indicated by an arrow. Friesen et al. (2004) postulated that an alternative *attentional* set dictated by the task demands might overrule automatic settings. As a result, an arrow might no longer trigger involuntary orienting. In the colour Stroop test, the task assigned by the psychologist is to attend to and name the colour of the ink in which a word is printed (Spreen et al., 2006). During the test, the printed words may read colour names that are different from the colour of the ink in which they are printed. Numerous trials have shown a strong tendency for subjects to respond to the content of the word (the semantic content) and not to the ink colour. Yeung (2010) has explained that colour naming and word reading are asymmetrical tasks that incur “switch costs” because, whereas little control is required when reading a word, strong control biases are required when naming a colour. Figure 10 juxtaposes an artwork by Jasper Johns with one version of the Stroop test.

Figure 10: Examples of the Stroop conflict has been removed due to Copyright restrictions. Left: Jasper Johns, False Start 1 (1959). Right: Colour words version of the Stroop test.

The area of Jasper Johns's False Start 1 (1959) at roughly 7 o'clock shows the word "white" in red letters over a yellow background. Although Johns is well known to be reticent about his work and art historians appear not to have explicitly made this link, it is certainly possible that Johns was familiar with the Stroop test and deliberately exploited its properties to his own ends.

The Stroop test (1935) has been used both to understand fundamental human information processing and clinically to assess *attentional* dysfunction. EEG and functional neuroimaging studies of the Stroop effect have consistently revealed activation in the frontal lobe. Numerous versions of the Stroop test exist by now, and researchers have adopted words other than colours, for example some that elicit emotions or pictures of threatening objects. Like much current psychological testing, it is common to use computerised versions of the Stroop task. What unites all these different versions is that the subject is presented with a stimulus that simultaneously activates two conflicting responses. One response is activated by the instructions, whereas the other is activated by elements in the array that strongly invite a contradictory response. In order to resolve this tension, the subject has to direct *attention* to the relevant task assigned. The time needed to resolve it is derived using "subtractive logic", and the results measure the efficiency of the *attentional* system (Stins et al., 2004).

The Stroop test and tests of binocular rivalry offer additional information about *attention* if taken by individuals with synaesthesia works since *attention* modulates the perceptions of synaesthetic individuals. Synaesthesia involves cross-modal perceptions in which, for example, one sees colours when hearing particular sounds (Palmeri et al., 2002). Sound can also induce the alternations seen during binocular rivalry (Parker & Alais, 2008). The Stroop test can determine whether synaesthetes actually see real or synaesthetic colours in conflict situations since synaesthesia involves particular constraints (Grossenbacher & Lovelace, 2001; Kim et al., 2006). For the synaesthete, the synaesthetic colour experiences are as perceptually real as actual colours are for non-synaesthetic observers. Therefore individuals with synaesthesia take longer to respond when the synaesthetic colours are incompatible with the real colours (Mattingley et al., 2001, 2006). Such individuals offer a window into perception (Ramachandran et al., 2001). *Attentional* conflicts are exacerbated when colour/form synaesthetes are presented with Stroop tests because the synaesthesia can cause conflicts with what is perceived (left side of Figure 11). Synaesthetic artists have provided additional information about the phenomenon in recent years since they are often themselves aware of the conflicting *attentional* demands (Berman & Steen, 2008). The right side of Figure 11 by an artist identified as Joe created a global pattern of Bush's face from small grid-like units, each displaying a soldier killed in the war in Iraq. I suggest that testing individuals with a variant of this image might offer additional information about the *attentional* system since it could test the modulation of *attention* by affective and social factors.

Figure 11: Response to local or global forms, composite, has been removed due to Copyright restrictions. Left: An illustration of synaesthesia elicited by local/global forms (Palmeri, 2002). The number 5 (global) is constructed from 2's (local). When the synaesthete looks at the global form, it will be perceived in one colour (here light green). If she attends to the local form, it appears in a different colour (orange). Right: Portrait of Bush: The artist (Joe) created a portrait of Bush's face, using the faces of dead soldiers as the small units that form the global view.

The same comments apply to the version of the Stroop test that I designed for art professionals below (Figure 12).

Figure 12: Ellen K. Levy, a Stroop test for art historians (2007).

My version establishes a conflict between the semantic content of the artwork with titles like Matisse's Joy of Life, Robert Indiana's Love, Durer's Melancholia, Bernini's St. Theresa's Ecstasy, and the contradictory emotional tone implied by their altered colours and tonal values. For example, Indiana's poster representing the letters "love" in green, blue, and red is superimposed with a label, "hate" in black. As another example, Durer's Melancholia is superimposed with a label, "envy". As a result of these alterations, the subject's ability to quickly name the artwork might interfere with his or her ability to quickly state an emotion that conflicts with the image. This version of the Stroop test might provide a way to test for cultural differences since western viewers might be more familiar with these artworks.

4.3.1 Conflict tasks involving binocular rivalry

Artist Gregory P. Garvey designed a Split-Brain Human Computer Interface (1999) that presented the eyes with dissimilar images. To create his artwork, Garvey used video from the contentious 1991 US Senate Judiciary Committee hearings to confirm Clarence Thomas as Supreme Court justice (Garvey, 2002). He presented Anita Hill's and Thomas's testimony separately (dichoptically) but simultaneously to each participant's visual field and each ear. His aim was to use his "split-brain interface" as a way for the user to physically experience the contradictory testimony of Hill and Thomas about Thomas's alleged sexual harassment in the workplace (Garvey, 2002). A still from Garvey's work shown in the top of Figure 13 consists of a dichoptic stimulation with different monocular views that results in binocular rivalry. This has been compared (bottom of Figure 13) to a standard face-vase ambiguous illusion that, like binocular rivalry, can cause subjects to experience bistable percepts. Equally valid but mutually exclusive interpretations of the visual input result in alternating percepts (Kleinschmidt et al., 1998). Examiners modulate the percepts of subjects through changes in stimulus strength, perceptual or semantic context, and *attention* (Conrad et al., 2010). Results have shown that the brain will draw on information coming from multiple sources to resolve conflicts in multistable perception and ambiguities (Conrad et al., 2010). To the mixture of bistability present in the face-vase illusion, Garvey has added notable additional social and emotional components.

Figure 13: Perceptual rivalry composite has been removed due to Copyright restrictions. Top: Gregory Garvey (1999). Bottom: heads/vase illusion.

According to Conrad's team (2010), relatively few studies have investigated multisensory interactions in multistable perception by analysing the influence of auditory signals while rivalling visual percepts are underway. Thus it is particularly notable that an artist devised such an experiment. Garvey delivered video separately to the two visual nasal hemi-fields in each eye and audio separately to the two ears of an individual in order to let viewers physiologically and metaphorically experience the meaning of a divided mind. In Garvey's work the audio signal corresponding to the digital video image in the nasal field of the right eye was routed to the right ear, and the corresponding procedure was applied to the left ear. The listener heard the overlap or alternation of the two dissenting voices. According to the artist, many viewers learned to voluntarily shift *attention* between Hill and Thomas recordings (Garvey, 2002, p. 323). Garvey stated that some viewers could view both digital video images by keeping the eyes focused on an imaginary central fixation point. The digital video image could thus be separately routed, with different stimuli to the two eyes (and to the right and left hemispheres).

A hierarchy of responses characterise binocular rivalry (Lee et al., 2007). The cortical expressions of different stimulus patterns of binocular rivalry and ambiguous figure rivalry are known to be similar (Maier et al., 2007). Oscillations are known to occur during the perception of ambiguous figure rivalry (Ditzinger &

Haken, 1989). Neuroscientists Francis Crick and Christof Koch have found that when binocular rivalry occurs, the inputs are not superimposed but alternated (Crick & Koch, 1992). In visually bistable patterns as well as during binocular rivalry, the structures give rise to an ever-changing percept. Neuroscientists Gerald Edelman and Giulo Toroni (2000) also confirmed that fusion does not occur and alternation results. Research involving perceptual rivalry demonstrated that high-level cortical structures are engaged (Ngo et al., 2008). Neuroscientist John Pettigrew conducted tests indicating that binocular rivalry and ambiguous figure rivalry such as seen in the face-vase image are both subject to the influence of voluntary *attention* (although possibly to different degrees), and he proposed a common mechanism of interhemispheric switching (2001). He pointed out that "Rivalry may thus reflect fundamental aspects of perceptual decision-making, with significant variation between individuals. The links that we have established between perceptual rivalry and the hemispheric processes of thought and mood, particularly the concept of interhemispheric switching, considerably widen the research horizon beyond V1 for those interested in the neural substrate of these striking alternations in awareness. Oscillations may be much more common in everyday perception than is commonly realised, especially when we consider that one phase of the oscillation may involve the left hemisphere process of denial, so that consciousness may be ignorant of some of its own processes" (Pettigrew, 2001, p. 85).

Garvey's research had attributes not generally part of scientific research. He referenced Julian Jayne's erroneous yet intriguing theory of the origins of self-consciousness (1976), focusing on the roles of the two brain hemispheres as well as referencing Michael Gazzaniga's split-brain research (1970). Binocular rivalry has been studied in split-brain patients to determine whether lateralisation is involved; O'Shea, R & Corbalis (2004) have maintained that the mechanism is duplicated at a low level within each hemisphere while others (e.g., Pettigrew) maintain it is higher up. The name of Garvey's project (Split-Brain Human Computer Interface) declared his interest in consciousness as a consequence of communication between the hemispheres. During early historical treatments of severe epilepsy, the corpus callosum was bisected (corpus callosotomy), and first Roger Sperry and then Gazzaniga (1970) analysed the responses of split-brain patients to determine conflicts between right and left hemisphere functions. Gazzaniga found that the left hemisphere is generally dominant, sometimes even attempting to force the right hemisphere to obey its commands. The left hemisphere might rationalise or reinterpret events when that proves impossible. The left-brain "observes" a conscious flow of visual information (acting as a "narrative interpreter") from the right visual field. The right hemisphere might also have an executive interpreter that observes information from the left visual field. The right-brain observer does not speak, but tends to deal better with anomalies requiring emotional strategies. It has been conjectured that full consciousness involves the participation of such "self-systems", which might be centred in the executive prefrontal cortex (Baars, 1998, p. 58).

Bistable stimuli are useful for studying subjective awareness (Logothetis, 1998; Leopold & Logothetis, 1999). Maier's team found that the firing of neurons in the visual cortex changed when presented with sensory ambiguity or visual conflict, thus showing perceptual modulation with different stimulus configurations. The results further showed that a group of neurons participate in reporting the perceptual outcome of a sensory conflict. The phenomenon of these "feature-responsive" cells was regarded with great interest because their activity was believed to draw at least partially upon "internally generated, interpretive information about a sensory stimulus" (Maier et al., 2007). Maier's laboratory suggested that a cell could signal using either a sensory or cognitive capacity. The scientists interpreted this experiment as explaining "how subjective mental states are supported in the visual brain". The team of scientists observed that the percept-related modulation seen with bistable patterns is similar to the modulation found in endogenous (top-down) *attention* tasks. This finding is relevant to the thesis since it suggests that an artwork like that by Garvey, through the alteration of the context, emotion, and/or semantic value of a precept, could train the participant's *attention*, resulting in the re-direction of one percept being chosen over another. This also has implications for amplifying qualities of self-awareness and validating concepts of "free-will".

4.4 Tasks involving categorisation

Because so many artworks elicit tasks of categorisation, I have made "categorisation" a separate heading in this chapter. More art examples are provided in the taxonomy in the supplement. Many of the artworks explored in this dissertation activate those areas of the executive *attentional* network involved with categorisation, which is critical to problem solving activities (Blair & Homa, 2009; Allen & Brooks, 1991), and animals also share in these capabilities (Martin-Malivel & Fagot, 2001; Fabre-Thorpe, 2003). One must recognise objects under a great variety of circumstances (Biederman & Gerhardstein, 1995), and neurons have been found in the temporal lobes that have category-specific visual responses (Kreiman et al., 2000). Evolutionary psychology regards the ability to categorise as a result of natural selection and adaptation. The human mind was conceived as an information processing system in which functionally specialised systems are domain specific (Cosmides & Tooby, 1994). These systems direct *attention* to relevant information in the world. The fact that a fearful response is more easily conditioned to objects that posed a significant threat throughout humans' evolutionary past (e.g., snakes) than to contemporary objects like cars (New et al., 2007; Neuberg et al., 2010) suggests the continuing influence of evolutionary origins.

Neuroscientist Charles Gross emphasised the importance of the discovery that medial temporal cells, which are known for processing memory, are also involved in visual categorisation (Gross, 2000). It is yet another indication that *attention* is integrated with the processes of learning and memory. As chapter two will show in the context of inattention blindness, neural responses are affected by the category that participants are tasked to search. Scientific findings suggest that the top-down *attentional* set usually determines which stimuli are processed to the point of recognition. Stimuli that are irrelevant on the basis of location can attract *attention*, but, the argument goes, only if they match a participant's search set (e.g., assigned category) (Peelen & Downing, 2007; Peelen, 2009).

One does not need causal evidence to point to categorisation as an important function of art. Philosopher Mark Rollins has observed that "*attention* to pictures will be itself guided by prior categorisations of the depicted objects, and thus interpretation will be top-down and not bottom-up . . .” (Rollins, 2004, p. 81). Scientific testing utilises a great range of tasks (Paramasuran, 1984), and I claim that many related to classification have artistic analogues. Ashby and Maddox (2005) specified four different kinds of category-learning tasks. These are rule-based tasks, information-integration tasks, prototype distortion tasks, and the “weather prediction” task. Rule-based or explicit reasoning tasks rely on frontal-striatal circuits and require working memory and executive *attention*. Information-integration tasks require a form of procedural learning and are sensitive to the nature and timing of feedback. The optimal strategy in information integration tasks does not lend itself to verbal description. Ashby et al. provided the example of a radiologist deciding whether an X-ray shows a tumour. This requires years of training, and categorisation strategies cannot easily be specified (Ashby et al., 1998, p. 153). The third task described is a prototype distortion task. It involves perceptual (visual cortical) learning and elicits a variety of strategies. The fourth task, which was identified as weather based, uses tarot cards as stimuli. The subject’s task is to decide if the particular constellation of cards that is shown signals “rain” or “sun”, which explains why the task came to be called the weather task. A probabilistic rule determines the actual outcome. This test allows the examiner to distinguish whether participants have made a category decision that is deterministic or probabilistic. According to Ashby et al. (1998), it shares characteristics of information-integration tasks and also rule-based tasks.

Rees and Frith (1998) pointed out that that the essence of *attention* is selection. *Attention* then shapes behaviour through influencing motor output. The *attentional* system mediates the process of categorising the stimuli. I suggest that a little-appreciated fact is that many artworks make viewers aware of their own process of forming distinctions among categories. In addition, art can help sort out the role of language relative to visual and other factors in making such distinctions. The unintended irony is that artists tend to resist categories even as art may help train the ability to make categorical distinctions.

4.4.1 Distinguishing art from non-art

One of the most essential tasks that face an art viewer is to distinguish an aesthetic object from ordinary objects, informally training viewers to make such distinctions. Panning Annex, a video from Ricci Albenda’s exhibition, “Panorama”, might have been mistaken for an empty room until the viewer noticed the space shifting. A video projection simulated a revolving, 360-degree view of the interior of a white cube. Albenda aligned his fictional space with the actual architecture so that the subtle image appeared to be a perfect extension of the room in which the viewer stood. Perspective lines continued those of the actual physical space. The alignment was brief during the continuous pan around the simulated room. The continuity was eventually disrupted, and the illusion revealed itself (Figure 14). This discrimination possibly involved rule-based and information-integration criteria. The (verbally-unexpressed) rule might simply have been that a seemingly empty room in a gallery exhibition calls for further examination.

Rollins (2004) suggested that the artist’s intentionality in creating an artwork marks the difference between an art object and a non-art object that has similar aesthetic traits. He has pointed out:

> "... there is some evidence suggesting that, although real and illusory contours draw upon the same mechanisms, there may be a "unique signature for illusory contour representations" that set them apart for the viewer's brain from contours that are really there . . . the use of artistic devices can produce a response in the visual system sufficient to produce the illusion of seeing an object, but in such a way as to signal the fact that they appear in a representational context, and thus by design. In that respect, I suggest, they are diagnostic, not only of objects, but of the artist's minimal communicative intent" (Rollins, 2004, pp. 184-185).

Figure 14: Ricci Albenda, Panning Annex (2007) has been removed due to Copyright restrictions. Video projection, installation view.

Rollins further posited that the patterns of *attention* that are produced in any form of artwork are distinctive. Evidence in humans for a regional substrate enabling one to distinguish art from non-art has been based partially on surface electrical recordings (EEGs) of the brain, with increased suppression of oscillations occurring when observing the hand-made as opposed to mechanically-typed words (Longcamp et al., 2005).

4.4.2 Recognition of distorted forms

Artists exploring unusual viewpoints and distortions include Robert Lazzarini and John Simon Jr., both of whom have explored topological distortions. The viewer's ability to categorise what she see relies on her successfully completing what Ashby designated "prototype distortion tasks". The title of Lazzarini's 2010 exhibition, *Friendly-hostile-friendly*, referenced shooting targets that are used in law-enforcement training as a point of departure (Figure 15). Lazzarini included both “friendly” and “hostile” figures in his exhibition, and they were mounted on cardboard and Styrofoam. In these artworks Lazzarini implicitly asked the spectator to categorise the figures as friend or foe. The works displayed were distortions of shooting targets after they have been fired at with various guns. Neuropsychologists study the ability of subjects to categorise distorted images through assigned tasks, bearing similarity to the implied task of Lazzarini’s targets. In Lazzarrini’s work, however, the viewer never sees an undistorted version except as a mental image. The recognition of a person as friendly or hostile in both the artwork and psychological test depends on the phenomenology of perception, in which collapsed and distorted forms can be identified as equivalent to more standard views of the same objects or people.

Figure 15: Robert Lazzarini, Target 535 (2010) has been removed due to Copyright restrictions. Mixed media, archival ink 44 x 33 x 1/2 inches.

4.4.3 Detecting change

Walter Benjamin famously noted that film is "consummated by a collectivity in a state of distraction" (Benjamin, 1992, p. 232). Flicker films of the 1960s emphasised the separate frames of the film, reflecting the movements of the camera and projector. Tony Conrad was one of the leaders of this genre. The exposure timing sheet from his film, The Flicker is reproduced in Figure 16, which illustrates a score of operating instructions, effects and timing instructions.

Figure 16: Tony Conrad, The Flicker (1965-1966) has been removed due to Copyright restrictions.

The conditions established by flicker films informally test the participants' ability to detect changes in images under varied conditions. Still frames are generally projected at 16 or 24 frames per second and give the illusion of continuity due to persistence of vision along with smooth operations of the camera and projector. By contrast, in flicker films *attention* is deliberately directed to the still frame by the action of the shutter, causing pulsation (Cornwall, 1979).

Psychologists also deliberately create flicker conditions to test participants' ability to detect changes in images under modified conditions. The "attentional blink" paradigm is believed to say something about our ability to categorise, and its duration depends on the target category presented (Einhäuser et al., 2007). One general finding by scientists is that categorisation becomes more efficient with experience. For example, eye blinks reduce the ability to detect alterations on static or moving images (Rensink et al, 1997). *Attention* is the key to understanding such phenomena. *Attentional* blink experiments (Simons & Levin, 1998) have demonstrated that when two stimuli are shown rapidly and successively, if the participants' *attention* was captured on the first stimulus, more mistakes were subsequently made in the detection of the second stimulus. Einhäuser et al. (2007) have also shown that the category involved has an impact on the duration of the blink under natural conditions. The attentional blink paradigm tests *attention* by overloading it. Scientists present stimuli such as letters, digits, or pictures in rapid succession at a single location at rates of 6-20 items per second. Participants monitor the list using two criteria (e.g., to detect the target and identify the probe). It was found that the ability of subjects to recollect stimuli dropped with the increase of presentation speed. The method of testing is known as rapid serial visual presentation testing and is very much like the rapid succession of images that is seen in some flicker films.

Much art intentionally either slows the process down or speeds it up as in the flicker films to interrogate the process of categorisation, itself. By contrast with the scientists who were studying how certain presentations of stimuli affect the brain, the images created by the flicker artists were done to ignite a change of consciousness and to play with vision. The artists involved in this arena made some of the fundamentals of motion pictures explicit in order to create a new kind of expanded cinema (Sharits, 1969). Conrad was highly aware of the modulations caused by the flicker effect and wished to engage the viewer's physiological responses to the projected image (Cornwall, 1979). The Flicker included rapid pulsations of the film, causing physiological discomfort for the viewers.

4.5 The influence of emotion and memory upon attention

Discomfort of a different nature was provided by photographer Mark Berghash in his art project. In the early 1980s, Berghash isolated Holocaust witnesses in a room where they carried out instructions related to their experiences. They were asked to photograph their own faces during their most intense emotional memory – a task that involved both emotion (recall) and motor activity (activating the shutter). Berghash's artistic approach also required witnesses to cope with the memory of past emotions. As he described in an interview with me (Berghash, 2008), in his exhibition, Jews & Germans: aspects of the true self (1985) the task he assigned participants ("recall their most painful memory") resulted in a specific choice of emotional recall (Figure 17). In this way, Berghash staged and acknowledged some of the conditions of spectatorship. We, as viewers, were invited to assess the expressions in the photographs as indexical of their inner emotions. Berghash's project pivoted on the viewer's belief that the photograph could evoke his subjects' internal state of mind.

A full description of the taxonomy and its functioning is available in the hard bound copy of this thesis.

Figure 17: Mark Berghash, Jews and Germans: aspects of the true self (1985) has been removed due to Copyright restrictions.
Photo credit: Mark Berghash

Part of the training of *attention* involves issues of emotional salience, and part of the training of artists involves controlling the artistic construction of emotion. We intuitively know that emotional events command increased *attention*. Based in part on his work on Nicolas Poussin's modes, art historian David Freedberg holds that there are specifiable rules that can suggest how feelings arise from viewing pictures and that artists have mastered these tools (Freedberg, 1989). Until relatively recently, emotion and its links with *attention* and control have often been insufficiently considered in standard scientific accounts of *attention*. One reason is that emotion was not tractable until developments in imaging and analysis of brain chemistry. Scientists such as LeDoux (1996) and Antonio Damasio (1999) increasingly take the interrelationships between emotion and *attention* into account. The team of Taylor and Fragopanagos (2005) have maintained that it is not possible to consider emotion processing without inclusion of *attention* and conversely that emotion functions to help guide *attention*.

Lastly, the taxonomy cites Bechara et al. (2003) for work on memory. They performed PET scans on subjects' brains as they recalled past emotional experiences, recalling aspects of Berghash's artwork. They developed a "somatic marker hypothesis", proposing that both the amygdala and the orbitofrontal cortex are parts of a neural circuit critical for judgment and decision-making. The researchers' aims were to locate the regions responsible for triggering feelings of aversion or pleasure. The procedure involved asking the subject to think about a situation in which she had felt a variety of emotions. Once the memory was described, she was then asked to image and re-experience each emotional experience. A control was also established by asking the subject to recall a non-emotional event.

Mateer and Mapou (1996) stressed two cognitive factors involved in *attention*: deployment and encoding. Deployment is concerned with the channelling of *attention*, whereas encoding is the ability to store it in memory. According to Eric R. Kandel who received a Nobel Prize for his research on memory, memory is itself preserved by *attention* (Kandel, 2006, p. 314). Like Berghash, psychologists have used photographs to test relationships between attention and memory, but with very different goals. For example, Intraub et al. (2008) tested how visual attention affects the memory of a scene. They found that divided *attention* enlarges the layout of a remembered scene, a phenomenon known as boundary extension. Enlargement was attributed to the belief that pictures are viewed as extending into the real world (Bertamini et al., 2005). According to Andrew Mathews and Bundy Mackintosh (2004), emotional scenes are remembered better than neutral ones and may lead to better encoding of information. They established this by showing highly emotional images to subjects (which they described in their publication but did not include). It was found that variations in emotional reactivity influence boundary extension; in fact, boundary restriction, that is choosing the close-up, more often occurred in individuals who were highly anxious or when viewing very negative pictures. The investigators concluded that emotion guides *attention* and highly-anxious individuals are more likely to attend to closer views of aversive pictures and give less *attention* to surrounding areas.

The evidence suggests that *attentional* systems are integrated with behavioural, learning, emotional, and memory systems. Tooby and Cosmides (2005) pointed out that an *attentional* system specialised for monitoring the behaviour of others is then used to predict the likely behaviour of others. In a malfunctioning system such as autism, the result can be an inability to correctly "read" the emotions of others. The *attentional* system allows one to assign categories; the process is so transparent that it is generally unnoticed, and it occurs in all sense modalities (Blair et al., 2009). In addition, Maddox et al. (2002a, 2002b) have found that multiple *attention* systems, involving perception, executive, and vigilance systems are utilised in categorisation processes that are posited to be functionally independent. When looking at people, humans match sensory cues with stored information about that specific individual. All these systems are linked and modulated by *attention*.

5 Additional contributions of art

Emotional resonance continues to be a key contribution of artwork. Research has demonstrated that framing can alter people's emotional responses (Gross & D'Ambrosio, 2004). Unfortunately, an emphasis on art's subjectivity may have diminished other insights that can result from engagement with art. As art historian Ernst Gombrich noted (1975, p. 124), "To insist on the subjective element in our visual experience does not mean to deny its objective veridical component. I believe much light is thrown on this question by Karl Popper's lifelong insistence (1972, p. 6) that a parallelism exists between the reactions of the organism to external stimuli and that of the scientist evaluating his observational evidence. The elimination of false guesses, the refutation through tests and probings of mistaken hypotheses play a decisive part in any area of doubt that demands *attention*".

That art could be of value to neuroscience was alluded to by ecologist Thomas Weber (1999). He claimed that there are good reasons to embrace a view of the sciences that emphasises disunity, methodological diversity, and a complex relationship between theory and experimentation. He noted that Alistair C. Crombie's *Styles of Scientific Thinking in the European Tradition – a History of Scientific Methods* (1994) identified six scientific styles of reasoning in Western culture. They encompass hypothesis, experiment, analogical models, comparison and taxonomy, statistical analysis, and genetic development. Weber pointed out that sociologist Ian Hacking added an additional style identified as the "laboratory style", characterised by the construction of apparatuses intended to isolate and purify existing phenomena and to create new ones (Weber, 1999, p. 527). In general, Weber concluded that a pluralism of practices is conducive to scientific creativity (Weber, 1999). I suggest throughout this dissertation that art can profitably fulfil some of this role.

6 Conclusions

In this chapter examples of contemporary art were shown to resemble scientific tests, and this has opened the door for a beneficial exchange between the neurological sciences and art. The general findings of this chapter were that ---

art serves as an *attentional* training ground. To apply such correlations, artists like scientists, would benefit by knowledge of prior work done in both fields. Artists can also benefit from looking at the variety of methods scientists use to test structures that they cannot see and through considering different kinds of approaches to their installations. In turn, art analysis affords scientists an opportunity to consider alternate ways of examining the *attentional* system. However, scientists would need to become familiar with the "coding" that is apparent to those versed in art's history and in contemporary art, and this knowledge would help enable them to determine in what ways their separate approaches could be appropriately compared.

Unlike the artistic examples provided by Philbrick, scientists tend not to situate their experiments within the public realm of social and political realities. Doing so might preclude the ability to control the test parameters. Artists have different goals. Art and *attention* are enmeshed in the fabric of politicised systems of motivation, valuation, and preferences. Whereas science has tended to direct the viewer away from external considerations of social, cultural, and economic factors in connection with *attentional* processes, many contemporary artists favour the inclusion of social contexts rather than the individual's response in isolation, deliberately calling *attention* to social and political realities and to emotional salience.

Although measurement is a basic activity in science, scientists increasingly recognise the difficulty of psychological testing with stimuli that do not correspond to what patients experience in the world or to what they find emotionally and socially affective. I concluded that researchers in psychology might find a rich source of experimental potential in the often broadly-allusive experiments of artists involved with the *attentional* system. Much of the contemporary art in this section (e.g., Philbrick, McCarthy) emerged from the perception of living in a world with a basic orientation toward action. Importantly, some of this art engages and/or elicits bodily response (e.g., interactive sculptural structures that elicit orienting behaviour).

The public is largely unaware of the complex functioning of the *attentional* system. An additional reason to view the subject of *attention* through the combined lenses of neuroscience and art is that art can encourage critical analysis and make facts more accessible to the public, offering modes of communication sometimes lacking in science. Art has been conceived as providing universal frames of meaning that allow us to understand the actions and intentions of others. It is easy to overlook the role of *attention* because it is so automatically engaging. In this chapter I explored how some art permits access to these otherwise invisible processes in order to interrogate the *attentional* apparatus and suggested how it can be correlated with scientific studies of *attention*. Doing so provides a consistent framework for interchange between these disciplines.

I concluded that, in the broadest sense, art *is* the study of *attention*. Many of the works discussed fostered self-knowledge about perception and the body. To the extent that such artwork attracts public scrutiny and participation the artists involved are contributing to *attentional* training (seemingly inadvertently). They could also be contributing their expertise to psychological experiments involving *attention* if scientists were aware of their works and included pertinent aspects of art presentations in their own research. Therapists might find a taxonomy that correlates artistic tasks with neurological testing useful in determining the benefits of art in *attentional* training. There may be a need for such a taxonomy since it might expand the range of images now used in diagnostic testing and direct more concern to images and how they affect the published findings of psychological research. The art shown in this chapter and throughout the thesis broadens the basis on which conclusions can be drawn regarding the value of images for understanding *attentional* functions. These issues will be further explored throughout this thesis.

Endnotes

1 Jane Philbrick was an International Fellow at Location One, New York. Her solo exhibition, "Pull," opened September 10, 2008.

CHAPTER 2: An Artistic Exploration of Inattention Blindness

1 Introduction

The phenomenon of inattention blindness or, more formally "inattentional blindness" as coined by psychologists Arien Mack and Irvin Rock (1998) has been examined by scientists for over 30 years. It is the phenomenon of not being able to see things that are in plain sight (Mack & Rock, 1998). To study inattention blindness in the context of an art exhibition, I utilised an animation that resulted from my collaboration with Michael E. Goldberg, Director of the Mahoney Centre for Brain and Behavior, Columbia University, NYC. My study involved two components: observing if viewers watching an animation in a gallery could be distracted from noticing that the animation also included the disappearance of stolen museum antiquities (the targets) by the overlaid flashing images of a card game (the distractors) and then observing whether repetition of the depicted targets throughout the gallery installation could facilitate an attention-switch that allowed viewers to perceive the targets not initially noted in the animation when re-viewing it again. The reasoning was that the informal "learning" taking place through contextual cueing might cause viewers to recognise the overlooked targets, thereby supporting my premise that art can serve as an *attentional* training ground.

While examining the phenomenon and pathology of *attention*, I became especially interested in the boundary between normality and pathology. The cognitive problem of ADHD often includes distraction, but part of the controversy over its diagnosis involves determining whether its symptoms fall within the bounds of normal perception and behaviour. Showing the animation within the experimental context of a gallery setting provided a way for "normal" viewers to experience a common failure of perception along with an opportunity to reflect upon this experience. The project raised the following four questions: What does *attention* make possible? Can *attention* be shifted? Does art training help prevent distraction? Can art train *attention*? My findings showed that, after viewing the entire installation and then re-viewing the animation, 64% of the viewers who did not initially remark on the targets in the animation were then able to see them. I have used the term "remark" rather than "see" because it is possible that pre-attentive viewing had occurred but had not yet been brought to conscious awareness. In this chapter I discuss the implications of these results with regard to the research premise that certain artworks can provide new insights about *attention*.

2 Discussion of inattention blindness

Inattention blindness, also known as perceptual blindness, is related to other phenomena, such as the attentional blink (discussed in chapter one) and "change blindness" (the inability of our visual system to detect alterations to details of our visual field that the brain has not yet stored). Inattention blindness has been related to visual neglect where patients with intact visual fields typically fail to respond to stimuli presented on the side of space contralateral to their lesion (Kinsbourne, 1987, 2006). However, neglect does not mean there has been a sensory loss (Humphreys, 2000). Inattention and change blindness have also been described as disruptions that occur between a physical stimulus in the external world and its associated percept. Neuroscientists accomplish the rupture by inserting a blank screen or "flicker", a "blink," by slowing the rate of change, or by the use of diverters like "mudsplashes", and the disruption can be caused by varieties of tools, including stereoscopes, visual masking (i.e., the reduction of the visibility of one brief stimulus by the presentation of a second brief stimulus, called the "mask") and dichoptic methods (i.e., each eye views a separate and independent field as in the work by Garvey in chapter one). Using dynamic visual displays, a series of studies of inattention blindness were conducted in the 1970s and 1980s. Observers were asked to report on a task; during the assigned tasks in these studies an unexpected event was staged to occur that was unobserved by most viewers. The results of these studies caused neuroscientists to conclude that people only remember those objects that receive their focused *attention.*

Other factors play a role in inattention blindness; cultural bias regarding what is noticed is, in itself, a whole area worthy of study as are pre-attentive processes. Repeated trials appear to make a difference with respect to perception. Vision scientists Vera Maljkovic and Ken Nakayama (1994) reported that in search for a singleton target (a target with a unique feature), when the unique feature varies randomly from trial to trial, the deployment of focal visual *attention* is faster when the target feature is the same as in past trials than when it is different, a phenomenon called priming of popout. (Note that the term, popout, as used here differs from its use as commonly-used popout ads on the internet.) Performance was also enhanced when the target occupied the same spatial position on consecutive trials (Maljkovic & Nakayama, 1996). Clearly advertisers rely on the phenomenon of subliminal priming. However, psychologists Anne Treisman and Brett DeSchepper (1996) found that ignoring a distractor on one trial made it easier to ignore the same item on subsequent trials. Inattention blindness has been explored by Ulric Neisser and Robert Becklen (1975) and Mack and Rock (1998) and has been expanded upon by psychologists, Daniel J. Simons and Christopher F. Chabris (1999) among others. In the latter's well-known study, "Gorillas in our midst: sustained inattentional blindness for dynamic events", a movie sequence of a complex basketball scene was shown to observers who were directed to count the number of ball exchanges made in a ball game. During the movie, few viewers noticed that an actor dressed in a gorilla suit walked through the scene. On the basis of their results, Simons and Chabris (1999) suggested that the likelihood of noticing an unexpected object depends on the similarity of that object to other objects in the display and on the difficulty of the priming monitoring task. They further concluded that observers attend to objects and events; the spatial proximity of the critical unattended object to attended locations did not appear to influence detection.

3 The contribution of art

Some objects, artworks, and performances draw *attention* not to informational data, but instead set in motion events that may involve a qualitative transformation in the viewers. These objects can be thought of as boundary objects, which probe the way the mind works. My goal was that an installation of my artworks would function in this manner and help the viewer see something that may have been invisible in viewing the animation alone. My assumption was that art audiences will sometimes have developed special skills; frequent gallery-goers often learn to look intensely and compare artworks with those from prior experiences. The installation was designed to foster informal learning through repeating the depictions of similar objects (images of both the targets and distractors) in different media as the viewer moved through the exhibition space. An important part of an artist's training involves the ability to contrive a believable scene or event with the realisation that it entails a falsification of vision. In addition, an art student must learn how to manipulate a viewer's *attention*. These skills are not only part of an artists' training but must also be developed in rehabilitative work involving the senses (this will be discussed in the next chapter).

The design of my study was different from the scientific studies I have described (levy, 2010; 2012). As far as I am aware, art experiments are seldom conducted that have explored inattention blindness in galleries. My exhibition offered an opportunity to try to assess the influence of an aesthetic environment to promote informal learning; commercial galleries are often conditioned by trends and will rarely accommodate this kind of interest. Another advantage of a public exhibition for a psychophysical test is that serious art visitors will often be engaged in visual search and discrimination tasks**.** Although viewers are generally free to wander at will, the layout and flow through gallery spaces are often carefully crafted. Many artists and curators juxtapose specific objects and images to build a totality of relationships.

Scientists, themselves, are increasingly investigating the operations of vision under more natural conditions (Felsen & Dan, 2005). As an early example, Neisser (1982) demonstrated the value of studying animals under naturalistic conditions. More recently Wilder's team (2009) underscored the importance of studying *attention* in the context of real-world environments and examined such activities as pointing, counting, and looking. Unlike such experiments, my art installation, "Stealing Attention", constituted a far from neutral test. It referenced the 2003 US invasion of Iraq and conceivably aroused some of the strong emotions many Americans felt in being thrust into war on a false premise. The gallery exhibition broadened the parameters of objective scientific testing in that the art encouraged viewers to identify emotionally with the loss of the Iraqi heritage signified by the looting of antiquities.

4 Concept

In the animation, Stealing Attention (Levy and Goldberg, 2009), images of looted Iraqi antiquities were programmed to gradually disappear over the course of a three-minute animation, and the distraction of flashing cards made them hard to discern (Figure 18). A directive was issued at the onset of the animation to "count the number of times the Queen of Hearts appears". After one playing, viewers were questioned about what they had observed; those who did not see the targets were invited to walk around the gallery and then re-view the animation. The aim was to assess whether the repetition of images of looted objects throughout the gallery in static displays could cause the targets to become more salient and result in viewers redirecting their vision from the foreground to the background of the animation.

Figure 18: Still image from the animation by Levy and Goldberg, Stealing Attention (2009). An overlay of images of hands playing "Three-Card Monte".

The distractors in my art experiment were hands with cards that flashed rapidly and were intended to symbolise a con game of Three-Card Monte. I based some of my images in the animation and throughout the entire installation on works by Caravaggio and de la Tour that dealt with the theme of card thefts (Figure 19). These are images well known to artists and art historians. Three-Card Monte has its counterpart in Europe. Many museum-goers will also recall the mid-sixteenth century work titled The Conjurer, by Hieronymus Bosch, an analogue to Three-Card Monte**.** In it, the magician performs the shell game for a crowd in medieval Europe, while pickpockets steal the belongings of the distracted spectators.

Figure 19: Caravaggio, The Cardsharps (1594) has been removed due to Copyright restrictions.

In psychological parlance, the hand movements of the card dealer in our animation would be referred to as "distractors" intended to direct *attention* away from the "critical stimulus" or true targets (the removal of antiquities). The animation symbolically linked the Iraqi invasion and stolen antiquities with the Bush administration's own hidden objectives. In my interpretation, the administration's false claims of weapons of mass destruction were meant to distract the public from the real targets of invading Iraq and toppling Saddam Hussein. Nevertheless, I underestimated the difficulty of choosing a disappearing, partially hidden object to be the stimulus that would capture the viewer's *attention,* especially when distracted.

4.1 Methods

The audience for the exhibition included predominantly gallery and museum goers, but also scientists, students, and the general public. My study was designed as an experimental investigation, to assess the effects of contextualisation upon *attentional* shifts. Written materials accompanied the exhibition, including the title of the exhibition (Stealing Attention), signage (the names of the artworks displayed and other information), a card, and a press release, all of which provided minimal clues as to the content of the exhibition. To prompt viewers who did not initially see the targets in the animation after several viewings, I strategically placed static objects as cues in the exhibition area to re-direct *attention* to the targets when viewers returned to the animation. I asked questions loosely adapted from a 2003 study conducted by the Isabella Stewart Gardner Museum and Institute for Learning Innovation Institute to determine what viewers saw before and after moving through the exhibition space.[1] To a limited extent I was able to assess the involvement of people by:

- Observing how they moved through the gallery and seeing if they read signage.
- Interpreting their responses and emotions.
- Soliciting their comments on what they thought the work was about to assess if they recognised my artistic intentions.

- Identifying problem-finding activities in which they requested information or proposed a hypothesis.
- Determining if flexible thinking occurred as evidenced by a revision of what they saw.

My study was repeated in several different contexts and with a variety of formats. The animation that I designed with Goldberg was modelled after the Simon and Chabris animation, but with significant differences. The program was randomised both positionally and temporally and prevented the viewer from predicting what card would flash and where it would be located on the screen or from determining what antiquity, assuming it was perceived, would next be removed. In each cycle all nine images of the hands of Three-Card Monte players were displayed once and were taken from a pool of nine "cells" of images of hands "playing" cards. Going through one cycle of nine random positions took approximately 2.7 seconds (0.3 sec x 9). One of the nine cells showed the Queen of Hearts. It stayed on the screen for about 300 msec. The construction of the animation included the additional image of a yellow circle that preceded each appearance of the image of the Queen of Hearts with which it was temporally linked. It was on view for only a moment, thus serving as a "flicker" that further distracted the viewer from noticing the disappearing relics. Every third time the yellow circle appeared, a target disappeared from one of the three depicted shelves in the background of the animation. It took 30 cycles to go from an image of ten relics on three shelves to three empty shelves. At this point approximately 81 seconds had passed, and the program then displayed a gradually fading mound of rubble suggestive of the aftermath of the looting of the museum. The program then paused for 20 seconds before starting the next iteration. A measure of the animation's success was the fact that during the give and take of the initial design process, my collaborator did not initially notice the disappearing relics despite a career spent studying visual *attention* and his full expectation of being distracted by the animation. This allowed me to realise that even experts trained in science and art can be successfully distracted, calling for sensitivity to weighing the parameters of timing and priming. It is also important to note, however, that my collaborator saw the animation before the speed had been adjusted and as an isolated entity rather than as part of a large installation. As a result, I learned by much trial-and-error what conditions would best foster recognition of the phenomenon in the context of an art exhibition. To collect as much data as possible, I created both a gallery-situated and studio-situated experimental situation that allowed me to assess the presence of redirected viewing among a sample of participants. Data came from the following sources:

- Gallery situated: Michael Steinberg Fine Arts (NYC) during the course of the exhibition (March 19 - April 18, 2009) and Ronald Feldman Fine Arts (NYC) (May 15 - July 23, 2010).
- Studio-situated: Two art class visits (April 30, 2010 and November16, 2010) and two Art/Sci Salons (April 8, 2010 and December11, 2010).

In its first gallery viewing at Michael Steinberg Fine Arts, the animation occupied a fully lit room that contained several mixed media two-dimensional representations (Figure 20). The exhibition title and signage were intended to offer suggestive clues as to the content of the exhibition without being "give-aways". The same antiquities were depicted in these artworks as those shown within the Flash animation. These mixed-media works on wood contained figure-ground illusions and Necker illusion perspective reversals, in which the depiction alternatively recedes and juts forward. Some of the wood support was left visible, and the viewer was invited to discriminate between simulated, painted wood and real wood. The representational setting for the depicted "thefts" was the interior of a museum sometimes identified through applied lettering as the National Museum of Iraq.

Figure 20: Ellen K. Levy, Installation view of Stealing Attention (2009). Animation is on the left wall.

Upon leaving this entrance space, the visitor entered a corridor that had six artworks, each 30 x 24 inches. These consisted of a combination of real and illusory montage in which some of the forms were painted to look like montage (illusory montage). The images depicted were of hands appropriated from either Caravaggio or de la Tour paintings. They grasped looted Eastern antiquities that were partially-hidden behind playing cards (Figure 21). The partial transparency of the hands and cards was very similar to the transparency of the targets in the animation.

The corridor opened into a back room, which had several more of my artworks and into a smaller installation room that was painted black (Figure 22) and featured a single empty white shelf. Suspended just above the shelf were prints from a database of looted Iraqi objects, which had images identical to those shown in the Flash animation. If someone viewed the entire exhibition and then returned to the animation, these additional clues were designed to make it more evident that the animation showed the disappearance of stolen Iraqi antiquities. The titles of the static works also provided such cues as Conning Baghdad, Graffiti in Iraq, and Fleeced Chariot.

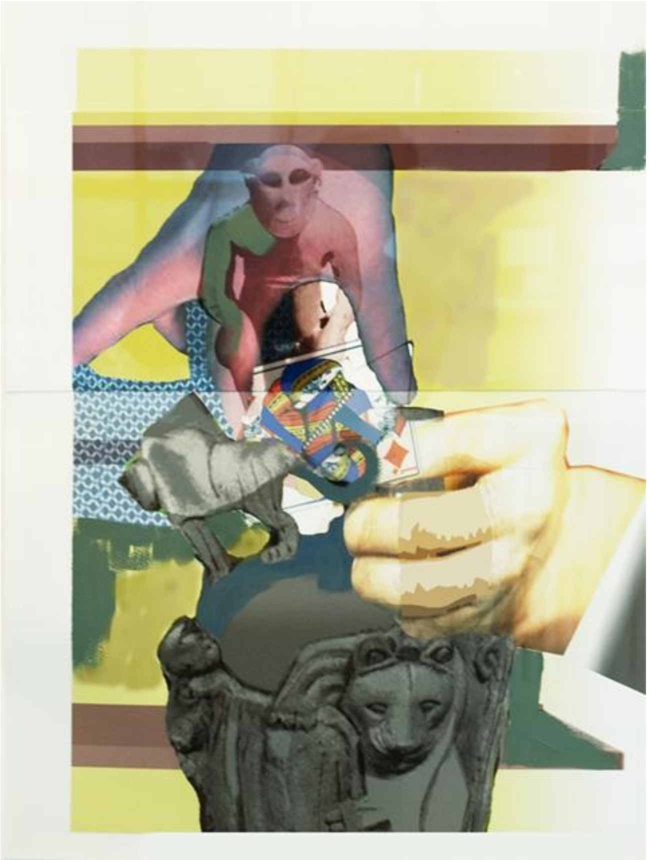

Figure 21: Ellen K. Levy, Disappearing Act (2009).

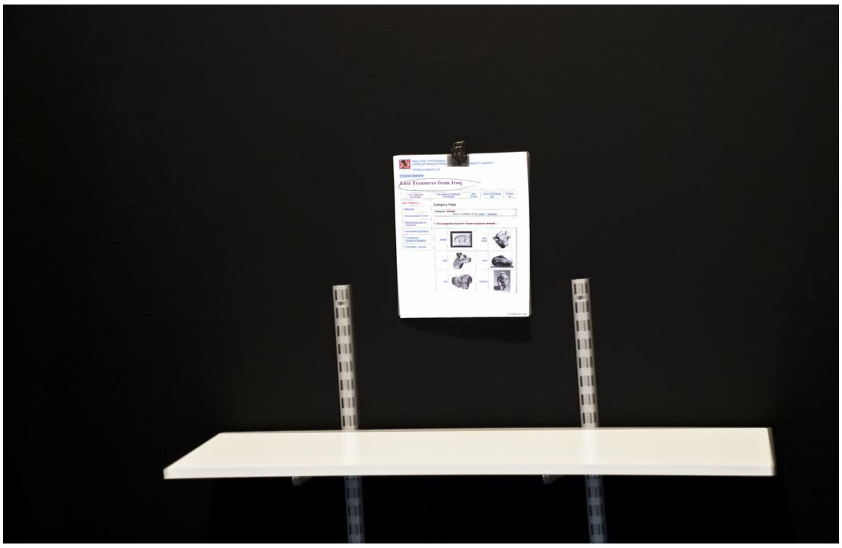

Figure 22: Ellen K. Levy, Black installation room (2009).
Prints of looted Iraqi antiquities are suspended from the shelf.

During the exhibition opening and a pre-scheduled class visit, a video camera was positioned facing out from the wall towards the viewers. Visitors were asked what they observed. I eliminated all but three of those interviewed at the opening, which, with these exceptions, did not offer a consistent testing situation. Having observed the difficulty of target detection during the opening (where there were additional distractions), I subsequently slowed the rate of the flashing hands to make target detection slightly easier.

I was able to approximate similar circumstances of viewing in my studio space to that of Michael Steinberg Fine Arts, including static artworks and database prints. This enabled me to document the responses of several different groups of visitors to my studio, including artists, historians, and musicians.

For a third display at Ronald Feldman Fine Arts, NYC, I created a multi-unit work (Figure 23). Since I did not have the entire gallery space to work with, I needed to provide more clues to the viewer within the animation. This time, instead of the header “Would you like to play Three-Card Monte?”, the text read “Would you like to play Three-Card Monte with George W. Bush?” When the image of rubble appeared at the end of each iteration, for a brief moment a subliminal message appeared that identified the scene as “The National Museum of Iraq”. Given the limited space I also needed to rely on depicted still images in one part of the three-partwork as a way to contextualise the animation. The animation was placed next to a painted collage, and both were juxtaposed with an empty shelf (over the monitor) from which prints of looted objects dangled. In this way a viewer could compare the images of missing antiquities in each of the three units and flesh out the connections between them. The viewer was therefore offered several ways of assimilating and correlating information.

Figure 23: Ellen K. Levy, Installation at Ronald Feldman Fine Art, NYC (2010).

5 Results

A total of 82 individuals, predominantly from the arts, were observed in the experiment at all three locations. More than half the participants were female; all were adults and predominantly Caucasian. Overall, 32 of these 82 (39%) remarked on the targets after their initial viewing of the animation. Of the 50 who did not initially remark on the targets, 32 (80%) did so after having seen additional visual prompts (Table 1).

During the scheduled visit of an art history class on March 28, 2009, several groups of viewers arrived at the gallery at different times. They totalled 19 viewers who consisted predominantly of art history students along with unidentified viewers who joined the groups. Since clusters of people were involved, I asked those present to indicate to me what they saw privately and not to discuss their findings aloud. Of this group, 13 of the 19 viewers did not initially see the targets (the disappearing antiquities). I asked the viewers what they saw in the animation both before they walked through the entire installation and then afterwards, while they re-viewed the animation. While people continued to watch the animation, I asked them to report on the cards and anything else they saw. Of 13 viewers, six now saw the targets. For those who still did not see the targets, I explicitly asked them to ignore the distractors; all but one viewer then saw the targets. While people walked around the exhibition, I would often ask them what they thought the work was about. I had opportunities to test the perceptions of other gallery goers in similar ways. Of 31 additional viewers to the show, 18 did not initially see the targets. Of these, ten saw the targets after moving through the exhibition and re-viewing the animation while being asked the same questions as previously. For those who still did not see the targets, when asked explicitly to ignore the distractors, all but one viewer saw the targets.

Table 1: Summary results of targets seen at 3 locations

Location	Occasion	Number of Viewers	Target Seen	Target Unseen	Target Seen on Re-viewing
Steinberg	Art class and others	19	6	13	6
Steinberg	Various	31	13	18	10
Studio	Art group	6	2	4	4
Studio	Musicians	7	2	5	4
Studio	Art/Sci	10	5	5	4
Feldman	Various	8	3	5	4
Studio	Viewer	1	1	0	0
TOTAL		**82**	**32**	**50**	**32**
PERCENTAGE SEEING TARGET			**39.0%**		**64.0%**

After the exhibition had concluded, a small art group of six people (experienced art goers) came to my studio; only two of the six initially saw the targets. Upon further viewing and walking around the studio to see the related still images, only two failed to see the targets. After being asked to disregard the hands while re-viewing the animation, all saw the targets. Another small group of seven musicians from The Juilliard School also participated. Of this group, two saw the critical targets (one almost immediately), and four succeeded in seeing them before being told to disregard the distractors. Eleven more people from two Art/Sci salons saw the experimental set-up at my studio at varied times; six of them initially saw the targets, and after further viewing, all did. There was one especially intriguing interchange. After only a single iteration one artist (viewer x) was able not only to provide the correct number of times that the Queen of Hearts appeared but was also able to see the disappearing antiquities. I asked her how she accomplished this so quickly, and she said that her art training had provided her with this ability.

I had further opportunity to test the phenomenon of inattention blindness during a group exhibition at Ronald Feldman Fine Arts that included my artwork. Of the eight viewers with whom I spoke, three saw the targets after two iterations. Four of the remaining five later saw them after several more iterations of the animation, and the fifth viewer saw them after I asked him to disregard the distractors.

I found support for my claim that art can serve as an *attentional* training ground based on the evidence that after walking around the full installation, far more than half of the viewers who had not originally been aware of the targets subsequently remarked on them when they re-viewed the animation. In addition, I had much opportunity to observe that as the participants moved around the entire installation, several voiced their awareness that a perceptual problem had been posed, identifying some of my intentions. Most responses included personal opinions and speculations, and at least ten viewers returned to the gallery over the course of the show. Touring the installation apparently encouraged some development of critical thinking skills in that some viewers were prompted to speculate how the animation and installation were linked.

5.1 Potential confounds

I could correlate my observations with the likelihood that learning (defined as “flexible thinking”) had occurred but could not make causal inferences about the effect of the repeated images on such learning, since several factors could have influenced the ability of some viewers to see the targets after first missing them.

One potential confound was interpreting the ability of viewers to remark on the target when re-viewing the animation after having seen the rest of the installation. There is the possibility of improved performance simply as a result of repeated viewing of the animation. However this explanation of the results is unlikely because viewers who initially saw the animation who did not remark on the targets generally also saw the animation several times but had not yet gone through the entire installation. Of course I could not know how much repetition would be needed for a target to attract *attention*. My understanding was that costs are involved in switching *attention*. Something else must occur to enable the perception of a target besides repeated viewing. It also seemed plausible that after failing to observe the target, repeated viewings could reinforce the blindness, which was the point that Treisman and DeShepper (1996) had made about the increased ability of viewers to ignore distractors after ignoring them once.

Another confound was that the animation was continuously playing so most viewers would have seen several iterations by the time they answered my initial question ("What do you see?"). Although I tried to direct people when to start viewing the animation, it was not always possible to control. Some viewers did not see the animation from the beginning, and, as a result, did not see the assigned task ("Count the number of times the Queen of Hearts appears!") at first viewing. In addition, questions often needed to be asked of groups of viewers rather than individuals raising the likelihood of influence from reports by others even though people were asked to speak with me later privately. Apart from those viewers who were questioned, no effort was made to control the flow of people through the exhibition space. As a result, an average viewer might have seen the animation at any point in its iteration while viewing the exhibition in its entirety.

The complexity of the large-scale works on wood might also have been a confound since these works did not offer instant recognition of the targets. For most viewers, however, the smaller works and dark-room installation with the database prints, in particular, were obvious in terms of identifying the targets.

Each of the three circumstances of viewing (the two galleries and studio installation) was somewhat different. Finally, I had no way of determining whether the visitors could apply/transfer knowledge gained about inattention blindness to other contexts. The actual risk of the experiment was that, if the clues provided to the viewer were insufficient, the viewer might remain entirely unaware of the relics disappearing and only perceive flashing hands and cards in the animation and view the animation and installation as being unrelated. At the other extreme, if viewers received too many clues, the risk was that viewers might not realise that their recognition of the existence of a fundamental perceptual problem comprised the basic content of the exhibition. The ideal situation was to enable the viewer to become suddenly and consciously aware that the relics were disappearing. To set up conditions to foster this "epiphany" proved a difficult challenge. It necessitated many preliminary trials varying the speed of the hands flashing and their degree of transparency until a successful balance had been judged to be achieved.

Finally, although not a confound, it should be noted that this was an art investigation that had no control group. As already observed, it was also difficult to control the parameters in a way that facilitated rigorous testing (e.g., starting and stopping the animation after each viewing to regulate the number of repetitions to which each viewer was exposed). In addition, such regulation would have been self-defeating as the project involved aesthetics in relation to learning. To create a minimal aesthetic condition a viewer must realise that a formal event and staging of images are intentional. It must also be recognised that the dynamics of *attention* actually structure what is perceived as relevant. To achieve these conditions, it was important to maintain the ambience of a gallery as opposed to a psychological experiment. As a result I collected information as unobtrusively as possible.

5.2 Contextual cueing of static works in Stealing Attention

Because the mixed-media paintings featured depicted images of stolen antiquities identical to those shown in the background of the animation, viewers were primed to recognise those objects. How might the repeated images have enabled viewers to shift their *attentional* set? Art historian Jonathan Crary supplied part of the answer in *Suspensions of Perception* (1999). He addressed the important issue of alternation between engagement and fatigue in *attention.* Crary's point was that that these poles of *attention* and distraction can best be understood as a continuum and that *attention* carries within it "the conditions for its own disintegration" (Crary, 1999, p. 47). But Crary also cautioned readers against viewing Cézanne's works as the results of faithfully portraying his "subjective optical impressions" (Crary, 1999, p. 301). Crary viewed Cézanne as recording *attention*, itself, during which time Cézanne's focused intensity became an embodiment of his *attentional* gaze – the countless shifts, saccades, and blinks as the scene changed before the artist. To me this insight into Cézanne's work shows the advantage that accrues to some static works like paintings. They can memorialise the eye's activities, something that could not be accomplished in the same way if the artworks were themselves in motion. In addition, still works can be contrasted and contextualised with a medium such as animation that relies on movement. There is no need to make a choice between these modes. This is why <u>Stealing Attention</u> was a multimedia exhibition, utilising a dark installation room, an animation, and collages: it attempted to offer the viewer several ways to confront and contrast information delivered both slowly and quickly.

The collage paintings reinforced the viewer's gradual realisation that perceptual issues were the subject of the installation. My process was to start by making a drawing that served as the basis for a digital print. The images in this series were generally of displays of antiquities within the setting of the National Museum of Iraq. The subsequent print was deliberately smaller than the wood on which it was mounted. A process ensued of cutting, rotating, and repositioning the print on the wood. When pulled apart, the print disrupted some of the continuity of perspective and forms (thus also disrupting the illusionism). All of the repositioning and superimposed painting created a disorienting maze of figure/ground reversals, rotations, and line displacements. The paintings visualised the circumstances under which illusion occurs and is cancelled. Perspectival illusions were also disrupted by mental attempts to piece the original units together, so these works served as another way to show the relationships between mental images and *attention*. Although the complexity of these works did not offer instant recognition of the targets, when coupled with the dark room installation and the smaller montages, sufficient clues allowed recognition of the targets. In addition, the incorporation of text within the large-scale works sometimes indicated that the National Museum of Iraq and looting were the subjects of the art. The role of the static artworks and black room installation within the exhibition was to provide "contextual cueing" as described by Chun and Jiang (1999). They also served as emotional signifiers, prompting recognition of the targets within the animation.

5.3 Conclusions of the trials

Mack and Rock (1998) pointed out that three kinds of conditions are generally involved in tests of inattention blindness: inattention, divided *attention,* and full *attention*. In my project, the trials were conducted as viewers watched the animation. The first trial was held after the viewer saw the first iteration of the animation and before viewing the entire installation. The second trial was held after subjects viewed the installation and while they re-viewed the animation. Both the first and second trials were inattention trials. The viewers were only asked to report on what they saw. During the second trial, as subjects continued to watch the animation, they were asked to observe the flashing cards and “anything else”. This was an explicit divided *attention* task since the viewers were asked to report on both the distraction and the presence of something else. The divided *attention* trial thus provided information about the subjects’ ability to see both the targets and distractors. If someone still did not see the targets, I conducted a full *attention* trial in which the subject was explicitly asked to disregard the distraction task (i.e., the flashing cards) and report only the presence of something else on the screen (e.g., the critical targets). With the full *attention* trial almost all the viewers succeeded in identifying the critical targets.

5.3.1 What does attention make possible?

Returning to the first of the four questions, I could now answer that *attention* is necessary for perception. The assigned task in the animation directed *attention* to the distractors, and more than half the viewers were effectively blind to the targets. This “blinded” group of viewers only succeeded in seeing the targets when their *attention* had been switched to the circumstances of either divided *attention* or full *attention*. Mack and Rock have made it clear that the important scientific measure is to compare reports of the critical stimulus in the inattention trial with those in the full *attention* trial because this difference indicates what is contributed by *attention*.

5.3.2 Can attention be shifted?

With regard to the second question, most viewers were engaged in a visual search task for the Queen of Hearts. The exceptions were those who disregarded the task, those who successfully divided their *attention*, and those who started viewing the animation after the counting task had been assigned and were initially unaware of the task. The assigned task guaranteed that many viewers would be looking in the general area without expecting or looking for the targets. My findings agreed with Mack and Rock’s observation that *attention* can be shifted when the viewer realises that something other than what is most visually obvious is at stake. In this case, the distractors were the most obvious thing. However, for more than half of the viewers who had not remarked on the targets at the first trial, the installation created a salient alternative: namely the disappearing antiquities. The way this switch might have occurred is discussed later in this chapter. But it seems to me that the important point was that, by viewing the installation in its entirety, many viewers recognised my artistic intention and could remark on the targets.

5.3.3 Does art training help prevent distraction?

The third question asked whether seasoned art viewers might integrate input from the animation into a framework of prior knowledge gained from their gallery or life experience and override the tendency to follow the instructions provided at the onset of the animation. Despite the fact that many viewers reading the instruction immediately started to search for the Queen of Hearts, many were able to see the targets after only a few iterations. In addition, there was evidence that a few could see both the distractors and targets simultaneously. I attributed this ability to the fact that most viewers in my survey were routine gallery-goers and had learned to encompass a whole visual field (this will be further explained later in the chapter). Other gallery-goers reported that they had difficulty tracking the cards and stopped counting them altogether. However, this did not seem to impact on their ability to see or not see the background targets. A similar result was reported by Simon and Chabris. My collaborator, who showed the animation to a group of physiology students and colleagues at Columbia (before it had been adjusted for speed and without benefit of any of the contextualisation of the animation), noted that most of his viewers saw only the flashing hands and cards. This difference of response between the scientists (at the laboratory) and artists (at the gallery) is suggestive of the difference in training between these groups, but it is inconclusive since the animation shown was not identical. More importantly, the viewers at Columbia would have had no way to identify my artistic intentions without the contextualisation from static images. For future studies it would be of interest to see how sound such as glass breaking and of rifles firing might instead serve to contextualise the images of antiquities.

5.3.4 Can art train attention?

Finally, with respect to the fourth and last question**,** the results indicated that artworks have the potential to redirect *attention* and thus switch a viewer’s “*attention*-set”. At the least, most viewers expressed awareness that a perceptual problem had been staged, and a few noted that their *attention* was being manipulated. My results therefore answered the question affirmatively that art offers a training ground for *attention*. Furthermore I concluded that *attention* can be trained by art, assuming that subjects engage with the artworks. Nevertheless, I must qualify my conclusions somewhat because of the lack of a control group, occasional difficulties of recording data at the time the tests were taken, inability to simultaneously control test parameters and maintain an aesthetic setting, the need to speak with groups on occasion, and the lack of fully consistent circumstances of viewing.

6 Art training

Posner and Rothbart (2007) suggested that we view learning as exercise for the brain, which might strengthen the neural circuits involved with memory work and *attention*. The basic idea about *attention* training is that the repeated activation of *attentional* networks through such training will increase their efficiency. Posner and Rothbart stated that early researchers dismissed the idea of *attention* training because they had concluded that training is domain-specific and cannot be more broadly applied to the general training of the mind. The example provided was mathematics, which was not believed to involve transferable properties. However, Posner and Rothbart demonstrated that *attention* is an exception to being domain-specific and that *attention* training can, in fact, be transferred to other areas of the brain. They claimed that “Attention involves specific brain mechanisms, as we have seen, but its function is to influence the operation of other brain networks”

(Posner & Rothbart, 2007, p. 13). Posner and his team found that art strengthened executive attention (2008). The presumption is that subjects utilise the same neural circuits while engaging with art that they would during formal *attention* training. Posner and Brenda Patoine (2009) posited that arts education offers transferable benefits to *attention* and general cognition. In addition, several studies have shown cognitive improvement with engagement in video games (Basak et al., 2008; Boot et al., 2008), suggesting that artworks involved with gaming may share similar advantages.

While many scientists might agree that *attention* can be trained, it has not been clear how art might actually train *attention*. Howard Gardner (1983) noted that individuals can have multiple intelligences such as visual-spatial thinking, which is a skill enjoyed by many art professionals. Hein and Alexander (1998) provided plausible evidence that people learn in museum environments. In the 1980s and 1990s, arts educators insisted on justifying arts education by reference to what could be transferred from the arts to other "more basic" school subjects (Fiske, 1999). By now several educational studies have suggested that art can train *attention*. Several examples out of many stem from cognitive psychologist Abigail Housen's visual thinking strategies (Housen & Yenawine, 2000a, 2000b, 2001; Rice & Yenawine, 2002) and from a paper that she cites given at the Minneapolis Public Schools Colloquy (Housen, 2002) and from the Isabella Stuart Gardner Museum's study program (2003-2007)[2] in which the Gardner Museum partnered with the Institute for Learning Innovation to test whether museum going would improve learning skills (Adams et al., 2006). Margaret Burchenal and Michelle Grohe at the Gardner Musum received a US Department of Education grant for three years to study the impact of a multi-visit program on two schools with which they have partnered for many years (Burchenal & Grohe, 2007). Reports from these studies claimed that art promoted critical thinking skills. The Gardner Museum study summarised that "Their intention was to document critical thinking skills and also to watch the impact of their program on test scores. The fact that the researchers found no positive trend in scores did not diminish the clear evidence of the changes in thinking, not seen in control students" (Burchenal et al., 2008, p. 3). The RAND Corporation also conducted an extensive study about the instrumental benefits of art education, concluding that the arts provided numerous learning skills and cognitive benefits. Specifically the study claimed that ". . . "doing" art provides a particularly effective way to develop the personal skills that are critical not only to becoming an effective learner, but to behavioural change as well . . . . the ability to translate attitudes and intentions into behaviour is tied to the development of such personal skills as the ability to understand the consequences of one's actions, the ability to plan to achieve a desired goal, and self-discipline and self-regulation" (McCarthy et al., 2004, p. 27). Other notable studies that assessed the benefits and transferability of skills of arts education included a pilot study called *Artful Citizenship* (Curva et al., 2005), a Solomon R. Guggenheim report, *Teaching Literacy Through Art,* managed by Randi Korn & Associates, Inc. (2007), and a report carried out by Harvard Project Zero, called "Investigating the Educational Impact and Potential of the Museum of Modern Art's Visual Thinking Curriculum, (Tishman et al, 1999, 2002). Nearly all such studies emphasised the importance of sustained engagement with the art as critical to its ability to promote aspects of learning.

Developmental psychologists Lois Hetland and Ellen Winner challenged instrumental claims that study of the arts can lead to improvement in standardised achievement tests (Winner & Hetland, 2000). Their scepticism does not, however, negate other possible benefits of art with regard to learning. They pointed out, "Indeed, we concluded that before further research on transfer from the arts to academic achievement could responsibly be conducted, two prior research steps were needed: (1) studies to uncover what is taught in arts classes; (2) studies to uncover whether what is taught is learned" (Hetland & Winner, 2008: 1). In *Studio Thinking* (2006), Winner and her team identified eight habits of mind that art training could foster, including "the dispositions to observe, envision, express, reflect, stretch and explore, engage and persist, develop craft, and understand the art world". Winner's approach was pragmatic, stating (2007),

> "To justify the arts in this way is to assume that the arts teach no important thinking skills in their own right. Arnheim warned of this in *Visual Thinking* (1969) when he wrote "The arts are neglected because they are based on perception, and perception is disdained because it is not assumed to involve thought" (p. 3). But, according to Arnheim (1969), "the arts are the most powerful means of strengthening the perceptual component without which productive thinking is impossible in any field of endeavor" (p. 3)" (Winner, 2007, p. 27).

Winner also pointed out that there is a long history of art being grounded in cognition as evidenced by both Rudolf Arnheim (1969) and Nelson Goodman (1976). The kinds of skills that Winner identified as promoted by art have included experimentation, problem solving, and observation. She also noted that Arnheim's concern was that visual literacy should be developed in many contexts besides art. However Winner also observed that, since this is a skill only taught in art studios, this is probably the only chance children have to develop this skill. It seems to me that, as in my own art experiment, Stealing Attention, galleries and museums can also play a greater role in developing such skills. Commercial interests would appear to minimise the likelihood of such developments. As mentioned previously, there is another factor involved; a scientific study with strict experimental parameters and controls would have destroyed an atmosphere of aesthetic contemplation, and this state was an important component of my project.

6.1 The role of aesthetics

As Kant pointed out over a century ago, the aesthetic object offers viewers a way to experience pleasure through the "quickening" of their "cognitive faculties". This process involves engaging cognitive powers without an ulterior aim (Kant, 1892). According to the philosopher Per Aage Brandt, "aesthetic quality is the mode in which the viewer's *attention* is made to travel effortlessly between the contents of two mental spaces, the presentation space and the reference space" (Brandt, 2006, p. 182). Brandt then described how a momentary polarization of *attention* can appear between a presentation and a reference that "triggers an acute awareness both of the sensory forms of things and of their emotional meaning. . . ." As philosophers and artists (notably Picasso) have frequently pointed out, in order to get to a truth that is invisible, art must falsify vision in some sense. Philosopher Brian Massumi has observed (2003) that “The artist must falsify vision in just the right way to produce a viable connection to what cannot be seen” (Massumi, 2003, p. 11).

For my study of inattention blindness, I sought a balance between the sometimes conflicted goals of creating a moving work of art versus designing an effective experiment. Despite these conflicts, what artists can provide to the study of *attention* are ways to design situations where self-discovery on the part of the viewer might suddenly occur as the viewer registers a moment of surprised recognition of something significant that was previously missed.

As was seen earlier in this chapter, Caravaggio, de laTour, and Cézanne created paintings of card cheats and players, establishing networks of glances as well as examples of distracted vision. Art historian Michael Fried has long been involved in issues of *attention* within the context of formalism (1980, 2007, 2008). According to Fried, Chardin’s work The House of Cards singled-out “the telling juxtaposition of two playing cards in the partly open drawer in the near foreground” (2007). Fried noted that in the depicted open drawer in The House of Cards, which marks the plane closest to us, the Jack of Hearts is fully facing the viewer and open to his or her gaze. Fried pointed out that this is in contrast to the second card, which is hidden. He then concluded that Chardin’s intentionality is made apparent by his creation of the fiction of a card that is hidden to the depicted figures in the artwork and responsible for the work’s meaning. The intentionality that Fried prized in Chardin is signified by the fact that in Chardin’s work, a posed, painted actor looks like he is oblivious to the hidden card and to our viewing of him (Figure 24). As Fried has emphasised, we, the viewers, must accept what we know cannot actually be the case, since the likelihood is that this painting, like others of that period, was made from a posed model well aware of the card placement.

Figure 24: Jean-Baptiste-Siméon Chardin, The House of Cards (ca. 1737) has been removed due to Copyright restrictions.
Oil on canvas, 82.2 x 66 cm (32 3/8 x 26 inches), National Gallery of Art, Washington, Andrew W. Mellon Collection.

Although Fried does not specifically mention the concept of inattention blindness, I suggest that what Chardin staged within the painting was the simulation of its occurrence. This painting can be viewed as an early demonstration of how artists have been trained to manipulate the viewer's *attention*.

6.2 Cognitive tests and art tests

I suggest that just as cognitive examinations can test for flexibility, so can artworks. One of the tests used to help determine whether an individual has ADHD is the Wisconsin Card Sorting Test, a neuropsychological test of "set-shifting" (Figure 25). Stimulus cards that contain shapes of different colours, amounts, and designs are presented to the subject. The person administering the test asks the subject to match the cards by colour, design or quantity. To accomplish this, the participant is then given a stack of additional cards and asked to match each one to one of the stimulus cards, thereby forming separate piles of cards for each. The matching rules are changed unpredictably during the course of the test, and the time taken for the participant to learn the new rules and the mistakes made during this learning process are analysed to arrive at a score. The test is considered to measure the flexibility in being able to shift mental sets, and it also assesses perseveration and abstract (categorical) thinking. It has thus been considered a measure of executive function.

Figure 25: Wisconsin Card Sorting Test (Dehaene and Changeux, 1999) has been removed due to Copyright restrictions.

The patient who has a frontal lobe deficit lacks a "supervisory attentive" system. When that patient takes the Wisconsin Sorting Card Test, he or she does not become aware of the changes in the examiner's strategy and will perseverate, repeating the same mistakes (Changeux, 1999; Dehaene & Changeux, 1999). Significantly, Changeux has compared the difficulty held by such patients to their inability to intuit the intentionality of an artwork. He stated that "It would appear then that the frontal cortex intervenes both in the genesis of hypotheses and in the elaboration of critical judgment, both faculties being essential for viewing a painting, as we have seen" (Changeux, 1994, p. 192). In this way Changeux made explicit the generally unrecognised ability of an artwork to test the viewer's mental flexibility. I suggest that Changeux's summary further validates the interest among neurophysiologists in examining artworks. In addition, since the neural circuits for testing the *attentional* system may overlap with some of the neural circuits involved in training *attention*, my assumption is that flexible learning might also be fostered by the test.

7 Switching attention

Attentional selection has been distinguished as either goal-directed (top-down) or stimulus-directed (bottom-up) (Lamy & Bar-Anan, 2008). Top-down selection, a volitional act, is an executive function of experience and expectations. It is an endogenous control of *attention* that refers to the ability of the observer's goals or intentions to determine which areas, attributes, or objects are selected for further visual processing. By contrast, bottom-up or exogenous control refers to the capacity of certain stimulus properties to attract *attention*. Bottom-up attentiveness originates with the stimulus and is almost impossible to ignore. Neuroscientist Charles Connor and his team speculated that a complex dynamic interplay occurs between bottom-up and top-down *attention* that determines our awareness (Connor et al., 2004). This issue remains controversial (Theeuwes, 2004). More recent research has focused on the relative contributions of these two sources of guidance and investigated the extent to which the *attentional* set adopted by the observer can control which objects in the visual field receive *attentional* priority. In the absence of any particular intention, stimuli we happen to encounter evoke tendencies to perform tasks that are habitually associated with them.

Neuroscientists have contended that the cognitive task we perform at each moment results from a complex interplay of deliberate intentions that are governed by goals and the availability and frequency of the alternative tasks afforded by the stimulus. What happens when we switch tasks? In task switching experiments, responses to the same set of stimuli differ depending on the goals of the individual at any point in time (Monsell, 2003). What is known is that a switch from one task to another brings about increased response times and increased errors.

As confirmed by psychologists Catherine M. Arrington and Gordon D. Logan in discussing “switch costs”, “. . . voluntary task switching requires subjects to choose the task to be performed on a given trial and thus ensures that a top-down act of control is involved in task switching. The voluntary task switching procedure inverts the usual question in task switching experiments. Instead of asking whether switch costs reflect a top-down act of control, it asks whether a top-down act of control produces switch costs” (Arrington & Logan, 2005, p. 683). These researchers concluded that switch-costs are incurred, determining that top-down accounts typically focused “on the processes that enabled a new configuration of subordinate processes (or task set). The enabling processes may involve updating goals in working memory . . . or adjusting *attentional* biases and priorities suggesting that the extra endogenous act of control that occurs on switch trials can be initiated, and at least partially carried out, prior to the onset of the target stimulus” (Arrington & Logan, 2005, p. 684). Task switching has been found to take place under the circumstances of divided *attention* and also when viewers are instructed to ignore the task in favour of another. However, even voluntary (top-down) choices appear to be influenced by bottom-up factors.

The way in which this information pertains to my art experiment is that, in Stealing Attention, a task was assigned to the viewer. This made it likely that the uninitiated viewer would initially utilise top-down guidance in following the instructions. As documented, those viewers interviewed who did not initially remark on the relics disappearing (around 60%) were generally able to identify the disappearing antiquities after they viewed the entire installation and repeatedly viewed the animation. How did they accomplish an apparent switch in *attention*? My hypothesis is that priming had enabled the viewers to identify the targets in the animation. It also seems that one could account for the new ability of viewers to see the targets by top-down mechanisms, or by combinations of both top-down and bottom-up mechanisms. If top-down, the viewers would now actively seek out those images of targets in the animation that were identical to those in the installation. If a combination, the salience of the targets would now have attracted the viewer’s *attention* through priming.

It seems highly significant that some *attention* switches can be volitional, raising the issue of free will (Yeung, 2010). As was noted in chapter one in the discussion about binocular rivalry, the two eyes view dissimilar patterns, and perceptual dominance alternates between each monocular view. It is known that, although *attentional* shifts are associated with perceptual reversals during binocular rivalry, subjects could nevertheless be pre-trained to fix continuously in order to suppress the gaze shifts found in observers who did not receive instruction (Kleinschmidt et al., 1998).

7.1 Models of inattention blindness

Computational models of inattention blindness have tried to account for the many possibilities involved. The Block computational model of an *attention* capture framework as discussed by Gu et al. (2005, p. 183) relies on the cooperation of an internally-driven top-down setting and external bottom-up input. The *attentional* set consists of a pool of task prominent properties that are maintained in memory. At any given moment only one object has a coherence map that can receive focused *attention*, and it is designated as the most compelling. This then drives a viewer's gaze (Figure 26).

Figure 26: Block diagram has been removed due to Copyright restrictions.
Computational framework of capturing *attention*.

The "Contingent-Capture Hypothesis" relies on filters (Gu et al., 2005, p. 185). The premise of the model is that the *attentional* set held by the subject determines when an object receives *attention*. A transient orienting response to the object must occur before an object can be considered for *attention*. This approach therefore explains why the likelihood of noticing an unexpected object increases with the object's similarity to the currently attended object (Figure 27).

Figure 27: Workflow of three filters has been removed due to Copyright restrictions.
This figure demonstrates how three filters work to determine different habituation and capacity.

The first filter involved in this model is the sensory conspicuity filter, which discards an object that is not physically salient enough to catch *attention*. As a result there is no conscious awareness of it. Even if the object is sufficiently salient and has many properties that matched the *attentional* set, it can still be discarded due to the capacity bottleneck. The last filter is a semantic one and is fully processed in conscious perception. To me this model suggests why the signage in the gallery may have helped shift the viewers' *attention* to the targets.

7.2 Other implications of inattention blindness

According to philosopher Alva Noë, work on change blindness and inattentional blindness in the psychology of scene perception has provoked a new scepticism as evidenced by belief in "the grand illusion", which claims that the richness of our visual world is an illusion (Noë, 2002b). Noë has pointed out that failure to notice change is a pervasive feature of our visual lives. Many of those who have investigated change blindness support the grand illusion hypothesis that the richness and presence of the world are illusions. O'Regan and Noë pointed out that we are sometimes perceptually aware of unattended detail (amodal perception). They repeated Koenderink's example of our perception of solidity when experiencing a tomato as three-dimensional and round, even though you only see its facing side (O'Regan & Noë, 2001a). According to O'Regan and Noë, mastering sensorimotor contingencies generates our conscious visual experiences. Noë concluded that the sensorimotor account can explain experience not represented in our brains (Noë, 2002a, 2002b). These considerations are important to artists who tend to embed abstract concepts in the sensuality of the world.

Stanislas Dehaene and Jean-Pierre Changeux (2005) also developed a neuronal model for inattention blindness. Their simulations demonstrated how the "global workspace" establishes a central processing bottleneck such that, in the presence of two competing stimuli, processing of the first temporarily blocks high-level processing of the second. They explained that a key hypothesis of the workspace model is that workspace neurons are “the seat of a permanent spontaneous activity that creates a succession of active internal states”. These circuits act to restrict access in many circumstances. Their model takes into account a neuromodulatory substance that causes the network to exhibit a surge of activation, involving synchronised gamma-band oscillations of increasing amplitude. They proposed that this corresponds to the state of vigilance or being awake and have also proposed a second state transition, involving a temporary increase in synchronised firing. This state of activity competes with sensory processing, leading to an extinction of sensory processing that they believe may account for the phenomenon of inattention blindness. They also suggested that temporary blocking can occur with spontaneous trains of thought, unrelated to external stimuli and instructions. Dehaene and Changeux concluded (2005, p. 0921) that “studies, obtained in diverse paradigms including masking, binocular rivalry, change blindness, the *attentional* blink, and perceptual hysteresis all suggest that the onset of conscious perception is associated with a sudden coactivation of parietal and frontal areas, often including the anterior cingulate”. Their model included various loops that assist and modify the sorting decisions along with a “reasoning” process, consisting of an auto-evaluation loop.

8 Implications for learning

In my interpretation, the auto-evaluation loop in Dehaene and Changeux’s model of inattention blindness is similar to the viewers’ ability to reflect on what they have seen, thereby understanding the intentionality of the art. In other words, viewing art can bring about a state of critical post-reflection, which, along with experience and development, is considered to be necessary for transformational learning in adults (Merriam & Caffarella, 1999). Transformative learning involves the meaning one makes of one’s life and is considered to involve a change of perspective. Adults clearly draw upon a greater wealth of life experience than is available to children, and the kind of education that takes place needs to be distinguished from children’s learning.

In order for learning to occur, children and adults need to gain control over the focus of their *attention*. This permits them to attend to more information, switch their focus of *attention* as needed, and inhibit *attention* to distracting, irrelevant information. These factors in turn play a role in the development of working memory (Conway et al., 2001). Psychologists have investigated learning and memory by dividing it into categories such as nonassociative and associative (Thompson, 1986). An example of nonassociative learning is habituation, which often involves a single event. For example, driving a car requires less *attention* than when first learning to drive. By contrast, associative learning involves the conjunction of several events and is divided into Pavlovian conditioning (e.g., the ringing of a bell is associated with food) and instrumental conditioning (e.g., pressing a lever to obtain food). Classic psychological studies have determined that the amygdala complex impacts on the amount of *attention* an object receives; it assigns an emotional salience (significance) to objects or events through associative learning (Pauli et al., 2008).

Much evidence shows that emotion impacts the *attentional* system (Bonifacci et al., 2008). Researchers Michela Gallagher and Peter C. Holland (1994) provided evidence that a subsystem within the amygdala provides a coordinated regulation of *attentional* processes. This is pertinent to my study of inattention blindness because the cues that were supplied by the full installation were not neutral ones but ones that referenced the war in Iraq and the destruction of a cultural heritage. I suggest that those viewers who made the associations between the targets and what they represented would have "learned" to associate the targets with the war and be more likely to recognise the targets when they returned to the animation. In other words, this learned association would have given a charged significance to the target and impacted the *attentional* system. As discussed in chapter one of this dissertation, Posner has shown that different operations within the *attention* networks are responsible for such activities as disengaging *attention*, shifting *attention*, and engaging a selective focus of *attention*. Routes of neuroanatomical connectivity between the amygdala and other brain systems allow some regulation over the *attentional* system (Gallagher & Holland, 1994). The role that emotion plays in regulating *attention* (and "capturing" *attention* through arousal) can and has been traditionally capitalised upon by educators, performers, and by artists. To summarise, greater learning occurs with engagement with salient examples and associations.

Art students exercise a great deal of *attentional* control at every stage of art making, particularly with respect to making use of emotional salience. According to neuroscientist, Rebecca J. Compton, two stages are involved in the processing of emotional information. The first stage involves preattentive evaluation by a subcortical circuit involving the amygdala, and the second involves competition among stimuli for emotion priority. Both top-down (from frontal lobe regions involved in goal setting) and bottom-up influences (from the amygdala) are involved (Compton, 2003). To me this suggests why scientific studies of inattention blindness might profit by adapting artworks that have emotional impact upon viewers for some of their experimental designs. In addition, artworks may offer clues to the understanding of how emotional salience can best be used to motivate learning. As noted by Taylor and Fragopanagos (2005, p. 356), "Independence of any brain processes from attentional resources is deemed as the defining condition for automaticity". Art is demanding of attention and therefore helps insure that a participant does not go on auto-pilot. This sets up a condition which is essential for learning.

8.1 Constraints

Art students must learn to work within *attentional* constraints, developing flexibility in the process. Many scientists have sought to identify the "computational constraints" (Marr, 1982) that govern cognitive performance. One of the constraints involves modularity, which proposes that there are self-contained areas in the brain that store mental processes such as the "lower level" reflexes. As a rule, in cognitive psychology literature, discussions about modularity have presupposed that a system is unaffected by top down (*attentional*) influences (Fodor, 1983).

One of the problems that Barbara Stafford noted (2007) was that much work of the brain involves automatic processes and, as a result, selective *attention* is but a small proportion of our vision. The automatic processes are carried out by modular units, consistent with Fodor's concept of the modularity of vision in 1983. In fact, modularity would seem to prevent the brain from any contact with an external world unless there was a way to allow for top-down modulation by neurons that had access to the outside environment, including cultural factors and interpretive faculties. Barrett and Kurzban (2006) proposed a reconciliation of the diversity of views about modularity by framing the issue in terms of "functional specialization" instead of automaticity and encapsulation. They pointed out that the encapsulation which was part of the modularity theory originally advanced by Fodor and then by Marr precluded the modules (visual elements like line and shape) being influenced by outside information. Rollins stated that strict modularity like that proposed by Fodor must be false and "even if a subsystem is informationally encapsulated, with regard to its own internal operation, it can still be harnessed together with other subsystems to produce a distinct perceptual strategy" (2001, p. 25). Brain plasticity itself would seem to argue about strict encapsulation (Buller & Hardcastle, 2000, p. 311).

Churchland et al. (1994) have questioned a strictly hierarchical, modular, input-output theory of seeing, which raises the possibility of influence from high level to lower modular levels. McMahon distinguishes between two kinds of visual processing. The fine grain (strongly modular) involves the processing of the elements themselves such as shape from movement while the coarse grain (weakly modular) can be influenced by expectation and cultural learning. According to this theory, only coarse-grain processing reflects influence by interaction with the physical properties of the world (McMahon, 2003). McMahon stated that these distinctions correspond to Willats's distinction between secondary and primary geometry (1997). McMahon suggests that they might explain how so many variations of art can satisfy their appearance in nature when the artists are all looking at the same elements. Such theories provide a possible explanation of how learned expectations and memory can play a role in determining what we see.

McMahon's theory of "Perceptual Style" proposes that each kind of approach (e.g., linear, volumetric, textural) will bring about a particular modular recognition in the brain. Modularity is an important part of Semir Zeki's discussion in *Inner Vision* (Zeki, 1999). Of course, this kind of perception fractures an object into multiple parts, and artists may use various strategies to capitalise on the ruptures. In McMahon's view (2003), when normal perception occurs, our *attention* is generally drawn to the literal meaning of a work. But if the work exploits particular strategies, it can draw our *attention* to focus on the phenomena themselves. This conceivably offered an explanation of why many viewers can understand artistic intentions in exhibitions. In my study of inattention blindness, by exploiting the conflicts inherent in *attention*-switching, the animation allowed viewers to experience the phenomenon directly and then be able to reflect upon it.

These theories of perception might prompt one to ask how the brain is made efficient, given the constraints of vision. By one account, the brain relies on "externalist" strategies such as using features of the environment in order to limit the reliance on internal systems in the brain. For example, O'Regan (1992) and

Mark Rollins (2004) have independently suggested that the world, itself, can be used as an external memory. Rollins (2005) considered the fact that interactions across systems are mediated by higher order, polysensory neurons. He allowed that cross-modal effects (e.g., sights and sounds) could also limit the reliance on internal representations.

8.2 The gaze

The term "bottleneck" is often associated with *attention*, emphasising the physical limits of *attention*. What is the actual nature of this limit? Does it involve shape at all (like a physical constraint)? If so, exactly what is constrained? According to Posner the concept of constraint is a highly disputed idea about *attentional* function (Posner, 2010). Some do not believe in any physical limit but just various forms of interference. I elected to make a work about inattention blindness because it is a phenomenon that reflects constraints on our *attentional* system that everyone experiences but of which few are aware. My experience in staging it was also filled with many constraints, not just those experienced by viewers, but the limits of space and time during the various exhibitions. What became evident is that all learning proceeds within constraints. This forces prioritising to take place if an action is to be performed. It is also important to consider the constraints caused by our ways of formulating *attentional* disorders (explored in chapters four and five). For example, does gaze avoidance in children indicate the distractibility of ADHD or do some children simply find it easier to concentrate this way? The question was posed by Doherty-Sneddon et al. (2009) who found that children diagnosed with Williams syndrome (it shares some symptoms with ADHD) are apparently unaffected by the overload associated with prolonged eye contact and can seemingly stare forever.

The control of the gaze is a consequence of learning the "probabilistic" structure of the environment (Droll et al., 2007). Most individuals learn how to direct their gaze to advantage, and this is particularly fostered in circumstances of viewing art. Through making art one learns to look and to guide the *attention* of others. For example, a subject is often instructed where to focus *attention* and expect a visual cue. Wise et al. concluded (1988, p. 736) that *attention* controls access to memory and prompts behavioural responses. People scan the surfaces of objects with their gaze, and visual *attention* is typically accompanied by a succession of fixations and saccadic eye movements (Baldassi et al., 2004).

In 1986, vision specialist Douglas Marschalek noted (1986) that, because the useful *attentional* field surrounding the centre of the fixation is fairly limited, the eyes must move in order to gain information about objects in the environment. The duration of a fixation is very short, ranging from about one tenth of a second to about one and one half seconds, and saccades are characterised by direction, pattern, sequence, and frequency (Marschalek, 1986). Fixations represent points of *attention*, where the fovea is directed and held stationary over a specific position on a visual scene. At this time stimulus input is processed in detail. Saccades, by contrast, denote rapid movements between fixations, which shift the fovea from one point of interest to another. It is possible to attend to different peripheral objects while maintaining eye fixation (an example of covert *attention*), but evidence suggests that eye movements tend to induce concurrent shifts of *attention*. Although there is a clear relationship between shifts of *attention* and eye movements, as early as 1912, psychologist Wilhelm Wundt speculated about the possibility of shifting *attention* without eye movements, separating the fixation-point of *attention* and the fixation-point of the field of vision (Wundt, 1912, pp. 19-20). Posner (1980) showed that it is possible to displace the general correlation between fovea and *attention*, which occurs because of normally high demands for high acuity. *Attention* shifts actually occur prior to eye movements towards a particular event. Based on single cell recording, the team of Goldberg and Wurtz showed (1972) that the superior colliculus fired prior to the occurrence of eye movements. Posner has likened this relationship to that existing between the eye and hand. These physiological systems are distinct even though they appear coordinated.

Eye-tracking technology can provide a precise measurement of overt *attention*, which comprises the muscular movements that orient an organism to access information selectively from the environment. The covert processes that selectively bias the neural processing of particular streams of information are not measured by eye-tracking (Blair et al., 2009, p. 331). Since human visual resolution declines when the fovea is not directed to objects of interest, the direction of the eyes is a good indicator of what is considered to be important. Key work was conducted on eye-tracking by Yarbus (1965) who showed that the trajectories followed by the gaze depend upon the task that the observer has to perform (see chapter one). He led the way for scientists to study the gaze, often relying on the viewing of paintings. It is by now well-accepted that fixation points determined relevant to viewers are influenced by the task assigned, and gaze positions will change accordingly (Yarbus, 1965).

The gaze now sometimes serves as a starting point for artists to explore "looking", itself. In conjunction with the Wasily Kandinsky exhibition at the Solomon R. Guggenheim Museum in NYC (September 18, 2009 – January 13, 2010), an accompanying forum took place at the City of the University of New York (CUNY).[3] The discussions centred on eye-tracking and the video made by filmmaker Grahame Weinbren, who was commissioned to make a video of how people actually look at Kandinsky's paintings. The result was Kandinsky: A Close Look, a three-part film in which each segment (Essay, Eyetracking, and Synesthesia) focused on a different work from the exhibition (Weinbren, 2009) (Figure 28).

Figure 28: Eyetracking Forum in conjunction with Guggenheim Kandinsky exhibition (2009) has been removed due to Copyright restrictions.
Video playback technology of a full scale print of Kandinsky's Small Pleasures (1913).

The three parts explored different ways of looking at the work of Kandinsky. Weinbren made the film with the technical assistance of Kenneth J. Ciuffreda and George A. Zikos, both vision scientists. In one part of the film, Small Pleasures (the second painting), Weinbren contrasted the viewing patterns (through eye-tracking) of experienced Kandinsky viewers with that of an inexperienced Kandinsky viewer (a Korean artist and confirmed art viewer and not naïve as identified). The viewers were tasked to look at the Kandinsky print for three minutes while their chins rested on stands, preventing the subjects from moving in relation to the picture. A fixed camera system was used, and the eyes were illuminated by infra-red sensors and captured as video-base. The centre of the pupil showed a reflection of light off the cornea (Figure 29). As the eye moved the pupil moved and the reflection of the cornea moved. This relationship allowed the eyes to be tracked while a camera focused on the point-of-regard (the point on the retina at which the rays coming from an object regarded directly are focused).

Figure 29: Eye-tracking has been removed due to Copyright restrictions.
The centre of the pupil is located and a single light reflects from the cornea. The relationship of these two lets us know where the eye is looking.

The direction of eye movements was accurately recorded through monitoring of the gaze direction via infrared light reflecting off the dominant cornea and pupil. Parallel cognitive processes use parafoveal and peripheral retinal information to establish the location of the next fixation. Overall external features of the stimulus, in conjunction with inner concepts, also shape the “scanpath” pattern. Fixation *attention* is thus dictated by a combination of top-down cognitive factors, such as expectations, goals, and memory, as well as specific bottom-up processes, involving visual sensory input.

Ciuffreda noted (2009) that the scanpaths of the selected viewers were similar in all cases. Their gazes were drawn to the hill areas just above and to the left of the centre where they fixated. He commented that those who had an internal cognitive model generally made fewer fixations and stated that to separate top-down from bottom-up approaches, a time period must be limited to 10 seconds or less. He confirmed that top-down viewing tends to involve categories of objects; we confirm our cognitive knowledge and make eye sequences accordingly. The fact that many scan similarly, with similar fixation patterns, may indicate that they are applying such a cognitive model. By contrast, with bottom-up approaches, art acts as a stimulus that drives the oculo-motor movement. Ciuffreda allowed (as was previously noted in this chapter) that combinations of top-down and bottom-up approaches could also be possible. In general, when one looks at an artwork he or she makes saccades, and the fovea sees fine detail. Ciuffreda suggested that documenting how doctors look at X-rays with a possible diagnosis in mind could be instructive and used for training the gaze.

Vision research has demonstrated that stereotypical patterns of scanning and fixation exist although “different people may attend to the same picture in different ways, and the same person will attend to different pictures in different ways” (Noton & Stark, 1971a, 1971b; Rollins, 2004). Evidence has supported the view that, as people age, they become more efficient in scanning. In addition, young children may view non-objective art in a different manner from representational art. Scientific research suggests that particular areas of a representational picture are recipients of *attention* regardless of the age (above age six) and training of the individual (Marschalek, 1986). When viewing representational art, individuals trained and untrained in the visual arts and school aged children exhibit similar viewing patterns (Marschalek, 1986). A later study concluded that “formal art training results in a global recognition of the pictorial structures involved along with narrative concerns. *Attention* is shifted away from local feature analysis and information gathering” (Nodine et.al., 1993, p. 227). Research also indicates that people tend to look at something, i.e., semantic information tends to influence fixation more than visual information (Henderson and Hollingworth, 1998

In Weinbren’s film the fact that repeated cycles of eye movements were made to the same areas by the viewers indicated that they were attracted to the same salient features of the painting regardless of their prior experience. Eye-tracking Kandinsky’s Small Pleasures showed that, for four viewers, although the centre of the canvas and some representational images received preferential viewing, most other parts were also scanned. Artist Jeong-Seok Park started in the centre but then explored different features. Simon also explored the centre but did not gaze to the edge often, while Julian Lethbridge and Karole Vail (an expert on Kandinsky) gazed over the entire surface. The viewing patterns also seemed to reinforce the fact that vision takes advantage of constraints on *attention* and memory. Since when viewers looked at Kandinsky paintings, the eyes returned again and again to the same fixation points, the implication is that viewers did not commit the picture to memory but relied on *attention* and some minimal internal "representations" (Ballard et al., 1997). Unlike my animation, Stealing Attention, which assigned the viewer a specific counting task thus immediately guiding the viewer's *attention* from top-down, Weinbren's eye-tracking was cued by a generalised task – simply to view the Kandinsky painting. This would have likely led to a bottom-up approach in which stand-out features attracted the eye. This assumption was supported by the fact that all three viewers returned repeatedly to an area that contained more dense figurative content than other areas (at roughly above and to the left of centre).

An area of potential debate was raised by art historian Caroline Jones during the discussion. She pointed out that psychoanalyst Anton Ehrenzhweig (1971) had developed a theory that "de-differentiated" viewing was a mark of creativity as opposed to "gestalt-based" viewing proposed by Gestalt theorists such as Rudolf Arnheim and Ernst Gombrich that singled out one particular area of a visual field at the expense of others (Jones, 1996, p. 325). Piaget and Inhelder (1967; 1971) had advanced the term "syncretistic vision" as a distinctive feature of children's art, explaining that syncretism involves the idea of looking at a field without differentiation (such as seeing the figure at the expense of the ground). Ehrenzweig championed this approach to creativity, stating (1962, p. 1010) that no single act of *attention* can take in the whole of the visual field, but the mark of good art was to be able to create a work in which every detail was viewed as part of the overall structure. Findings have suggested that highly creative individuals deploy their *attention* in a diffuse rather than a focused manner (Ansburg & Hill, 2003). Ehrenzweig concluded that grasping the picture as an indivisible whole is accomplished by a scattering of focus and serves the vital purpose of aiding survival in the real world. According to Ehrenzweig, this de-differentiated viewing would also allow us to see the two profiles of Rubin's vases simultaneously (Figure 30) although he had no way of proving this at the time. Ehrenzweig also described low level vision as syncretic, meaning as a form of vision that can ignore the distinctions between figure and ground. The idea was that a viewer can be receptive and take in a mass of concrete detail without needing to consciously identify it. Another word for this visual talent is flexibility. This explanation is suggestive of why one artist in my study was so quickly able to see the targets and distractors simultaneously. It also explains how the training that artists receive is essential to developing such flexibility, which I also believed to be a significant reason why some regular art-goers could see both targets and distractors in my own experiment. Artists are generally trained to understand that the relatively low-information, repetitive grounds that often set off figures of higher information in two-dimensional artworks are critical visually and psychologically to achieving a satisfactory aesthetic effect. They anticipate that the repetitive units that constitute a ground will build a rhythmic visual crescendo and set off a figure at intervals.

Figure 30: Rubin's Vase illusion has been removed due to Copyright restrictions.

The associated discussion touched indirectly upon the two issues raised at the onset of this chapter: (1) whether *attention* can be trained and (2) the implications for art using scientific tools contributing to scientific knowledge. The stated aim of the Guggenheim Museum curatorial staff was to provide viewers with knowledge of some of the enhanced visual tools used by medical researchers in order to augment their journey through the exhibition. I viewed the film as an excellent way to consider the implications for art contributing to scientific knowledge, in part because the artists involved were using some of the same tools used by vision scientists. Nevertheless, what remained unclear at the eye-tracking forum was exactly how Weibren's film might lend insight to vision science apart from the more typical function of art offering a subject and subjects (viewers) for analysis. It was evident that the scientists and film-maker used different approaches; Ciuffreda asked the same questions of subjects unlike Weinbren, who tended to ask questions spontaneously. There was no explicit control group, such as viewers altogether unfamiliar with artworks. The Guggenheim curatorial staff informally addressed the question of whether *attention* could be trained by encouraging people to return to the Kandinsky exhibition after they had viewed Weinbren's film and to ask themselves whether they saw more perceptively as a result. Despite the absence of measurable outcomes, Weinbren's film and the related symposium were solid contributions to trans-disciplinary research. The film's approach constituted a significant public development in encouraging diverse art and science communities to pool their expertise on these important topics.

9 Conclusions

Accumulated evidence has shown that *attention* can be trained and redeployed when the viewer is made to realise that something other than what is most visually obvious is at stake. This realisation was frequently linked to the viewer's ability to recognise the artist's intentionality. The additional question asked in this chapter and answered affirmatively was whether art can serve as an *attentional* training ground. Scientists have recently explored how the *attentional* system is tractable to both learning and emotion. This chapter also looked at issues of associative learning and how emotional salience can influence *attention*. My findings were that the *attentional* set could be changed by some viewers by careful looking and reflection upon the targets depicted in various settings. The fact that so many viewers could re-direct their *attention* to locate the target after going through the entire gallery installation was, to me, suggestive that learning had taken place; they could now compare the images of the targets they had viewed in static displays to the targets in the Flash animation. This ability to learn new information made it possible for viewers to switch their *attention*. I concluded that art enhances mental flexibility and the viewer's ability to identify the underlying content of an artwork.

This chapter also discussed other art experiments that explored "looking" under natural circumstances as opposed to laboratory conditions. During the eye-tracking of Kandinsky's painting, free-rein was allowed viewers since the point of the study was to examine each viewer's path of *attention*. As people viewed the Kandinsky painting during the free-scanning task, the pathways of saccade sequences could not be known in advance. The results showed that the viewers selected for the eye-tracking project tended to scan and fix on detailed passages in the work in similar ways. The task I initiated in Stealing Attention was somewhat different in that a counting task was assigned in order to divert viewers from seeing the target. Part of my experiment involved the ability of viewers to disregard this task based on contextual cues and on their familiarity with art.

Several artworks discussed in this chapter attempted to integrate scientific and artistic elements in an integral, "aesthetic" way that included the recognition of an artist's intentionality. This helped to invest the art with interpretive value and emotional salience. Although there is increasingly methodological overlap between some scientific and artistic tests of *attention*, artworks invariably stresses the social and metaphoric dimensions, calling forth memories and associations that might lead to a more impassioned response on the part of the viewer. Images assume an emotional resonance, which is quite different from traditional cognitive science, which deemphasises emotion, motivation, and context (Kenrick, 2001). Much art can be justly characterised by (1) a refusal to compartmentalise feelings from cognition and (2) assigning high value to subjective experience and social and political context. These are issues of increasing importance to neuroscience since they offer a window to understand how experience relies upon specific memories, especially when summarised as models of cognition. The processes involved with *attention* are not just conceptual but physical, resulting from knowledge that comes from handling material, directing the gaze, and living in the world. *Attention* cannot be owned by a single discipline like science since it is essential to most others, particularly art.

It seems to me that by reverse logic the Wisconsin Card Sorting Card test supports the hypothesis that art has potential to train *attention*. This test identifies precisely those features some individuals do not have – the ability to discriminate among categories and identify artistic intentionality. These are the very qualities that might be promoted during engagement with art. After all, as Winner, Fried, and my own experience with testing inattention blindness have suggested in this chapter, through promoting discrimination and identification, art offers a potentially valuable training system for *attention* skills.

Endnotes

1 http://www.gardnermuseum.org/education/research

2 http://www.gardnermuseum.org/education/tta/tta.html

3 http://www.youtube.com/watch?v=VN7gVg7EWug

CHAPTER 3: Embodied Art and Perceptual Recalibration

1 Introduction

The main goals of this chapter are to explore how art experiments focused on the body can help train *attention*, how technology can extend the parameters of such testing, and how artist-designers can use *attention* to assist the therapeutic needs of users. Most of the art in this chapter explores the response to information issuing from the body, such as proprioceptive, kinaesthetic, and vestibular signals. One question asked is how one might cope with reduced or compromised vision. I analyse *attention* in relation to the tasks of orienting oneself in space, separating interior from exterior perceptions, and processing information from different sense modalities. Some of the art uses technology to shift the participant's relationship with the outside environment. Technology, itself, can change this relationship; typically an alteration of the sense of the body's boundaries will occur (e.g., parking a car makes us aware of the amount of surrounding space available for the task, an avatar in a video game may displace our sense of self-location). Art using technology in this way can augment recognition involving the body's interfaces and recalibrations, bringing these adjustments to conscious recognition. The latter part of this chapter explores some of the work of two artist-designers who utilise *attention* for therapeutic purposes. In one case this is accomplished by recruiting *attention* as a distraction from pain. In the other, *attention* and feedback are used as ways to help foster sensory substitution. The ways in which the artists approach these goals may complement scientific studies of *attention*, a main consideration for this thesis. The training of *attention*, itself, is viewed critically within the framework of the body and its extension through new technologies.

2 The kinds of attentional learning offered by art

The growing ability to quantify emotional states has helped to foster their examination by cognitive scientists; other subjective "qualia" like our relationship to the awareness of our own bodies are similarly undergoing scientific scrutiny. The increased scientific capability to explore what had previously been a black box may help to make some of the artwork discussed in this chapter very pertinent to neuroscience. In his book, *The Hand: How Its Use Shapes the Brain, Language, and Human Culture* (1998), neuroscientist Frank R. Wilson concluded that artists are invaluable to the processes of re-learning and self-awareness, starting with traditional tasks of eye and hand coordination. In addition Wilson pointed out that many artists attend to the way the body moves and constructs frames of bodily reference. Artists today often enlist multimodal communication, and others are trained to develop kinaesthetic skills. All these tasks have their counterparts in scientific research.

A kind of basic teaching (in the sense of furthering the understanding) has always been accomplished by art, often in tandem with developing technologies. Multiple modalities are often used in learning situations because they have proved to be a way to retain interest and facilitate the process of learning (Kress & Jewett, 2001). Art historian Martin Jay has questioned the generally monolithic view of Cartesian perspectivalism, reiterating William Mills Ivins's observation that viewers of Renaissance art had to learn to make perceptual judgments involving multiple perspective systems and readings of depth. Even then artworks explored and trained other senses. Jay demonstrated the simultaneous existence of other "scopic regimes" that challenged purely ocular accounts of the world (Jay, 1988, p. 17). He considered Buci-Glucksmann's account in 1986 that Baroque art appeals to a viewer's haptic sense. In addition, Svetlana Alpers (1983) has pointed out that a tradition of Northern seventeenth century Dutch art rendered the textures of the surfaces in paintings, appealing to touch. These art historical examples support the kind of somatic knowledge that artworks have typically "embodied". This viewpoint agrees with that of Thomas J. Csordas (2002) who claims that modes of *attention* are somatic and the process of attending is a bodily activity. Participants now interacting with artworks that employ immersive and interactive technologies may be encouraged to adjust to new perceptual circumstances by recalibrating their senses. Viewed in this way, the function of art becomes adaptive. To the extent that the participant is made aware of the recalibration, new modes of understanding the world may open up. I have suggested throughout the thesis that some of these artistic approaches to the *attentional* system and new findings in neuroscience will be mutually reinforcing. This chapter explores works exemplifying these valuable interconnections.

3 Hand and eye coordination

Neuroscience has identified a range of adjustments as integral to our daily experience of an embodied self; they include coordinating multisensory perception, vestibular perception, and mental imagery (Leggenhager et al., 2007). Our sense of how this unity is achieved has changed. For example, multisensory integration appears in brain areas that were once considered unimodal (Foxe et al., 2002; Hurley & Noë, 2003). In addition, the sense of spatial unity between the self and the body can be disrupted. The space near the body (peripersonal space) has proven to be particularly critical.

3.1 The space near the body and the hand

With the realisation that animals need to experience the visual effects of their own motions in order to perform accurate reaching movements, perception and action should be viewed as integrated (Reed et al., 2006, 2010). Tactile tasks appear to recruit cortical regions that are active during corresponding visual tasks (Prather et al., 2004). Areas that were once considered to process only sensory information like posterior parietal areas have been found to play a major role in motor control. It appears that premotor and parietal areas are neurally integrated. They control more than motor action, also constructing an integrated representation of the objects acted on and the locations toward which actions are directed by *attention* (Gallese et al., 1996; Rizzolatti et al., 2001).

Neurophysiologists Michael Graziano and Charles Gross (1994, 1996) demonstrated in immobilised, anesthetised animals that bimodal visual-tactile neurons found in the frontal lobe, the parietal lobe, and the putamen respond not only to somaesthetic stimuli at the body part but also to visual stimuli near the body part and may facilitate movement near the body. Unlike visual fields in the occipital cortex, these visual fields have a three-dimensional component as they ignore distant stimuli. Graziano and Gross proposed that combined visual and tactile representations are based on the body part that is closest to the stimulus and that these representations aid in object manipulation. In general bimodal neuronal populations respond differentially to visual stimuli presented near the hand. They encode space on the basis of hand-centred coordinate systems, not in retinal- or head-centred coordinates. Unlike other cells that respond exclusively to visual stimuli, the visual receptive fields of these neurons are not stationary but instead actually move with the hand so long as the hand remains within view. Graziano et al. (1999) later showed that neurons in the premotor cortex integrate not only visual but also auditory information about the location of objects within peripersonal space.

Continuing the tradition of Wilson’s book of relaying the importance of the hand in human evolution, Vernon Mountcastle (2005) also wrote an influential book, *The Sensory Hand,* about the grasping hand and its centrality to how we define ourselves, offering an account of somaesthesis. Gross & Ghazanfar (2006, p. 1314) pointed out that haptic-visual interactions should not just be thought of as an adaptive by-product of blindness. Instead, since the extrastriate visual cortex is often activated by tactile object recognition, one can actually think of the haptic sense or touch as a substitute for vision. It has been established that even pointing a hand to an object will direct *attention* to specific regions of peripersonal space. Scientific findings have underscored that events occurring near the hand are attended to differently than more distant objects so that the appropriate action – either grasping or defence movements – can be performed (Reed, 2006, p. 175). As Catherine L. Reed et al. stated (2006, p. 166), “the importance of objects in peripersonal space is that you can grasp them – and they can grasp you!”

Gross was among the first to recognise that the space around the hand is clearly different from other regions of bodily space. He personally relayed the importance of this accidental discovery to me, explaining that when first starting out in his field, as he left his laboratory he casually waved at the monkey still immobilised within the equipment. He was surprised to note that the neurons in the inferior temporal cortex of the macaque immediately spiked in response, indicating a strong neuronal response to his waving hand (Gross et al., 1969, p. 1305). Gross later found that even images of hands evoked *attention* from the macaque (Figure 31).

Gaining this additional information allowed me to realise that my choice of images of hands playing Three-Card Monte in my own art experiment in the last chapter was actually a far from neutral selection with respect to the mechanism of inattention blindness. Findings from neuroscience have repeatedly shown that the area surrounding the hands is privileged and constitutes a form of salience, thus exerting an inordinate pull on the viewer’s *attentional* system.

Figure 31: Figures used in experiments with monkeys (Gross et al., 1972) has been removed due to Copyright restrictions.
Examples of shapes used to stimulate an inferior temporal cortex neuron having very complex trigger features. The hand shadow shapes triggered strongest responses.

3.2 Topographic mapping

It has been known since Helmholtz that perceptual experience is affected by the motor system (Block, 2005). The importance of topographical maps in the motor system is that they provide an efficient mechanism for sensory motor transformations. In humans, multimodal neurons in the superior colliculus respond to visual, auditory, and tactile stimuli. Patricia S. Churchland explained with respect to the superior colliculus that "The topmost level is retinotopic and the bottommost layer appears to be a motor map. When a given location on the motor map is stimulated, the eyes move so as to foveate the location that is the receptive field for the cell in the retinotopic map perpendicular to the stimulated motor cell. This enables the eyes to foveate quickly on targets discerned in peripheral vision, a sort of visual grasp reflex" (Churchland, 1989, p. 120) (Figure 32). The sensory map is aligned with the motor map and generates saccadic (i.e., rapid and ballistic) eye movements when attention shifts (Schiller, 1984). The close topological distribution of the cells of visual and tactile fields facilitates their acting in tandem on the attentional system.

Researchers have suggested that the "premotor area, parietal region, and putamen form an interconnected, multimodal integration system coding peripersonal space centred on body parts" (Reed et al., 2006, p. 167). As a result, the hand modulates the allotment of *attention* to either prioritise space or shifting locations. These observations provide an insight into why the arts have always instinctively emphasised the importance of eye and hand coordination. Artists are likely to find the actual description of the mechanisms involved to be an inspiring affirmation of their beliefs; in turn evolutionary biologists may be confirmed in viewing art as having adaptive value.

Figure 32: Eye and hand-coordination (Churchland, 1989: 443) has been removed due to Copyright restrictions.
Joint eye position is registered in the upper map at a unique intersection. A signal is conveyed down to the motor map. Activity is then conducted out both of the intersecting motor fibers, with the result that each arm joint assumes an angle appropriate to the fiber containing the signal.

3.3 The body and technology

Perception and hand manipulation are recognised as central to our ways of being in the world, and phenomenology, rejecting a Cartesian separation between body and mind, reinstated the importance of the dimension of corporeality and embodied experience. After elaborating on historical theories of phenomenology from Heidegger to Merleau-Ponty, Paul Dourish (known for his work at the intersection of computer science and the social sciences) created a working definition of embodiment as “the common way in which we encounter physical and social reality in the everyday world. Embodied phenomena are ones we encounter directly rather than abstractly” (Dourish, 2001, p. 100). Dourish took great care to establish that embodiment has a participative and intentional aspect rather than being a physical quality alone. He viewed it as the relationship between action and meaning. Conceptualised in this way, our *attentional* system can be thought of as embodied since, to be effective in the world, we require our spatial *attention* system to coordinate visual and bodily information (Reed et al., 2010, p. 236).

Dourish’s definition of embodiment expanded as he grappled with how technology has altered these relationships to include, for example, human-computer interactions (HCI). He then arrived at the following definition: “Embodied Interaction is the creation, manipulation, and sharing of meaning through engaged interaction with artifacts” (Dourish, 2001, p. 126). For example, using a reference from philosopher Michael Polanyi of a person using a walking stick to find her way in a dark environment (Polanyi, 1975), Dourish pointed out that *attention* is transferred to the distal phenomenon (e.g., the barrier probed by the stick) even though action is local. These and other examples demonstrate that the adjustments in our bodies have implications for our prospective actions.

To advance the argument that art serves as an *attentional* training ground, I explore how some art both with and without extensive technology has created an awareness of embodiment in the participant. Some of the art has fostered recognition of physical senses such as proprioception and tactility. Later in the chapter, I examine how some of the individuals working with technologies such as human computer interfaces and virtual reality have utilised *attention* as a resource for healing.

3.4 The body as a source of shared attention

As ethnologist N.J. Enfield stated, "It is possible to view all of culture's visual products as cognitive artifacts, tools at the perceptual interface between individual cognising minds and the social world they collectively construct and inhabit" (Enfield, 2005, p. 73). He pointed out that if paper and pencils are not available, hands and gestures will sometimes substitute, making the link between gesture and drawing. This insight has been available to art students from their earliest encounter with Vitruvian Man. Leonardo daVinci's drawing of 1487 visualised the body as the basis for measurement. It underscored one of art's most cherished tenets: namely that all abstraction is grounded in our body (Figure 33).

Figure 33: Leonardo daVinci, Vitruvian Man (1487) has been removed due to Copyright restrictions.

Enfield viewed the body, itself, as a "cognitive artifact" claiming ". . . the body is a visuospatial representational resource not to be overlooked. . ." (Enfield, 2005, p. 51). He itemised how hand gestures, bodily positioning and gaze create non-verbal communications that can be visualised through diagrams oriented to engage and guide the *attention* of others. Pointing and tracing gestures have been employed to construct virtual diagrams. Such pointing is fully in keeping with Tomasello's ideas of the kind of shared communication made possible by directed *attention* (Tomasello et al., 2005) and recent theories of the social brain (Johnson, 2007). According to semiotician C.S. Peirce (1932), the hand gestures which accompany speech differ from language in more ways than a change of modality; they are more iconic and indexical than symbolic, indicating the direct relationship to the body. Measurements related to the body often determine how we construct our prosthetic devices and technological artifacts. Obvious examples are that door handles and electrical outlets are placed at appropriate heights – heights that are modified for the aged and disabled. Figure 34 depicts a virtual diagram that illustrates gestures made by a non-Western man with three brothers (Enfield, 2003, p. 32). Such body language and pointing are physical in nature and universally understood. The speaker has used the nodes depicted in the diagram as targets for pointing gestures while referring to his other brothers who are mapped onto those locations. The vertical dimension represents relative age (i.e., the older individual is higher), and the spacing of siblings along the lateral dimension represents their "side-by-side" status as heads of new lines of descent. A complex map is formed by the hand gestures combining lateral and vertical dimensions in space by which means the speaker differentiates visually between siblings. The result is an uneven diagonal line. Enfield (Enfield, 2003, p. 66) observed that such pointing gestures are made over time and constitute a "technology of conversation" as identified by sociologist Harvey Sacks (1984).

Figure 34: Hand gestures as language has been removed due to Copyright restrictions.
Non-Western family relationships represented on a diagonal line in gesture space (Enfield, Figure 11, 2005).

This hand language was meant to elicit an appropriate response from the listener, forming a communication network. Although not the same, it could be conceived as a forerunner of what has developed into media interactivity in that both rely on acts of shared *attention* to establish a basis of communication. For example, the gestures just described can be viewed as presaging research scientist Andrew Lippman's mapping of dialogs in his own model of interactivity (Brand, 1988). According to Stewart Brand, Lippman's model was designed within the context of computer art with rules to govern how the system responds to user interaction although a distinction was made between lectures and conversations in describing the kind of interactivity desired. The idea was that the user and artwork interacted and affected each other in turn to form a loop. This "feedback loop" was considered to make an integral whole of a dynamic system, involving the observer, artist, and artwork in shaping an interactive environment (Ascott, 2003, pp. 110-111). Although there are many differences between the hand mapping and the interactivity described by Lippman, both are rooted in ideas of shared *attention*, cultural learning, and intention-reading.

3.5 Disrupting eye and hand coordination

The hand language described by Enfield is also very much related to the basic act of drawing as a gesture in space. Artists sometimes deliberately place obstacles to carrying out fundamental processes of hand coordination in order to force them to conscious awareness. Some of these impediments have restricted sight, itself. For example, sculptor Robert Morris's self-imposed art experiment showed the difficulties involved in producing two identical sets of marks while he worked blindfolded with bare hands to create a series of drawings, Blind Time (Berger, 1989). Both his hands moved in concert during this action performance. He stated some 20 years later that he undertook them "in favor of investigations leading to revelations of a certain somatic knowledge that has nothing to do with the theorized wholeness of vision" (Morris, 1993, p. 620). He further stated that "Vision is always mediated. We always believe before we look. We always assume (theorize) a wholeness of the visual. We believe to such an extent that we do not "see" the absences. Can seeing sometimes obscure dark reason? What did Morris see with his eyes closed?" (Morris, 1993, p. 624) (Figure 35).

Figure 35: Robert Morris, Blind Time (1973) has been removed due to Copyright restrictions.

The viewer was provided with a way to understand what was involved because the legends accompanying the drawings described the procedure used to produce them and the time interval concerned. The legend in Figure 36 stated that “Working blindfolded and estimating the lapsed time the hands begin at the bottom, just to the right of estimated centre and work upward to the estimated horizontal median and then outward to the right margin. After several passes I attempt a mirror image of this on the left side. Time estimation error: -2':08"” (Morris, 1993, p. 619).

Figure 36: A detail from Blind Time (1973) has been removed due to Copyright restrictions.

How did Morris psychologically orient himself to the paper when blinded? Psychologists identify three bodily reference frames: the other-centred allocentric (also called exocentric), the hand-centred egocentric, and the body-centred egocentric. Allocentric coordinates define the location of one object relative to another; an allocentric framework often involves mentally manipulating objects from a stationary point of view. The reference point is generally independent of the subject’s orientation. It is known that prior allocentric knowledge influences kinaesthetic learning (Lafon, 2009). The egocentric frame defines the location of objects in space relative to a person’s own body axes (Stein, 1989). Data derived from mental rotation tasks have suggested that the blind depend on a combination of multiple reference frames, but that the hand-centred reference frame plays the central role (Volcic et al., 2007; Volcic & Kappers 2008). The sources of information can be visual, sensorimotor, haptic, or auditory and can be coded in several reference frames, within or between modalities. Volcic and his team (2010) confirmed that each modality encodes separate information about objects in separate reference frames. The information is shared and unified (Marks, 1978). Ultimately it is combined in a time-dependent manner (see section 4 for a discussion of mental rotation tasks). The active and, in Morris’s case, blinded actor has combined what was needed to achieve his goals.

Sensory deprivation was sought as a way to foster self-realisation, and the viewer was expected to empathise with Morris’s enactment of the changed sense of the body during the self-assigned task. Morris hired a woman who had been blind since birth to execute, under his direction, the second series of Blind Time

Drawings (Morris, 1993). By doing so, Morris suggested that he regarded his artwork as analogous to a scientific experiment in which he varied the parameters. (This is consistent with my developing a taxonomy for the thesis,) It would, after all, be expected that a person blind from birth would have established an alternate relationship to the drawing task than Morris, and Morris was interested in determining the differences.

3.6 Dual-task interference

Another example of an artist extracting information from drawing with both hands was presented by artist George Quasha (Figure 37). His "axial" drawings referred to the axis around which movement occurs while the drawing takes place. His work encompassed self-balancing but also working with hand-centred and body-centred reference frames, which are those involved in haptic spatial processing.

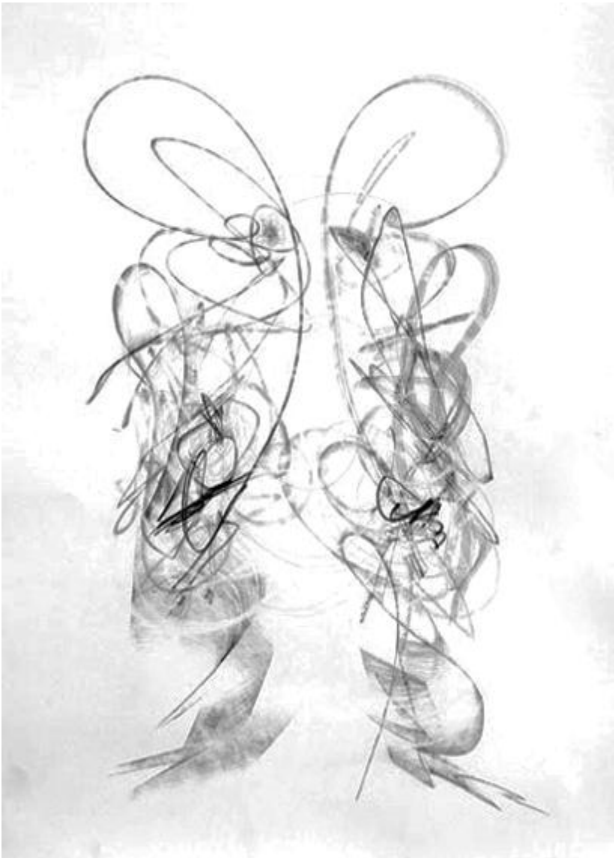

Figure 37: George Quasha, Axial Drawing 8 (2006).
Graphite drawing on paper, 18" x 24.5", Photo credit: Susan Quasha

Quasha emphasised a different aspect of this dual-hand coordination than Morris, calling *attention* to the formation of complex patterns without controllers and stressing a dynamic unfolding. In Quasha's own words on his website, "The action of the hands is of course synchronous in the sense of two hands drawing simultaneously. But they go apparently separate ways, handling different aspects of a unified field. The drawing embodies the integrity of the emergent field, which like certain complex formations by flocking birds look totally "together" but are never the same twice. I study these movements and can feel the "body" of the field. When a wave moving toward the shore hits a reef, it splits and goes separate ways, but these ways never lose contact with the "mother force" of the body of water that keeps them subtly united. I've watched this for long periods, and it helped me understand tai ji and to find that integrity in my own body. The drawing is one result" (Quasha, 2011). It may be pertinent to note that related experiments have taken place in music. For example, the composer Karlheinz Stockhausen composed the polyphonic structure of Himmelfart (Ascension, 2004-05) for organ (or synthesiser) in such a way that the left and right hands of the player would always be played in different tempi (Moritz, 2007).

As the drawings of Morris and Quasha verify, it is almost impossible to perform two tasks simultaneously without one being favoured or emphasised; preferential *attention* to one side typically results. Generally one finds interference in drawing performance when the two hands perform incongruent motions even after extensive practice (Albert & Ivry, 2009). The latter scientific team determined that the primary source of interference must occur in the translation of cues into movement, which involves a single lateralised brain region. In this regard it is notable to consider that one of the few tasks that split-brain patients (epileptics whose disease was treated by having the corpus callosum severed) can succeed in accomplishing relative to others is to draw different things with the right and left hand simultaneously (Gazzaniga, 2000, p. 1299). In other words, conflicting motor programs can be carried out by the split-brain patient because the spatial representations of movements are isolated to each hemisphere. This example offers one more instance of drawing providing important information about the brain (see chapter four). Holzman et al. observed (1984) that separated brain hemispheres do not share access to a common data base but do utilise common processing resources that are distributed between the hemispheres. They hypothesised that this might account for an absence of perceptual interference between the hemispheres, enabling split brain patients to draw separate images with each hand (Holtzman, et al., 1984, p. 380). Gazzaniga noted that processes involving *attention* are particularly complex since some kinds of *attention* are independent in separated hemispheres while others are integrated at a subcortical level (Gazzaniga, 2000, p. 1299).

It was established that lateralised hand use and sensorimotor skill in humans are linked and, further, that there is a negative relationship between these skills and the size of the motor cortex (Gross & Ghazanfar, 2006). Children diagnosed with ADHD often show spatial *attentional* deficits caused by lateralisation, exhibiting a subtle rightwards bias, possibly due to dysfunction within the right hemisphere fronto-parietal network. Approximately 50% of children with ADHD diagnoses also show signs of movement dysfunction. This became apparent when drawing tasks established that these children showed difficulties in accuracy of movement towards the right (Johnson et al., 2010). These findings perhaps also suggest that drawing might be of value in retraining children diagnosed with ADHD some of the principles of basic coordination.

4 Mental rotation tasks

Roger N. Shepard and his students, first Jacqueline Metzler and then Lynn A. Cooper, asked subjects to determine whether two drawings of differently oriented three-dimensional objects were of the same or different objects (Shepard & Metzler, 1971). This kind of task is central to evolutionary survival since, to protect oneself from a predator, one might need to recognise an attacking animal from an angle never previously seen.

Some of the stimulus figure pairs used by Shepard and Metzler (1971) are reproduced below (Figure 38). Shepard measured the response time that it took subjects to make their determinations, expecting that this might elucidate the underlying mechanisms employed by the subjects. Subjects correctly determined that most of these pairs were of the same or different objects, but what was particularly notable was that the response time was proportional to the angular separation of the two depicted objects. From this, Shepard's team concluded that subjects performed their comparisons by mentally rotating one of the two objects into the same position as the other, imagining that they could visually manipulate them as if they were external objects in real space.

Figure 38: Mental rotation studies has been removed due to Copyright restrictions. Forms used in studies (Shepard & Metzler, 1971).

Just and Carpenter (1976) argued against Shepard's interpretation. They tracked subjects' eye movements while performing a version of the Shepard and Metzler task. They argued that the linear increase in reaction time might arise instead from a need to make more eye movements between the two pictures (in order to compare their features) the more they were rotated relative to one another. Other experimental designs were subsequently used to probe the various objections raised about Shepard's conclusions.

It was found that recognition becomes increasingly difficult when stimuli are rotated away from the familiar viewpoint (Vauclair et al., 1993; Logothetis et al., 1994). Perceptual characteristics are often compared to stored representations in the process of recognising visual objects. They must first be subjected to mental transformations that reorient them in space because the objects are seen from different viewpoints by the subjects (Gautier et al., 2002). Scientists theorised that an abstraction of mental images is encoded at such a level that visual information is combined regardless of orientation. Since, in addition to vision, we relate to the surrounding world through tactile, auditory and olfactory information, mental images must also be accessible through different sensory channels. For example, an object representation built from tactile sensory messages must be reactivated through visual information.

Cohen et al. (1996) confirmed that mental rotation was akin to seeing real objects in space and engaged pre-motor areas in the brain. Cooper and Shepard found that human subjects are able to identify a visually presented hand as a left or a right hand even in the absence of extraneous correlated cues (Cooper & Shepard, 1975). This determination is seemingly made by imagining one's own preferred hand in the position of the visually presented hand and, then, by testing for a match or mismatch between the appearance of the externally presented hand and the internally transformed visual-kinaesthetic image of one's own hand. The scientists concluded; “Thus, without the brain having either to preserve or to search through a store of fixed two-dimensional templates corresponding to all possible retinal projections, the desired discrimination may be made more economically by retaining a single internal representation or “phantom” for each hand. This phantom can then be mentally maneuvered into any position, where it can serve as a sort of template for comparison against a visually presented hand” (Cooper & Shepard, 1975, p. 48) (Figure 39).

Figure 39: Mental rotation studies has been removed due to Copyright restrictions.
The four alternative hand versions that could appear as test stimuli are exhibited in the 2 x 2 array in the 0° orientation. The partial outline used to indicate only the orientation of the upcoming test stimulus is illustrated at the right (Cooper & Shepard, 1975).

Levy et al. (2004) found that many artists (e.g., Robert Smithson, Al Held, Robert Morris) had conducted experiments akin to Shepard's during the same time period as his canonical studies. During the 1960s and 1970s parallelism existed between the worlds of art and science concerning the investigation of issues of spatial orientation and ambiguity (Vitz & Glimcher, 1984). In addition, the artists then working considered highly theoretical texts regarding perception. Jones noted (1996) that Smithson, for example, was studying the work of Anton Ehrenzweig in 1967. In turn, Shepard looked at artworks, in part because they simulated aspects of seeing the real world, thereby holding a key to how perception occurs. He saw the importance of art as its being ". . . much more freewheeling than the tightly controlled experiments of psychologists . . ." (Shepard, 1990, p. 9). With respect to this thesis, Shepard offered a prime example of how art and art theory can inform experimental psychology as well as the reverse. For Shepard, the spatial sense was paramount, and it encompassed not only the visual but also the haptic and auditory senses. His goal was to understand the functioning of creativity, itself.

The experiments about mental rotation have continued, not only in science but in art, although not generally identified as such. Artworks, in particular, have explored this subject in relationship to the *attentional* system, thus expanding the scope of investigation in ways that may intrigue and communicate with the general public. The artworks to be described can help viewers consciously acknowledge routine issues of perception, and by so doing, can establish a framework for further learning. The artistic medium that is used to present concepts dealing with mental rotation necessarily plays an important role because it must have properties that allow for suitable engagement. The significance of the ability for artists to track an orientation task in real time with the technology of video is comparable to scientists having gained the ability to study the awake animal with microelectrodes. The medium of video effectively allowed artists to uncouple representations of the image from the body and see how *attention* is, itself, dynamically affected under different circumstances. For example, Joan Jonas's video <u>Left Side Right Side</u> (1972) uses the camera to explore and challenge pre-established notions of bodily orientation in real time (Figure 40)

Jonas pursued a relatively simple task. She pointed to the left or right eye of an image of herself on a video screen, and she stated "This is my left (or right) eye." The monitor first displayed her face, and then showed its reversed mirror image. The video and mirror images were then displayed next to one another and also became interchanged with each other. Disorientation arose from comparing the two images, and it became increasingly difficult for Jonas to carry out her task and for viewers to understand the orientation presented. Viewers became unsure of her location in space and their own viewing position.

Figure 40: Joan Jonas, Left Side Right Side (1972) has been removed due to Copyright restrictions.

Jonas used video and sound in Left Side Right Side (Figure 40), and we, as viewers, were implicated in the internal representations that must be constructed in an ongoing fashion as we watched. Viewers built these representations in their minds from a combination of visual and somatosensory information (Schendan & Stern, 2007), likely recruiting the same mechanisms as mental rotation tasks. As was just seen, in mental image rotation, even the simplest task, such as judging the handedness of a drawing of the human hand, required motor imagery that followed the same rules that real movement engaged. This includes compliance to biomechanical and physical constraints (De Lange et al., 2006). Watching Jonas's video entailed a constant, seemingly unconscious checking of the body axis and frames of orientation. I suggest that this artwork thus subtly trained the viewer to learn what is involved in the body's recalibrating of its own co-ordinates in space. In light of what has since been learned about the mirror neuron system (see section 5.5), it appears likely that the viewer would have mentally recreated some of the same motions made by Jonas. Peter Campus's video installation Interface created in the same year as the work by Jonas (1972) also opened up new possibilities in dealing with distinctions of right and left orientation (see supplement).

Jennifer Allora and Guillermo Calzadilla similarly shifted the body's reference frame as they staged an art experiment in which a performer played "Ode to Joy" for a prepared piano (Figure 41). A young Juilliard student stood in a hole that had been cut into the piano, playing it upside-down and inside-out. I suggest that because their performance was so visually powerful, it is likely to linger in the viewer's memory. As cognitive neuroscientist Merlin Donald has observed, "Art is aimed at a specific cognitive outcome. It is designed to engineer a state of mind in an audience . . ." (Donald, 2006, p. 7). This comment is relevant because the states of mind engineered by artists have in turn established initial conditions for certain kinds of learning (in the sense of bodily understanding) to take place.

It is not just the function of the object that has changed; the body's frame of reference has also been changed in this artwork, and the audience empathetically can share in the orientation shift elicited. The fact that the visual and motor systems are interrelated helps explain why people's subjective experiences can be made accessible to others. Embodied simulation (reconstructing a mental enactment) suggests that our thinking and viewing is never purely abstract but engages our bodily senses. The most recent development of ideas about the unity of vision and motor action is the mirror neuron system, soon to be discussed.

Figure 41: Jennifer Allora and Guillermo Calzadilla, Stop, Repair, Prepare: Variations on Ode to Joy for a Prepared Piano (2008) has been removed due to Copyright restrictions.

5 The body's boundaries

None of the examples just discussed involved elaborate technology unlike the artworks about to be explored. Simon Penny (1997) raised justifiable concerns about digital technologies embedding the value system of the engineering world view, which he identified as fundamentally reductive and deterministic. His point was that artistic skills typically refute reductive approaches and may now be endangered. Although his text underscored the value of traditional artistic skills, we do not need to choose between traditional and new media. As developed by some media artists, technology has allowed for the staging of certain situations not previously possible and some reflect a "disturbance in the representation of information about the current state of one's body – its posture, kinaesthetics and gravitational orientation" (Brugger, 2004; Brugger & Mohr, 2009. p. 137). Artist Nicole Ottiger disrupted the self-orientation involved in drawing by displacing herself as a subject through using experimental virtual reality apparatus at the Brain, Mind Institute in Lausanne, Switzerland (Figure 42). Her research as an artist involved drawing herself under conditions that manipulated the sensation of where her body was located in space by attaching it to an avatar. This "avatar" is actually a recorded image of herself from behind her back. As Ottiger explained, while she wore a set of virtual reality

(VR) goggles, her image (an external or out-of-body perspective) was projected in front of her on a virtual plane. The drawings made during this process thus became recordings of her new state of corporal awareness.

A participant's understanding of her own location in space may become modified since the seeing body may no longer appear centred. Ottiger stated on the artists-in-labs website that her goal was "to record inner images involved in the displacement of a body. A displacement is awareness and a form of self-consciousness, which I attempt to measure visually, objectively, subjectively, in a phenomenological way with the video camera and other visual media"[1]

Figure 42: Nicole Ottiger, Hangman (2006) has been removed due to Copyright restrictions.
Photo credit: Nicole Ottiger

It was established earlier in the chapter that proprioception influences the allocation of *attention* towards the hand or its movement in visual space (Jackson et al., 2010, p. 37). The source of illusion in Ottiger's work stems from conflicting sensations and a shifting perspective (Salamin et al., 2010). The two sensory modalities of vision and proprioception are generally integrated as a single percept. When discrepancy is created between them (as it is in virtual reality) participants may see their hands as being between the proprioceptively- and visually-cued location. An example is the touch on skin in conjunction with a visual stimulus. Or the two stimuli might be sound and vision. Lenggenhager et al. (2007) induced an illusion through multisensory conflict (visual, tactile, proprioceptive, and vestibular) and virtual reality that allowed participants' virtual bodies when stroked synchronously to be experienced as if they were real (Figure 43).

Figure 43: VR experiment (Lenggenhager et al., Figure 1, 2007) has been removed due to Copyright restrictions.
(A) Participant (dark blue trousers) sees his own virtual body (light blue trousers) in three dimensions through a head mounted display, standing 2 m in front of him and being stroked synchronously or asynchronously on the participant's back. In other conditions (study II), the participant sees either (B) a virtual fake body (light red trousers) or (C) a virtual noncorporeal object (light gray) being stroked synchronously or asynchronously on the back. Dark colours indicate the actual location of the physical body or object, whereas light colours represent the virtual body or object seen on the head mounted display. Illustration by M. Boyer.

Neurologist Olaf Blanke and his team have been manipulating signals of balance and limb position in order to understand how the way the body is represented in the brain can lead to understanding of the self.[2] Attending to information originating in different sensory modalities allows an individual to function optimally in the environment, and produces corresponding shifts of *attention* among the modalities (Driver & Spence, 1998). When the balance of information is disrupted or set in conflict, illusions of the body's displacement can occur. According to Ferdinand de Vignemont, "Tactile stimuli are remapped into a visual frame of reference because of the dominant role of vision in action. Thus, the spatial content of tactile sensations is not only relative to the skin, but also relative to the current disposition of the body part that has been touched, as given by vision and proprioception" (de Vignemont, 2007, p. 436).

The displacement permitted by technology can involve "autoscopic" phenomena such as body duplication and out-of-body experiences. As described by neurophysiologists Olaf Blanke and Shahar Arzy (2005), these are defined as a group of illusory visual experiences during which the subject has the impression of seeing his or her own body in extrapersonal space. The reasons may involve the integration of information pertaining to personal and extrapersonal space (Blanke & Arzy, 2005). What is at stake in these investigations is understanding the basis for the sense of a unified body.

Readers may have experienced the related "Pinocchio Illusion" (Lackner, 1988). A typical demonstration of it has involved the illusory elongation of the nose via vibration applied to the biceps tendon while subjects were touching their own nose with a finger on that arm. As a result of this conflict, subjects reported a phantom elongated nose. The hand was felt 30 cm away from the face while the sensation of contact with the nose was maintained. Apparently, the brain "filled in" the gap between the perceived hand location and the spatial position of the tip of the nose (Lackner, 1988).

The conclusions to be drawn from such demonstrations are that proprioception (either engaged directly or sometimes perceived even second-hand) integrates personal and extrapersonal space. In turn, proprioceptive cues manipulate visual *attention* (Jackson et al., 2010) and undergo recalibration in both young and older subjects (Cressman, 2010). Proprioception also integrates several types of information (e.g., homeostatic information, vestibular information, and touch) (Eilan et al., 1998). As stated in the introduction to the thesis, art experiments are pertinent to these displacements of sensory phenomena since they make them accessible and more memorable to a broader public than is typically the case in scientific experiments. A taxonomy that documents such art experiments might therefore offer neuroscientists ways in which to expand upon their own related experiments.

5.1 Technological displacement of the body

The sense of embodiment in those with prosthetic limbs has also been shown to have been shifted. The image below, After Image RD 2 by artist Alexa Wright (Figure 44), relates to current psychological research and philosophical reflections on presence and absence. Some amputees continue to sense that the missing limb is still present, and some scientists have attributed this feeling to their innate "body map". Others disown body parts that are clearly their own. In some way the boundaries of the body have been altered either through amputation or through prosthetic devices. In turn, *attention* modulates the responses to the displaced body part (Carruthers, 2009) and to the sense of oneself as a totality (Carruthers & Smith, 1996).

Unlike Nicole Ottiger, Wright did not work with advanced technology. Instead, the viewer of her photographs of amputees was made to understand the subtle body shifts induced in her photographs through empathy with the subject. In Figure 44, the amputee's hand is made to appear disjointed from the elbow stump.

Figure 44: Alexa Wright, After Image RD 2 (1997) has been removed due to Copyright restrictions.

Some viewers might associate the image with “the rubber-hand illusion”, which demonstrated that vision contributes to a sense of bodily ownership (Peelen & Downing, 2007, p. 642). The point is that the sense of ownership of the body can be altered by artificially generating so-called “intermodal matching”. To experience this illusion a normal subject is seated with one arm stretched out on a table. A screen is then placed to block the subject’s view of his or her arm and left hand. A rubber model of that hand is then placed in front of the subject who watches it as different parts of it and the subject’s hidden hand are brushed synchronously with a paint brush (Botvinick & Cohen, 1998). Subjects who have experienced the rubber-hand illusion have reported that they felt the brush touch where they saw it touch the rubber hand, not on their obscured left hand. Many subjects reported that they felt as though the rubber hand was now their own (Botvinick & Cohen, 1998, p. 756). After experiencing the illusion, subjects were blindfolded and asked to indicate the location of their hand by sliding their right hand underneath the table until it was beneath their left hand. Those who experienced the illusion typically stopped closer to the rubber hand than the controls. The spatial content of tactile sensations relies more on vision than on proprioception and touch, leading to the distortion of the sense of body location. Art can make us aware of this alteration, which might cause some viewers to investigate why this occurs. The likelihood that art may prompt such informal learning is part of my thesis premise.

5.2 Disrupting self-orientation

While all of us realise that we can manoeuver with reasonable accuracy in the absence of vision (i.e., in dark spaces), some artists have capitalised on the effects of visual deprivation. They have manipulated visual *attention* in ways that disrupt the sense of bodily orientation in space, one recent example being sculptor Anthony Gormley. He addressed the viewer's ability to self-orient in a glass room filled with a dense fog, which wiped out all visual cues. Upon entering, a subject's visibility was limited to less than two feet as he or she became immersed and disoriented in an endless ground. The grope of the subject's hand in Gormley's fog maze was palpable as it located the exterior wall of the container (Figure 45). If another fog-enshrouded visitor approached the subject with an outstretched hand, bimodal visual-tactile neurons would have responded to the stimulus approaching the subject's face even before touching it and helped to establish firm coordinates in the midst of uncertainty (Berti & Rizzolatti, 1992; Graziano & Gross, 1994).

Figure 45: Anthony Gormley, Ghost (2007) has been removed due to Copyright restrictions.

Acclimation to the surroundings can occur even in a dense fog because proprioception allows the maintenance of a sense of the position of our limbs and posture (Peelen & Downing, 2007). The orientation of our trunks and hands guide our movements (Paletta & Rome, 2007). Without visual perception, somatosensory input still contributes to our ability to sense the position of our limbs. Sound and touch, when present, also helps guide the viewer. Neuropsychologist Stephen Kosslyn has posited the existence of a spatiotopic mapping subsystem in the brain that can convert the retinotopic coordinates of the visual buffer to more stable coordinates (Kosslyn, 1999a). These coordinates are believed to assist the visual system with object identification in degraded images and to provide a reference system that is based on parts of the body or on another (allocentric) object. Such a map is postulated to help in navigation and orientation and in directing eye and body movements (Kosslyn, 1999a, p. 1284).

Gormley's artwork invites us to participate in an experience of disorientation and sense first-hand some of the influence of this map. Such work supports the premise of the thesis that art heightens our *attention* to normally unseen body recalibrations. In the last chapter I demonstrated that an animation within the experimental context of a gallery setting could provide a way for "normal" viewers to experience and reflect upon inattention blindness, which is a common failure of perception. In this chapter I similarly suggest that some of the art seen in exhibitions can foster awareness of the *attentional* system by manipulating our body's sense of its boundaries, thresholds, and spatial orientation. It can stretch one's experiential knowledge of what "normal" functioning can include by providing knowledge of the constant perceptual recalibration required in maintaining one's self-location, as in Gormley's work.

Two kinds of signals are involved in generating awareness of a body image. One is internal; corollary discharge neurons from the motor centres inform the sensory systems about incipient movements. In the case of eye muscles issuing saccades, a "corollary discharge" can be routed to both hemispheres from a subcortical location (Gazzaniga, 2000, p. 1299). One knows the intended location of one's arm because motor centres provide corollary discharge to inform sensory systems where users intend to place it. The second signal is "reafferent feedback" from receptors in the moving limb (Stein & Stoodley, 2006, p. 231). The user knows whether the arm got there because of reafference from propriocentres (Figure 46). Proprioception involves an individual's ability to perceive body segment positions and movements in space and is derived from complex somatosensory signals provided by multiple receptors in the muscles, joints, and skin. It influences the allocation of *attention* in visual space. Studies involving individuals with diminished proprioception have demonstrated that proprioceptive feedback is necessary for optimal motor performance. A lack of proprioceptive feedback from "deafferentation" leads to deficits in most aspects of motor ability (Goble & Anguera, 2010).

Figure 46: Visual and vestibular information (Goble & Anguera, 2010) has been removed due to Copyright restrictions.
The perception of one's own body in space.

5.3 Separating interior from exterior perceptions

Artist Kurt Hentschlager's 17-minute long artwork, ZEE (2009), is an immersive sensory experience composed of a loud noise audio composition coupled with background lighting and strobe lights (Figure 47). Viewers were enveloped in a cloud of thick fog denser than the one created by Gormley. As a result, they could only barely see their hands in front of their faces. Artificial fog fully obscured the physical installation space, disconnecting the subject from the exterior environment. Stroboscopic light filtered through the fog, augmenting an impression of a luminescent kinetic space, eliminating depth of field, and inducing a complete loss of spatial orientation.

The viewer experienced rapidly-changing, coloured, geometric (almost kaleidoscopic) patterns – "seen" whether the eyes were open or closed. It was impossible to distinguish whether patterns were generated from within the head or from outside. With multiple sources for the strobe lights, frequency interference patterns were generated. What the brain synthesised from this event was a kaleidoscopic, three-dimensional spatial impression, which really was not present in the space but inside the cortex. The experience proved overwhelming for some viewers, who experienced anxiety. In addition there was some concern about seizures being induced in individuals prone to photic-induced epilepsy. The artist did not know the cause of the visual effects produced despite consulting a number of neuroscientists. ZEE does, however, seem related to other kinds of subjective phenomena. Visual phenomena have been reported by individuals with migraine headaches, as phosphenes induced by eyelid pressure and as hypnopompic and hypnagogic hallucinations associated with transitional states between sleeping and wakefulness.

Figure 47: Kurt Hentschlager, ZEE (2009).
Photo credit: “Otto Saxinger & Kurt Hentschlager

For some, the flickering forms induced by ZEE were also not unlike sensations produced by hallucinogenic drugs. For others, the sense of dissolving boundaries in ZEE resembled artificially-induced synaesthesia since the patterns seemed at times to link with the sounds. However, the artist firmly disavowed such linkages stating in an E-mail to me that “the sound emerges clearly from within the outside, while the prominent part of the imagery is synthesised inside the brain, thus we have two unbalanced sensory instances incapable of creating one coherent moment”.

How might this phenomenon be explained? According to Daprati et al. (2009), perceptual and motor information are both likely involved. Both motor plans and the resulting activity must be continuously mapped on a reliable body representation (Figure 48). Nonetheless, this explanation does not consider the possibility that a paralyzed viewer lacking motor input might experience the same visual phenomena.

Figure 48: A model of the body (Daprati et al., 2009) has been removed due to Copyright restrictions. This diagram models the sense of the body in action in the parietal lobes. Conscious perception of the body in action arises from a circular, asynchronous process involving the integrated activity of *attention* and intention. This process stems from the sustained activity of two forms of internal representations, one supporting a sense of corporeal identity, as the physical basis for perception of reality in egocentric coordinates, the other a sense of acting on the environment through voluntary motor acts (Daprati et al., 2009).

5.3.1 Visual field patterns

Is there any physiological explanation for the kinds of visual patterns perceived when experiencing ZEE? In 1968 Hubel and Wiesel found evidence for a physiological columnar organisation of the striate cortex. Column-like features were also found in the prefrontal cortex and assumed to be of significance for information processing (Churchland, 1989, p. 133). Mathematicians Paul C. Bresslof and Jack D. Cowan have since theorised (2003) that the "crystalline" structure of the cortex can spontaneously produce patterns of flickering intensity, stating:

> "the spontaneous activity patterns generated in cortex are seen as hallucinatory images in the visual field, whose spatial scale is determined by the range of horizontal connections and the retino-cortical map . . . " (Bresslof & Cowan, 2003, p. 223).

In 2009, Tanya I. Baker and Cowan explored spontaneous activity patterns formed in the cortex to see if they might account for geometric visual hallucinations (Figure 49).

Figure 49: Orientation map of macaque V1 (Blasdel, Figure 1a, 1992) has been removed due to Copyright restrictions.

Figure 49 resembled patterns that I saw while watching ZEE. Corroboration of Baker and Cowan's work comes from Joshua A. Goldberg et al. (2004), who have also observed the presence of spontaneous activity in the cerebral cortex that exhibits complex spatiotemporal patterns in the absence of sensory stimuli. The team attributes these patterns to either a single background state or multiple attractor states encoding many features. It should be added, however, that I could not find any scientific corroboration for Baker and Cowan's claim that the structure of the cortex is crystalline. Art historian Mark Cheetham concluded (as I do) that positing links between the shape of the cortex and the shape of visual patterns (as Barbara Stafford does in *Echo Objects*) is scientifically unfounded but "hopeful" in the sense that the links would, if proved true, offer an exciting concordance of internal and external form (Cheetham, 2010, pp. 254-255).

5.4 Augmented reality

Artist Matthew Briand is part of the augmented reality research community. His work has also considered the impact upon the participant of shifting the usual frames of bodily reference and blurring the boundaries that separate one individual from another. He invented a haptic device that allowed a viewer to experience some aspects of another's perceptions (Figure 50). In effect the device allowed the participant to merge first and third-person perspectives. His Audio-Visual Exchange Helmets consisted of customised helmets that were outfitted with cameras and forced a participant to see what another participant was viewing. His work required active viewer participation, raising questions about shared social spaces and the potential for HCI to alter some basic relationships. The interface used by Briand was not restricted to the stationary computer but was attached to the body like a prosthetic device, allowing for a creative engagement with a shifting environment (Jones, 2006). Not all the implications are positive, however, since the work raised questions about infringements of personal space, identity, and independence coupled with information overload as the participant must still be mindful about his or her own ambulation. It also tended to reduce complex issues of "shared *attention*" and theories of mind. Nevertheless by raising such questions in a highly demonstrable way, Briand indirectly pointed out the need for reflective thought and conceptual analysis to assure that humanist values are imported into designs made possible by HCI.

Figure 50: Mathieu Briand, Audio-Visual Exchange Helmets (2001) has been removed due to Copyright restrictions.
Photo: Denis Prisset.

5.5 Mirror neurons

Briand's work also highlights issues about empathy that are related to the debated concept of "mirror neurons". The theory is that the same neurons discharge when an action is observed as when it is executed (Gallese et al., 1996; Ferrari et al., 2003; Gallese et al., 2004). In thinking about how this might apply to viewing artworks, art historian David Freedberg and neuroscientist Vittorio Gallese proposed that the marks on artworks can activate stimulation of the motor program that produced them. They stated that the mirror system shows that, simply by viewing the graphic results of a past action, our brains can reconstruct them. After locating this response in the premotor cortex (Gallese et al., 1996), they identified the reconstruction as an embodied simulation mechanism (Freedberg & Gallese, 2007, p. 202). Freedberg and Gallese thus proposed "a theory of empathetic responses to works of art that is not purely introspective, intuitive or metaphysical but has a precise and definable material basis in the brain" (Freedberg & Gallese, 2007, p. 199). They pointed out that their proposal resonates well with Merleau-Ponty's description of understanding a pictorial action: "The sense of gesture is not given, but understood, that is recaptured by an act of the spectator's part" (Merleau-Ponty, 1962, p. 466). The findings of Rizzolatti et al. (2001) identified the mirror neuron system as a cortical network composed of part of the parietal lobe, part of the inferior gyrus, and an adjacent part of the premotor cortex.

Although still a subject of dispute (Brass et al., 2007; Kilner & Frith, 2007) and perhaps over-burdened with meaning by now, the concept has had wide ramifications in terms of explaining social interactions and aesthetics. Some claim it underlies empathetic understanding of the action of others (Gallese et al., 2004). For example, mirror neurons may help in grasping that the initiation of motor actions imparts a feeling of what it is like to perform a certain act. Gallese and Lakoff (2005) and Lakoff (2006) have suggested that this interpretation also supports how a form can both be abstract and embodied. To the extent that proprioception reflects the embodiment proposed by the mirror system, it can also give rise to aesthetic sensations as, for example, when spectators can share in a dance performance (Montero, 2006). By providing a possible explanation of the mechanics involved in metaphors, mirror neurons have helped forge a bridge between the presumed objectivity of science and subjectivity of art.

5.6 Meditation and dance

The question of whether special training is responsible for certain artistic groups having a heightened sense of the body also deserves consideration. Scientific studies have in fact been conducted to address this query. One explored meditation (Manna et al., 2010), suggesting that mental practice can implement a functional reorganisation of brain activity patterns for focused *attention*. Another study explored whether people with special training in dance would show "high coherence" between their subjective emotional experience and various objective physiological measures based on skin conductance, finger pulse transmission time, ear pulse transmission time, respiration period, respiration depth, systolic blood pressure, diastolic blood pressure, and general somatic activity (Sze et al., 2010). Those undertaking the study restricted measurements largely to the heart, since they stated that among autonomic organ systems, it plays a large role in providing physiological support for emotion-related behavioural adaptations (e.g., for fighting and fleeing in anger and fear).Their hypothesis was that groups that had specialised training in visceral awareness would show high coherence between their emotional experiences and awareness of heart functioning, and this proved to be the case.

Just as dancers have cultivated their *attention* to a somatic awareness of their body, meditators (in this case those trained in Vipassana meditation) have cultivated a visceral awareness of breathing and heartbeats as opposed to the control group without special training. An alternate interpretation was that the people selected for such training already had high coherence scores, but this was ruled out on the grounds that there were no differences among the groups tested in terms of personality traits and emotional reactivity. Sze et al. concluded that the study re-confirmed the important role that organs controlled by the autonomic nervous system play in emotion and the critical contribution that afferent feedback from these organs plays in the construction of subjective emotional experience.

These statements were generally consistent with research on emotion conducted by Damasio (1994, 1999) and others. The cerebellum is a subconscious part of the brain that controls many autonomic functions. As described by Tandon et al. (2006), visceral responses issue from projections from the cerebellum. According to Jänig (2006, p. 37), the brain receives afferent messages from the internal organs, registering neuronal, hormonal, physical, and chemical signals. These convey information about a number of states, including satiety, blood pressure, and endocrine activity in order to achieve precision about homeostatic regulations in the body. Findings have shown that organ-specific physiological responses differentiate emotional feeling states (Harrison et al., 2010). Emotional feelings can be evoked by afferent activity from the viscera and deep somatic structures that are involved in facial expressions (Jänig, 2006).

The basic idea was that the ability to perceive visceral responses impacts measures of subjective emotional experience and contributes to the sense of the "self". The findings suggest that the fine arts (often involved with meditation and the body) offer an informal kind of *attentional* awareness for participants. This is an asset that had been more obviously exploited in dance until some art practices came to exemplify a new approach to performance in the late 1960s (Jones, 1998). As a result some performance art offers viewers a similarly heightened sense of bodily awareness.

6 Training attention

Chapter two explored how art constituted a training ground for the *attentional* system by helping the viewer maintain focus and also by assisting a switch of *attention* when desired. This chapter explores other related aspects of training.

6.1 Rationale for developing attention training methodologies

In 1949, D.O. Hebb published, *The Organization of Behaviour*; in which he argued that every psychological event is represented by a flow of activity in sets of interconnected neurons. Learning was defined by a change in synaptic strength during excitation and discharge activities, leading to ideas of neuroplasticity. Hebb's goal was to provide a fully integrative psychology. Several neurophysiologists following up on insights developed by Hebb have attempted to place *attention* within Hebb's brain network framework, recognising that, in the broadest sense, *attention* underlies our awareness of the world and is involved with the regulation of our thoughts and emotions.

Many scientists concluded that ADHD symptoms are the result of fixed biological differences and viewed pharmacological interventions with stimulants like methylphenidate as offering temporary relief unless used chronically. Behavioural interventions were not often viewed at having carry-over benefits (Swanson et al., 1995), but new understandings about brain plasticity have led Tamm et al. (2007) to the hypothesis that training could be beneficial for children diagnosed with ADHD. They cited work by McCandliss and Noble (2003) suggesting that inefficient neural networks during early development could be strengthened by specific experiences delivered by adaptive training with regard to developmental dystexia.

According to Posner and his team (2008), both memory and *attention* in children diagnosed with ADHD can be improved through art training. They offered the following hypothesis of how improvement occurs (Posner et al., 2008, p. 1):

1. there are specific brain networks for different art forms;
2. there is a general factor of interest or openness to the arts;
3. children with high interest in the arts, and with training in those arts, develop high motivation;
4. motivation sustains *attention*; and
5. high sustained motivation, while engaging in conflict-related tasks, improves cognition.

Attention training methodologies were developed based on the idea that repetitive practice would increase the efficiency of the involved networks (Posner & Raichle, 1994). Many studies indicated that training impacted *attention* skills positively, especially for pre-school children. Tamm et al. concluded (2007) that *attention* can be trained and that such therapies offered promising interventions for ADHD. Contrary to beliefs held by many psychologists that training involves only specific domains, *attention* is generally viewed as an exception; Posner & Rothbart claimed that a key function of the *attentional* system is to influence the operation of other brain networks (2007, p. 13). Given this fact, scientists hypothesised that training could affect the performance of all the networks involved in the *attentional* system. Several studies found that these networks can be influenced by social and cultural factors as well as by genes (Posner & Rothbart, 2007, p. 18). Posner and Rothbart further pointed out that the training of *attention* either explicitly or implicitly is sometimes a part of the school curriculum and particularly of special education, but they maintained that additional studies were needed to determine how best to proceed.

6.2 Neurofeedback and video games

Animated games have been used in conjunction with biofeedback technology to help reduce stress and achieve concentration. Biofeedback is a technique used to regulate physiological processes generally controlled by the involuntary autonomic nervous system. It has been found that control can be exerted by some individuals over brain waves, muscle tension, blood pressure, breathing rate, temperature, or sweating.

Neurofeedback (biofeedback applied to the brain) has been used to mitigate ADHD since the 1970s (Butnik, 2005). The method is based on observations that children diagnosed with ADHD generally have slower brain waves than normals. In one videogame-based method, the goal is to have ADHD children increase their brain wave frequency. In that game, their avatar navigates as fast as possible through a graveyard with randomly-placed grave stones (Johnson, 2004). While the child can control the direction of movement with a keyboard or joy stick, the avatar’s speed increases as brain wave frequency (measured by EEG and transmitted to the video game) increases.

Basask et al. (2008) found significant benefits of strategy-based video game training in older adults on executive control functions. They also observed transfer of training from video game training to the mental rotation task and speculated that it resulted from improving the perception of the relationships between multiple objects and events in the video game (Basask et al., 2008; Achtman et al., 2008). Steven Johnson pointed out a less-noted result (2004). He observed that, rather than thinking of neurofeedback as a tool-sharpening device one could instead conceive of it as a way to shift between different tools, depending upon the *attentional* tasks desired. The larger issue about such training, however, involves the basic aim of this therapy. It seems apparent that, while undergoing neurofeedback, participants can learn to improve their reaction times from playing video games, but more is at stake with children diagnosed with ADHD. One must ask whether this will necessarily translate into the ability to pay greater *attention* to a teacher delivering a lecture or to interacting with others. As Johnson pointed out, listening to speech is about interpretation on many levels, including bodily gestures and semantic meanings. Unless also approached therapeutically from the perspective of social integration, neurofeedback may offer fewer benefits than its advocates have claimed.

6.3 Virtual reality (VR)

VR has been increasingly used as cognitive training for the enhancement of *attention* (Cho et al., 2002; David, 2010). Media engineer Rizzo and his team (2000, 2002a, 2002b, 2004) designed virtual classrooms with the goal of training children to be less distracted. The virtual classroom consisted of a standardised classroom environment replete with a teacher, blackboard, desks, and a window looking onto a playground and street with moving vehicles. Children sat at a real desk while wearing a head mounted display. This allowed them to see a virtual desk within a virtual classroom while their *attention* was manipulated, and measurements were conducted in terms of reaction time. A series of distractions was systematically presented to children such as typical classroom noise and activity outside the window. Participants were presented with two ten-minute conditions: one without distraction and one with pure audio, pure visual, and mixed audiovisual distractions. The scientists reported no actual findings about either short-term or long-term effects on ADHD symptoms apart from concluding that VR presents welcome new options for *attention* rehabilitation.

6.4 Survey of research findings

Barkley (2002) issued a consensus statement on behalf of an independent consortium of leading scientists emphasising that ADHD is a genuine disorder, causing adverse impact on lives. I do not dispute the statement. The issue in this chapter is whether and to what extent exercise and therapies like VR can provide substantial relief. Halperin and Healey (2011) reviewed the scientific findings and found that relatively few studies assessed the important question of brain changes as a function of cognitive training. The basic premise of this training is that ADHD symptoms relate to particular cognitive deficits, and remediation will lead to lasting improvements. Halperin and Healey (2011) singled out a study conducted by Rueda et al. (2005) that showed that a brief five-day *attention* training intervention with preschool children resulted in changes in executive functioning as well as in changes in event related responses. They noted that many such studies had problems with retention and compliance, and because most of the children had multiple impairments, the approaches were too narrow to be of great benefit. One of the questions they raised was whether the interventions must be technologically-driven. It is understandable that to avoid long term medication that could have detrimental effects a parent would look into feedback training as an alternative treatment for their child's ADHD symptoms. According to many physicians (e.g., Larry Diller, Halperin and Healey), sometimes the obvious has been overlooked. Even those in favour of medications (e.g., John Ratey) have pointed out the benefits of environmental enrichments and physical exercise. Unfortunately, sufficient human studies about this are lacking. Halperin and Healey pointed out that most interventions to date have involved *attention*-focused training programs (as opposed to exercise). One possible conclusion is that either time-saving concerns (on the part of parents) and/or profit motives associated with specific "*attention*-training devices" help account for this preference. According to Halperin and Healey, many common games target neurocognitive deficits associated with ADHD and could be enjoyed by a family playing together. For example, ". . . the game "Simon-says" involves inhibitory control, "my grandmother went to the market" involves working memory, and "hopscotch" involves physical exercise and requires motor control" (Halperin & Healey, 2011, p. 629). These common-sense observations about the creative use of "directed" play seemingly undermine the necessity for purely expensive, technology-driven therapies. They may thus also be in accord with the presumed benefits of some artworks.

7 Attention as a tool

Attentional skills must be developed in much rehabilitative work, and different exercises have been developed that aim to improve sensory perception, and static and dynamic balance. Some use vibratory stimulation and others are directed to posture. It is known, for example, that maintaining orientation draws on *attentional* resources. Vestibular training was found to help treat disorientation that may result from visual-vestibular mismatch, spinning, and the Coriolis illusion during flight manoeuvers (the simultaneous stimulation of two semicircular canals) by returning the system to equilibrium (Gresty et al., 2009). The dramatic situation was given of a pilot who needed to disregard the sensation that he was still rolling and attend to the cockpit instruments in order to survive. To protect against disorientation, the subject must learn to switch *attentional* priority to the desired cognitive task (in this case interpreting the instruments). The aim of cognitive behaviour therapy was to prepare the subject by telling them what to expect to keep them from being distracted, thereby desensitising them to the nausea.

7.1 Distraction from pain

While technologies such as VR have been formally developed for *attention* training, *attention* itself has been used as a major resource for pain therapy. In the late eighteenth century it was recognised that distraction made it possible to reduce pain (Hagner, 2003). It is also commonly known that distracting a child (shifting *attention*) can control the child's distress (Harman et al., 1997). Cauda et al. (2010) have pointed out that pain is inherently salient, demanding *attentional* and cognitive resources. They thus also corroborated that directing *attention* elsewhere was a good way to block pain. Edwards et al. (2009) reported that diverting *attention* away from a noxious stimulus diminished self-reported pain intensity by as much as 40%. They pointed out that biofeedback-like treatments using fMRI to train subjects to control their brain activation have met with some success although one might question the immediacy of fMRI feedback in this setting. Legrain et al. have stated that "an effective control of pain by *attention* should not only involve the disengagement of selective *attention* away from nociceptive stimuli, but should also guarantee that *attention* is maintained on the processing of pain-unrelated information without being recaptured by the nociceptive stimuli" (Legrain, 2011, p. 453). Meditation is generally used in conjunction with these technologies. A fundamental component of their use is to actively engage the user's *attention* as a resource for therapy or insight.

7.2 Pain therapy

Artist Diane Gromala asked a key question: can some of the experiences gained through the arts be adapted to manage chronic pain? Her response to this question was The Meditation Chamber (Figure 51). It was created in collaboration with a physician and computer scientist and is a combination of an immersive VR environment with biofeedback devices.

Figure 51: Diane Gromala, The Meditation Chamber (2001).
Diane Gromala, Steven J. Barnes, and Meehae Song. Not photographed: Chris Shaw, Pam Squire, and Banafsheh Zokai. Photo Credit: Stuart Davis, Vancouver Sun.

Using biofeedback devices, participants are guided through a series of relaxation and meditation techniques (García & Aróstegui, 2007). Audio and visual stimuli are synchronised to the users' continually changing physiological states (respiration, pulse rate, and sweat gland activity – a measure of calmness) and are monitored. VR provides an interactive, computer based distraction system that can occlude visual and auditory stimuli coming from the real environment and replace them with an interactive program of selected images and sounds transmitted via a specially designed visor (Leibovici, 2009). With Carlos Castellanos, Gromala researched the experience derived from human-machine coupling (2010), later describing how the interaction became embodied (Gromala, 2004).

There is increasing support for Gromala's approach on a scientific basis. Some neuroimaging studies have suggested that meditation can activate the same pain-inhibitory pathways as those involved in distraction (Edwards et al., 2009, p. 240). Habituation decreases the salience of pain, and this fact has also been used to decrease the user's depth of discomfort. Gromala's initial VR work was at the Banff Centre where it was undertaken periodically from 1991 to 1993 and then tested with children in a hospital. She later worked with computer scientists Larry Hodges and Chris Shaw, and they developed the Meditation Chamber. They tested the Meditation Chamber on 411 users at SIGGRAPH, and then it became a project at Virtually Better. From there, it was used in 20 hospitals and clinics worldwide. Gromala informed me (2011) that the concerns for those with chronic pain were different from those with acute pain. One designs a VR system for acute pain, using *attention* distraction, but one cannot reasonably distract one's *attention* for 18 hours a day for those in chronic pain. For the latter, patients used the VR + biofeedback system to learn mindfulness meditation (MM), which is a standard pain management tool. She pointed out that one doesn't need technology to learn this technique, but, stated the following:

> "The system provides real-time feedback (biofeedback data changes the visuals & sound) so it is more of feedback of one's environment, not just looking at a graph) . . . chronic pain, as a degenerative disease, leads to increasing immobility and social isolation (along with depression). . . . Although chronic pain affects an estimated 1 in 5 people in developed countries, it is not a well understood disease, so patients often go through years of undiagnosed pain (usually visiting 7+ doctors), and are usually told that they are malingerers or hypochondriacs). . . the disabling effects lead to social isolation -- it's difficult to be active, let alone get out of bed to socialise".

She concluded that:

- ` VR is more effective than opioids for acute pain.
- The VR + biofeedback + MM work may enable patients to reduce their use of opioids. They are measuring pain tolerance levels. In chronic pain, patients' biological changes make the efficacy of opioids problematic – in addition to requiring ever higher doses, their opioid-uptake channels stop working. .

7.3 Rehabilitation

In the last chapter, the phenomenon of inattention blindness epitomised how something in plain sight could be invisible. Rehabilitation (of a motor process) is often made possible by identifying something not normally attended to. Wilson gave the example of Moshe Feldenkrais, an Israeli physicist, who found that practice in attending to the body's movements could lead persons impaired with a variety of motor problems to a heightened sense of the mechanics of their own bodies and result in improved performance (Wilson, 1998). His experience confirmed that a physical deficit was more likely to be corrected if the patient became aware of the motions that were lacking and then learned to do them in a conscious way. The purpose was to enlist the "active, alert, motivated, and consistent participation of the patient" (Bach-y-Rita & Bach-y-Rita, 1990, p. 161).

7.3.1 Sensory substitution

Technologies of sensory substitution allow for testing to what extent one sensory mode can substitute for another. Much work in sensory substitution stems from Bach-y-Rita, who worked in the field of neuroplasticity. He and his team (González et al., 2005) were among the first to introduce sensory substitution as a tool to treat patients suffering from neurological disorders. The phenomenology of blind users of sensory substitution devices continues to be explored (Ward & Meijer, 2010).

James R. Lackner and Paul A. DiZio have pointed out that "multiple perceptual–motor remappings can occur. . . . The existence of these phenomena reveals the complex, layered, mutually dependent representations involved in spatial orientation and motor control" (Lackner & DiZio, 2000, p. 285). Multiple interpretations can accompany different physical situations. For example, someone on a moving merry-go-round can experience that either the merry-go-round or the world is moving. Both explanations are plausible.

Rehabilitation, like pain therapy, must direct the *attentional* system to the tasks involved. According to Laufer et al. (2007), the focus of *attention* during rehabilitative practice may play a role in skill acquisition and retention, particularly for balance training. Most commonly, instructors provide information related to the learner's body movements when teaching motor tasks. Laufer's group, however, directs subjects without impairments to focus on the effect of the movement rather than on the movement itself, believing it may be more effective in promoting skill learning. Subjects were instructed to keep balance on an unstable platform by stabilising the platform as opposed to maintaining balance by stabilising the body.

Cognitive scientist Nicholas Hatsopoulos pointed out (2009, p. 249) that the goal of neural interface research is to "create links between the nervous system and the outside world either by stimulating or by recording from neural tissue to treat or assist people with sensory, motor, or other disabilities of neural function". He identified four components as follows: (1) a recording array that extracts neural signals, (2) a decoding algorithm that translates these neural signals into a set of command signals, (3) an output device that is controlled by these command signals, and (4) sensory feedback in the form of vision and other sensory modalities (Hatsopoulos, 2009). Those involved with designing AI as well as interfaces are necessarily involved with issues of embodiment; they must consider that, as in biological systems, perception and action need to be coordinated in such a way that every action provides direct (e.g., proprioceptive) and indirect (e.g., visual, haptic) sensory feedback. Building robots is a way to flesh out some of the principles of embodiment (Pfeifer & Bongard, 2007; Pfeifer et al., 2007).

Media artist Jill Scott has been involved in enabling the visually disabled to increase their autonomy through possibilities offered by rehabilitative technology. She collaborated with artificial intelligence and electronic engineers to devise ergonomic tactile interfaces called e-Skin that utilise smart devices attached to the blind person, which are sensitive to temperature, pressure, vibration, and position (Scott et al., 2004, 2007). The interfaces are wearable circuits embedded with microsensors, actuators, and wireless technologies to enable the participants to create a cognitive mapping of their space. The electronic augmentation of the e-Skin allows for the participants' embodied interaction with a mediated stage. This hybrid platform uses surround sound and three screens to create conditions for an interactive environment. Basically, the screens manipulated a virtual object-filled environment that issued and received signals. The e-skin sensors worn by the blind participants either converted the sensory stimuli to other sense modalities or augmented them, enabling the blind participants to navigate through the space and communicate with others (Figure 52).

At all points of development, Scott et al. made active use of the participant's *attentional* focus to identify what was necessary to achieve success. An important component of the research was not just to develop the technology but to determine how actual use could direct its development in ways that empowered the users. The team therefore conducted workshops with the visually impaired to test the prototypes and gauge whether their usefulness would be increased by coupling their use with metaphorical associations, many involving personal recollections. One example they provided was the sound of a knife cutting bread. Such associations were aimed at making it easier to discriminate the sounds or touches of a variety of similarly-sized objects. In correspondence with me (2011) Scott noted that "During the prototype testing it was found that 3D actuators mounted on the embroidered circuits of eskin and work by blind actors could convert gestures into sound and by converting these gestures into codes this information could be sent to others where it was converted into tactile feedback". The guidance of the dancers helped enable the visually impaired participants to extend their perceptions. Through such testing, they were able to determine how cross-modal cueing could allow the impaired to successfully navigate, self-orient and interact within an enhanced environment. They explored proprioception, which is known to be a key source of sensory feedback for promoting neural plasticity (Xerri et al., 1998).

The team conducted extensive interface research with the goal of creating a kind of interactive second skin that conveys spatial information through pattern stimulation onto the human skin. Other skin modalities, like temperature, were combined with sound feedback and vibration used for orientation. The purpose was to provide empathetic access to the world of the impaired and to 'humanise technology' for the visually impaired. The main goal in such work is to understand how gestures, postures, and movements relate to a disabled participant's sense of herself as a totality. In this way the development of technologies may increase users' autonomy, enabling them to function relatively free of pain and impairment. A range of resources and information has thus been adapted to new purposes (Pfeiffer, 2007).

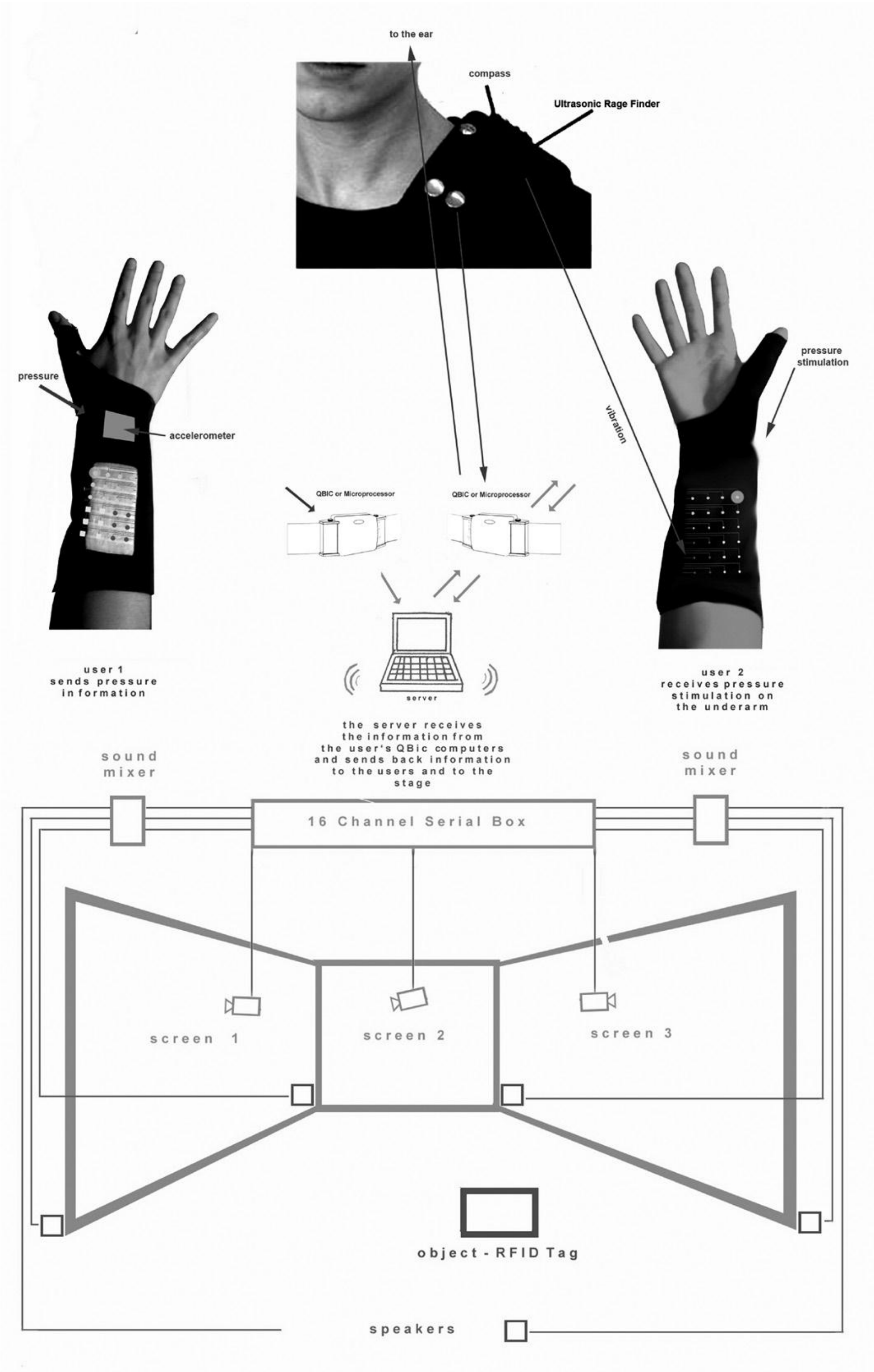

Figure 52: Jill Scott, <u>e-Skin for the mediated stage</u> (2006).
In collaboration with Daniel Bisig and the Artifical Intelligence Lab. Uni Zurich

8 Conclusions

The chapter had three main aims: to see how art experiments focused on the body can help train *attention*, how technology can extend the parameters of such testing, and how designers can use *attention* to assist the therapeutic needs of users.

Those artworks that manipulated our bodies' boundaries, thresholds, and spatial orientation fostered awareness of some of the multiple components that create our subjective sense of unity. Some of the artists revealed this unity by shattering it, and they have teased out the almost imperceptible facets involved, including autonomic acts of balancing, orienting, and proprioception. Many examples of art were presented that staged the experience of dislocation in space and demonstrated the results of interfering with acts of hand and eye coordination. Several of the artists eliminated or reduced the sense of sight (e.g., Morris, Gormly, Hentschlager), forcing themselves or the participants to rely on other senses. Coming full circle, one artistic approach dealt squarely with those who lack sight (Scott).

In keeping with the thesis premise, the chapter showed how body art that includes technology could contribute to the understanding of the *attentional* system by questioning how one locates oneself in space (e.g., Gormley, Hentschlager, Ottiger); how we take for granted a sense of unity (e.g., Wright); how we dissolve our body's boundaries (e.g., Hentschlager); and how we can alter the sense of our body's coordinates (e.g., Jonas). Part of the significance of the artworks discussed for neuroscience was the way in which situations were staged (both with and without extensive technology) that involved participants attending to their bodily sensations. As a result, the participants could more readily modify their expectations of what normal perception entails. This, in itself, is a form of learning.

The art encompassed in this chapter ranged from traditional art to newer technologies such as HCI and VR. Artists as well as scientists have looked to technology as a way to implement new understandings of our bodies. Nevertheless there is also danger in overlooking the obvious (as we saw was the case in inattention blindness as discussed in chapter two). For example, there are potential advantages of directed "play" involving exercise in *attention* training and rehabilitation that should be pursued. The scientists along with the artists must grapple with the limitations presented by the technologies. For example, to advance rehabilitative efforts, it would be important to have a perspective from social psychology that deals with broad questions of social integration, particularly with respect to individuals diagnosed with ADHD.

In the last section, which also dealt with technology, two artists/designers explored other uses of *attention*: how we can utilise *attention* as a distraction from pain (Gromala) and how *attention* can augment our autonomy through assisting the implementation of sensory substitutions and new interfaces (Scott). This section raised questions concerning how design decisions impact the individual's holistic sense of self. For example this issue was raised in the context of HCI and its use by Briand versus its use by Scott. Whereas Briand offered a somewhat reductive, literal experience to participants of "seeing through another's eyes" (and simultaneously limiting their ability to move safely in space), Scott was instead concerned with enlarging the autonomy of someone with a sensory deficit. What is at stake is not the technology but the goals to which it is applied.This chapter like the last suggested that defective *attentional* capacities can be trained. The critique just leveled at some HCI applications also applies to some applications of *attention* therapy for those diagnosed with ADHD. It is not always apparent that the improvements (whether through medication or neurofeedback) involve broader social and communication goals but seem instead limited to treating the specifics of *attentional* symptoms.

Since some of the tools used in *attention* research are shared by artists and scientists alike (e.g., VR and biofeedback), some of the research methodologies have been aligned, although the art has not generally involved quantification except during scientific collaboration. While both disciplines have explored how *attention* can be guided and recruited as a therapy, the artists have generally opted for more freedom, allowing for greater leaps of imagination but eschewing the benefits of quantification for standardised future applications. In reality, art culture has tended to discourage quantitative approaches in art. One reason is that the avant-garde has with some consistency used irony to subvert audience expectations; another is that it has tended to avoid overt scientific process. As more collaborations between artists and scientists take place and as new generations mature along with the Internet, it may be expected that some of these accepted rules of artistic communication will change.

The chapter confirmed that a central function of spatial *attention* is to plan physical actions; several decades of work in neuroscience have suggested that cortical premotor areas contain neurons that respond to multimodal sensory stimuli. Much of the art discussed highlighted the fact that more than one modality can send and receive information. That may be why artworks that call us to attend to a variety of modalities are likely to heighten the user's awareness that an internal bodily adjustment occurs in response to stimuli. Scientific evidence supports a view of perception in which each sensory pathway is modulated by other pathways. We can select information from a common external source across several modalities, despite the fact that each modality codes the initial source quite differently.

In order to span the visual and motor dimensions of experience, philosophic and scientific concepts of embodied cognition were presented in numerous ways. What still remains unknown is how a theory of embodied cognition would actually work at the neuronal level. Regardless, in the art experiments that have been presented in this chapter, many artists have always acted on its principles. By comparing the various experiments in art and neuroscience, a way may emerge to challenge some of our ingrained perspectives on reality and erect deeper understandings of the sensorium.

Endnotes

1 http://artistsinlabs.ch/portfolio/nicole-ottiger/
2 http://www.sciencenewsline.com/medicine/2011021712000021.html

CHAPTER 4: Imaging the Norm

1 Introduction

While ADHD is a common diagnosis in the United States, it continues to elicit controversy. Although focusing on the images and imaging associated with *attentional* pathology will not resolve the underlying conflicts, it may offer some insights about the boundary that has been constructed between normality and abnormality. It may suggest why what was once conceived as a continuum between health and illness has tended to be re-drawn as a firm border with the pathology expanding into areas formerly designated as healthy. While the chapter analyses how *attentional* pathology is established and measured by scientists, in keeping with the premise of my studies, it also demonstrates how some artists have questioned measurements of medical and behavioural norms in exhibitions and associated activities.

Although there is no definitive test for ADHD – a role filled, for example, by tissue pathology in diagnosing cancer – many tools are available to assist in ADHD diagnosis (Strauss et al., 2006). These include the American Academy of Child and Adolescent Psychiatry's seven "Common Rating Scales" for assessing symptoms of ADHD in children as well as lists issued by The American Academy of Pediatrics that include the Conners' Parent and Teacher Rating Scales- Revised (CPRS), and the Diagnostic and Statistical Manual of Mental Disorders (DSM) that is published by the American Psychiatric Association. Most physicians accept ADHD as a diagnostic entity. In its support, Barkley issued a consensus statement in 2002 emphasising the neurological and genetic components of ADHD and its disruptions on families and harm to the individuals afflicted. The concern expressed was that people in need were not seeking treatment in part due to undermining reports issued by the press. Indeed, the view of ADHD as a diagnostic entity has been seriously challenged by social scientists and educators, including some in the medical community. For example, the CPRS has been questioned for the information it provides. Gianarris et al. observed that "the CPRS is not a direct measure of the child's behaviour, but a reflection of parental perception" (Giannaris et al., 2001, p. 1086). Gianarris et al. also found limited normative data for the CPRS as a diagnostic tool. After examining much of the reported research, paediatrician Lydia Furman concluded in a special article in the *Journal of Child Neurology* that "the working dogma that ADHD is a disease or neurobehavioural condition does not at this time hold up to scrutiny of evidence" (Furman, 2005, p. 994). Furman remained pessimistic about the validity of ADHD diagnoses in a subsequent article (2008). Social scientists Peter Conrad and Deborah Potter observed that "The elasticity of the medical category of ADHD has helped it to expand its boundaries and become more inclusive . . . . Medicalization studies have demonstrated that agents such as self-help and advocacy groups, social movements, health-related organisations, pharmaceutical companies, academic researchers, and clinicians can be central in creating specific diagnoses" (Conrad & Potter, 2000, p. 560).

In order to explore how images and imaging play a role in adjudicating ADHD, this chapter compared four medical diagnostic case studies. The first three rely on images in decisions of health or pathology. They are the Clock Face Drawing Test, which is used to reveal deficits in planning/organisational skills in children with ADHD and also serves as a diagnostic indicator for Alzheimer's disease and other illnesses and two ADHD screeners for children known as the Terry and Dominic. The fourth approach involved medical imaging. The first three studies applied psychometric principles to tests of psychopathology that purport to result in developmentally-sensitive diagnoses. The purpose of the tests, which involve the interpretation of images, is to define deviance within the context of age-specific norms (Faraone et al., 2000, p. 36). I suggest these areas remain problematic despite the intentions to clarify judgments of illness and, in conjunction with other causes, may have helped lead to the expansion of ADHD diagnosis. The fourth test involved medical imaging for diagnosing ADHD. At issue in all of these studies was the selection of normal controls as well as the sensitivity and selectivity of the tests, themselves. After discussing these tests, I then analysed two artworks that critiqued aspects of medical diagnosis of cognitive function. The first was an installation that placed questions of normality within a broad framework of theories of mind and agency. The second, a video essay, confronted how medical care manages extreme ranges of behaviour and offered a personal account of mental illness and ADHD. Illness was further explored in conjunction with these last two studies within the context of the gradual "medicalisation" of ADHD that some view as marking its expansion into the adult population.

Analysis of the case studies highlighted different aspects of the same problem – determining what is normal and what is pathological – and viewed the ramifications of these decisions at different levels of the brain, the person, and society. The approaches of medical science were contrasted with art. I suggest, in accordance with the thesis premise, that the public "airing" of *attentional* issues such as ADHD diagnosis through critical analysis of its associated images and imaging technologies may help raise visual literacy and awareness of some of the bases of categorical judgments, themselves.

A good deal is at stake in the determination of pathology. Part of the concern is that defining a medical norm may bring about social inequities (Conrad & Potter, 2000). Studies have shown that different methods of classifying a diagnosis can have a dramatic impact on the prevalence of a disorder (Heiligenstein et al., 1998). Categorisation is at the heart of science, and the classification of wellness or disease is basic to health care. Evelyn Fox-Keller has noted that "the demarcation between culture and biology (or between nature and nurture), is now made by the demarcation between normal and the abnormal" (Fox-Keller, 1993, p. 298). The presumption in the case of ADHD is that the common pharmaceutical intervention, methylphenidate, acts on an abnormality in the brain and then returns the individual to a "normal" or "natural" state. Sociologists may disagree with psychologists about their criteria for determining whether a behaviour is normal or abnormal and are often critical of the effects of the expansion of medical jurisdiction.

This chapter is an attempt to examine to what extent images and imaging technologies play a role in influencing the demarcations of illness in the absence of causal evidence of pathology. The further question this chapter raises is whether art can help the public discriminate between medical and social factors.

2 Clock Face Drawing Test

The first case study reviewed is the Clock Face Drawing Test, generally used as part of a comprehensive neuropsychological evaluation to diagnose ADHD (Freedman et al., 1994). The test more commonly diagnoses other abnormalities, including hemi-neglect in patients with unilateral brain lesions resulting, for example, from stroke and brain cancer. To understand how the test can convey neurological information about *attention* disorders, it is necessary to see how the drawings reflect its underlying theory. It is claimed that the Clock Face Drawing Test can measure visual-spatial skills and graphomotor abilities (Mendez et al., 1992). Clock drawing performance in children with ADHD who did not have comorbid learning disabilities or psychiatric disorders was investigated by Stern et al. (1998). They found that children with ADHD, even those with adequate visual-spatial and graphomotor abilities, performed significantly poorer than "normative" children. Other researchers have found that the Clock Face Drawing Test is also sensitive to verbal reasoning abilities (Ishiai et al., 1993). Kibby et al. (2002) reported findings by Freedman et al. (1994) and by Delis & Kaplan (a 1983 poster presentation given at an International Neuropsychological Society meeting) that claimed the test is sensitive to language comprehension, visual–spatial retrieval and planning/execution. Because of this sensitivity, the test has been used to assess certain brain functions affecting the parietal lobes, frontal lobes, mesial-temporal regions, and the left temporal lobe (Freedman et al., 1994). In general, however, increased sensitivity of any test often comes with a cost of decreased specificity, i.e., identifying as abnormal what in fact is normal. It is the test's measuring of executive functioning (the ability to make plans and persist) that makes it especially pertinent to diagnosing ADHD (Royall et al., 1998). Executive function generally refers to a variety of behaviours and abilities related to planning and to the maintenance of *attention*, in which individuals with ADHD are typically deficient.

The basic procedure of the test is that the child or adult is asked to draw an analogue clock face, first by creating a circle and then positioning the numbers and setting the hands to a specified time, but many variations exist. One task might require that a child only place numbers on a pre-drawn circle. The task of clock copying requires some of the same set of skills as those called upon in drawing an analogue clock face from memory, but it was found that copying skills can remain intact in the presence of impaired memory (Dilworth et al., 2004). Dilworth et al. have determined that participants need to rely heavily on visuomotor and visuoperceptual skills subsumed in the occipital and parietal lobes when they copy. By contrast, drawing the clock from memory requires abilities mediated by the frontal and temporal lobes. These include comprehension, memory of instructions, visual memory of an analogue clock face, and executive abilities to plan and carry out the task (Freedman et al., 1994). (Incidentally, these findings about memory versus copying suggest why, in the late stages of Alzheimer's disease, Willem de Kooning was able to continue to paint when provided with pre-stretched canvases and a palette with which to work. Conceivably memory was not needed to carry out his painting later in life.)

Figure 53 shows the principles of the test and its scoring. Psychiatrists Peter J. Manos and R.W. Wu (1994) traced a four-inch diameter circle in the chart and then asked subjects to write in the numbers that appear in the face of a clock. When the subjects had finished that task, they were asked to make the clock read ten minutes after 11, with the reviewers consciously avoiding mention of the hands of a clock. Their scoring system gives points for appropriate positioning of the times assigned. Scoring involves the investigators' subsequent division of the clock face into octants, although one might expect this division to create some unnecessary confusion (see the text under Figure 53). This is because the clock times of 12, 3, 6, and 9 should actually fall on the lines separating the octants, themselves, with each of the other eight numbers falling discretely into a corresponding octant. Although not an insurmountable problem, this is one that I believe would be easily addressed by graphic designers.

Figure 53: Scoring the Clock Face Drawing Test (Cohen et al., 2000) has been removed due to Copyright restrictions.
Subjects are asked to draw the clock and make the clock read at ten minutes after 11. A. Score = 0. B. The number 1 is in the correct position (octant); score+ 1. C. Numbers 1 and 2 are in the correct positions; score = 4. D. Numbers 7, 8, 10, and 11 are in the correct positions; score = 4. E. Numbers 1, 2, 4, 5, 7, 8, 10 and 11 are in the correct positions; score = 8. No points for hands of approximately equal length regardless of position. F. Numbers 1, 2, 4, 5, 7, 8, 10 and 11 are in correct position for 8 points. The little hand is on the 11 (1 point) and the big hand is on the 2 (1 point); score = 10 points (modified from Manos & Wu, 1994).

The Clock Face Drawing Test has been used for children since 1986 (and longer for adults), but a normative scoring system for children was first presented nationally in 1993 (Edmonds et al., 1994). Another normative scoring system was cited in 1996 (a poster presented by Kirk et al., 1996 at the International Neuropsychological Society), and the 2000 paper by Cohen et al. extended this work. The scoring is applied to various errors. Some of the more common errors made by subjects taking the Clock Face Drawing Test (as recorded in the literature with various populations) have included omission, substitution or repetition of numbers, number rotation or reversal, deficits in spatial arrangement of numbers including neglect and poor planning, deficits in motor control (agraphia), incorrect sequencing of numbers, perseveration (numbering beyond 12), incorrect placement of hands to a specified time, and incorrect proportion of hour and minute hands.

2.1 Clock face drawing in normal children

The Clock Face Drawing Test (CFDT) appears to be the same thing as the Clock Drawing Test (CDT), used primarily to diagnose dementia but now applied to children. Its use for ADHD diagnosis is infrequent. When I conducted a search on Medline for the terms "clock face drawing test and children", only four publications were identified of which two pertained, one of which seemed particularly relevant. This was the "Developmental Progression of Clock Face Drawing in Children" by Cohen et al. (2000). I then used Scientific Citations Index to identify seven subsequent publications that cited it. Of these seven, only four were relevant, demonstrating the relative paucity of research in this area.

Cohen and his team (2000) investigated the development of clock face drawing in normal children from 6 to12 years-old (Figure 54). In their cross-sectional study, they stated that the development of clock drawing abilities parallels age-related increases in executive function skills, providing support for empirical observations of multistage frontal lobe development. Their findings were that the ability to tell time by the hour, half hour, and minute increased significantly from 6 to 8 years-old. In addition, most 8-year-olds no longer exhibited neglect of whole quadrants, and most 10-year-old participants were able to successfully construct a clock.

Figure 54: Clock drawings of children aged 6, 7, 8, 10, and 12 has been removed due to Copyright restrictions.
Children were asked to place the hands to represent 3 o'clock (from Cohen et al., Figure 1, 2000).

Their sample consisted of 429 “normal” public school children 6 to 12 years of age. The researchers used a 13-point clock construction scale designed to assess visuospatial, planning/organisation, and motor skills and a five-point time-telling scale with the aim of measuring clock drawing ability. They also qualitatively evaluated number reversals, spatial neglect, number spacing, and erasures. The procedure involved the children in three tasks. For the first, the participants were instructed to draw a clock face, numbers, and a time setting of 3:00. The second and third tasks involved depicting 9:30 and then 10:20 in predrawn clock faces. They observed an improvement in clock construction related to age, and determined that, unlike 6-year-olds, the majority of the 7-year-old age group did not produce number reversals. Most 8-year-olds no longer exhibited neglect of whole quadrants, and most 10-year-old participants were able to successfully construct a clock.

One consideration in applying these results to studies of abnormal children relates to the “normal” population selected. To select from among a normal population, Cohen et al. recruited children from two schools in Georgia. Teachers asked participants to complete the Clock Face Drawing Tests. To restrict the data to normal children, teachers were then instructed to remove drawings by children who were not reading at grade level or who had a history of grade retention, behaviour disorder, learning disorder, or stimulant medication usage. The researchers then divided the remaining participants into seven groups based upon chronological age. As I interpret it, this method of selection insured that a normal population was pre-defined in a way that guaranteed some interpretive biases on the part of teachers (either the present teachers making the selection or past ones deciding impairment) would be included save for the criterion of grade level reading skills or stimulant usage. Cohen and his team also themselves commented that they used the scoring system for adults, the benchmarks of which may not be an entirely appropriate guide for children. They stated that their quantitative scoring system emphasised number positioning/spacing around the clock face (Cohen et al., 2000) and further commented that their scoring system has enhanced sensitivity to frontal lobe maturation and deficits in executive functioning.

2.1.1 Insufficient knowledge of norms of development

As Cohen et al. claimed, “Specifically, the data revealed that a greater percentage of normal 6- and 7-year-olds demonstrate a pattern of upper left quadrant neglect as opposed to lower left or lower right quadrant neglect. None of the children neglected the right upper quadrant. The progression in quadrant use suggests that neglect in young children is developmental in nature as opposed to neuropathological . . . . The neglect is believed to result from poor planning skills since the part neglected was the top left quadrant of the clock face [presumably this was the last space that needed to be filled in]” (Cohen et al., 2000, p. 69). The team used the word “suggests” because the relative lack of information about development would not allow them to actually claim that the quadrant neglect at a particular age of development is a normal pattern. In fact normal hemi-*attention* has been documented in children as young as 3 years of age (Temple, 1997), confirming that it might be hard to distinguish from a pathological situation.

In a subsequent report (Kibby, Cohen & Hynd, 2002), the researchers again identified what they suggested was a developmental pattern (as opposed to a neuropathological deficit) in quadrant neglect, but they noted that these are difficult to distinguish from each other (Heilman et al., 1985; di Pellegrino, 1995). This situation again supports the urgency of establishing norms; the researchers, themselves, acknowledge that too little is known about typical *attentional* development. Other related problems exist in understanding development; little is known about the longitudinal relationship between early neuropsychological functioning and later clock drawing ability.

To claim scientific validity about mental operations and physical skills, clock face drawings must be evaluated in terms of standards at specific stages of cognitive development. For this, knowledge of normal function is essential, but the norms have been difficult to establish and have been open to interpretation. The areas of choosing normal controls and establishing norms of development for both children and adults with regard to ADHD have offered some obstacles. For example, Furman pointed out (2005) that some of the core symptoms of hyperactivity and distractibility could simply be at one end of a normal distribution of school-aged behaviour. She further speculated that it would be of interest to measure “overattention” and “hypoactivity”, but they would rarely be tested for because these symptoms would be unlikely to cause disruption and thus unlikely to attract the notice of either teachers or parents.

2.2 Diagnosing ADHD with this method

In 2002, the team of Kibby et al. (with Cohen again as one of the researchers) addressed clock face drawing performance in a population of children, some considered normal and some with ADHD (Figure 55). Kibby et al. investigated the ability of children to plan ahead by tasking them to space numbers around the clock face. Spacing errors were noted at all ages for both normal and ADHD children, but for normal children the proportion of errors slowly decreased as they matured. All of the children with ADHD demonstrated poor spacing at ages 10 through 12. The researchers of the test commented that, since the sample of children with ADHD in their study generally had a mild form of ADHD, the differences between ADHD groups and controls were not as great as they presumably otherwise would have been. Although children with ADHD performed more poorly than controls, the researchers considered that their performance, although poor, was still within the “normal range”. Given that clock construction skill likely progresses past the age of 12 (the oldest child in their study), the team stated that extending the investigation to include adolescents would be beneficial in the future. The researchers, themselves, admitted that they lacked crucial information by not knowing what aspects of neuropsychological functioning could successfully predict clock drawing performance in normal children (Kibby et al., 2002, p. 543).

Figure 55: Examples of clock construction has been removed due to Copyright restrictions. Children, age 9, with and without ADHD were asked to place the hands on a clock face to indicate 3 o'clock (from Kibby et al., Figure 1, 2002).

One may have concerns about the usefulness of the Clock Face Drawing Test for diagnosis of ADHD since its credibility rests on reflecting the presence or absence of benchmarks of cognitive development. The questions that need to be answered are: Does the test show adequate sensitivity to diagnosing ADHD? Can it show specificity in distinguishing ADHD from normality or other deficits? The answers seem to be no and no, although some research has suggested that it could be otherwise since many publications about it have claimed value for the test in ADHD diagnosis, especially in conjunction with other tests. With respect to screening for illness, sensitivity is the probability that the test will correctly identify every tested person with the disease; 100% sensitivity means that there are no false negatives. Specificity is the probability that the test will not misidentify a normal tested person as having the disease; 100% specificity means that there are no false positives.

For example, Chiu et al. (2008) reported on the utility of the Rouleau scoring system for the Clock Drawing Test in northern Taiwan. Results showed that the test distinguished clear cut dementia from normal controls but showed low specificity in detecting questionable dementia from normal controls. There appear to be few comparable studies or reports describing sensitivity and specificity of the Clock Face Drawing Test to distinguish normal children from those with ADHD. This is a serious omission if the test is to be used in diagnosing ADHD in children. Addressing these issues with respect to ADHD diagnosis, Kibby et al. (2002) allowed that the performance in clock drawing will also be sensitive to visual–spatial perception, constructional praxis, verbal reasoning, and aspects of language functioning and not just to executive control. For example, Welsh's team (1991) determined that children at 6 perform comparably to adults on tasks requiring visual search efficiency and planning. Kibby et al.concluded (p. 542) that "Nonetheless, multiple causes for the difference in performance between children with ADHD and controls need to be considered".

2.2.1 Overlap of ADHD with other disorders

ADHD coexists with a number of other disorders, making it difficult to isolate. In referring to the Clock Face Drawing Test along with other related tests, Floriana La Femina et al. concluded that "none of these tests is able to disentangle the specific cognitive processes implied in the task execution" (La Femina et al., 2009, p. 692). Clock face drawings also identify *attentional* disorders apart from ADHD so there may be overlap of results from testing (showing a lack of specificity). Possible diagnostic overlap with ADHD is seen in neglect dyslexia. It is diagnosed when numerals are omitted or misplaced on the left side of the clock face test. In copying and drawing a clock from memory, spatial neglect patients may locate all hours on the right half of the clock face. The complexity involved in extracting *attention* problems from those of spatial neglect is considerable, including the problems of neglect dyslexia that issue from a failure to identify words or parts of words in the contralesional hemispace (Nazir et al., 1992). The complications extend into many areas; for example word frequency effects have recently been demonstrated for neglect dyslexic patients in a lexical decision task. There were fewer errors with high-frequency than with low-frequency words (Arduino et al., 2003).

Allochiria is a phenomenon in which neglect patients transpose left-sided elements to the right without realising or correcting their mistakes. But allochiria may have numerous causes, and representational, procedural, *attentional*, and premotor/intentional hypotheses have been put forward to account for it. Explanations of allochiria can involve neurological accounts of either *attention* or of mental representations, and it is not possible to establish which deficit is responsible for the transposition. Thus the Clock Face Drawing Test cannot, by itself, distinguish allochiria from ADHD (once more indicating a lack of specificity).

The traditional clock copying and drawing from memory tasks demonstrate the phenomenon of spatial transpositions but cannot provide an adequate theoretical interpretation to invariably account for this phenomenon. When asked to copy and draw a clock face from memory, a patient with allochiria wrote all numbers on the right half in both tasks, transposing left-sided hours to the right half of the clock face and also advancing the numbers in a counter-clockwise direction (Lepore et al., 2003) (Figure 56).

Figure 56: Clock face drawings in allochiria has been removed due to Copyright restrictions. (A) copied and (B) drawn from memory (from Lepore et al., Figure 1, 2003).

I have discussed the examples above because they show the many difficulties in establishing a test for ADHD with adequate sensitivity and specificity. The Clock Face Drawing Test, itself, probably needs to generate considerably more data before its use as a determinant of ADHD diagnosis can be assured. Researchers have confirmed that clock drawing appears to be clinically useful in paediatric neuropsychological assessment as part of a battery of tests. I therefore conclude that the Clock Face Drawing Test should be used as a diagnostic indicator (as one among many others), but with caution. In any case, in its current form, it is likely to soon become extinct as a diagnostic tool in light of the fact that young people's experiences with analogue clocks will continue to diminish in favour of digital clocks and watches.

2.3 The Clock Face Drawing Test as a representation

It seems that visual culture theorists have given little *attention* to the Clock Face Drawing Test and the particular issues of representation that it raises. I believe that the questions it poses are pertinent to understanding how images are accorded the status of knowledge. Science is, in the case of the Clock Face Drawing Test, assigned an interpretive function while the drawing of the Clock Face Drawing Test is used as an objective measure of cognitive function. In other words, by using drawing as an objective measure of a state of mental function, creativity and subjectivity rest with the doctors or neuroscientists involved in interpreting its results rather than the subjects who might incidentally have drawn certain of its features expressively (as in Dali's melted clocks). The Clock Face Drawing Test therefore seemingly inverts expectations that objectivity is identified with science and subjectivity is attributed to art since the drawing bears no personal or expressive features and the scientist must categorise images as opposed to sorting data. Ideas of the nominalist Nelson Goodman are pertinent to this analysis. His *Languages of Art* (1968) viewed art as a site of linguistic activity and symbolic systems. For Goodman, real clocks were devoid of expression unless deliberately made of interesting materials or shaped in artistic ways like a product design. In Goodman's terminology, the nature of the Clock Face Drawing Test is notational or "allographic" unlike the non-notational or "autographic" nature of a painting.

According to Trojano et al. (2009), drawing may reveal cognitive defects in patients and also can be used to assess the structure of conceptual knowledge in the semantic system. Interest in such kinds of relationships has lead to the development of the field of neuroaesthetics (Salah & Salah, 2008; Zeki, 1999). I suggest that the use of the Clock Face Drawing Test in diagnosis is analogous to using artworks (e.g., paintings) as a way to understand the brain in the field of neuroaesthetics, but with important differences. Both cases – diagnosing *attention* disorders on the basis of the Clock Face Drawing Test and attempting to understand the brain through an analysis of art – rely on the interpretation of drawn or painted marks. The chief difference is that the painting was designed by an artist to direct the viewer's gaze whereas the Clock Face Drawing Test was executed according to a received instruction (e.g., "Set the clock hand to 8:15"). In a real sense, a large part of the importance of a painting to neuroaesthetics is how it reveals the intentions of the artist and is indicative of larger patterns of top-down, conscious *attentional* brain decisions (made by the executive control centre). By contrast, the ability to draw conclusions of pathology from the Clock Face Drawing Test relies on determining the subject's lack of *attentional* executive control. In addition, conventions pertain to both approaches (carrying out the clock-drawing test and making a painting); paintings rely on conventions to direct the viewer's gaze, whether followed or ignored, and completion of the Clock Face Drawing Test relies on a mixture of conventions and innate skills presumed to be adopted at specific ages.

As is evident by now, the Clock Face Drawing Test offers a great deal more information about cognitive function than one might imagine. The questions it raises are thus very much intertwined with epistemological issues in art and science, which is why it holds interest for me as author of this thesis. Whereas scientists make experimental procedures and results public to insure that they are repeatable, art historians conduct what Michael Baxandall (1985) called "inferential criticism". According to art historian Mark Roskill, inferential criticism is not unlike science in that the statements of historians are also open to public scrutiny. As a rule, the description of objects and their explanation are interleaved, and art is examined with regard to the intentions of the artist and to the patterns of *attention* established by the artist (Roskill, 1989). For art historians, the goal of inferential criticism is to explain problematic artifacts, particularly works of art, by inductively reconstructing the "cognitive style" of the relevant period and the "patterns of intention" of the artists working during the period. As Roskill explained, for professionals in art, the first step in applying inferential criticism involves the validity of the art historian's (or neuroscientist's in the case of a drawing test) perceptions and judgments. The second concerns the insights gained into understanding the creative and perhaps neurological processes involved (with respect to the *attentional* system), and the third involves the construction of a theoretical framework that causes the evidence to be viewed in fruitful ways (Roskill, 1989, p. 20). However the correlations and possible statements of causality generated from the Clock Face Drawing Test also raise the question of whether it has been over-interpreted. It may be that, at times, both art history and neuroaesthetics over-interpret the information to be derived from images or imaging. However there is a significant difference: only the over-interpretation of symptoms in medicine and neurophysiology is likely to have negative, real-world consequences for patients in distress.

3 Screeners: The Dominic-R and the Terry

Another important factor in diagnosis concerns cultural analysis. When determining the results of psychological tests, researchers and clinicians have been aware for some time that manifestations of disorders, aspects of diagnosis, and response to treatment are influenced by cultural and racial differences. Nevertheless I could only locate one test involving drawing that took cultural and racial factors into account for ADHD: the Terry questionnaire for African-American children, which is based on behaviours identified in DSM-III-R and, in its subsequent computerised version, on DSM-IV. Computerized versions are also available for Asian and Latino girls and boys. The Terry is a variant of the Dominic-R, which was developed as a pictorial questionnaire to assess mental disorders in Caucasian children 6 to 11 years of age and was designed with young children's cognitive development in mind (Valla et al., 1997).

The Dominic-R test is not considered to be projective since it does not allow for latitude of interpretation and aims to show precise real-world situations (Valla et al., 1994, 2000) (see Figure 57).

Figure 57: The Dominic-R test for ADHD has been removed due to Copyright restrictions. From Valla et al., Figure 1, 1994.

The fundamental idea of the test is to have the child describe his or her own symptoms (as opposed to the parent or teacher), but, given the cognitive immaturity involved, this is a difficult task. The child is intended to identify with a cartoon character named Dominic, who faces a variety of common and uncommon situations. Dominic could be interpreted to be a boy or girl. The children are asked if they act, think, or feel like Dominic. The basic question is "Are you like Dominic?" The pictures reflect the behavioural content of DSM-III-R criteria, and the pictorial screener mixes normal situations with DSM-III-R abnormal behaviours. The extensive use of a visual presentation distinguishes it from most diagnostic tests and is an important and welcome innovation, especially since it permits a way to communicate with children whose language skills are undeveloped. It also reflects Gardner's insight (1983) that children can have many different kinds of intelligence.

A later study (Valla et al., 1997) was done to decrease ambiguity and to introduce a combination of visual and auditory stimuli, which have been determined to be most effective in attracting children's *attention* (Frostig & Maslow, 1979; Shojaei et al., 2009). Face-to-face interviews were conducted; the interviewer sat across from the child and read the question to the child (Figure 58). The sentences read to the child offered a description related to the visuals. It was found that older children are more reliable in their responses than younger children. Valla et al. (1997) determined that there is a pressing need to gather standardised information from children themselves on their own mental health, and he claimed that this test provided access to such information.

Figure 58: The Dominic-R test for ADHD has been removed due to Copyright restrictions. The words on top of this figure are upside down because they face the interviewer who sits across from the child and reads them while the child looks at images related to the description. (Valla et al., Figure 1, 1997).

A 2000 study (Valla et al.) was undertaken to review the Dominic-R and the Terry (see Section 3.1 below) questionnaires, respectively, for white and African-American children, both DSM-III-R-based, and more recent DSM-IV-based computerised versions. The researchers concluded that the pictorial approach was successful. With respect to Dominic-R they concluded that it was suitable for screening purposes and respected young children's shorter *attention* span (Valla et al., 2000) Table 2 lists the main characteristics of the test. A questionnaire was also developed interactively, that illustrated 90 situations within a video game-like ambiance. The interactive Dominic screens for the most frequent DSM-IV mental health problems, including ADHD. A voice-over that describes the symptom inquires how the child would react to different situations. The options open to the child are yes/no boxes, and the choices are recorded and analysed by the computer.

Table 2: Characteristics of the Dominic-R has been removed due to Copyright restrictions. (Valla et al., 2000)

3.1 The Terry

The “Terry” was developed for minority children in the testing of interview protocols for children and adolescents (Bidaut-Russell, 1998) (Figure 59).

Figure 59: The Terry and conduct disorder has been removed due to Copyright restrictions. From Bidaut-Russell et al., *Child Psychiatry Hum Dev*, 1998, 28:4, pp. 249-63.

Because children develop an awareness of ethnic differences by age 4, Terry, an African-American character, was developed for African-American children 6 to 11 years of age (Valla, 2000). The Terry questionnaire depicts an African-American boy named Terry in various DSM-III-R-based situations identical with those in the Dominic-R. Children are typically presented with 97 cartoons of Terry engaged in different activities, each with a question for the child. An algorithm analyses the responses and arrives at a variety of behavioural diagnoses. Michelle Bidaut-Russell et al. (1998) tested the Terry in 36 boys with various disorders; six carried psychiatric diagnoses, five of them being ADHD; the other 30 were drawn from nonclinical populations (e.g., elementary or church schools and transitional centres). The researchers determined that the children's responses corresponded to a clinical diagnosis of ADHD but concluded that the sample was too small to be of significance. They also recognised that the decision to consider ethnic contexts regarding diagnoses of ADHD and build them into testing was somewhat undermined because The Terry lacked sufficient data. At the time of the test, relatively few African-American children had been included in the testing of most structured and semi-structured interview protocols for children and adolescents, and results from cross-racial comparisons of these instruments had not been reported.

3.2 Social considerations in diagnosis

One issue needs further consideration and relates to the intrusion of social factors in the diagnosis of ADHD. In fact, problems at school were considered so stressful that Velez et al. (1989, p. 864) noted that researchers considered that such events were "most difficult to disentangle from the diagnoses themselves". Anthony D. Pellegrini and Michael Horvat (1995) observed that the increase of ADHD diagnoses tends to coincide with the entrance of children into formal primary schooling. Pellegrini and Smith (1993) found implications of school recess for attention (e.g., the release of pent-up energy) and education. The DSM-III-R criteria for ADHD recognise that schooling is a factor since it requires that ADHD be diagnosed before age 7, by which time most US children will have already had 2 years of schooling. It is not known whether this dramatic shift in children's status is related primarily to endogenous processes in children, such as "maturation," or exogenous processes, such as the structure of primary schooling. Pellegrini and Horvat speculated that the reality of school pressures might "unmask" a disease that was present all along. However, the manifestation of ADHD is believed by many to represent an interaction between endogenous and exogenous factors (Pellegrini & Horvat, 1995, p. 15).

Gretchen B. LeFever and her team reported (2003) that there was a hundred-fold increase in methylphenidate use from 1960 to the turn of the century. Many believe that ADHD's excessive diagnosis points to a strong social component. Classroom dynamics may be important in understanding the increase in medication and in the numbers of children diagnosed with ADHD since, as Noah W. Sobe claims, the classroom "is at once an active site of spectatorship, of *attentional* demands, of mediation between formal governance and parental authority, and of charged power relationships" (Sobe, 2004, p. 283). It may also be that teachers and parents are happier providing a "diagnosis" of ADHD and coping with the behaviour through medication rather than blaming a child (or parents) for disruption. The classroom is often the first place where ADHD diagnoses are made. In fact, in1915 Montessori, a key proponent of progressive education, identified the significance of *attention* stating "When you have solved the problem of controlling the *attention* of the child, you have solved the entire problem of education" (Sobe, 2004, p. 283). *Attention* is linked with successful social integration within the institutional context of the educational system, and education for an individual with ADHD can be problematic. ADHD children often fall into the categories as "special needs children" that necessitate medical examinations (Copeland, 1997). A bio-psychological model of disease in which medicine is standard thus becomes opposed to one rooted in the social sphere. In 1999, children diagnosed with ADHD were 3 to 7 times more likely than other children to receive special education, be expelled or suspended, and repeat a grade (Le Fever et al., 1999, p. 1359, Le Fever et al., 2003). A continuing difficulty is that parents find it difficult to oppose drug therapy in favour of alternate treatments. In contemporary times, according to Sobe, the child's *attention*, the theorisation of *attention*, and how *attention* works as a surface for pedagogical intervention are central to understanding modern schooling and its building of a "modern subjectivity" (Sobe, 2004). This has, in turn, led to the educational system exerting perhaps undue influence over the agency of both parents and children. Most of the testing of the DSM-IV has taken place in psychiatric settings as opposed to paediatric or family practice settings. As a result of such concerns, the American Academy of Pediatrics stated in 2000 that the diagnostic criteria reflected consensus without clear data that support a diagnosis (Homer, 2000, p. 1163). This report also pointed out that the questionnaires were subject to bias and subjective in rating.

4 Diagnostic medical imaging

In the preceding paragraphs I have considered how interpretations of the images resulting from Clock Face Drawing Tests and screeners may influence the determination of medical classifications of *attentional* pathology, a central part of my research. In order to see how brain imaging approaches issues of cognitive development I looked for and located one brain imaging study that attempted to locate developmental differences between children and adults with respect to the executive system and *attentional* ability. During a test in which fMRI was employed to characterise differences in brain activation between children aged 8-12 and adults, a developmental pattern was observed that suggested a shift occurred in cognitive strategies between childhood and adulthood (Bunge et al., 2002, p. 305). In the experiment, two fundamental components of cognitive *attentional* control were tested. One is the ability to filter out irrelevant information and is known as "interference suppression". The second is the ability to inhibit inappropriate responses and is called "response inhibition". Cognitive control is believed to relate to the development of the prefrontal cortex (PFC). The purpose of the experiment was to examine the maturation of neural circuitry underlying the cognitive development, and fMRI was used to characterise the changes in brain activation. The tests utilised were flanker tests (e.g., involving directional arrows discussed in chapter one and go/no go paradigms, which require a participant to perform or inhibit particular actions given certain stimuli. Both tests provide information about the *attentional* system.

The results dealing with interference suppression showed that during suppression, children recruited different brain regions from adults. The researchers stated that this developmental pattern, which had not previously been observed in a brain imaging study, suggested a shift in cognitive strategy between childhood and adulthood. The implication was that children recruit a subset of adult neural circuitry in the pre-frontal cortex (PFC) as they develop, permitting increased control of their responses to stimuli. The results (Figure 60) showed significant lateralisation differences in the prefrontal cortex between the children and adults.

Whereas the adults activated the right ventrolateral PFC and insula, children exhibited activation of and brain behaviour correlations for the left, rather than the right, ventrolateral PFC and insular cortex (associated with language). In other words the opposite hemisphere from adults was involved to carry out the same task in children. The researchers attributed their results to transformations taking place between ages 12 and 19. Some of the confounds involved in the experiment were that nonneural factors might have influenced the fMRI study. The changes of interest that the neuroscientists looked for (because of their links to understanding development) were the recruitment or maturation of neural circuitry, underlying task performance, synaptic pruning, myelination, and changes in cognitive strategy.

Figure 60: fMRI related to interference suppression in children and adults (Bunge et al., 2002) has been removed due to Copyright restrictions.
(A) Group contrast and (B) regions exhibiting a positive correlation between activation and success of interference suppression.

Those changes that were artifactual included baseline glucose consumption and blood flow. In general, the epistemic issues regarding fMRI stem from the fact that, during the performance of a cognitive task, there are changes in blood flow in various brain regions. Questions are therefore raised about the origins of the signal (Gusnard & Raichle, 2001). However there can also be problems in "normalizing scans" and then averaging over them (Victor, 2005). In imaging studies, investigators seek to establish a relationship between a 'categorical' variable, such as the presence or absence of a behaviour and a 'high-dimensional variable' such as an image. The averaging of imaging data can lead to large divergences in its interpretation. The difficulty is that despite the advantages of averaging (e.g., it can identify the average response corresponding to each stimulus and offer a rule that determines which response will be elicited by a particular stimulus while simultaneously improving the signal-to-noise ratio), averaging can obscure important data when the data are non-uniform, may fail to recognize synchronizations among different locations, and it does not provide a way to identify dynamic patterns of activity. Regardless, fMRI is generally considered to provide reliable information about neural activity. By connecting mental illness to physiological abnormalities within the brain, clinical psychology has facilitated treatments for many psychological disorders, including methylphenidate for ADHD (Routh & Reisman, 2003). Nevertheless, medical imaging does not do away with the subjectivity of interpretation that determines medical classifications. Bunge et al. commented (2002) that techniques for normalising children's brains, which are expected to have greater structural variability than adults, are generally lacking and are needed. They also stated that another related data problem concerns the variability of cognitive maturation in children.

The Clinical Practice Guideline on "The Diagnosis and Evaluation of the Child With Attention-Deficit/Hyperactivity Disorder" issued by the Committee on Quality Improvement and Subcommittee of ADHD of the American Academy of Pediatrics clearly objected to using encephalography to diagnose ADHD, stating:

> "Although some studies have demonstrated variation in brain morphology comparing children with and without ADHD, these findings do not discriminate reliably between children with and without this condition. In other words, although group means may differ significantly, the overlap in findings among children with and without ADHD creates high rates of false-positives and false-negatives . . ." (Homer et al., 2000).

This statement could apply equally to fMRI. Diagnostic difficulties were also found with functional neuroimaging studies using positron emission tomography (PET) and single-photon emission computed tomography (SPECT). These, too, were criticised because the studies have variably included control groups with symptoms overlapping the ADHD group (Furman, 2005). The results of such studies again support my premise that some of the problems in determining *attentional* pathology may reside in the determination of norms and also in the selection of "normal" controls. And, in the case of PET imaging, Victor and others have raised practical considerations about the ability to "normalise" data from voxels (volumetric picture elements) to decrease noise-to-signal ratios without affecting "partial-volume averaging".

According to Duncan E. Astle and Gaia Scerif (2008), studies of executive *attention* have traditionally focused upon the age at which children achieve adequate performance on particular tasks. As with the researchers above, they are in agreement that examining the course of changing abilities over developmental time is far more relevant than performance mile-posts. Although fMRI studies are undertaken to inform our understanding of the neural mechanisms that underpin dysfunction they instead realised that ". . . whilst these studies have enabled us to understand in more detail the neural differences which mirror behavioural dysfunction, they are rarely developmental per se. That is, they rarely compare a group or sub-group over a period of developmental time. Instead, it is typically the case that control and experimental groups are carefully matched on the basis of chronological age, mental age, task ability, or gender. . ." (Astle & Scerif, 2008, p. 109). This may be true but it would unfortunately appear to be of limited use in diagnosing and recommending treatment for children with ADHD whose needs are urgent. They also noted that "fMRI studies of executive control in children tend to have smaller sample size than is ideal. When designing paradigms one should consider carefully not only which tasks are chosen, but also such practicalities as session length and matching participants across experimental groups for individual differences" (Astle & Scerif, 2008, p. 115).

5 Art therapy, art, and ADHD diagnosis

As already discussed, the purpose of the Clock Face Drawing Test was to diagnose ADHD by connecting, for example, the omission and rearrangement of clock numerals to malfunctioning sites within the brain. The purpose of the two screeners, the Terry and Dominic-R, were to have children disclose their symptoms by identifying with a range of behaviours depicted in cartoon characters. These drawing tests contrast with the next study: an artwork that looks at the individual as a totality. Artist Robert Buck installed forty-four drawings in New York City during 2007.

Each of Buck's artworks appropriated a drawing from patients of psychoanalysts such as John N. Buck (not related) from his manual, *The Tree-House-Person-Technique* (1948). Note the depicted presence of a tree, house, and person in Figure 61. The 2007 CRG Gallery (NYC) art installation How Am I To Sign Myself? by artist Robert Buck incorporated drawings that reflected psychoanalyst Buck's method. He undermined the idea that there are inflexible norms of behaviour by appropriating art therapy drawings that some have challenged in recent decades into his own work.

Pyschoanalyst Buck considered his technique to be a projective rather than diagnostic, test. Projective techniques are intended to evoke responses from the subject as opposed to assigning tasks. Nevertheless, evaluations of the subjects' responses took place. According to a procedure that psychoanalyst Buck developed (1948), children in a classroom setting were given paper and pencil, asked to draw a house, a tree and a person, and were allowed five minutes to complete each drawing. Following Buck's instructions, the number of non-essential details was counted (e.g., ears, fingers, fingernails, buttons, belts, shoes). Finally, the height of the figure was measured from top to bottom. Each of the children's drawings was evaluated by four persons. Items that did not receive full agreement were not included in the final analyses.

Figure 61: Robert Buck, Untitled "How Am I To Sign Myself?" (2007) has been removed due to Copyright restrictions.
"Interpreting Children's Drawings" by Joseph H. Di Leo, M.D. in "Childhood Revealed: Art Expressing Pain, Discovery and Hope" ed. by Harold S. Koplewicz and Robin F. Goodman, 2000-2007; acrylic paint, charcoal, colored pencil, conté crayon, graphite, ink, and latent fingerprint powder on paper, 9 1/2 X 8 inches.

Unlike the clock face drawings, Buck's artwork was very much engaged with interpretive, social, and artistic issues. His art dealt with the relation between what was really seen and what was imagined by the patients. The finished work was structured by forming analogies between the depicted features of the drawing's subject matter and the search for evidence of pathology. It involved the viewers in reconstructing some of the historical medical records of psychological functioning. In addition to the appropriated drawings, each artwork included a typed excerpt of psychoanalyst Buck's evaluation and interpretation of the patient's representation of a tree, house, person, and, occasionally, a dream from the psychoanalyst's manual. After completing house-tree-person drawings, the subject was generally asked a series of test questions, though due to the subjective nature of the technique, the examiner was able to ask the child only unscripted questions, such as "Is that a happy tree?" or "Is that tree alive?" In the second phase, the subject was asked to redraw the drawings, and another set of questions followed. The test drawings were scored using both objective-quantitative and subjective-qualitative criteria. The qualitative evaluation was derived from the examiner's subjective interpretation of the drawings. As noted by artist Buck (2007), "A tree with a narrow trunk but out-reaching branches could be interpreted as the subject's need for satisfaction, while the walls of a house might correspond to the subject's strength of ego, the windows or absence of them to the subject's relation to the outside world."

The scoring raised the question as to what extent drawings can be interpreted as direct records of the psyche. How much depends upon the artist's own fluency and knowledge of art conventions? To what extent can such drawings be used to assess the level of a child's cognitive development? Violet Kalyan-Masih distinguished between what psychoanalyst Buck called the House-Tree (HT) test and what he called the House-Tree Person (HTP) test although acknowledging that they were related. For example, for the HTP test, a transparency implied sexual guilt or a deficit whereas for HT, a transparency implied a particular level of cognitive functioning (Kalyan-Masih, 1976, p. 1027).

Kalyan-Masih pointed out that support for house-tree drawings derived from Jean Piaget's notions of drawing as one of five semiotic functions in child development: deferred imitation, symbolic play, drawing, mental image, and verbal evocation (Kalyan-Masih, 1976, p. 1026). A conceptual framework, called the Luquet-Piaget sequence, subsequently itemised the developmental stages involved (e.g., scribbling, fortuitous realism, failed realism, intellectual realism, visual realism). Piaget incorporated some of Luquet's ideas into his own idea of developmental stages. According to Glyn V. Thomas and Richard P. Jolley (1998, p. 130), it was Georges-Henri Luquet who noted that an internal model directs children's drawings; thus the development of children's attentional faculties may allow them to become self-critical.

Although many notable psychologists have stressed the cognitive underpinnings of art, including Rudolf Arnheim (1964, 1987) and Jerome S. Bruner (1985), Piaget's concepts of stages have been highly controversial. Howard Gardner criticised them on the grounds that the media and thought processes used in the arts are not fully commensurate with Piaget's model of rational cognition (Gardner, 1979). The incorporation of Piaget's paradigm in theories of developmental progress in art history such as that of Suzi Gablik (1977) has also been heavily criticised because she assumed that a parallel exists between childhood cognitive development and cultural evolution for which there is no evidence (Pariser, 1983).

In 1980, Gardner presented an overview of the relationship between drawing and cognitive development from early childhood through adolescence, concentrating on the role of symbols. This theory was in turn reviewed by Duncum (2003), who noted that part of the problem is that although you can characterise the norm by a "stage theory" of development (e.g., a "U" Curve), it will not account for drawings that fall outside these bounds.

In 2010, Perets-Dubrovsky et al. claimed that having subjects aged 8-10 sequentially undergo a human drawing test and HTP drawing test could distinguish between subjects with ADHD as opposed to those with learning disabilities. They claimed that creating the more complicated HTP drawing placed greater demands on those with ADHD. The hypothesis was that when the test required making a picture of not only a simple figure but also a house, a tree, and a person, it may involve *attentional* issues and emotional resiliency. But the researchers also acknowledged that inability on the part of the subject to complete the assignment satisfactorily might simply reflect a drop-off of interest on the part of the child. The researchers presupposed that cognitive and emotional values could be fully separated by their test, an assumption that has been challenged. Those with views stemming from cognitive developmental neuroscience such as Annette Karmiloff-Smith, have interpreted changes in children's drawings as part of their natural development and not just as a response to external influences (Karmiloff-Smith, 1990, p. 79). Projective tests have become increasingly questioned as lacking conclusive evidence of health or pathology. One critique pointed out that projective drawings that reflect healthy levels of adjustment are typically less considered than those describing pathology (Groth-Marnat & Roberts, 1998, pp. 219-220).

5.1 The art installation

Buck (the artist) recreated the test drawings in his installation, adding latent finger print powder, the substance used by forensic investigators to recover finger prints at a crime scene. In this way he signified his own understanding that the drawings had been used as "evidence" of pathology. Many questions were raised by the art installation, involving evidence, interpretation, agency, and identity. Buck also raised a question about the relationship between the work and the alteration of the gallery's architecture. In addition to the works on paper, he covered the gallery floors with a maze-like text pattern in white chalk, with repeating statements on the floor that include the title of the exhibition (based on a letter of James Joyce) along with variations on the phrases in the letter such as "saw myself signing". As viewers walked through the exhibition, they shuffled the words, making them difficult to reconstruct. As one reviewer noted, any attempted reconstruction on the part of viewers was thus made analogous to the process of psychoanalysis itself (Truong, 2007). In looking at Buck's entire installation, the viewer might become aware, as I did, of the arbitrary nature involved in the analysis of drawings, whether viewed with a clinical or aesthetic eye. For example, relating self-esteem to the size of a depicted figure may have more to do with Western ideals than a clinically-validated observation (LaVoy et al., 2001). The critical comments embedded within each work in the art installation were also reminders that analysis might constrain the creativity to be found in art.

By appropriating the results of the HTP tests and placing them within his own artworks as if they were surrounded by quotations, Buck questioned not only the basis for a drawing's determinations of cognitive function but also asked to what extent these drawings can even begin to define an individual. His "original" part of each drawing was its re-drafting in charcoal, conté crayon, graphite, ink, and latent fingerprint powder and his decision to retain the psychoanalytic comments. The clinical judgments within Buck's drawings are assimilated within them, and it is we, the viewers, who may now pass judgment on how they were originally used in the 1940s.

Semiotics is considered to be a science of signs and/or sign systems and is integral to the understanding of art. In semiotics signs are socially shared, and it is society that establishes their meaning. As art theorists Mieke Bal and Norman Bryson have pointed out, psychoanalysis "is a mode of reading the unconscious and its relationship to expression, and as such it is a semiotic theory" (Bal & Bryson, 1991, p. 195). They have shown that even the notion of a "context" is, itself, governed by interpretive strategies that must be explored. They have also pointed out that the interpretive aspect of semiotics has posed a dilemma for art theory that aspires to certainties. Despite the fact that some of the problems entail the lack of fixed, unambiguous meanings, Bal and Bryson proposed that semiotic tools can further art historical analyses since psychoanalysis involving art can be framed as an interaction conducted among the psychoanalytic theorist, the work, and the critic.

5.2 Projective tests

Projective drawing tests have been criticised for the lack of controls for considerations of cultural/racial variables, parental level of education, and artistic instruction (Palmer et al., 2000). According to Thomas and Jolley (1998), the meaningful psychological evaluation of children from their drawings is highly uncertain since so many factors can influence the outcome. As one possibility, children's emotional attitudes not only towards the depicted objects or persons but towards the topics depicted are factors. As with the Clock Face Drawing Test, one must re-examine the conceptual and experiential bases on which these evaluations rest. Thomas and Jolley concluded that any of the bases of judgement lack credibility. Whether clinicians try to assess the drawings on the basis of personality traits, emotional states, the personal significance of the depicted topic, the developmental level, or the possible neurological impairment, all these aspects have been insufficiently developed. In addition, they objected that much of the clinical use of drawing is not well informed by either research into drawing and contemporary cognitive or developmental psychology (Thomas & Jolley, 1998).

Assessment difficulties are inevitably raised where drawings are concerned since problems arise from their interpretation (Kim et al., 2007). Subjective scoring usually results in notable statistical error because human-scored image analysis is qualitative (Carpenter et al., 2005). Tools have been developed to help achieve the goal of objective scoring for today's professional art therapist, including public domain image analysis software (PDIAS) programs that have been developed to evaluate tests and complement subjective scoring (Mattson, 2009). Increased validity of computer-assisted art therapy assessment may result as processes of image analysis techniques become standardised. Although there are many indications that studio art can facilitate problem-solving abilities, stimulate pleasure and self-esteem (Kaplan, 2000), it would appear that a goal of full objectivity is not inherently likely for drawings and paintings. Nevertheless, studies have begun to explore objective methods of analysis applied to the assessment of art. A combination of objective measures (e.g., formal assessments; behavioural checklists; portfolio evaluation) and subjective measures (e.g., the patient's interpretation of his or her artwork) are generally intertwined (Betts, 2003, 2006).

The HTP is rooted in psychoanalytic theory and its untested assumption is that asking a child to draw a person inevitably results in a picture that directly reflects the drawer's own self image (Machover, 1949). This presumption that a drawing can reflect the person drawing in a direct way stems from psychoanalysis, which holds that all our actions are influenced by powerful unconscious processes. As Thomas and Jolley stated:

> ". . . analysis of a drawing proceeds on the basis that some emotion-activated process modifies the execution of what would otherwise be a visually accurate representation of the selected topic, making due allowance for the age and level of skill of the artist" (Thomas & Jolley, 1998, p. 130).

The problem is similar in one respect to that encountered in the Clock Face Drawing Test; sufficient information may not be known about the course of normal drawing development. The judgments of the HTP and Clock Face Drawing Test consider the inclusion or omission of a feature or its exaggeration or minimisation with respect to the entire drawing and assign them values. Many questions are unanswered such as what is normal for a child of a particular age. Another problem is how one distinguishes increased size because of its contextual importance from socially defined importance. Furthermore, to what extent is it valid to consider a child's drawing as a conscious or unconscious symbol? Is there in fact any fully reliable interpretation of a drawing? In light of the doubts surrounding the HTP, Thomas and Jolley further asked whether the use of drawings in clinical assessment should be discontinued. They decided it should still be used, but as only one slight indication and with an understanding of the limitations involved, which seems fully appropriate and in keeping with my own conclusions about using the Clock Face Drawing Test.

5.3 Other diagnostic approaches through images

More useful approaches to diagnosis through images may by now be available than the Clock Face Drawing Test, the Terry and Dominic-R, or the HTP. One is an approach developed in part by Warren Jones who applied his skills as an artist to problems of autism in children. As he explained in conversation with me, his work in Yale's Magnetic Resonance Research Center focused on combining eye-tracking technologies with functional neuroimaging in order to characterise and quantify neural responses during natural viewing. His collaborative work with paediatrician Ami Klin (2002a, 2002 b) contributed to an understanding of how the gaze could explain autism, often considered a comorbidity of ADHD.

Two participants (seen in the figure below) are juxtaposed; the focus of the view with autism is marked on the left image with crosses below the eyes and that of the typically developing viewer's point of regard is on the right one between the eyes. The boldest crosses mark each viewer’s visual focus while watching the film; the gradational crosses reveal the direction from which the viewers’ visual focus travelled. Figure 62 shows that the autistic child tries to gather information from the mouth of the “shocked young man” in the photograph as compared with the normal child who searches the eyes (Klin et al., 2002b). Klin et al. commented that “the possibility that profoundly abnormal social experiences with onset in the first year of life may affect specific neuropsychological as well as brain processes, rather than the other way around, is typically not discussed or studied” (Klin et al., 2002b, p. 898). These findings may also be relevant to ADHD since many of the symptoms of autism overlap with ADHD and support the value of allowing a joint diagnosis of ADHD and autism (Clarke et al. 2011, p. 229). The model of social development increasingly being looked at today for ADHD reflects a “theory-of-mind” methodology that focuses on social interrelations and empathetic understanding (Uekermann et al., 2010).

Figure 62: Visual focus (Klin et al., 2002b) has been removed due to Copyright restrictions. An autistic man and a normal comparison subject shown a film clip containing the face of a shocked young man (crosses indicate the focus of view).

“Typically developing” infants engage in acts of shared subjectivity (Trevarthen, 1977; Trevarthen & Hubley, 1978). Trevarthen (1977, 1978) demonstrated the importance of the gaze in establishing intersubjectivity. Following the act of attending, the eyes move in coordination with the head and body to permit the fovea to attend to the object of interest. This sequence allowed individuals to communicate their plans to others, assisting their survival. Intersubjectivity relies on eye contact, voice mimicry, and other forms of physical synchronisation. For older infants this intersubjectivity was transformed and extended so that objects of mutual interest, such as toys, succeed in coordinating mutual *attention* and establishing more abstract sorts of communication. Tomasello (2007) later speculated that coordinating visual *attention* may have provided a foundation for the evolution of human language. This supposition was based on Tomasello's work revealing how children and adults engage in "scenes of joint *attention*" prior to children acquiring language. They show preferential *attention* to social rather than inanimate stimuli, and they also prefer to focus on the more socially revealing features of the face, such as the eyes; in contrast, individuals with autism seem to lack these early social predispositions and focus on the mouth. Curiously, it has been noted that autistic individuals are often better at visual search tasks (O'Riordan et al., 2001). This ability has been attributed to increased "stimulus discriminability" as opposed to strategy.

6 Art projects about drug regimens

At just what point does impaired health start to become pathology? Visualisations of this boundary have been little-explored from the standpoint of art history. The last study looked at in this chapter is by video artist Janet Biggs. She addressed the boundary between health and disease in several installations featuring medical states named after such drugs as Ritalin® (methylphenidate), BuSpar® (buspirone), and Risperdal® (risperidone). Her exhibition addressed issues of societal control, and one was led to understand that the term "normal" indicates a relational state. She specifically addressed the *attentional* system in her video essays, BuSpar and Ritalin. In preparation of BuSpar (named after the anti-anxiety drug), Biggs kept the medical records of a beloved aunt over decades as she became her aunt's guardian. The aunt was diagnosed at different times by different physicians as having autism, obsessive-compulsive disorder, ADHD, and apraxia (a disorder of the nervous system characterised by an inability to perform complex, purposeful movements) (Figure 63).

Figure 63: Janet Biggs, BuSpar (1999).
Still from a three-channel video installation.
Photo credit: Janet Biggs

Biggs conducted extensive observations of the effect of different places of rehabilitation as her aunt was moved from one institution to another. This body of work, which includes Ritalin and Apraxia, reflected her ongoing concerns about gender, social codes, aging, values, and behaviour in the context of the individual's relationship to the medical industry and society at large. Biggs attempted to understand and represent the world of someone who could not function in society. While Biggs's work has been interpreted as a critique of an over-medicated society, it developed as an empathetic response to her self-assumed role as arbitrator of another person's perceptions, personal safety, and social interactions. Biggs witnessed profound changes in medical treatment as her aunt was shunted from place to place. Her aunt was initially shown in an institutionalised setting, and the site of responsibility slowly shifted from the professionals to the caretaker. In discussion with Biggs (2008) it was apparent that in her videos, equestrian training (dressage) is often juxtaposed with the suffering of individuals, representing the constricting effects of social habituation and training on creating or disrupting physical and psychological balance.

The boy in the film Ritalin was a friend's son who, in fact did not have ADHD (Figure 64). Nevertheless, to characterise ADHD, the artist presented him as acting out in an uncontainable fury of activity. In an interview with Andrea Inselmann she stated that "Even though the boy is not actually on Ritalin, his drumming has an intensity and commitment that border on obsessive-compulsive disorder. Through editing and other post-production techniques, like altering sounds, I was able to set up a situation with so much input that individual components could no longer be isolated, thus replicating what it might be like to need Ritalin" (Biggs & Inselmann 2002, p. 23).

Figure 64: Janet Biggs, Ritalin (2000).
Still from a four-channel video installation.
Photo credit: Janet Biggs

Biggs later added (2008) that she wished to create uncertainty about whether the boy was actually on the drug. I think this is significant because some artists have a unique ability to raise issues of ambiguity and depict how heath can masquerade and even be mistakenly identified as illness.

Ritalin and BuSpar situated the afflicted individual within a tangible, but minimal social context. The resultant videos offered no programmatic answers to questions about the regulating of human behaviour through drugs to create an acceptable order in society. Biggs has dealt obliquely with issues of free will, but for her, video is a way to examine systems of power and control, asking at what point are we no longer ourselves. Film also has the potential to allow the audience to experience developmental stages of visual *attention*. In 1970 filmmaker Stan Brackage created images as if viewed through the eyes of children in the opening shots of Scenes from Under Childhood (1967-1970). The film opened with red lights as if filtered through closed infant eyes before turning into whiteness. It was shot handheld, incorporating flickers and jumps that mimicked saccades and fixations. For some viewers it suggested the passage of birth and was accompanied by images that look like human cell in processes of duplication (Dworkin, 2005). Through such depictions of subjectivity and childhood development, Brakhage expanded outwards to suggest the place of the individual within the world. These works were not created as a form of healing, but they do speak to everyone's potential to create his or her own meaning.

7 Metaphors of illness in art

One of the implications of visual culture studies is that objects such as health posters and drug advertisements are representative of visual culture and offer important statements about our society. This discipline constitutes a non-hierarchical approach to the visual. Images are considered neither as passive documents to illustrate text nor in isolation from the rest of the world (Cooter & Stein, 2010, 2011). As a teacher of visual culture, W.J.T. Mitchell (1994, 2002) has described his aim ". . . to make seeing show itself, to put it on display, and make it accessible to analysis" (2002, p. 166). Nicholas Mirzoeff (1999) demonstrated how the "visual event" is embedded within social, political, and economic contexts. Part of the goal of this approach to art is to point to the complex forces behind the imagery and aesthetics of the familiar. ADHD may be invoked as a metaphor for the ills of today's society, just as Susan Sontag demonstrated that a body's wasting due to such illnesses as cholera or tuberculosis was associated with particular psychological traits. In more recent times, the cancer victim was held in some way responsible for the body's disease (Sontag, 1966, 1989).

As evidence that visual culture and understandings of contemporary neuroscience are now influencing interpretations of artwork I offer Christine Ross's critical analysis of Rosemarie Troeckel's work at the 1999 Venice Biennale (Ross, 2001). Her review discussed Troeckel's artwork, consisting of three films projected in three separate rooms entitled Eye, Sleepingpill, and Kinderspielplatz. Troeckel's first work, Eye, featured a "technological" eye making constant saccades that "ignored" the spectator. Ross stated "In Troeckel's installation, *attention* is deficient from a cognitivist perspective: the eye is without anchor and is unable to fix a targeted object". Ross pointed out that the film also dealt with the subject of *attention* by using subliminal images, which, like subliminal advertisements, are consciously unregistered by most viewers. Ross concluded that Troeckel's installation considered aspects of vision in "relationship to the growing field of investigation in cognitive science and neurobiology dedicated to the study of *attention* and sleep disorders". Her finding is very much in accordance with my hypothesis that some of this art has harnessed the power of images to question society's values, goals, methods, and public policies. In this way, the art may provide a model of resistance for marginalised groups. In Ross's view, *attentional* disorders reflect a malaise that permeates our society.

7.1 Dimensional versus categorical judgments

As social science critic Peter Conrad observed (1976, 1992), the medicalisation of ADHD has greatly expanded (Conrad, 1976, 1992; Conrad & Potter, 2000). Thomas Skrtic, a professor of special education, noted that psychiatric determinations support a bio-psychiatric model of mental disorders over approaches that stress social conditions (Skrtic, 1991; Skrtic & Sailor, 1996). Danforth and Navarro (2001), writing about public school special education programs, have pointed out that determinations of ADHD are based on guidelines in the DSM, which is periodically updated. A critical aspect of understanding how the DSM determines diagnosis involves its balance between categorical and dimensional measures (Kessler, 2002). Critics see the DSM as an adversary that has constrained individuals through adjudicating illness based on debatable standards (Harwood, 2006). Danforth and Navarro (2001, p. 181) concluded that what is at stake is "the issue of how a culture views individual difference and how it tolerates non-normative behaviours". The DSM reifies the institutionalisation of the diagnosis and abets the potential of medicalisation. Conrad has shown that if a problem has a genetic component, the problem is revisited in light of the potential of new medical treatments with pharmaceutical drugs (Conrad & Potter, 2000). As Conrad and Leiter have stated "Medicalization narrows the definition of health and widens the definition of sickness" (Conrad & Leiter, 2004, p. 171). The categorical diagnostic model of the DSM-IV has many advantages in a clinical context, yet it has coexisted uneasily with the traditional psychometric standard of assessment (such as the Clock Face Drawing Test). The DSM has been useful to provide clinicians with a set of criteria to diagnose *attentional* disorders, but their routine application may result in measurement methods that have less than optimal validity (Heiligenstein et al., 1998).

ADHD is a multifactorial disease; administering methylphenidate to children with ADHD has raised concerns for public health due to possible persistent drug-induced neurobehavioural alterations. Data from animal research have indicated that methylphenidate can induce short-term changes in neural plasticity, as seen by modulation of expression of key genes and functional changes in striatal circuits (part of the basal ganglia). The concern is that these modifications might in turn trigger other changes, consisting of altered processing of incentive values and a modified flexibility/habit balance (Adriani et al., 2006). The DSM continues to be based on symptoms as opposed to biological causes since no single physical cause has yet been identified for ADHD. The US National Institute of Mental Health (NIMH) wants to close this gap by finding ways to classify disorders that are based on neural circuits (Miller, 2010). A new effort is underway called Research Domain Criteria (RDoC). The aim is to specify brain regions or neurochemical signalling pathways. The impetus to do so is the fear that the DSM is hampering research. Bruce Cuthbert, an NIMH psychophysiologist, claims that ". . . the problem with the DSM disorders is that they're very heterogeneous and may involve multiple brain systems" (Miller, 2010, p. 1437). As a result, workshops are being established to refine the RDoC entries with the hope that they will eventually replace DSM criteria.

According to Boris Groys, art has become a life form in the age of biopolitics, and the artwork has become a documentation of this life form (Groys, 2002). Increasing numbers of artists now create artwork in relation to the body, biology and medical practice. Some of the artistic practices have held potential value for therapeutic practice, such as works by Krysztof Wodiczko and Lygia Clark (Marxen, 2009). These approaches actually constitute a new form of artistic production. Foucault (1994) offered an indictment of clinical medicine and its dehumanizing gaze. Susan Sontag (1966) popularised the metaphorical analysis of disease and its overlying of moral meanings onto illness. Artists Biggs and Goodman, in tacit agreement with Sontag, have used art to challenge the politics of health representation, interrogating the social, political, and environmental factors that influence our perceptions of health and affliction. Some contemporary artist activists have championed strategies of community-based activism. For example, artist Suzanne Lacy (1995) shifted the nature of the art discourse during the 1970s towards a greater consideration of communication and political intention as opposed to a focus on media and spaces. She identified a "deepening health and ecological crisis" as important factors that have inspired community-based artwork (Lacy, 1995). Charles R. Garoian concluded that art educators can further the understanding of the implications of health-related images through a curriculum reform that includes visual culture. Such programs would value students' ability to interpret the ideological content of visual images that affect health. To accomplish his goal, Garoian identified six metaphors of illness that have visual equivalents. These consisted of 1) the surveyed body (as seen in delineations of linear perspective and anatomy), 2) the sanctified body (as viewed in some of the moralising of religious art), 3) the simulated body (visualised according to scientific categorisation), 4) the surrogate body (as affected by industrialised medicine), 5) The commodified body (as viewed under corporate capitalism), and 6) the repositioned body (reflecting multicultural politics) (Garoian, 1997).

Each of the categories of metaphors listed above could be discussed at length, but such a discussion is beyond the scope of this thesis. The main point is that language helps to reify notions of illness. Garoian (p. 13) cited Stafford's view that classifications of states of health into binary oppositions like "the normal and the deviant, the well and the sick" have helped to ensure that anything that deviated from the authority of "higher" normative constructs was considered abnormal (Stafford, 1991, p. 29). Deborah Lupton (1994) has also characterised physical types of metaphors that have been used to "boycott" the afflicted. They include mechanical metaphors that represent the body as a construction of component parts (p. 59) and military metaphors that represent the body's immune system as a defence against the invasion of alien bodies (p 61).

According to Lupton (p. 177) the surrogate body is an idealised body that relies on 20th-century devices such as technological imaging devices, life support systems, and “boosters for the body's immune system” in the form of immunisation and modern drugs**.**

The conclusion pertinent to this dissertation is that artists have the ability to “intervene in a wider arena of representation: the mass media, medical discourse, social policy, community organising, sexual identity” (Garoian, 1997, p. 20).[1] They have accomplished this through publications and by offering alternate, compelling images.

In the course of my research I spoke with a small number of artists who had been diagnosed with ADHD. Several attributed their artistic curiosity and experimentation to what the medical profession deemed a liability – namely distractibility. In general, few well-known artists were willing to make any public acknowledgment about their having been diagnosed with ADHD. This situation is bound to change. As one example, Kóan Jeff Baysa, an immunologist turned curator, organised an exhibition, *Neurodiverse Neuroplastic Universes*, which interrogated concepts of neurodiversity, embracing atypical development as a normal human difference.[2] The basic thrust of this chapter has been to provide reasons why society should periodically reassess its categories of wellness and illness since society, itself, is implicated in the process of medicalisation.

8 Conclusions

In this chapter I attempted to cross-correlate images and imaging associated with attentional pathology from both cultural and scientific contexts. In addition I compared the scientific diagnosis of ADHD and its dependence on establishing norms of behaviour with several approaches by artists that question the validity of established norms of behaviour. By analysing Clock Face Drawing Tests, I illustrated how variations of objectivity and interpretation with regard to images and imaging have, at times, helped to create unsupported perceptions of what constitutes the norms of behaviour in children with regard to diagnoses of ADHD. As my analysis of the documented tests in major medical and psychological literature shows, the scientists who have contributed to this literature have also questioned whether there are sufficient data about sensitivity and specificity on which to draw firm conclusions.

Although attempts have been made to factor social and racial factors into considerations of behaviour with regard to diagnoses of ADHD through the use of methodologies like the Terry tests, the efficacy of these tests has been hard to gauge since they have not yet been applied to sufficient numbers of subjects. The lack of knowledge about what is considered “normal” behaviour and “standard” human development necessarily affects the interpretation of all imaging. ADHD is currently understood as a group of behavioural symptoms that reflect impulsivity, hyperactivity, or inattention to extreme degrees. This chapter has determined that how one defines “extreme” and “normal” has not been fully resolved.

The review of particular artworks that questioned medical diagnosis supported my claim that art can provoke new insights about the neurobiology of *attention*. The discussion of how these artworks opened up audience debate substantiates that part of my thesis premise that art can successfully air such issues. I outlined the advantage of bringing art and interpretive images into considerations of diagnosis and how art can capture how others see the world. I concluded that images can become a way to challenge some of our ingrained perspectives on reality. The art discussed in this chapter extended the level of discussion from beyond the brain to the larger world and the place of the individual within it. It became apparent that issues of norms, categorisation, social trends, and illness are not easily parsed. The artworks succeeded in visualising how large social issues frame the context in which diagnoses are made.

The various tests analysed in this chapter also offered a way to reflect upon the value of visual literacy and to understand some basic differences between an artistic endeavour and a scientific activity. In science, the researcher is the one who defines the conditions of the experiment and controls how the test is used. The scientist using a predefined method interprets those results. By contrast, in art, the artist is the one who defines the conditions of the experience, and he or she must be attentive to the event. His or her *attention* is part of the meaning of the experience, which aims to capture qualities of emotional engagement. I also pointed out a similarity between scientists and artists. As in art, the physician must actively engage with the process to create a meaning. The further conclusion was that art and visual literacy can help the public discriminate between medical and social factors. Those who have been opposed to the medicalisation of *attentional* problems like ADHD view them less as illnesses and more like variations of the norm and seek to change some of the rulings of the DSM. Artist activists fight to change public perception through the power of their visual narratives, and some artists have re- drawn some of the connections between our biological faculties and shortcomings and our social contexts. The malfunctioning of *attention* involves powerful metaphors, and artists like Briggs and Buck, in particular, have adapted some of the images associated with pathology to probe society’s values and public policies that frame the context in which medical discoveries are made. Because directing and holding *attention* belong to the essence of art-making, artists may be able to contribute new insights in the future into the state of neuro-diagnostic analysis under particular circumstances and assuming pertinent medical knowledge.

Endnotes

1 In this passage, Garoian cites J. Dykstra (1995), ‘Putting herself in the picture: Autobiographical images of illness and the body’, *Afterimage*, vol. 23, no. 2, 16-21. Dykstra, in turn, cites Maruschka.

2 See Kóan Jeffry Baysa website; accessed 2011, <www.senseight.com>.

CHAPTER 5: Visual Inscriptions of Health and Disease

1 Introduction

This chapter looks closely at visualisations associated with *attentional* pathology, particularly those marking the borders between health and disease. Using ADHD and methylphenidate (MPH) as models respectively of an *attentional* disorder and its management, I start with an analysis of the chirality (handedness) of methylphenidate and then explore the ramifications of the isomeric technology that separates chiral molecules into their mirrored components. The molecular structures that result from this process can exert a profound modulating influence upon the *attentional* system. The unique relationships of form to function that are found in chiral structures have been instrumentalised by the pharmaceutical industry, and I discuss how this may have played a role in reinforcing the growing medicalisation of ADHD in the US.

One of my aims in this chapter is to show how some artists and designers have discovered ways to re-insert humanist values into technologies associated with *attention*. The last chapter questioned the role of images and imaging with respect to classifications of *attention* pathology. This chapter explores how visualisation techniques and the borrowing of a methodology from economics might help raise public awareness about the basis for categorisation judgments in medicine. In keeping with the thesis claim that art can visually inscribe some of the social forces that frame a disease's diagnosis and treatment, chapter five is therefore largely focused on design and data visualisation with respect to *attentional* pathology and the socioeconomic infrastructure in which it is embedded.

2 Instrumentalising chiral molecules

Methylphenidate (a.k.a. Ritalin®, Concerta®, Metadate®, or Methylin®), along with other drugs used to treat ADHD has a chiral structure. Such structures were first recognised in 1848 when Pasteur observed that crystals of sodium ammonium tartrate obtained by slow recrystallisation at room temperature were of two mirror image crystallographic forms. In this way it was discovered that amino acids come in two forms, called L (laevo-, or left-handed) and D (dextro-, or right-handed) (McManus, 2002). One form rotates polarised light to the left and the other to the right. The two different types of amino acid are chiral; virtually all biologically active forms of amino acids are of the L-form, and most biologically relevant sugars are of the D-form. DNA is a right-handed helix (Hargittai, 2007).

Figure 65 shows a simple chiral molecule, a carbon atom with four different groups attached to it (Flack, 2003). The carbon atom is considered to be a chiral centre (sometimes also called a stereogenic centre, asymmetric centre, or stereocentre). It is characterised by an atom that has different groups bound to it in such a manner that its mirror image is non-superimposable.

Figure 65: Chiral centre has been removed due to Copyright restrictions.

Stereoisomers are two molecules that have the same chemical formula and bond structure but a different spatial arrangement of atoms. In turn, there are two types of stereoisomers: enantiomers and diastereomers. An enantiomer is a special type of isomer in that it contains the same type and number of atoms as its mirror image, but the atoms are all connected in the same order. The only structural difference between one enantiomer and the other is the geometry of the spatial arrangement of the atoms (visualise the left and right hands). Diastereomerism occurs when two or more stereoisomers of a compound have different configurations at one or more (but not all) of the equivalent (related) stereocentres and are not mirror images of each other as seen in Figure 66 below. When there are two chiral centres in a molecule and identical groups from each centre are on the same side of the plane of the molecule, the prefix "erythro" is often used; when the groups are on opposite sides, the prefix "threo" is used instead.

Figure 66: Stereoisomers and diastereomers has been removed due to Copyright restrictions.

Methylphenidate, the drug of choice for treating ADHD, is a norepinephrine and dopamine reuptake inhibitor (Challman & Lipsky, 2000). The prefrontal cortex needs a proper level of catecholamines to function optimally, and therapeutic doses of stimulants can augment catecholamine transmission in patients with inadequate dopamine and/or norepinephrine levels. Too little or too much catecholamine (norepinephrine and dopamine) release can impair the prefrontal cortex (Arnsten, 2009). It would seem counterintuitive that a stimulant (methylphenidate) might be used to slow down hyperactivity. One theory is that methylphenidate activates the inhibition that is present in normal brain centres, causing a behavioural effect. Methylphenidate is posited to correct neurotransmitter imbalance, and it increases the amount of dopamine signalling that occurs.

Methylphenidate has two chiral centres (represented as 2 and 2', which means a total of four stereoisomers exist. Figure 67 shows the chemical form of the pharmacologically active enantiomer of methylphenidate. When equal amounts of enantiomeric molecules are present together, the product is termed racemic; thus a racemic mixture will not rotate light. Methylphenidate was first marketed as a mixture of two racemates, 80% (±)-erythro and 20% (±)-threo. Subsequent studies of the racemates showed that the central stimulant activity is associated with the threo racemate, thus directing subsequent efforts into the separation and interconversion of the erythro isomer into the more active threo isomer. Beginning in the 1960s, the racemate form was used to treat children with ADHD or ADD. (This was one reason my thesis dates from that point in time.)

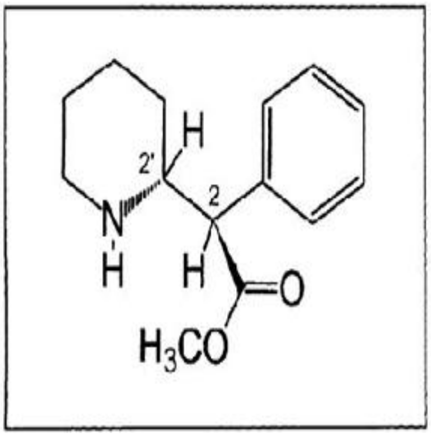

Figure 67: The structure of d-threo methylphenidate.
The pharmacologically active enantiomer of methylphenidate.

The beneficial effects of a drug like methylphenidate can reside in one enantiomer with its paired enantiomer having no activity, some activity, or antagonist activity against the active enantiomer (Cayen, 1991). The full implications of chirality became understood following the tragedy of birth defects that were caused by the drug, thalidomide. It was marketed in Europe in the 1950s and was withdrawn after it was found to cause severe birth defects (e.g., defective limb development) when taken during pregnancy.

To advance my claim that art can air some of the social and economic realities involved in marketing medicine, it is first important to understand why chiral drugs have had a significant economic impact: worldwide sales of chiral drugs reached more than $159 billion in 2002, and in 2007, chiral molecules comprised more than half of all drugs approved worldwide (Darrow, 2007). Chirality is a key principle in designing a drug for treatment of the *attentional* system, such as methylphenidate (Markowitz & Patrick, 2008)**.** Judicial decisions about chirality have notable economic consequences for the pharmaceutical industry since isomeric separation can extend the length of a product line.

Some of the factors involved in chiral drug marketing include the expense involved and how the law impacts on decisions to grant patents for the single enantiomer. Among other considerations, proof is required that the invention (i.e., the constructed molecule) is new, useful, and nonobvious (these are required of any patented innovation)**.** Part of the problem of providing such proof is that, as knowledge of enantiomers increases and resolution techniques improve, less inventiveness is required to make a single enantiomer from its racemate. It therefore becomes increasingly "obvious" in legal terms. The history of legal cases surrounding enantiomers reflects these difficulties and motivations (Darrow, 2007).

By 1998 a generation of single-enantiomer drugs was coming off patent. Around the same time, single-enantiomer drugs were becoming the standard within the pharmaceutical industry (Darrow, 2007). Due to the difficulty of separating the enantiomers from one another, many chiral drugs were initially sold in racemic form. As the patents covering these racemates expired, pharmaceutical companies have, whenever possible, used isomeric-separation technology to create the single-enantiomer versions of the drugs in order to extend product life.

2.1 The technology of attention

The technology of *attention* has typically been associated with various forms of entertainment that captivate the viewer. Jonathan Crary examined how the understanding of *attention* changed during the nineteenth century as the environment became filled with apparatuses and spectacles; a current example would be the incorporation of 3D technologies into commercial cinema. Another current trend concentrates on how multi-tasking can distract one's *attention*. This dissertation presents a lesser-known technology that also affects *attention*. Isomeric separation technology has yielded profound effects in the way its products, chiral molecules, modulate the *attentional* system. Since Pasteur first discovered the chirality of molecules, technologies have developed to measure and make "enantiopure" materials. Among them is the chromatographic separation of enantiomers, with preparative supercritical fluid chromatography in addition to high performance liquid chromatography. To do this on a commercial scale has entailed developments in analytical technology that allow detection of one enantiomer in the presence of the other at concentrations found in biological fluids. The advent of nanotechnologies has recently opened up new possibilities for enantioseparation (Sancho & Minguillón, 2009).

The increased feasibility of such efforts led the FDA to issue a formal stereoisomeric drug policy in 1992 (Darrow, 2007). The decision to develop the racemate or single enantiomer, as with nonchiral drugs, revolves around safety, efficacy, and the goal to develop new candidate drugs using optimum cost and time resources (Hutt, 1991). To sum up the possibilities, there are situations (e.g., physicochemical characteristics, economics, chiral inversion) where, depending upon safety and efficacy evaluations, enantiomers or racemates can be reasonably justified, and, according to FDA's 1992 Policy Statement, it is required that such justifications are clearly delineated in new drug application submissions.

For the purposes of this thesis, my intention in exploring this in such detail has been to establish that considerations of molecular chirality are important to industry. Besides market incentives, the pharmaceutical industry is always motivated to obtain commercial products with improved properties; indeed, improvements depend upon product innovation (Higgins & Graham, 2009). Sometimes this will be a racemic drug, but more often today is an enantiomer. To emphasise an important point, I note that while single-enantiomer drugs may be more effective at the same dosage as the racemate, clinical equivalence can be achieved by simply increasing the dosage of the racemic drug. Ultimately, the determination of whether and when enantiomers should be patentable is a public policy question (Darrow, 2007). I suggest that artists and designers can and should have a role in this debate if they so wish. This thesis asks whether and how art might make some of these critical factors better known to the public (without surrendering a claim as art). Doing so may raise awareness of some of the market forces surrounding a drug such as methylphenidate.

3 Chirality in art

By contrast with industry which has used chiralityas a basis for producing drugs and delivery systems for disorders such as ADHD, artists have generally used its structures to create art and designs, often of unexpected breadth since these principles can reflect upon the origins of life, itself (e.g., Robert Smithson's Spiral Jetty). Carbon nanotube configurations are defined by chirality, and some artists/engineers are involved in the construction of nanomolecules while others are investigating applications related to water pollution and purification. Chirality is not just a feature of molecules invisible to the eye but is also a property found in nature, including pine cones, quartz crystals, and snails, which have long served as artistic models. Artists' explorations of chirality have tended to focus on both aesthetic and cultural concerns. Artists like Mario Merz have often used the Fibonacci spiral as a geometric form representing both expansion and growth. Some artists following the lead of Stephen Wolfram (who, in turn, followed the lead of D'Arcy Thompson) have used cellular automata to model growth relationships found in spiral forms. As other examples, after the working draft of the human genome was announced in 2000, many artists appropriated the double helix structure of the DNA molecule, which offered chiral structure and instant iconic recognizability. Scientist Keith Roberts of the John Innes Centre at Norwich observed that artists frequently got the chirality of DNA wrong; a common error was to make it into a left-handed double helix.[1] Unlike the scientists, however, most artists were more interested in the symbolic potential of chirality than strict accuracy.

By assigning the title, Enantiomorphic Chambers, to his sculpture (Figure 68), artist Robert Smithson made it clear that his reference to chemistry was deliberate. He fully intended to base his sculpture on crystalline compounds with a mirrored relationship to each other. Enantiomorphic Chambers initiated what several art historians have viewed as a broad discourse on concepts of opticality. As elaborated by Ann Reynolds (2003), Jennifer L. Roberts (2000), and Caroline A. Jones (1996), his sculpture defeated a viewer's expectation of a coherent, binocular image. Roberts noted that ". . . Smithson synthesises stereochemistry and crystallography with physiological optics, locating the enantiomorphic dislocation right between the eyes of the seeing subject. The piece was constructed from two wall-hung steel supports holding mirrors set at oblique angles precisely calculated so that when a viewer stood between the two chambers, the mirrored images canceled themselves out and 'abolish[ed] the central fused image'" (Roberts, 2000, p. 555). Roberts pointed out that the inner quote – "abolish[ed] the central fused image" – was taken from Smithson's *Pointless Vanishing Points*. She amplified upon Smithson's stated ideas of the "incapacity" of mirrors in which Smithson stressed their tendency towards dispersion and fragmentation as opposed to their specular potential. (Specular light bounces off a surface in a preferred direction rather than bouncing in all directions like a diffuse light.) She located the source for this notion in crystallography (Roberts, 2000). She further observed that Smithson applied the concept to most of his oeuvre, all of which involved reflection, and she concluded that ". . . the central axis, or hinge of the enantiomorphic reflection, called a dislocation in crystallographic terminology, perfectly encapsulates the empty centre of postmodern subjectivity" (Roberts, 2000, p. 555). As David Joselit summarized (2003, p. 620), "This sculpture is an amended model of a stereoscopic viewing device fitted with mirrors rather than photographs. Instead of reflecting back the viewer, the mirrors in this work conjure her away".

Figure 68: Robert Smithson, Enantiomorphic Chambers (ca. 1964) has been removed due to Copyright restrictions.

Smithson's study for the sculpture was a sketch drawn on top of a stereoscopic diagram by James P.C. Southall in his 1961 book about physiological optics (Figure 69). Reynolds claimed that Smithson's intervention into an extra-aesthetic discourse on perception was fostered in part by the artist's close readings of Gombrich (1960) and perceptual psychologist M.D. Vernon. She also made the point that Smithson exposed the limitations of formalism as part of a more extensive discourse on vision.

Figure 69: Robert Smithson's notes superimposed over Southall diagram (ca. 1964) has been removed due to Copyright restrictions.

Smithson's 'afterthoughts' about his sculpture were made apparent in a subsequent sketch and collage (Figure 70), which shows the body intervening between a fused binocular image. It emphasized that the viewer, when standing between the mirrored images, would not find convergence of the two images where it would be expected to occur. As a result, a kind of blindness appears as the subject of the artwork. The writing below the "headless body" in the image below includes the phrase, "Stopping of Sight . . . by lowering the head".

Figure 70: Robert Smithson, After-thought Enantiomorphic Chambers (ca. 1965) has been removed due to Copyright restrictions.

Other works of Smithson, including Spiral Jetty (1970), also involved chirality within the context of crystals. Spiral Jetty is located in the Great Salt Lake in Utah and was constructed of basalt rocks and earth from the area (Figure 71). Many have commented upon its spiralling echo of the Milky Way. The jetty that Smithson created is 1500 feet long and 15 feet wide and displays its handedness by stretching counterclockwise into the water. I suggest that, through selecting this site for Spiral Jetty, Smithson called attention to the mysterious origins of chirality. Smithson was intensely moved by the presence of primordial forces (Holt, 1979, p. 113). He was intrigued by the presence of salt crystals and by knowledge of the ancient archaebacteria (causing red colouration) surviving in such a salty environment. Archaebacteria live in extreme habitats reminiscent of the environmental conditions in archaean times. They are sometimes viewed as living witnesses of early stages in biotic evolution since their cell membranes are chemically different from all other living things (Wildhaber et al., 1987). While bacteria and eukaryotes have D-glycerol in their membranes, archaeans have L-glycerol in theirs, in this way reminding us of the mystery of handedness in the universe.[2]

Figure 71: The "handedness" of Smithson's Spiral Jetty (1970) has been removed due to Copyright restrictions.

4 Visual literacy

The artistic interests in handedness and its links with opticality and evolution could hardly be more different from those shown by industry. As one example, industry has analysed the gaze of the consumer to assess left/right viewing patterns, removing its analysis from the original objectives of testing and training *attention*. Industry has conducted considerable research on what captures *attention* and has concluded that, for viewers who read left-to-right, an "F-shaped" heat map viewing pattern of web pages based on eye-tracking compilations improve the effectiveness of ads (Nielsen, 2006). The first eye movement is generally horizontal and is then followed by a second horizontal movement further down a page. In addition, viewers tend to scan the content's left side vertically. Market researchers have also constructed models of visual *attention*, such as the "Attention Capture and Transfer to Elements of Print Advertisements" seen below (Pieters & Wedel, 2004) (Figure 72)**.**

Consumer testers distinguished between the different features of an ad that compete for *attention*. These factors include an ad element's surface size and visual pop-out. The extra amount of *attention* that an ad element captured beyond baseline *attention* because of increases in its surface size defined incremental *attention*. The fact that the gaze and *attention* can be so readily appropriated for commercial purposes makes it important that artists and designers learn to make use of similarly sophisticated tools to direct *attention* in meaningful ways.

Figure 72: Analysis of attention capture (2004) has been removed due to Copyright restrictions.

Many would agree with physician Thomas Bodenheimer's observation that media technologies have altered the arena of drug development, marketing techniques, and advertising in undesirable ways (Bodenheimer, 2000). W.J.T. Mitchell made a different point, observing that "The great achievements of modern technologies of representation – propaganda, advertising, surveillance – are scarcely conceivable without modes of realistic representation" (Mitchell, 1991, p. 31). Mitchell also suggested a remedy; he stated that this tendency can be countered with educational strategies for understanding the implications of health-related images. Programs can be developed, in other words, that would enhance the students' and public's ability to interpret the ideological content of visual images that affect their health (Mitchell, 1994, p. 16). For this, training in visual literacy is central, one of the points made in my thesis introduction. Training and knowledge of visualisation techniques and graphic design offer important ways of developing such literacy.

Just as advertisers have appropriated the ways the brain processes information for profit, many graphic designers have explored data visualisation for its ability to communicate mathematics and statistics to the public. This has been invaluable in medicine; visualisation plays an increasingly essential role in displaying the causes of failure of healthy physiological regulation, in aiding the development and monitoring of therapies, and in drug development.[3] In general, medical concerns no longer emphasise one organ, one cell, or one molecule, but are conceived in terms of complex systems of interacting agents that make up an organism. Some data visualisations have made these concerns more visible than others. According to medical statisticians, Ulf Grenander and Michael I. Miller (1994, p. 549), "The objective of statistics is the understanding of information contained in data. To achieve such understanding statistics employs a variety of methods, one of the most powerful being the graphical display of characterising functions derived from the data. We can speculate that a reason for this is that the visual processing in man is so formidable, not only in terms of its computing power but especially in its ability to organise its inputs into coherent structures".

4.1 Capitalising on principles of visual attention

To what extent are interpretive decisions already embedded in our medical technologies and visualisation tools? As designer Colin Ware pointed out, a variety of techniques have been developed by software designers to solve problems of focus and context in medical visualisation, including distortion, rapid zooming, elision, and multiple windows; many of the solutions have been developed in tune with our ability to process information (Ware, 2004, p. 339; Ware & Mitchell, 2008). It was noted in chapter three that, in many regions of the brain, neurons are arranged topographically. For vision, this means that adjacent spots on the retina are represented by adjacent neurons in the lateral geniculate nucleus and the primary visual cortex. To Ware and Knight, the topological arrangement suggested that the pattern that will excite a neuron is the pattern that the neuron inherently responds to (Ware & Knight, 1995). They have made designs in accordance with this information.

Designers can capitalise on a viewer's preattentive processing by restricting the number of colours used in a design to eight or fewer colours. For related reasons, the number of orientations or sizes should also be limited since only four can be visually distinguished (Ware & Knight, 1995). Ware and Knight stated that this kind of information can also be applied to the visual perception of texture just as it has been used for colour. Many of the theoretical accounts of textural perception were conducted by David Hubel and Torsten Wiesel (1968) and were based on a class of neurons (called "bar" and "edge" detectors) that were found in the visual cortex of mammals. Bela Julesz subsequently found (1975) that only the "first-order statistics" of textons (graphical texture primitives) have perceptual significance since further distinctions cannot be processed by preattentive vision. The human vision system has "channels" that selectively respond to spatial frequency and orientation. Mathematical models were made of the neurons, and texture perception was modelled using what is known as the "Gabor function". A Gabor function is a product of two functions (a Gaussian function and a sine function). Gabor filters are used for edge detection. According to Ware and Knight (1995), the frequency and orientation representations of the Gabor filter are similar to those of human visual system and have been found to be particularly appropriate for texture representation and discrimination. This knowledge has been used by some designers to insure that textures do not interfere with each other visually.

Tradeoffs are invariably involved in making design choices regarding colour, texture, and elements of form. As a general rule, clear delineation of a symbol from its ground enables fast, easy detection by a viewer. Multidimensional data has also been used as a way to take advantage of the limitations of the visual system. A glyph is a graphical object that conveys multiple data values (Ware & Knight, 1995, p. 145). In making a glyph, multiple data are mapped that show different aspects of the appearance of the graphical object. Colour might represent severity of an illness, shape might represent the gender most affected, and location could be related to the x-y coordinates where the glyph is plotted. Glyphs can also be designed in ways that enhance visual search.

It is apparent that designers and artists who have knowledge about the visual system can take advantage of the operations of visual search by facilitating the detection of key points in their work. This is yet another reason that artists can profit by in-depth knowledge of neuroscience. As was evident in the discussion of inattention blindness in chapter two, information that is unattended to will not be likely to be seen. Knowledge about visual *attention* can be used as an expedient way for designers to organise data visually and take advantage of a viewer's preattentive processing. Creators can make use of the knowledge of how visual processing takes place in order to maximise the possibility of effective communication.

4.2 Values embedded in software

To challenge the rising influence of advertising, media, and the market, Pierre Bourdieu (1993) urged intellectuals to combine competencies of scientific analysis with creative communication. Certainly one way to do this is through the images and visualisations produced by some artists who are very much aware of the seduction of advertisements and have countered them with images that have attempted to unearth power structures and market forces. The reasoning is that since people have designed the technologies on which medicine, education, and politics depend, they may need to transform it to accommodate its original aims.

Martin Heidegger (1889-1976) questioned technology, realising that it was critical because it related to our way of being in the world (1977). This questioning is also urgent today. Software tools embed the decisions of their designers, and artists are increasingly involved in creating the tools. For example, some artists have invented alternative approaches to designing computer interfaces (Perlin & Fox, 1993). Scott Sona Snibbe of Interval Research Corporation described how he collaborated with artist Golan Levin to create an interface based on the aesthetics of Paul Klee, with the aim of using the line's potential for dynamic expression (Snibbe & Levin, 2000). In light of the earlier discussion about handedness, note that one of their software designs resulted in work that was "handed". The designers insured that a counter-clockwise movement of the user's hand resulted in a collapse and inversion while the opposite movement resulted in expansion. They stated that the platforms under which the tools developed influenced their aesthetic range. The aim was to create "phenomenological user interfaces" that directly engaged the body (Snibbe & Levin, 2000). Today, Apple offers a range of multi-touch applications like pinching on its iPhones that are based on intuitive gestures. According to Sara Diamond (2011), many artists have developed software, resulting in commercial products that embed the aesthetic decisions. She pointed out that "Softimage, a large commercial enterprise once owned by its makers, then by Microsoft, and then by Avid, emerged from the desire of artists and designers for a 3D software that would realise their vision and facilitate creative work" (Diamond, 2011, p. 189).

One of the aims of database art is to force the consideration of information that is often overlooked by exposing the underlying data relations (Paul, 2003; Manovich, 2007). I argue that, whereas in science and medicine the goal of data visualisation is often efficiency, artists instead tend to draw *attention* to contextual factors. Examples include works by Josh On (2001) and Mark Lombardi (1999), who charted social and political relationships. Edward Tufte has documented a range of such works (1997). These examples support my claim that artists can productively participate in public debate about important social issues through their visualisations.

In keeping with my thesis premise, the work of many of these practitioners has confirmed that designers inculcate very different aesthetic values from those in industry; these values are typically marked by an interest in promoting agency and expression.

5 Two art projects about ADHD

At issue in the last chapter was how images and imaging relate to the diagnosis of ADHD. This chapter asks how artists and designers can raise awareness of the socio-economic factors involved through their visualisations. My research resulted in two works: an annotated chart of the history of methylphenidate production and a novel visualisation, Navigating ADHD (Figure 73). The work in Figure 73 relates to the chart drawings of political intrigues during the 1990s by Mark Lombardi and They Rule by Josh On (2001).

5.1 Navigating ADHD

The image in Figure 73 is my interpretation of the growing medicalisation of ADHD in the US as signified by the increase in incentives for methylphenidate production. I manipulated an image of the volcanic fissure zone (Mid-Atlantic Ridge) that runs through Iceland and separates the North American from the Eurasian tectonic plates. I mapped data about methylphenidate production onto this division as a metaphor of the deepening rift between the "continents" of the normal and abnormal.

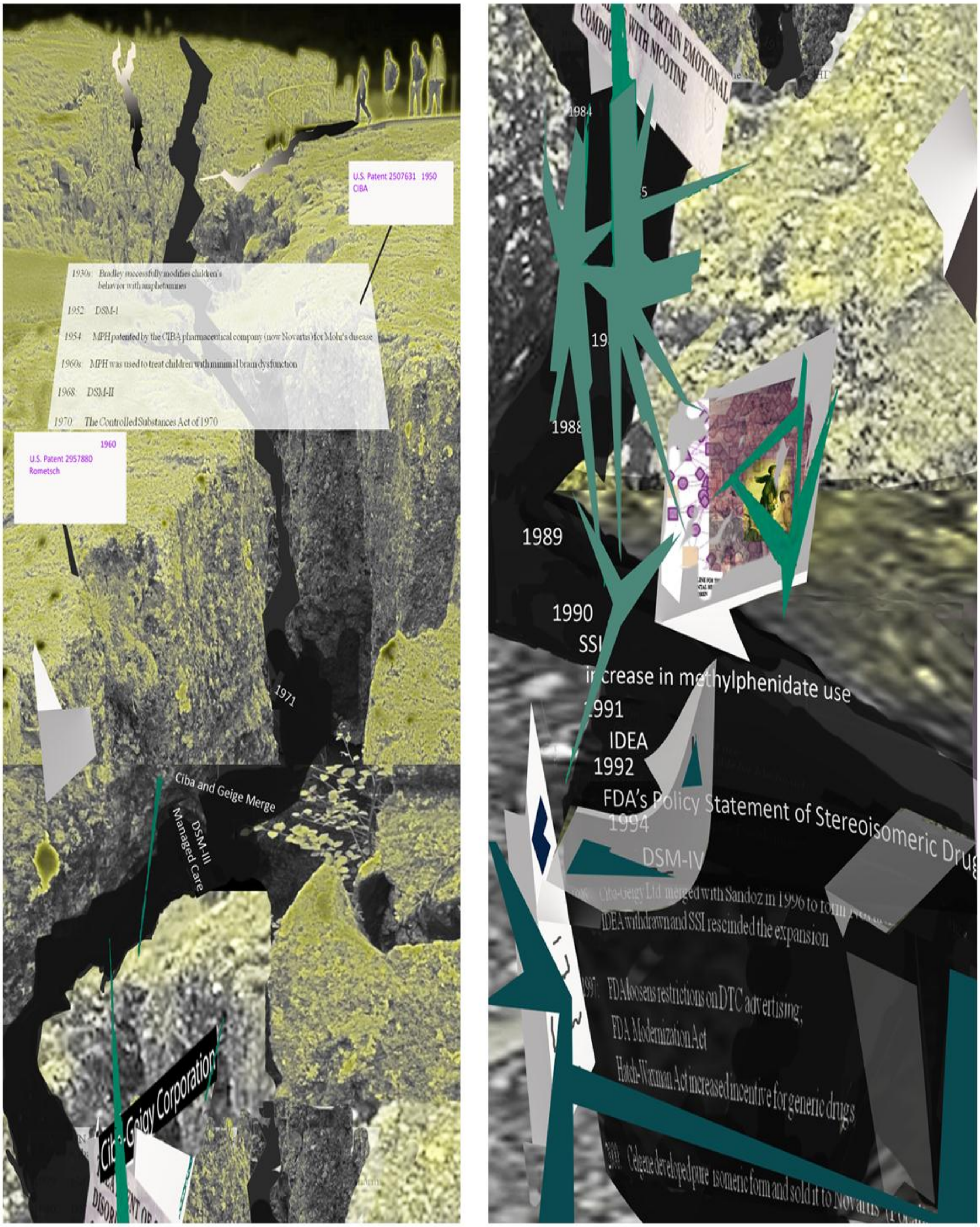

Figure 73: Ellen K. Levy, Navigating ADHD (2009).
The top and bottom halves of the scroll are respectively placed side by side from left to right

This visualisation includes information derived from the DSM and US Patent and Trademark Office (USPTO) that protected new manufacturing technologies of methylphenidate, which in turn permitted the exploitation of new socio-economic incentives in marketing. It is a way to address some of the consequences of classification systems and statistics. An extended fissure is defined and enforced arbitrarily by regulatory bodies and bureaucrats that maintain and increase the distinction between normality and pathology. The rift widens towards the bottom of the scroll, showing the increased rift between health and illness. Fissures appear as individuals are required to fit into neatly divided categories. The immediate goal was to illustrate how some of the underlying systems expressed social and political realities that affect determinations of illness and how art can communicate this information to the public. The long-range goal is to have art challenge what is meant by progress, asking whether advances in technology necessarily lead to better lives.

5.2 An annotated chart of the history of methylphenidate in the US: a conceptual artwork

The remainder of this chapter is used to construct the second artwork. It is a conceptual art project in which I explored some of the complex issues surrounding methylphenidate production. It comprises an analysis of the economic and social conditions underlying determinations of ADHD. The reader is first led through a concept map of dynamic factors influencing judgments of ADHD pathology, including the changing directives of various regulatory agencies. A conceptual chart of factors influencing methylphenidate production was created that attempts to show the relationship of key decisions of regulatory bodies to the increased use of methylphenidate at select periods.

A mixture of environmental and genetic factors is likely to be the cause of ADHD, but the agencies and regulatory bodies have exerted an enormous influence in ADHD diagnosis. The successive changes in diagnostic criteria of ADHD reflect a combination of empirical research findings and expert committee consensus. The increased number of diagnosed cases in the US in the absence of one clear diagnostic determinant has raised the question of contributing social factors and may point to a dilemma in medical classification. To provide a sense of this increase, in 2001 the *Journal of the American Medical Association* (JAMA) reported that methylphenidate (Ritalin®) was taken daily by 4- 6 million children in the United States (Vastag, 2001). To estimate rates of parent-reported ADHD diagnosis and medication treatment for ADHD, the Centers for Disease Control and Prevention (CDC) analysed data from the 2003 National Survey of Children's Health (NSCH). The report indicated that, in 2003, approximately 4.4 million children aged 4--17 years had a history of ADHD diagnosis; of these, 2.5 million (56%) were conservatively reported to be taking medication for the disorder.

ADHD is often thought of as a spectrum of "*attentional* disorders" rather than a single entity. Its severity occurs along a continuum, and medical criteria are used to determine at what point a shift is made from normal to abnormal. The range of factors to consider regarding ADHD diagnosis includes but is not limited to biological, dietary, genetic, and environmental causes. In addition many social and economic factors play a role in the diagnosis of ADHD, including governmental regulatory agencies, the health, pharmaceutical, and insurance industries; the educational system; intellectual property rights, and legal determinations (Figure 74).

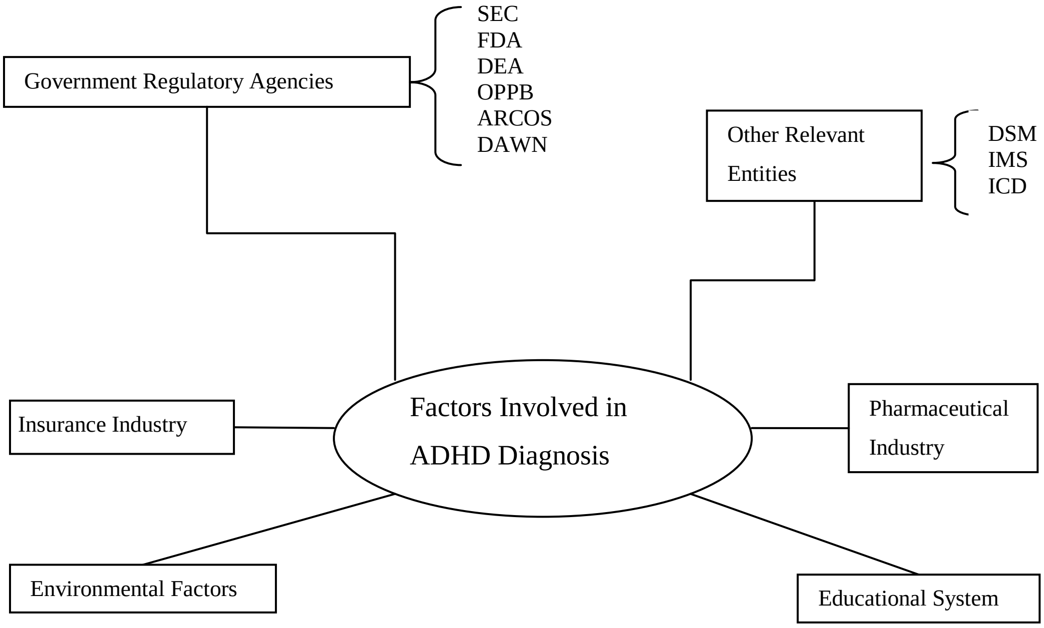

Figure 74: Concept map of factors in ADHD diagnosis, Levy, 2011 .

5.3 The Diagnostic and Statistical Manual of Mental Disorders (DSM)

The American Psychiatric Association's DSM represents a detailed classification system for mental disorders universally used in clinical and especially research settings. A DSM diagnosis is typically required for mental health professionals to be reimbursed for their services, which is a very important consideration (Mead et al., 1997). Changes in DSM categories and items result in some changes of diagnostic assignments (and consequently prevalence rates). All of the diagnostic codes in the DSM-IV and DSM-IV-TR (Text Revision, formerly DSM-IV-R) were selected to permit mapping on to valid International Classification of Diseases, Ninth Edition, Clinical Modification (ICD-9-CM) codes. However, since minor revisions are made to the ICD-9-CM system on a yearly basis (with changes becoming mandatory each January 1st), subsequent printings of DSM-IV-TR have incorporated the few minor changes in ICD-9-CM codes that have occurred since its adoption.

The first empirically-based official set of diagnostic criteria for ADHD was delineated in the DSM III in 1980. Early focus on hyperactivity symptoms shifted toward *attention* and impulsivity symptoms that were later reflected in the changes taking place in the DSM Revised Third Edition (DSM III-R). The current classification, DSM-IV, allows diagnosis of subtypes as predominantly inattentive, predominantly hyperactive, or combined. As outlined in DSM-IV, criteria related to inattention would include difficulty in filtering out distractions and being distracted by movements of people or objects. To complete the list of symptoms, the DSM-IV criteria for impulsivity are acting before thinking, demonstrating a short temper, and behaviour that includes yelling or hitting. The DSM-IV text revision (DSM-IV TR) was published in 2000 and is currently (2011) used by clinicians and psychiatrists to diagnose psychiatric illnesses. The next DSM guidelines will be published in 2013 and are expected to contain numerous revisions for ADHD, especially in light of the fact that it is now recognised as a disease that extends into adulthood.

A critical aspect of understanding how the DSM determines diagnosis involves its balance between categorical versus dimensional measures (Kessler, 2002). Sociologists consider that dimensional assessments more accurately predict distress syndromes than those that are dichotomous (yes/no decisions regarding whether a person has a mental disorder). Skrtic (1991, 1996), and Danforth and Navarro (2001) pointed out that psychiatric determinations support a bio-psychiatric model of mental disorders over approaches that stress social conditions. Critics see the DSM as an adversary that has constrained individuals through adjudicating illness based on debatable standards (Harwood, 2006). Danforth and Navarro (2001) concluded that what is at stake is how society views deviant behaviour (p. 181). One argument against calling ADHD a clearly defined illness is that its core features, including hyperactivity, impulsivity and inattentiveness, can be seen in many conditions other than ADHD and apparently have their source in a combination of biological, psychiatric and environmental conditions (Stein, 2010). Table 3 shows the main organisations involved in ADHD diagnosis. The DSM was discussed in chapter four, and it and other federal agencies are known to much of the public such as the SEC, FDA, and DEA.

Among those organisations that are less known, the IMS is a private company that provides health and pharmaceutical intelligence reports. The OPPB of the Eunice Kennedy Shriver National Institute of Child Health and Human Development, part of National Institutes of Health (NIH) was established in 2004. It collects and disseminates clinical trial information. The Branch was created to centralise research, clinical trials, and drug development activities for paediatric and obstetric pharmacology within a single organisational entity.

ARCOS is an automated, comprehensive drug reporting system that monitors the flow of DEA controlled substances from their point of manufacture through commercial distribution channels to point of sale or distribution at the dispensing/retail level – hospitals, retail pharmacies, practitioners, mid-level practitioners, and teaching institutions. Included in the list of controlled substance transactions tracked by ARCOS is Schedule II material (considered by the DEA to be highly addictive and subject to abuse while still having legitimate medical uses). Methylphenidate is a Schedule II stimulant, which is structurally and pharmacologically similar to amphetamines.

DAWN keeps records of the number of emergency department references to methylphenidate. It provides a source of data about methylphenidate abuse (it can be ingested, injected intravenously, and snorted intranasally) and misuse. For example, those who take it without a prescription to stay awake or improve school performance typically take the drug orally. Abusers attempting to get high often snort or inject crushed tablets (Prosser &Nelson, 2008).

Table 3: The main organisations involved with ADHD diagnosis and the regulation of drugs

ICD	International Classification of Disease (published and updated periodically by the World Health Organization)
DSM	Diagnostic and Statistical Manual of Mental Disorders (compiled and updated periodically by the American Psychiatric Association)
SEC	Securities and Exchange Commission: (a US Federal agency that regulates the securities sector and provides various reports)
IMS	originally Intercontinental Medical Statistics, developed by the pharmaceutical industry and now, simply IMS, a private company that provides health and pharmaceutical intelligence reports
FDA	Food and Drug Administration (a US Federal agency that regulates the food and health industry and supervises drug labelling)
DEA	Drug Enforcement Agency (a US Federal agency that controls potentially addicting drugs)
OPPB	Obstetric and Pediatric Pharmacology Branch (part of the US National Institutes of Health, NIH)
ARCOS	Automation of Reports and Consolidated Orders Systems (part of the DEA)
DAWN	Drug Abuse Warning Network (part of the US Department of Health and Human Services)

5.4 Factors affecting methylphenidate production in the US (1930-1970)

The history of methylphenidate that I have created in this chapter is coarse-grained and is annotated with economic and social information. Creating and circulating an annotated chart is one way to insure that ideas are disseminated. Philosopher Bruno Latour identified the concept of "immutable mobiles", noting that they showed how information is distributed and made accessible to others (Latour, 1987). By immutability, Latour referred to the capacity of the object to retain key features while in transport. Within this group of objects Latour included writings, inscriptions, documents, and illustrations. Their mobility assists the distribution of knowledge in technoscientific networks. To create a chart, some basic facts must be included such as methylphenidate's synthesis in 1944 and its identification as a stimulant in 1954. The following table (Table 4) shows the relevant features from 1930-1970.

Table 4: Relevant features of an annotated chart of methylphenidate production: 1930-1970

Date	Event
1930s:	Bradley successfully modifies children's behaviour with amphetamines
1944:	methylphenidate synthesised
1952:	DSM-1 appears (displaces ICD for diagnosis of mental disorders in the US)
1954:	methylphenidate was patented by CIBA (now Novartis) as a potential cure for Mohr's disease
1960s:	methylphenidate was used to treat children with ADHD or ADD, known at the time as hyperactivity or minimal brain dysfunction (MBD).
1968:	DSM-II appears
1970:	the Controlled Substances Act of 1970

The table above is self-explanatory except for the last item. The Controlled Substances Act of 1970 created the requirement for manufacturers and distributors to report their controlled substances transactions to the Attorney General. The Attorney General delegates this authority to the Drug Enforcement Administration (DEA) (shown in Table 3). The DEA records the amounts of Schedule II substances distributed within the United States via its Automation of Reports and Consolidated Orders System (ARCOS), which provides data at the state level.

5.5 Factors affecting methylphenidate production in the US (1971-1990)

Table 5 below shows the relevant points to consider from 1971-1990. In the latter half of the 1980s, several major clinical and policy developments related to ADHD and stimulants converged. This helped spark the great increase in the number of children who were diagnosed with the disorder and prescribed stimulant medication in the following decade. During the early part of the 1980s, spending on mental health services and treatment increased, initially marked by the expansion of inpatient psychiatric facilities for adolescents and those with substance abuse problems. The antidepressant Prozac® was introduced in 1987 leading to an increase in treating outpatient mental illnesses with medications. As a result, psychopharmacology became dominant, in which a diagnosis is made and a medication matched with the patients' symptoms (Carlat, 2010). The advocacy group, Children and Adults with Attention-Deficit/Hyperactivity Disorder (CHADD), was founded in 1987 in response to the frustration experienced by parents and their children with ADHD. Their mission is to help insure that children with ADHD are eligible for special education services or accommodation within the regular classroom when needed and that adults with ADHD may be eligible for accommodation in the workplace under the Americans with Disabilities Act.

Managed care grew out of an effort to contain costs. Health Maintenance Organizations (HMOs) were the first US form of widespread managed care. Managed behavioural health companies emerged in the late 1980s and searched for less expensive ways of treating mental disorders. They focused on countering the expansion of inpatient psychiatric facilities, in particular, with shorter lengths of stay, greater use of primary care physicians, limited psychotherapy, and increased use of psychotropic drugs.

Table 5: Relevant features of an annotated chart of methylphenidate production: 1971- 1990

Date	Event
1971:	UN Convention on Psychotropic Substances agreed not to market Schedule II drugs to consumers directly (but this is not a US law)
1971:	Ciba and Geigy merged in 1971 to form Ciba-Geigy Ltd.
1979:	National Alliance for the Mentally Ill (received substantial funding from Big Pharma)
1980:	DSM-III: first appearance of ADD (more than 100 new disorders identified)
1980s:	Increased spending on mental health
1980s:	Managed care
1980:	Bayh-Dole Act
1987:	The American Psychiatric Association (APA) revised DSM-III to shift from hyperactivity to inattention and changed the emphasis to ADHD

The Bayh-Dole Act permitted universities using federal funds for research to own patents. The links thus forged between universities and industry have been considered controversial by some who believe the university should conduct research without financial obligations to those underwriting the research.

5.5.1 Changes in the DSM

Classification systems inevitably reflect the state of science at the time they are formalised (Bowker & Star, 2005). Social scientists Sara Shostak, Peter Conrad, and Allan Horwitz (2008) stated that the definitions in the DSM-II (APA, 1968) were very general and that, during the 1970s, the lack of precise diagnoses created problems in viewing the psychiatric profession as a fully scientific discipline. Contributors to DSM-III tried to reverse this, initiating a number of developments that resulted in a thoroughgoing medicalisation of ADHD. In 1980 theoretical explanations were avoided in favour of “diagnostic reliability” that led to the flourishing of evidence-based research (Kieling et al., 2010). At the institutional level, health care providers would often restrict treatment of attention disorders to those having DSM diagnoses. Similarly, insurance companies and federal programs would only pay for the treatment of ADHD conditions that met DSM diagnostic criteria. The trend was away from psychosocial factors and toward the biological and biochemical abnormalities as defined by the DSM (Shostak et al., 2008).

A maximum age at onset as a diagnostic criterion for ADHD was introduced in DSM-III on the basis of clinical experience. In DSM-IV-TR, this criterion specifies that "some hyperactive-impulsive or inattentive symptoms that caused impairment were present before age 7 years" (DSM-IV-TR, 2000). Over the intervening years, a number of studies have addressed the utility of this criterion, generally questioning its contribution to the validity of the diagnosis of ADHD. (I pointed out in the last chapter that most children in the US will have already had two years of schooling by age 7.) Despite the doubts of many qualified professionals and a lack of empirical support, the maximum age 7 onset criterion was retained across three DSM editions. Although historically defined as a disorder of childhood, Conrad observed that the medicalisation of ADHD has greatly expanded (Conrad, 1975, 1992). Indeed, by July 2008 the FDA approved ADHD treatment for adults aged 18-65. However, the age at onset criterion is problematic because of the questionability of retrospective recall (Kieling et al., 2010).

Changing criteria from DSM-III-R (1987) to DSM-IV (1994) resulted in a substantial increase in the diagnoses of ADHD (Wolraich & Baumgaertel, 1996, p. 180). The increase was attributed to the identification of children meeting criteria for the newly created subtypes of ADHD-AD (predominantly inattentive) and ADHD-HI (hyperactive impulsive) in the DSM guidelines. The ICD-10 criteria of the World Health Organization (1992) for the equivalent diagnosis required a considerably higher degree of pervasive behavioural manifestations and maintained hyperkinesis as the primary symptom rather than inattention. According to Wolraich and Baumgaertel (1986, p. 82), differences in prevalence rates found between the US and European children were in the applied diagnostic criteria and not due to cultural differences that manifest themselves in the children behaving differently. They later concluded that the ". . . presence of the symptoms alone without considering impairment or pervasiveness may overdiagnose the condition" (p. 184).

5.6 Factors affecting methylphenidate production in the US (1990-2000)

In 1991, Congress adjusted IDEA to include ADHD as a protected disability due largely to lobbying pressure from parents of children with ADHD. As a result, children diagnosed with the disorder became eligible for special accommodations on tests (including the SAT), homework, and other school-related activities. In the first half of that decade, rates of new children enrolling in the program with a qualifying diagnosis of ADHD increased almost three-fold (Strawn, 2003). Low income children with ADHD could receive the same benefits in school plus cash assistance for their families from SSI. In part because of the expansion of the number of children eligible for Medicaid in the early 1990s a public backlash occurred in the latter half of the 1990s (Strawn, 2003). After the expansion was rescinded in 1996, many children with ADHD were cut from the SSI program.

Table 6 shows pertinent developments from 1991-2000; one needs to be further singled out for discussion. The FDA Modernization Act of 1997 provided new financial incentives to pharmaceutical companies by extending patent exclusivity. This encouraged the development of long-acting stimulants.

Table 6: Relevant features of an annotated chart of methylphenidate production: 1990-2000

Date	Event
1990:	Supplemental Security Income (SSI) program
1990:	Dramatic increase in methylphenidate use; expansion of children eligible for Medicaid.
1991:	Individuals with Disabilities Education Act (IDEA) included ADHD as a protected disability
1992:	FDA's Policy Statement on the Development of New Stereoisomeric Drugs
1994:	DSM-IV
1996:	Ciba-Geigy Ltd. (formed from earlier merger of Ciba with Geigy) merged with Sandoz in 1996 to form Novartis
1996:	IDEA withdrawn and SSI rescinded the expansion of children eligible for Medicaid
1997:	FDA loosened restrictions on direct-to-consumer (DTC) advertising; FDA Modernization Act
1997:	Waxman-Hatch Act gave increased incentive for generic drugs, leading in the view of some, to decreased innovation; State Children's Health Insurance Program (SCHIP) was created that increased children's eligibility.
2000:	Celgene developed a pure isomeric form of methylphenidate and sold it to Novartis (as Focalin®)

A broad coalition of medical professionals, antipoverty activists, and disability and children's health and welfare advocates led to changes in public policy. The result was an increase in ADHD diagnosis linked with methylphenidate production between 1990 and 1993. This increase is shown in Table 7 below.

Table 7: Diagnosis and Treatment of ADHD and US Production of Methylphenidate: 1990-1993, has been removed due to Copyright restrictions.

Figure 75 below displays the distribution of methylphenidate in six regions of the US in 1990 and in 1995 (Morrow et al., 1998). One readily notes that urban areas were much more affected than rural ones, with almost four times the per capita distribution.

Figure 75: Increase of methylphenidate distribution (Morrow et al., 1998) has been removed due to Copyright restrictions.

Figure 76 below shows that from 1991 to 2001 real spending per enrolee in Medicaid increased almost 9-fold, while the number of prescriptions increased 6-fold. Using data from the 2002 National Drug and Therapeutic Index (NDTI), it was calculated that Attention Deficit Disorder, Conduct Disorder, and not otherwise specified Overactivity Disorders accounted for 92% of the conditions for which stimulants were prescribed (Cuellar & Markowitz, 2006).

Figure 76: Methylphenidate data (Source: Medicaid Drug Rebate) has been removed due to Copyright restrictions.
Stimulant spending (solid line, left axis) and prescriptions (broken line, right axis).

Stimulants like methylphenidate comprised one of five different medication groups (along with antipsychotic medication, antidepressants, anxiolytics and hypnotics, and mood stabilisers). All of these groups showed increases in prescription rates. For example, according to Olfson et al. (2006), based on records of visits to physicians, approximately 275 per 100,000 children and adolescents received a prescription for antipsychotic medication annually between 1993 and 1995, compared to 1,400 per 100,000 in 2002. In other words, there were around five times as many prescriptions in 2002 as there were in 1993.

Table 8 shows another large increase in methylphenidate production from 1998-2007. Increased distribution appeared to be driven by the increasing frequency of ADHD diagnoses.[4] According to the United Nations 1993 statistics on psychotropic substances, the US produced and consumed five times more methylphenidate than the rest of the world combined.

Table 8: Methylphenidate aggregate production quotas (posted 2010) has been removed due to Copyright restrictions

I created the figure below (Figure 77) from data issued by the CDC[5] and DEA[6]. The CDC analysed data from the 2003 National Survey of Children's Health (NSCH). This report indicated that, in 2003, approximately 4.4 million children of those aged 4-17 years (7.8%) were reported to have a history of ADHD diagnosis; of these, 2.5 million (56%) were reported to be taking medication for the disorder.[7] As of 2006, the CDC reported that 4.5 million children (ages 5-17) were diagnosed with ADHD. MPH production information was also provided as thousands of kilograms.[8] The information from the DEA displayed in Table 8 is incorporated in Figure 77.

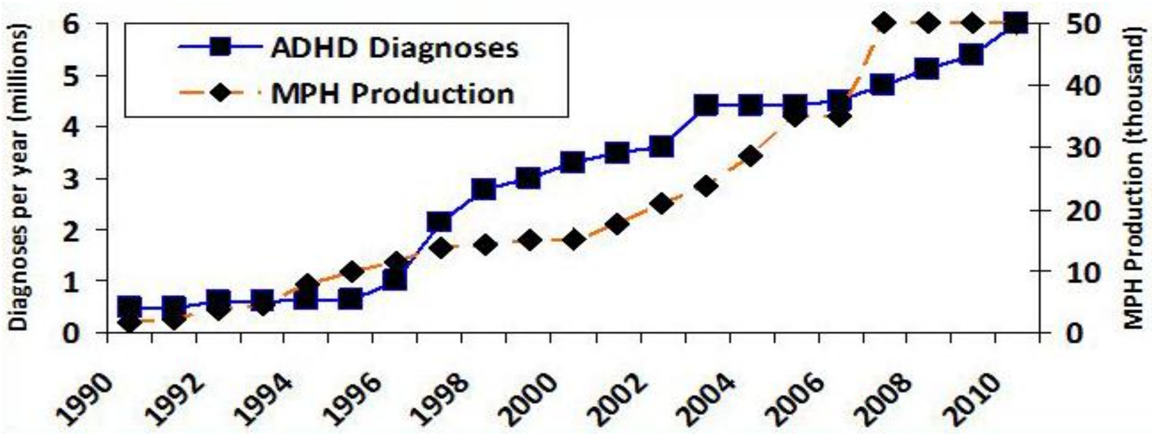

Figure 77: ADHD diagnosis and methylphenidate production.
The relationship of ADHD diagnoses (in millions, squares/solid lne) and production of methylphenidate (in kg*1,000, diamonds, broken line) from 1990-2010.

5.7 Patent citation methodology and NBER

My annotated chart (a conceptual artwork) is intended to address how regulations of prevention and control structure our definitions of illness and well-being with regard to attentional pathology. To include some of the economic factors surrounding the history of methylphenidate, I looked for information from patents in addition to entities like the DSM. As was established earlier in this chapter, the financial incentives to produce pure isomeric forms of chiral drugs like methylphenidate are considerable and may account for the growing technology that has developed around the separation process. One way to picture this incentive is to incorporate some of the information from patents and patent citations which impact the production of methylphenidate. These would include patents related to isomeric separation technologies and to improvements in drug delivery methods.

In this chapter I suggest that the patent citation method now used in economics can be a valuable resource for art and art historical research. It offers a method (incorporating data from patents) to indicate some of the market forces at work in society. It thus becomes a way to reference “real” influences on systems just as the “real world” provided artists with perceptual models. I have adapted the method used by the National Bureau of Economic Resources (NBER) to insert pertinent facts concerning methylphenidate into an annotated map of its history.

Economists Adam Jaffee and Martin Trajtenberg (2002) determined that patent citations correlate well with the importance of innovations both technologically and economically. Hall, Jaffee, and Trajtenberg (2001) set a methodological tool in place for use by economists. The importance of technologies involved with isomeric separation can be assessed by looking at the numbers of patents and patent citations related to these technologies in the USPTO. As an earlier, related example, after their introduction in 1975, computed tomography (CT) scanners initially dominated medical technology, both in sales and in terms of technological advance. The significance of technologies involved with isomeric separation of chiral drugs like methylphenidate can be similarly assessed. To be able to undertake such a study requires access to database records of pertinent medical innovations, and these records were generally unavailable and unmanageable as large datasets until advances in computer technology eliminated difficulties during the late 1980s (Jaffe & Trajtenberg, 2002). The USPTO is therefore positioned to yield valuable information about technological innovation and serve as a research methodology for artists and art historians as well as economists.

The NBER database is comprised largely of data from the USPTO and offers a way to locate valuable information that pertains to medical technologies. For example, it can be used to track methylphenidate from initial patent application to commercialisation. The time taken to commercialise a new invention related to attention deficit disorder reflects, in part, the valuation of that invention by industry. (I am aware of confounds like complexity and expense of the development process.) The database can also track new technologies (e.g., techniques of isomeric separation and new methods of drug delivery). Linkages can be traced between inventors, inventions, firms, locations, and scientists, and NBER has data on citations made and citations received. Simple patent counts may not adequately describe the importance of an innovation but citations provide useful additional information since they identify those past innovations that were found to be pertinent for new developments. Jaffe and Trajtenberg (2002) proved that the growth of various technologies was accurately reflected by patent counts especially when weighted by an index based on subsequent citations to index patents. By comparing the number of citations made in subsequent patent applications to various index patents, information is gained about the relative importance of different patents at particular points of time.

Information derived from this NBER database was incorporated into my annotated chart of methylphenidate production in the form of patent numbers and patent citations. The following example pertains to the incorporation of data about isomeric separation technology. Celltech filed a patent for an enantiomer of methylphenidate in 2001 (US Patent 7164025) that was issued in 2007. The single enantiomer obtained in this manner was the d-threo isomer, the active structure of methylphenidate. To accomplish the separation, Celltech invented an overall process including racemisation that allowed complete conversion into the required isomer. The earliest citation listed within Celltech’s patent was from 1980, involving racemisation by Miller et al. Thus the more recent patent embedded considerable information about the history of the separation technology.

I conducted a “quick search” on the USPTO for patents referencing methylphenidate and ADHD. This search produced 36 entries and 57 exclusive citations. The earliest patent was 1950 (US Patent 2507631) by Hartmann et al. and assigned to Ciba (bottom of Figure 78). It showed that central stimulant activity is associated with the threo racemate and focused on the separation and interconversion of the erythro isomer into the more active threo isomer. Another frequently cited patent was Number 2957880 by Rometsch, filed in 1960, which was a process for the conversion of stereoisomers.

US Patent References:

5283193	Process for producing optically active α-substituted organic acid and microorganism and enzyme used therefor	February, 1994	Yamamoto et al.	435/280
5217718	Method and device for administering dexmedetomidine transdermally	June, 1993	Colley et al.	424/449
5114946	Transdermal delivery of pharmaceuticals	May, 1992	Lawter et al.	514/279
5104899	Methods and compositions for treating depression using optically pure fluoxetine	April, 1992	Young et al.	514/646
4992445	Transdermal delivery of pharmaceuticals	February, 1991	Lawter et al.	514/279
2957880	Process for the conversion of stereoisomers	October, 1960	Rometsch	546/233
2507631	Pyridine and piperidine compounds and process of making same	May, 1950	Hartmann et al.	260/294

Figure 78: Patent citations (conducted 2009).
Screen shot of USPTO citations listed for United States Patent 5908850.

The screen-shot (Figure 78) from the USPTO shows seven citations listed for US Patent 5908850, "Method of treating *attention* deficit disorders with d-threo methylphenidate". This patent was filed for Zeitlin et al. in 1997. The assignee, Celgene, was granted the patent in 2000 for developing a pure isomeric form of methylphenidate (dexmethylphenidate) and sold it to Novartis (as Focalin®). Among the patents cited is invention 2957880 (second from the bottom in Figure 78), which relates to an enantioselective method of making methylphenidate and derivatives. The method involves use of a rhodium catalyst, and selectively produces the d-enantiomer of the methylphenidate derivative in excess of the L-enantiomer. The method is thus suitable for synthesis of d-threo-methylphenidate.

Figure 79 shows relationships within the NBER database among the state (sta) of invention, the country (cnt), the assignee sequence number (assgnum), and the city (cty). The pdpass is the unique assignee number. The ptype is the patent type, the patnum is the patent number, and pdpco refers to the company ownership (Bessen, 2009).[9]

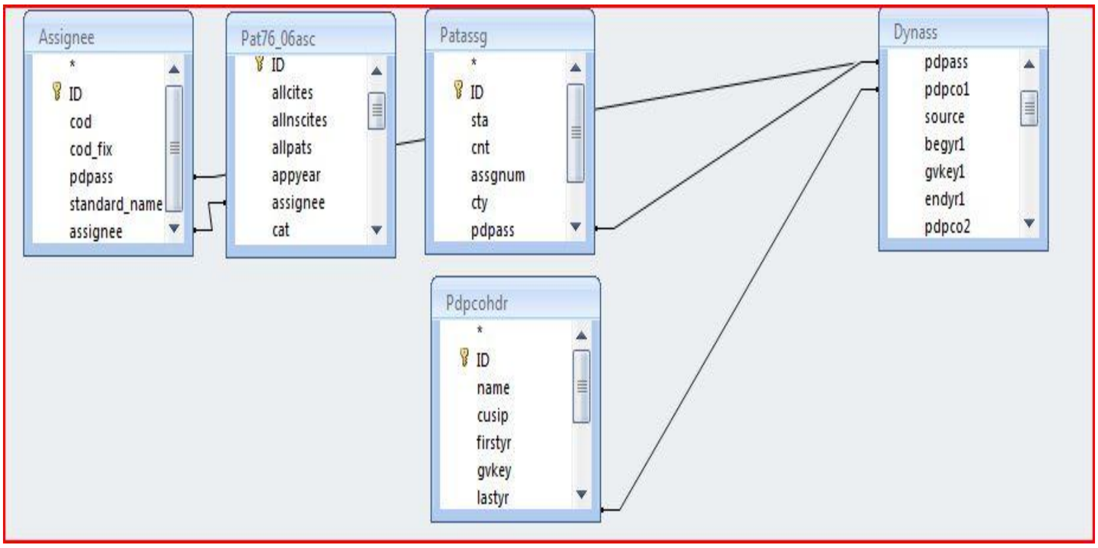

Figure 79: Relationships among NBER tables.
The lines link congruous field names in the different tables (e.g., pdpass, asignee) although not all of them are visible in this screen shot.

Jaffe and Trajtenberg (2002) have stressed the necessity of linking the information contained in patent data to outside data of various sorts to prevent the analysis from being self-contained, with all the limitations that implies economically. One way to do this is to connect the data from patents to Compustat, which is the data set of all firms traded in the US stock market (Hall et al., 2001). NBER thus allows various crosslinks, including those to industry. Figure 80 below demonstrates how I used NBER to identify some of the relationships between the patents and the corporations that own them. Information from a single search linking data from NBER and Compustat is displayed as two panels in order to avoid reducing the print excessively. The eight rows of these two panels pertain to patent number (patnum) 4192827 for water-insoluble hydrophilic copolymers (invented by Karl F. Mueller and filed in 1980) and links that patent to assignee CIBA GEIGY CORPORATO (standard name).

As seen in the following tables, although computerisation has made it possible for NBER to visualise multiple relationships, it should also be pointed out that the electronic storage of historical sources (like the DSM and ICD) further improves their accessibility and can empower these systems along with the inequities they may engender (Bowker, 1999). In other words, computerisation can be a double-edged sword.

Query Form 10/5/2009

patnum	Patassg.pdpass	assignee.pdpass	pdpco	allcites
4192827	10036456	10036456	213449	18
4192827	10036456	10036456	213449	2
4192827	10036456	10036456	213449	3
4192827	10036456	10036456	213449	4
4192827	10036456	10036456	213449	6
4192827	10036456	10036456	213449	3
4192827	10036456	10036456	213449	3

Pat76_06asc.as	assignee.assigne	standard_name	name
104245	104245	CIBA GEIGY CORPORATO	CIBA SPCLTY CHEMICALS -
104245	104245	CIBA GEIGY CORPORATO	CIBA SPCLTY CHEMICALS -
104245	104245	CIBA GEIGY CORPORATO	CIBA SPCLTY CHEMICALS -
104245	104245	CIBA GEIGY CORPORATO	CIBA SPCLTY CHEMICALS -
104245	104245	CIBA GEIGY CORPORATO	CIBA SPCLTY CHEMICALS -
104245	104245	CIBA GEIGY CORPORATO	CIBA SPCLTY CHEMICALS -
104245	104245	CIBA GEIGY CORPORATO	CIBA SPCLTY CHEMICALS -

Figure 80: NBER crosslinks.

5.8 Analogies between biological and technological evolution

Art may also exemplify the process of technological innovation, itself, which is a little-remarked upon but important by-product of much art. This matters because what art can do with its interpretive powers which data alone cannot is to show the impact of our technologies in a broad, human-scaled framework. Sometimes inadvertently, artists are making contributions to issues of cultural evolution. I stated at the onset of this chapter that patents and patent citations fulfil an important function in addition to providing socioeconomic facts. Patents can be viewed as dynamically-evolving large-scale information systems, and patent citations suggest the network of influences of specific inventions over time. Citations indicate what prior novelties were required to build the present ones. These processes bear analogy with certain aspects of biological evolution. For example, palaeontologist Niles Eldredge (Wertheim, 2004) created a kind of citation methodology through charting the cultural development of cornets in Figure 81.

Figure 81: Niles Eldredge and his charts (2007) has been removed due to Copyright restrictions. Cornet phylogeny (Tëmkin & Eldredge, 2007:149)

Eldredge stated in an online interview with Belinda Barnet (2004), “The history of the Perinet valve in cornets is in large part a story of patents, alternatives – and finally a winnowing process and ultimate selection of one-of-many designs, after the patents have long-since expired”.[10] Eldredge went on to point out that there are patterns that signify the degree of stability or change of individual bits of information (valve design type, for example) and details of rates and modes of whatever change occurs in the system. He pointed out that stasis, gradual change, and abrupt change occur in both biological and material cultural systems.

As I have shown with the case of the cornets, parallels can be made between biological and technological evolution. It seems to me that the ability to place the technological systems that we use within the larger framework of evolutionary change and the adaptive nature of innovation is, in the end, a valuable contribution that some artists have made accessible through their work.

5.9 The annotated chart of methylphenidate production

The conceptual chart that I created constitutes the final figure of this chapter (Figure 82). The emphasis is upon the evolutionary-like unfolding of information as much as it concerns information, itself. It builds a picture through selecting and incorporating many of the social and economic factors that were discussed throughout this chapter. Financial incentives are expressed through incorporating some of the patent numbers and citations concerned with the production of drug treatments for ADHD and for techniques of isomeric separation and drug delivery. These data were cross-correlated with sociological trends to suggest the pace of technological development. In addition, in both artworks created for this chapter I aimed to envision the way technological innovation does and does not bear analogy to biological evolution. Unlike biological evolution, the technical processes transform themselves, engaging in transfer and retroactivity and engendering new structures (Simondon, 1958). I have attempted to portray a large evolutionary framework in order to suggest the contexts in which multiple forces operate on methylphenidate production and produce effects such as determining those in the population who are diagnosed with ADHD.

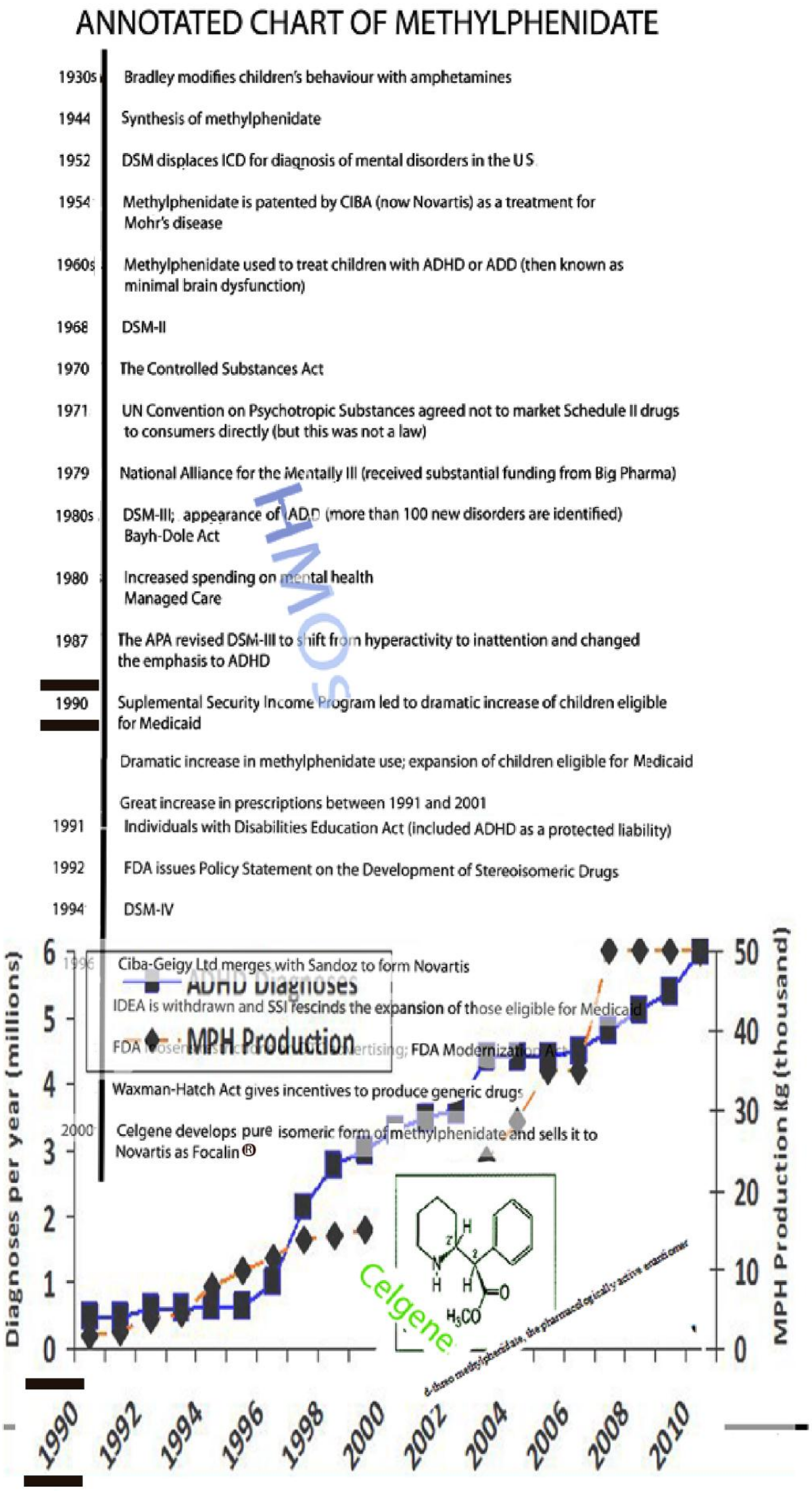

Figure 82: Ellen K. Levy, conceptual artwork.
An annotated chart of methylphenidate production.

6 Conclusions

This chapter attempted to delineate how some designers have used the knowledge of *attentional* and visual constraints to improve their ability to communicate with the public. It also considered how some designers have embedded their understanding of the visual system and aesthetic values in the software they have created.

To isolate some of the social and economic issues involved in diagnoses of ADHD, an effort was made to conceptualise how these relationships could be informed by economic data. This chapter therefore looked closely at the ways data visualisations can portray patterns of social behaviour in terms readily grasped by the public. I provided two examples of my own artwork, both involving methylphenidate production that incorporated data provided by patent citations. In addition, these inclusions drew analogies between biological evolution and technological innovation, pointing to the larger framework in which drug development takes place and questioning ideas of progress. The conceptual artwork was an attempt to visualise the relationship between methylphenidate production and adjudications of ADHD from roughly 1930 to 2000. The final figure uses black bars and a change of orientation of the time line from vertical to horizontal in order to single out 1990 as an important year (note the bottom of the figure). I attempted to make explicit the fact that some of the increase in diagnoses of ADHD between 1990 and 2000 was tied to changing regulations of the children eligible for Medicaid under the Supplemental Securities Act of 1990. The horizontal chart on the bottom of the figure also shows a second increase in methylphenidate production around 2008 following the growth of isomer separation techniques. By annotating the history of methylphenidate with social and economic information, the identification of possible biases that underlay official medical classification methods was facilitated. For example, it elaborated upon the DSM's relationship to numerous social and ideological issues and indicated that a change of DSM classifications resulted in an increase of diagnoses of ADHD at particular times.

One conclusion to draw from this chapter is that designers might consider utilising the *attentional* processes themselves as ways to direct viewers to important, perhaps little-known features that impact decisions of health or illness. Borrowing a methodological tool from economics as I did with NBER may help reveal some of the lesser known political and economic consequences of classification systems. I demonstrated that it allowed me to correlate the pace of technological development pertaining to drug innovation with sociological and political trends. This was a way to exemplify some of the financial incentives involved in drug design involving the technology of chiral separation.

I anticipate that artists, as frequent visualisers of data, will play an increasing role in helping to uncover hidden biases. The larger point in this chapter was the importance of using a variety of visual analytic techniques to help prevent rigid, institutionalised systems from being viewed as providing unalterable views of abnormality. To this end I have argued that art can help maintain flexibility for classifications of health and illness that include ambiguous economic and organisational dimensions. In the absence of demonstrable causal evidence of pathology, the boundaries between health and illness may not be as rigid as they are often portrayed. However a broader contextualisation of *attention* might be necessary to explore the current trajectory of these studies and to find the correlations between art and neuroscience.

Endnotes

1 During AICA symposium held in Dublin, Ireland in 2009
2 http://www.ucmp.berkeley.edu/archaea/archaeamm.html
3 SIGGRAPH 2010 conference
4 http://www.deadiversion.usdoj.gov/quotas/quota_history.pdf
5 http://www.cdc.gov/ncbddd/adhd/data.html
6 http://www.justice.gov/dea/pubs/cngrtest/ct051600.htm
7 http://psychservices.psychiatryonline.org/cgi/content/full/60/8/1075
8 http://www.methylphenidate.net; also see http://www.enotalone.com/article/4583.html
9 The NBER/Hall-Jaffe-Trajtenberg Patent Data File for 1975-1999 offers a way to access detailed information on almost 3 million US patents granted between January 1963 and December 1999, all citations made to these patents between 1975 and 1999 (over 16 million), and a reasonably broad match of patents to Compustat. The main data set extends from January 1, 1963 through December 30, 1999 (37 years), and includes all the utility patents granted during that period, totaling 2,923,922 patents; 4 are referred to as PAT63_99. This file includes two main sets of variables; those that came from the Patent Office ("original" variables), and those created from them ("constructed" variables). The citations file, CITE75_99, includes all citations made by patents granted in 1975-1999, totaling 16,522,438 citations. In addition, detailed data has been collected on inventors and assignees, etc. The patent data themselves were procured from the Patent Office, except for the citations from patents granted in 1999, which come from MicroPatent. There are 6 main categories: Chemical (excluding Drugs); Computers and Communications (C&C); Drugs and Medical (D&M); Electrical and Electronics (E&E); Mechanical; and Others.
10 Barnet, B 2004, see < http://www.fibreculture.org/journal/issue3/issue3_barnet.html>.

CHAPTER 6: The Evolution of Attention

1 Introduction

Chapters four and five explored *attentional* pathology. Chapter four considered definitions of the norm in adjudicating ADHD, and chapter five examined how artists addressed some of the lesser known political and economic consequences of medical classification systems. This last chapter now returns to the framework of the larger art/neuroscience discourse, asking why artists and neuroscientists are poised to intersect in their investigations of *attention*. Chief among these considerations is the shared interest in *attention* as seen in art and scientific perception studies, second is the merger of neuroscience with other science research, and the third is new understanding gained from the study of complex systems. A fourth reason is the increasing similarity of processes and methodologies in art and neuroscience. A fifth consideration is that science can now better analyse affect, expanding its resonance with art practice. The ongoing development of the emerging field of neuroaesthetics is a sixth indication that the fields of art and neuroscience are converging. The seventh and last reason is the development of new investigations of creativity and learning among cognitive scientists.

The remainder of the chapter investigates how the cognitive and cultural dimensions of experience might be spanned. To do so metaphors and models about *attention* are explored, which indirectly reflect on the ability of art and neuroscience to foster the processes of convergence.

2 Cognitive studies in art

Gardner pointed out that Gombrich, Arnheim, and Goodman acknowledged the value of a cognitive approach to images early on but that fewer people did so during the 1950s because it countered a romantic view of art as "freedom" (Gardner, 2006, p. 28). He further stated that it was not just the general public and scientists who held the belief that art was ineffable, but artists, themselves, who fostered such beliefs. During the 1950s and beyond, this attitude was seen as enlarging a growing gulf between the arts and sciences. Even now, at a time when cognitive studies are once again prevalent, some art professionals consider that using neuroscience to inform art diminishes the artist's sense of self-determination. For example, commenting on Patricia Albers's biography of Joan Mitchell, which explored the artist's presumed synaesthesia, Perl stated "I am troubled by her [Albers's] insistence on establishing some physiological explanation for the brilliance of Mitchell's abstract evocations of sights and emotions. What I see here is a dangerous objectification — and maybe even medicalization — of the imagination. I do not think that Albers gives enough weight to the aestheticization of memory and sensation as self-conscious, even willful acts . . ." (Perl, 2011, p. 4). Although I accept the possibility that Albers may have overstressed synaesthesia in the biography, it is not unusual for art professionals to view neuroscientific description of artistic perception as comprising a limit to artistic freedom. However, it is entirely possible to see neuroscience in the opposite way. I conclude that a "proper" emphasis on neuroscientific description can be viewed as enabling the conditions for free artistic choice. This is because, in completing a work of art, the artist must make conscious decisions about whether to accept even her most unconscious aesthetic decisions. Being true to a synaesthetic perception does not "explain' the appearance of an artwork any more than being "true to nature" has explained the artist's production of a landscape painting in the past.

The current interest in neuroscience in the arts is largely fuelled by the recognition that because cognitive studies are important to understanding our own natures and our cultures, the models of art and art history we construct would do well to consider these processes. I would add that this understanding has also helped foster the recognition that the influence is not unidirectional, from science to art. One sees this recognition among neuroscientists such as Changeux (1994), Zeki (1999), Livingstone (2002), Cavanagh (2005), and Ramachandran and Hirstein (1999), who have all implicitly or explicitly acknowledged the artist as a kind of inadvertent neuroscientist. Art has had a long engagement with embodied understandings of emotion and memory and their impact on the *attentional* system, and these areas have, themselves, gradually become more accessible to scientific analysis. I have suggested throughout this dissertation that just as many neuroscientists might profit by broadening their base of artistic models, artists and art historians might gain by expanding their knowledge of experimental findings in neuroscience. This chapter summarises why a convergence of interests are taking place in *attentional* research.

3 Convergence in artistic and scientific studies of attention

Artists are not insulated from ideas of the cultures they inhabit, and this is particularly true of artists who choose to interpret neuroscience, some situating it within a social and political context. It is critical how the fields of art and science are brought into relationship. As Linda Henderson proved, early Cubism was not influenced by Einstein although each exploration occurred during the same time (Henderson, 1993). However, during the early 21st century, *attention* has become increasingly critical to both art and neuroscientific studies, resulting in a convergence of interest for the following reasons, which are, themselves, entangled:

3.1 The emergence of a shared interest in attention as seen in art and scientific perception studies

A primary consideration for the convergence is that art has been inspired by perception studies in science and its contributions to the philosophy of phenomenology. When, in 1962 Merleau-Ponty's *The Phenomenology of Perception* became known in the US, it had a positive influence on the thinking of many art professionals (Krauss, 1977, 1985). Exhibitions like the "Art of the Real: Aspects of American Painting and Sculpture 1948-1968" that was exhibited at The Museum of Modern Art, New York (1985) traced the branches of American art that encouraged prolonged observation. Psychologists increasingly dealt with illusions and real phenomena from both artistic and psychological viewpoints (Vitz & Glimcher, 1984). While Roger Shepard was conducting tests in mental rotation during the late 1960s and 1970s (see chapter three), Donald Judd, Robert Morris, Richard Serra, and other minimalist sculptors directed viewers to the conditions of viewing and spectatorship. They and many other artists were involved with phenomenological issues stemming from Merleau-Ponty, stressing the important role of the body in vision (Michelson, 1969; Nemser, 1971).

Today the trend towards the real is even more pronounced along with an emphasis on all the senses rather than vision alone. A subset of artworks is involved with the staging of spectatorship through the presentation or literal creation of phenomena. Van de Vall (2009) noted that such works often involve the spectator perceptually and affectively in the formation of his or her experience. Within the medium of film, the visual field has been re-defined as one of "haptic visuality" by theorists such as Laura U. Marks (1978, 2002) who have researched the changing subject/object relationships of embodied spectatorship. She has described an intercultural cinema that emphasises the relatively neglected senses of smell, taste, and touch.

Attention has been used by artists in a range of ways: taking a cue from science, some artists have used *attention* to direct brainwaves and helped to effect an immersion into VR; others have focused on kinaesthetic senses that stress the body as opposed to rational knowing alone. For example in chapter three I posited that in Hentschlager's ZEE, *attention* dissolved inside and outside perceptions and became an awareness of vibrations. An alignment of sensations seemingly occurred among sound waves, strobes, pulsations, and breathing. Other artistic examples (see the taxonomy) included explorations of the body's displacement (e.g., Nicole Ottinger).

As a result of interest in perception, some artists have followed research in neuroscience. This thesis now indicates why there is growing reason for neuroscience to look closely at some recent developments in art. In part this is because phenomena, whether occurring naturally or invented and staged by artists, lend themselves to scientific scrutiny and can foster new creative insights and hypotheses.

3.2 The merger of neuroscience with other science research

A second reason for the convergence is the realisation that *attention* refers to a whole set of phenomena to be explained rather than to a single process (Allport, 1992). For example, within the umbrella field of science studies, neurology, developmental psychology, and evolutionary biology impart important, complementary knowledge for *attentional* studies. To explore *attention,* science must link physiology and psychology, analyse the interactions between psychology and neuroscience, and produce explanations which relate not only to psychological processes but also to neural processes (Driver, 2001). Information from molecular, neuronal, and behavioural fields needs to be linked and delineated along with numerous feedback paths. New experimental techniques are needed to enable the connections between physiological states and perceptual states (Churchland & Sejnowski, 1988). It is clearly difficult to span disciplines since it is even hard to span the specialties that exist within neurobiology. For example, Churchland and Sejnowski pointed out (1988) that at one time learning at the neuronal level was considered so remote from understanding at the cognitive level that these disciplines were separated. This has changed, and cognitive science (that asks "how" a computational problem is solved) is now sharing its experiments with neuroscience (that asks "what" is implemented by the neural architecture). A psychological phenomenon like *attention* depends upon neuronal levels as well as different areas of the brain. The merger among different disciplines offers a way for each component to contribute a different level of understanding (Duncan, 1998).

To address questions about the biological substrates of mental processes, cognitive neuroscience calls upon a varied range of skills. Laboratory methods may derive from experimental cognitive and clinical psychology, developmental psychology, and cognitive neuroscience. As Marcus Raichle pointed out, "The availability of large amounts of new information on the human brain – especially from functional brain imaging studies of the normal human brain – has begun to stimulate the integration of information across multiple levels of investigation in neuroscience" (Raichle, 2003, p. 761).

Cognitive neuroscience is increasingly attuned to phenomenological accounts of experience (e.g., embodiment, intersubjectivity, spatiality, intentionality, and temporality). This has led to the development of a "social cognitive neuroscience" that treats mind and the world as overlapping (Fuchs, 2002). The body is seen as a basis for mutual understanding or intersubjectivity. In addition, art acknowledges accounts not consistent with standard ideas of phenomenology, including dissembling and Machiavellian urges (Cole, 2008). For example, we learn to conceal and obscure; our social interactions are not always representative of our embodied emotional state. According to Gallagher and Zahavi (2008, p. 185), "Bodily behaviour is neither necessary nor sufficient for a whole range of mental phenomena . . . which is why lying, deception and suppression is possible, but this is not to say that this is generally the case". That is one reason why the way artists utilise emotion, context, and memory may hold particular import for scientific *attentional* studies.

As a result, neuroscientists are increasingly aware that the understanding of *attention* entails combining insights from within and, significantly, also across disciplinary fields. The transfer of knowledge between diverse scientific fields has likely helped open up inquiries across science to include the performing and visual arts. As one notable example, Randi the Magician was invited to a Magic of Consciousness symposium in 2007 sponsored by the Association for the Scientific Study of Consciousness. Such symposia now provide a way for magicians and neuroscientists to learn about *attention* from each other (Maknik et al., 2008).

3.3 The study of attention as a complex system, rather than a single process

A third reason for convergence has been the influence of complex systems; the study of *attention* unavoidably engages with the dynamics of complexity. For example, ambiguous percepts have often been explained by simple satiation or the fatiguing of neural circuitry coding the percepts, and several scientists have successfully formulated compelling explanations based on nonlinear dynamics (Ditzinger & Haken, 1986). According to computer engineer David DeMaris (1997) who specialises in oscillation phenomena in networks and cognitive modelling, *attentional* aspects are manifested in eye movement fixation times, switching time distributions, and residency times in the reversible states, all of which involve non-linear dynamics. Churchland (1981) challenged a functionalist understanding in cognitive and behavioural neuroscience that results in causal explanations in psychology. Today new philosophical content along with the use of simulation and innovative methodologies have been integrated in complex studies of *attention*.

Reductionism in science (concurrent with Modernism in art) involved breaking down phenomena into (literal or figurative) cellular, molecular, and atomic parts in order to examine them. Complex systems instead stressed time-dependent effects on the properties of developing, hierarchically-organised systems and how interaction among the various components may occur; they relied on many factors interacting at different phases. One component may affect and be affected by other components, showing a cascading effect or feedback (Bechtel & Richardson, 1993). If a researcher tested self-organising systems, considerations needed to be taken into account about homeostatic mechanisms that might maintain an equilibrium state despite perturbations. Self-organising systems helped to explain the developmental role of spontaneous neural activity, which plays a role in constructing neural circuits (Wong, 1999).

Some have suggested that phase transitions underlie cognitive development (Quartz & Sejnowski, 2000). Research on emotion and its interaction with the *attentional* system has been studied from the standpoint of complex systems, including the networks and feedback involved (e.g., McGaugh et al., 1995; Damasio, 1994). Today genomics and neuroscience are often informed by an understanding of complexity science; evidence has supported multi-modality at molecular, chemical, and genetic levels and described the interactions of the senses. Research in complex systems has suggested that information cannot be reduced to a genetic code but becomes a field of possible pathways and influences of an interdependent and interactive nature.

As a result of complex systems, artists realise that modulations between chaotic and periodic behaviour may create expressive form. Artist Rafael Lozano-Hemmer (exploring simulation techniques) stated on his website (Lozano-Hemmer, 2010) that “the new mathematics allow for emergent behaviours to arise, given particular initial conditions, constraints and perturbations. Artists that use these techniques (Knowbotic Research, Christa Sommerer, Ulrike Gabriel, Golan Levin, for example) generate ever-changing environments that simulate life”. Such artists are attuned to the flow of *attention* they create in artworks. Complexity studies have fostered a range of approaches, including non-linear narrative and the layering of information. Although the structures created are varied, artists can tap into natural material processes or simulate natural processes (thereby creating actual phenomena) through repetitive, simple actions and invented computer algorithms. However, this history should not and cannot be overly simplified. For example, Kandel and Mack (2003) have pointed to the continued value of reductionism in both science and art. There is no need to choose; both approaches are valuable.

3.4 More sharing of processes and methodologies between art and neuroscience

A fourth reason for convergence is that some artists and neuroscientists share many of the same creative and methodological approaches although the tools tend to be different. Artists, like scientists, have manipulated *attention* either deliberately or intuitively, and I have provided many examples throughout this thesis along with a related taxonomy in the supplement.

Due to a lack of access, only a few artists would use standard tools found in neuropsychology laboratories. Media artists today may use tools of virtual reality, 3D modelling, eye-tracking devices, and motion capture along with various sensors. A typical laboratory set up to study *attention* would likely include eye-tracking devices and mixers to manage stimuli. According to correspondence I had with Michael Posner, some neurophysiology tools would include virtual reality and perhaps cinematic tools in addition to fMRI, PET imaging, and older tools like mental chronometry (the use of response time in perceptual-motor tasks to infer the content, duration, and temporal sequencing of cognitive operations). An equipped laboratory would include MATLAB (programming language), various imaging and statistical tools (e.g., FSL), and a scanning probe microscope. Most laboratories can carry out full genome scans using polymerase chain reaction **(**PCR**)** and even newer techniques to amplify DNA and check candidate genes for ADHD. More access to these tools could provide the public and the artists with deeper insights about the scientific process.

During the 1960s and 1970s a parallelism existed between the worlds of art and science concerning investigations of spatial orientation and ambiguity (chapter three). Many artists became involved with a durational experience as opposed to an immediate, single gestalt, such as that championed by formalism. In addition, the artists often eschewed craft techniques, using standard industrial materials and fabrication (Jones, 1996). As a result, the process of creativity became more similar among artists and neuroscientists. Just as neuroscientists have extended the parameters of their testing, artists have sought to expand their own practices. Practitioners in both camps have disrupted vision and spatial orientation and constructed interactive and immersive techniques. Both groups realise that their tools and processes guide and serve as constraints on the analogies that are created and the data that can be gained. As particular methods become available, analogies can veer in new directions. In the case of Lozano-Hemmer, a complexity toolkit of generative equations and interactive technology made it possible for him to intimate a “searchlight” metaphor of *attention*. As a practicing media artist, Scott (2003) was in a position to point out that the growth of interactive media was directly linked to the growing understanding of crossmodal interaction in the brain and that immersive technologies helped foster HCI studies in proprioception.

3.4.1 Imaging technology

In the 1990s fMRI became widely used to measure brain activity (or, more accurately, blood flow) and correlate it with mental states and processes. As Raichle (1998, p. 772) stated, “We have at hand tools with the potential to provide unparalleled insights into some of the most important scientific, medical, and social questions facing mankind”. The ability to conduct noninvasive imaging allowed scientists to probe how *attentional* processes and structures work together and offered a way to bridge psychology and biology (Kosslyn, 1999a). It allowed for new work in *attention* rehabilitation since brain networks and their plasticity could be tracked in real time following physical damage or while undergoing *attention* training.

Imaging techniques have had wide cultural ramifications since they dissolve boundaries between the inside and outside of the body, making external what had previously been internal (Kevles, 1997; Dumit, 2004; van de Vall, 2009). Some artists working today (e.g., Andrew Carni and Susan Aldworth) have used neuroimaging methods to look into the brain's machinery and explore issues of identity. The question raised is to what extent these images can cast light on psychological phenomena. Hagner has been somewhat sceptical, noting that there are great limitations to the belief that imaging can exteriorise our inner, psychological selves (Hagner, 2009). Nevertheless, such imaging has inspired some artists to conduct imaging experiments in collaboration with scientists (e.g., artist Eva Lee with neuroscientist James Coan).

3.5 The scientific analysis of emotion compared to effect of emotion on art practice

A fifth reason for the convergence is the scientific analysis of emotion that has been taking place in recent decades. Why are emotion and *attention* linked? As anthropologist Terrence Deacon stated, emotion "is the attached index of *attention* relevance in every percept, memory, or stored motor subroutine" (Deacon, 2006, p. 37). The disciplines of neuroscience and art are better positioned to speak the same language in part because of emotion studies like those conducted by Damasio (1999), LeDoux (1994), and Lim and Pessoa (2008). Neuroscience has developed new ways to measure emotion, enabling the quantification of qualia formerly considered intractable to science. For example, Olsson and Phelps (2007) have shown that emotionally arousing information actually facilitates the speed with which the information is processed. Phelps et al (2006) have found that emotion actually facilitates perception. Viewing the study of emotion as an information-processing network that computes our degree of positive or negative reaction toward stimulus events has enabled measurement and brought this field closer to cognitive studies (LeDoux, 1989; Phelps & LeDoux, 2005).

Posner has demonstrated that negative emotions, which are related to activity in the amygdala, can be modulated by left prefrontal cortical activity. It has been observed that *attention* can distract an individual from noxious stimuli (Derryberry & Rothbart, 1988). In light of this finding Posner has stated "*Attention* may serve to control levels of distress in adults in a somewhat similar way to that found early in infancy. Indeed, many of the ideas of modern cognitive therapy are based upon links between *attention* and negative ideation" (Posner & Rothbart, 1998, p. 1921). "Putting your mind elsewhere" has thus been validated as a way to cope with distress, and artist Diane Gromala has made good use of this approach.

Massumi makes a distinction between affect and emotion; he views affect as having an autonomic nature (2002, p. 28). As Lisa Blackman and Couze Venn have also pointed out (2010), "affect" might be reconsidered with respect to notions of embodied experience. Constantina Papoulias and Felicity Callard (2010) posited that the new neuroscientific concepts of affect along with ideas of Daniel Stern in developmental psychology (1999, 2009) have resulted in constructing a new model that has ramifications across art and science. They stated that "The turn to affect is thereby a turn to that "non-reflective" bodily space before thought, cognition and representation – a space of visceral processing. Importantly, this non-reflective space is not without intelligence: although it is characterised by a certain kind of automaticity, this does not equal dumbness but is understood to be a 'different kind of intelligence about the world'" (Papoulias & Callard, 2010, p. 34).

As a result, artists as well as neuroscientists have produced new information about the intersections of affect, emotion, and *attention*. Much of the current thinking in brain science involves autopoeitic self-organisation and emergent states, involving embodied processes. Some artists have attempted to make these states experientially visible. For example, new media theorist Mark Hansen explored the way in-between, hard-to-see emotional states have been revealed in new uses of film and video by Douglas Gordon and Bill Viola that may elicit a physiological response from an involved viewer (Hansen, 2004).

3.6 The emergence of neuroaesthetics

The interest in neuroaesthetics that has accompanied its emergence constitutes proof of the convergence between the art and neuroscience disciplines. Mark Rollins defined its goal, stating that "The point of neuroaesthetics is that the style and content of a work of art can be identified and understood through the type of perceptual, cognitive, and emotional response it evokes, and that response must be characterised with reference to neuroanatomy and neurophysiology" (Rollins, 2009, p. 378). From the standpoint of my thesis, part of the attraction of neuroaesthetics is the belief that we can learn something about the brain from analysing the different *attentional* responses elicited by different artworks. The assumption is that a successful artist has manipulated the viewer's *attention* to best generate the impact the artist seeks. In addition to the content of art (Rollins, 2001), issues of beauty have been insightfully addressed by, for example, Jennifer McMahon (1999, 2000). Some of these analyses attempt to inform us of how aesthetic drives become motivations for learning as well as for making art and conducting scientific experiments. Many neuroscientists have been productively engaged in neuroaesthetics. Changeux (2011, p. 3) foresees a "plausible program of multidisciplinary research for the next decade at the crossroads of the biological sciences and the humanities". As my dissertation suggests, although I do not believe that art is likely to be fully understood by attempts to locate the neural correlatives of, for example, beauty, neuroaesthetics has already been of value to art history. Insights combined from art and the neurosciences have resulted in broadening the scope of both fields in a productive way. For example, Zeki's discussion of ambiguity (2006) marks a high point in broadening the scope of what neuroscience can contribute to the comprehension of art.

In considering neuroaesthetics overall, one of the difficulties is whether one can find neural mechanisms that link private experience and cultural meanings (as a social repository of experience) and, assuming that one could find a neuronal basis for common understanding between people within the same culture, how the translation of meanings between different cultures might occur. How higher order sensory neurons may link private experiences with cultural meaning is not yet known and may never be known given the complexity of factors involved. Even if known, they may never "explain" art. One of the recurrent objections of the humanities to neuroscience has been science's emphasis on universal, biological patterns as opposed to subjective experience. Merlin Donald stated (2006) that no technology is available to measure associations that rely on cognitive-cultural interpretations that may be unique to individuals within society. It would therefore seem unlikely that a common pattern of neural processing can ever suffice to explain our individual reactions. However, John Onians proposed (2007) that neuroplasticity now enables neuroscientists to explain how an initially common pattern of neural response can nevertheless address the individual. In *Neuroarthistory*, he pointed out that “The subjectivity of the individual is not, as some have argued, just a social construct. It is embodied in the brain, and can be analysed at many levels” (Onians, 2007, p. 14). In an interview with Eric Fernie published online, Onians further explained that neural plasticity would help us understand universal preferences while realising that, although all brains undergo change, each individual’s brain will develop in unique ways according to its intersection with the environment and therefore lead to brains that reflect individual experiences (Onians & Fernie, 2008).

It has been noted that the Western mentality tends to be analytic; it focuses on the object and categorises objects by their attributes. By contrast, the East Asian mind tends to be holistic, focusing attention on field attributes (Nisbett, 2003). Tests have been devised to try to separate out the biological from the cultural components. One of the promises of neuroaesthetics is that individuals bringing insights from other fields to bear on neuroscience might, together with neuroscientists, help to identify cultural, learned responses and separate them from those resulting from hard-wired biological differences. It is demonstrably useful to have people from several kinds of backgrounds and perspectives explore these findings. For example, it was a group of anthropologists in collaboration with psychologists (Segall, Campbell & Herskovits, 1966) that demonstrated that individuals who grow up in particular kinds of visual environments during their first two decades of life are not susceptible to the Müller-Lyer illusion. They correctly see the horizontal lines as being of equal length (Figure 83). The researchers determined that culturally influenced differences in visual experience substantially affect how people experience the stimuli and found that cross-cultural variation is greater among children than adults. Various plausible explanations of the Müller-Lyer illusion have been offered by now: one is that the visual system assumes the angles are right angles (and infers the corresponding depths), and another posits that the exposure to perspective in art leads to the biases that create the illusion.

Figure 83: The Müller-Lyer illusion (Segall et al., 1966) has been removed due to Copyright restrictions.. The horizontal lines are actually of the same length.

Important ramifications of these studies have resulted, touching on concepts of evolutionary development. The illusion has, for example, been used to challenge Fodor's ideas of "cognitive impenetrability" although Fodor, himself, pointed to it as evidence for the modular encapsulation of information of the visual input system as innately specified and as "supporting the possibility of theory-neutral observation" (McCauley & Henrich, 2006). The basic concept of theory-neutral observation is that knowing that what one views is an illusion does not alter what one actually perceives.

In the previous chapter (five), patents were utilised for the information they could provide about the economics of marketing medicine. Patent drawings, themselves, offer evidence of our some of our visual assumptions. For example, the expectation that light should come from above is considered to be hard-wired rather than culturally determined and has been explored by art historians such as Baxandall (1995). Even the most minimal of patent designs reflects this expectation. For example, William Rankin (2006) noted that in 2004 an upgraded manual of the patenting procedure explained how to make two-dimensional orthographic views understandable as three dimensional objects. The manual instructed the drafter of the patent design that "light should come from the upper left corner at an angle of forty-five degrees" to the surface of the paper. Edges to the bottom and right should thus be made graphically thicker, to indicate a shadow (Rankin, 2006).[1] This convention can still be seen today in the shading of some desktop icons such as Windows and is illustrated in the drawings below (Figure 84).

Figure 84: Darkened (shaded) lines on patent drawing indicating 3-dimensionality has been removed due to Copyright restrictions.
Left: the left column in the left drawing has no shade lines. The right column in the left drawing shows how the ambiguity of 3-dimensionality is resolved by shade lines. Right: detail of a patent drawing showing how the shading convention is applied.

The field of neuroaesthetics has been somewhat contentious (e.g., the 1999 neuroscientific theory by Ramachandran and Hirstein (1999) and ideas about the "peak-shift" (exaggerated images and caricature in relation to aesthetics) were subject to much debate). Stafford and others have noted that neuroscientists involved in neuroaesthetics have focused on art that supports their conclusions (Stafford, 2007). In addition, the studies of neuroscientists have largely been restricted to traditional art forms, and relatively few publications by contemporary art historians or artists have been referenced in the neuroscientific literature. However, this field is rapidly changing and the participation and critiques of art historians, historians of science, and artists such as Warren Neidich (2003) and Amy Ione (2008) have already been productive. Artists in particular bring visual expertise, skills of philosophy, and hands-on experience to this field.

3.7 The development of new investigations of creativity and learning among cognitive scientists

Attention – its strengths and deficits – has been shown to be critical to cognition and learning throughout this thesis. As discussed in chapter two, scientists increasingly realise that the arts and arts training offer important insights about creativity and cognition. D.T. Campbell's *Blind Variation and Selective Retention in Creative Thought as in Other Knowledge Processes* (1960) was based on a Darwinian approach to how people learn. A similar, somewhat modified approach to understanding creativity was later championed by D. K. Simonton (1999). By the 1970s many in education reconsidered creativity and the value of self-reflective questioning, metacognition, and aesthetics. In 1966 Bruner commented that "There are *attention*-saving skills in perception that are imparted and then become the basis for understanding the icons we construct for representing things by drawing, diagram, and design" (1966, p. 26). The newer models of cognition validated the importance of context and affect, along with aesthetic response to artworks. *Creative Cognition* (1992) by Finke, Ward, and Smith was followed by *Discovering* (1989) by Robert-Root Bernstein and many publications about creativity by Bruner (1985) and Howard Gardner (2006). *Creative Cognition* was valuable in understanding the cognitive forces underlying creativity and its roots in "associationism" while *Discovering* explored how creativity might be fostered. Growing evidence has shown that perceptual learning (considered a bottom-up approach) that is visual, fast-paced, and often focused on classifying problems can build up intuition and be transferred to different areas of knowledge (Kellman & Massey, 2010).

Neuroplasticity also holds implications for *attention* therapy and for learning. It is by now generally accepted that the cognitive structure changes with learning (Doidge, 2007); it is also realised that more change can take place in both children and adults than was ever thought possible. Posner and his team have viewed neuroplasticity as validating *attention* therapy for those diagnosed with ADHD since the *attentional* system affects many other cognitive systems.

Evolutionary biology has offered valuable considerations about the *attentional* system, including its phenomenon and pathology as well as learning. Within science departments, the separation of developmental psychology and developmental neurobiology rests on distinctions of whether an organism has learned or biologically matured, and according to Quartz and Sejnowski (2000), this distinction is breaking down. A "nativist-selectionist" controversy has been tentatively resolved by proposing a flexible constructive kind of learning in which the developing brain responds to its environment without the need for innate domain-specific structures. Quartz and Sejnowski (1997) have considered the effects of constraints for computational models of development. They also stressed the implications of plasticity for the understanding of higher level cognitive processes like *attention*. Biologist Annette Karmiloff-Smith (1992) has found evidence to support a "dynamic, epigenetic view of development" in which the timing of cortical events is important for the developing infant. Such views add immensely to knowledge about *attentional* pathology.

The views of evolutionary biologists with regard to adaptation have contrasted with structuralists who have instead tended to emphasise constraints and universal laws of forms. For evolutionary biologists, the fact that mankind developed as nomads in a very different kind of environment has led some to consider exercise as a part of a regimen to treat ADHD. We saw in chapter four of this thesis that knowing the norms of development was crucial for ADHD diagnosis, and evolutionary biology may cast light about this important topic.

Today *attention* is regarded as a valuable and increasingly scarce currency, exacerbated by the conditions of information technology and media. These new technologies also have implications for the fostering of learning, both good and bad (e.g., overload).

3.8 Additional results of the convergence

Many artists are inspired by but critical of scientific findings. To undertake research in a serious way, they often seek additional training and information beyond that typically provided by art schools or universities. Collaborations between artists and scientists have been fostered in several US universities; the MIT Media Lab, Carnegie Mellon University, and Rensselaer Polytechnic Institute have assisted such exchanges. Abroad, foundations such as the Wellcome Trust and Gulbenkian Foundation are active in areas of art and science. Artists have also contributed to some of the neuroscientific work on *attention,* some working with scientists and others in their own studios. As one example, the Swiss artists-in-labs program was founded in 2004 as a collaboration between the Zurich University of the Arts ZHdK, Institute for Cultural Studies in the Arts ICS, and the Federal Office of Culture. Such developments have provided opportunities for interchange on a high level between artists and scientists.

The benefits offered by the convergence of research on *attention* in both the art and neuroscience fields are continuing to unfold. For example, I suggest that it makes sense that neuroscience should impact our understanding of art movements. One reason it makes sense is that neuroscience suggests why "formalism" never totally lacks embodiment. Several theories of embodiment have been proposed to explain how the brain's cognitive structure is linked with experience derived from the world (e.g., Zbikowski, 2006). One is a modification of "embodied cognition", involving a "grounding by interaction" hypothesis. It combines the view that concepts are, at some level, both abstract and symbolic, with the idea that sensory and motor information may "instantiate" conceptual processing by the brain. Mahon and Caramazza (2008) define this instantiation as including the retrieval of specific sensory and motor information. From this standpoint, a person's physical experience of the world can be reproduced in the mental representation of a conventional sign. Lakoff's "cog hypothesis" similarly attempted to explain how a form can be both abstract and embodied in the sensorimotor system; he concluded that cogs are secondary structures with connections to the primary neural structures that permit actions (Lakoff, 2006, p. 164). It seems to be the engagement of the motor system that fosters metaphorical interpretation.

Social theorists Papoulias and Callard (2010) regard each discipline as already embedding aspects of the other. By no longer considering art and neuroscience as binary oppositions, perhaps we can more easily see what may be gained by encouraging their ongoing interactions. This approach is in keeping with Gombrich who, in agreement with Karl Popper (1972), noted that focusing on subjectivity would not entail denying its objective veridical component.

4 Metaphors and models of attention

Metaphors conceived by scientists have actually helped contribute to the forging of theoretical models, which is one reason they are important to consider (Rentetz, 2005). Another reason is that the creating of metaphors is yet another way that the activities of artists and neuroscientists converge.

4.1 Metaphors of attention

In 1984, Francis Crick proposed a searchlight of *attention* model. He wrote, “What do we require of a searchlight? It should be able to sample activity in the cortex and/or the thalamus and decide ‘where the action is’. It should then be able to intensify thalamic input to that region of the cortex, probably by making the active thalamic neurons in that region fire more rapidly than usual. It must then be able to turn off its beam, move to the next place demanding *attention*, and repeat the process” (Crick, 1984, p. 4588). This analogy provided a wealth of productive associations (Baars, 1998). Supporters of this analogy tentatively identified the anterior temporal lobe as a place where conscious visual information come together (Baars, 1998, p. 59). Baars pointed out that Crick’s model for visual *attention* was expanded by the idea, not only of frontal executive control but by inhibitions or “automatic interrupts” from the amygdala, the brain stem, and pain systems. These systems were conceived as allowing significant stimuli to penetrate into consciousness. His metaphor produced testable hypotheses stemming from his envisioning of a theatrical “setting” for the searchlight metaphor. It suggested that some anatomical structures could integrate, shape, display, and disseminate conscious contents, to be received by other brain structures and to receive feedback from them (Baars, 1998).

The use of metaphor in science dovetails with its importance in art (Lakoff & Johnson, 1980). Diego Fernandez-Duque and Mark L. Johnson pointed out that metaphors are immersed within scientific and social practices. In addition other factors, including technical advances, mathematical elaborations, cultural influences, and empirical data, constrain how metaphors are used (Fernandez-Duque & Johnson, 1999, p. 102). There are many examples of what is identified as the spotlight metaphor in the scientific literature (e.g., Posner, 1980). Technological advances, such as the emergence of imaging techniques, have resulted in scientists reframing the spotlight metaphor just as they have resulted in artists asking how imaging affects notions of identity. Fernandez-Duque and Johnson speculated that, in part because of developments in imaging technologies, the spotlight of *attention* metaphor may have shifted from an *attention* spotlight shining externally upon objects in a field to an "inner spotlight" focused on the brain and neural connections within it (Fernandez-Duque & Johnson, 1999, p. 99).

4.2 Attention models

Scientists often date the start of the modern era of *attention* from 1958, when psychologist Donald Broadbent offered a filter model of *attention*. His filter model attempted to explain how the senses screen out an overabundant, confusing information flow (Solso, 2005). In Broadbent's dichotic listening experiments, subjects were asked to listen with headphones to three digits in one ear and simultaneously to three different digits in the other ear. Two digits were given simultaneously each second. A subject might hear 4, 9, and 3 in the right ear and 6, 2, and 7 in the left ear. They were then asked either to recall the digits by ear of presentation (e.g., 493, 627) or to recall the digits in the sequence in which they appeared (e.g., 4/6 or 6/4; 2/9 or 9/2; 3/7 or 7/3). In all, the task required that each participant recall six items. Most participants in the study recalled the digits ear by ear, rather than pair by pair. Thus, the recall favoured 493 and 627 rather than 46-29-37 (Solso, 1979, pp. 124-126). Broadbent interpreted the poor recall in the sequence condition as reflecting the necessity of switching "channels" from one ear to another. Broadbent's model explained that a bottleneck occurs before pattern recognition and that *attention* determines what information reaches the pattern recognition stage. It challenged the dominant reign of behaviourism in psychology in favour of cognitive approaches. Although the model was itself later amended by Broadbent, it constituted an attempt to relate psychological phenomena to information-processing concepts that were derived from mathematics and computer science (Driver, 2001).

4.3 Subsequent attention models

Broadbent's theory had to undergo modification when it became clear that some unattended information does, in fact, get through. For example, people can respond to their names, even when attending to something else. In 1969, Anne Treisman proposed her attenuation version of filter theory in light of the fact that subjects could actually follow a message to the other ear, verifying that the participant is able to follow the switch between ears in continuing a message. She stressed the key roles that partial information and priming can have (Driver, 2001). Treisman and Gelade's theory of feature-integration (1980) concerned the role of binding features into a saliency map that then guides *attention.* A later theory suggested that simple physical features are coded in parallel preattentively, whereas more elaborate coding requires a serial attentive process. Thus auditory and visual messages can be more easily processed in parallel. Interference was then interpreted as arising within a sub-system rather than between them (Kahneman & Treisman, 1985, p. 33).

Much of the debate involved in selective *attention* research addressed early versus late selection. In the early selection models that were first proposed by Broadbent and Treisman, most of the important perceptual processing follows *attentional* selection (Kahneman & Treisman, 1985). In the late selection models (first proposed by J. Anthony Deutsch and Diana Deutsch) perceptual processing to the semantic level is automatic and independent of *attention*, and *attention* controls the stimuli that are acted upon (Duncan, 1980). The "category effect" in which information can pop out under particular circumstances (e.g., recognition of one's name) is viewed as support for late selection, but the issue is still unresolved.

Some of the models of *attention* have been space-based (involving location) and others are object-based (involving units of information). Some of the models combine aspects of both. Eriksen & St James (1986) explored the spatial characteristics of a zoom-lens model, showing that attention has a focus, but that the focus bleeds out into the area around it. Considerable evidence now suggests that selective *attention* in vision is constrained not only by the location and spacing of stimuli, but also by how the visual system groups these stimuli together or apart (Driver & Baylis, 1998).

4.4 What is gained by the merging of perspectives from art and neuroscience

In Broadbent's dichotic listening task, the participant received different information in each ear through headphones. As we saw, the results revealed limited ability to report what was heard in the unattended ear. All was filtered except for whether the voice was a male or female voice. His experiment has its philosophical counterpart in a 2004 artistic experiment by Philbrick. Her artwork, Voix/e (2004), took the Biblical poem, the *Song of Solomon,* and internalised its dialogue of love and seduction for listeners (Figure 85). She recreated the *Song of Solomon* in both male and female voices with a voice synthesiser and also separated out the vowels and consonants. Philbrick used a speech synthesiser to speak bride, groom, and companion parts. The recordings were scanned digitally and each word was separated phonemically, between the percussive consonants and the soft vowels. The recording was hard panned (the sound in this circumstance comes from front and centre). The artist's explicit aim was to set up a situation in which, when the recording is played back, the words, split phonemically, would resolve themselves in the listener's body. The visual setup was important as well; separate sounds were fed to each ear via headphones. Rather than resulting in one attended and one unattended feed as in the Broadbent experiment, according to the artist the sounds were fused within the listener's brain. The presentation enhanced the participant's sense of the body's role in comprehending language. As Massumi pointed out (2002, p. 140), "Every attentive activity occurs in a synaesthetic field of sensation that implicates all the sense modalities in incipient perception, and is itself implicated in self-referential action". We are part of the flow of sensations, and it is this flow that is experienced in Philbrick's work.

Figure 85: Jane Philbrick, Voix/e (2004).

Broadbent and Philbrick suggest what is to be gained by considering both scientific and artistic investigations. It is apparent that both experimenter have filtered their conclusions through their own disciplinary frames, and both offer valuable insights. My transdisciplinary approach in this thesis was undertaken to make it less likely that too much of value might be filtered out by viewing through a single disciplinary lens.

5 Conclusions of the chapter

This chapter explored seven reasons for the convergence of art and neuroscience, showing that, unlike scientists, artists have tended to embed social and cultural factors within their art experiments and to offer critiques of the very technologies they embrace. Today there is increasing realisation that those outside the discipline of science may be able to ask questions of science that have not been adequately addressed. It is clear that some of the new models of learning and *attention* training are starting to consider contributions across the fields. The scientific investigation of *attention* would seem to profit from multiple perspectives, especially from the field of art, which is constitutive of *attention*, itself.

The chapter also examined scientific models and metaphors of *attention*, allowing for creative insights. For scientists, the framing of metaphors has suggested ways they could follow up implications through further testing. Just as an invaluable asset of metaphors is the part that constitutes the unknown, those aspects of artworks that are seemingly extraneous to *attentional* research (e.g., political content) may prove to yield new insights about the functioning of *attention* within and among cultures.

In the converging of interests between art and neuroscience, several different approaches became possible that had not previously occurred. For example, the scientific approach has traditionally rejected ambiguity wherever possible in favour of data and resolution. Yet within the context of neuroaesthetics, Zeki found “ambiguity” well worth considering. Similarly, the artistic discourse, while typically rejecting measurement as a general practice, could nevertheless consider it under particular circumstances (e.g., collaborations).

It is apparent that phenomenology has become a mediator between the first-hand accounts of art and the third-person objectivity of science. Science must address social needs as well as those stemming from the body, and, as we have seen throughout this chapter, art can make us aware of some of them. It also became evident in this chapter that one of the most important things we do in art is to prioritise our values and concerns. This is part of the reason why we, as artists, make art. *Attention* reflects and drives that prioritisation.

Endnotes

1 Manual of Patent Examining Procedure , (Washington: USPTO, May 2004), 600-94

CONCLUSIONS OF THE THESIS

In chapter six I examined why Broadbent's filter model was a significant event in *attention* studies and analogised it to Philbrick's more recent art experiment (2004). This was one of many such comparisons discussed in my thesis, and it suggested that viewing the filter model through a single disciplinary lens might, itself, filter out too much of value. The accumulated comparative analysis of *attentional* experiments in my dissertation has allowed me to explore some of the advantages gained by an exchange of ideas across the disciplines of art and neuroscience.

In this thesis, exploring the premise that new insights about *attention* would be provided by combining perspectives of the neurobiological discourse about *attention* with analyses of artworks that exploit the constraints of the *attentional* system has led me to conclude that art, when engaged, is an *attentional* training ground with potential scientific and clinical value. Furthermore, art can not only enhance public awareness of *attention* disorders but can question the basis for defining norms of behaviour. Therefore, art and neuroscience enable complementary observations to be made about the *attentional* system. This dissertation has proposed a taxonomy of correlated *attentional* tasks, ArtLinks to Neuroscience, as a way to increase communication between these fields. Its contents coupled with more detailed analysis throughout the text suggest there are advantages to artists and neuroscientists combining their insights and methods. The following is a deeper analysis of my conclusions.

Art is an attentional training ground

In chapter one it was shown that the *attentional* system has limited resources and, as a result, the functions of its different networks can be isolated and identified. As I have confirmed in this thesis, art can be correlated with scientific testing of the *attentional* system since both exploit *attentional* constraints in similar ways. Many scientists support the theory that *attention* training results from repetitive practice that increases *attentional* efficacy. Carrying out particular tasks is believed to improve formal performance within particular networks. --
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-- By contrast with the scientists who were studying how certain presentations of stimuli affect the brain, the images created by artists were constructed to stimulate a change of consciousness. Since complex object properties like social attributes also trigger *attentional* orienting and these qualities are replete in artworks, they may be worthy of additional consideration from a scientific standpoint. Those features that are embedded in artworks, including emotional salience and social significance, may actually increase the likelihood that the informal *attention* training of art is successful. The reason is that they are motivational factors that may result in the artwork being encoded in memory.

Engagement with art has been established to enhance mental flexibility, foster visual discrimination, and enable the understanding of an artwork's underlying content; these abilities often signify that learning has actually occurred (chapters one and two). As my own art experiment about inattention blindness demonstrated, participation in an art installation enabled the viewers to re-direct their *attentional* set to see images that they had not previously noticed. This result supports the concept that active engagement with art in the informal setting of a gallery offered benefits similar to *attention* training in formal therapeutic or laboratory settings (chapter two). I corroborated the potential of art to enhance learning by referencing the findings of a museum study held at the Gardner Museum that the kinds of training artists typically receive can promote other skills involving observation and reflection.

In chapter three, artworks were again correlated with neurological testing of the *attentional* networks but within the context of how new technologies have extended the parameters of behavioural responses. I attempted to demonstrate that art offers neuroscience examples of embodied and interpretive approaches to cognition that are important to *attentional* learning. The processes involved were shown not to be only conceptual but physical, resulting from knowledge that comes from handling material, directing the gaze, and gaining experience of the world. In addition, artworks fostered self-knowledge, which is important for both therapeutic social integration and for learning. I posited that self-learning also takes place when art reinforces how some of its knowledge is motor knowledge (e.g., Philbrick). Neuroscientific investigations of sensorimotor actions offer reasons why this is so.

Art has potential value in expanding scientific research

I claimed that art has offered neuroscience important insights in areas of sensory experience, emotion, and the staging of experiences. Artists' investigations of the sensorium (chapter three) are of increasing importance for scientific understanding of crossmodality. The knowledge of images, imaging, emotional states, and social context deeply embedded in art practice can supplement neuroscience's understanding of *attention* and its disorders, involving neuroimaging and mapping. Throughout the thesis it was shown that art broadens the basis on which conclusions can be drawn regarding the value of images for understanding *attentional* functions. But this potential is likely to remain untapped unless art and neuroscience share a common language.

In chapter one I discussed the utility of a taxonomy for enlarging the scope of experimental design in scientific research in the future. Here I explored a great variety of *attentional* tasks and how they are processed in the brain. I demonstrated with my own artwork (chapter two) and other artwork (chapter three), that the creation and staging of phenomena by artists has expanded the repertoire of *attentional* responses that art elicits from engaged viewers. These might be adapted to scientific use if made accessible to the scientific community. To some extent this is already happening in documented examples of particular collaborations. However, a greater awareness of the possibilities of expanding the scope of *attentional* experiments can result from providing examples within a taxonomy that indicate the range of artworks that have resulted from collaborations (e.g., Dennis Pelli and Chuck Close; Scott and The Institute of Molecular Science). Within the taxonomy I identified *attention*'s interactions with other systems, which also offer potential value to research scientists. For example, they might adapt some of the artworks to experiments that analyse the modulatory influences of memory and emotion upon *attention*. To accomplish this, they could regulate the levels of activation through adjusting the salience of the images.

To make these correlations, I needed to delve deeply into the scientific and *attention* testing literature and relevant debates from the neurobiological perspective. This raised the question of the extent to which artists need to understand neuroscience research. If the artist wants to be socially engaged and promote a dialog about perception, this depth of research could be important as a way to validate the art from a neuroscientific standpoint, enabling neuroscientists to take artists' experimental proposals seriously.

The taxonomy I created may help to set a shared language in place with some neuroscientific and clinical value. It may also help correct for the relative paucity and variety of images used in some scientific publications that analyse visual discrimination and related topics. Art generally offers stimuli closer to what people actually experience in the world than the deliberately contrived tests of neuroscience. Some scientists have, themselves, acknowledged that certain kinds of scientific research would benefit by grounding more tests into the real world (Felsen & Dan, 2005). Describing and visualising how *attention* operates in the real world can guide new ways of conceptualising and testing the *attentional* system. In this manner, art offers a way to question some basic assumptions in neuroscience.

Art has potential therapeutic value

My first conclusion was that art is an *attentional* training ground because the same skills developed by *attention* training are believed to benefit the operation of other networks related to general intelligence and to improved social integration. I now further conclude that art may have therapeutic value. Not only can art enhance mental flexibility, which has been noted as a benefit of *attention* therapy (chapter two), but, according to Posner and Rothbart, *attention* training can be more broadly applied to the general training of the mind. There is no doubt that artists and designers have recruited *attention* to assist the therapeutic needs of those with *attentional* pathology or those who suffer from disabilities (chapter three). In this light, various artistic and scientific practices were correlated such as Gromala's artwork and related scientific work, utilising

VR systems and biofeedback. But chapter three also stressed the importance for art to keep the larger goals of social integration consistent with the theories of mind and intersubjectivity. Artworks were analysed that fostered awareness of some of the multiple components incorporated into our subjective sense of unity that is, in turn, essential to people's well-being. For example, the question was raised if an assessment of HCI designs could incorporate concern for human values. Here I examined how several artists straddle the line between art and art therapy in order to show how some contemporary art practices have expanded approaches to art therapy. On the one hand, the advantage of bringing art and interpretive images into therapy is to understand how others see the world. In addition, there are potential advantages of directed "play" involving exercise that can be pursued in *attention* training and rehabilitation. Some of this play involves art.

I assessed some of the therapeutic benefits of active engagement with certain artworks in several chapters (two, three, and four). As I pointed out, it has been difficult to prove that *attention* training is successful because incommensurate approaches have been compared (e.g., tasks of divided *attention* as compared with sustained *attention*). To insure that I made appropriate comparisons I constructed my correlations on the three *attention* networks and their interconnections. My taxonomy provides information about which neural networks are activated by engagement with particular artworks. Attention network tests might then be used to assess possible improvement.[i]

I also analysed how designers have created ways to direct the viewer's gaze that cause viewers to incorporate information more efficiently (see chapter five). This has therapeutic implications. For example, scientists have established that children diagnosed with autism, which many consider co-morbid with ADHD, often fail to look directly at the faces and eyes of people (see chapter four). In addition, shared pointing and gazing patterns have been found to establish a basis for intersubjectivity (see chapters three and four). It would therefore seem that using material specifically designed to direct *attentional* scanpaths might help children diagnosed with ADHD and serve as an adjunct to traditional therapeutical methods.

Art can enhance public awareness of attention disorders and question norms of behaviour

Throughout this thesis examples of artwork were analysed that have encouraged the public to be critical about adjudications of health and illness. In my experiment (chapter two), I provided viewers with a way to experience the limitations of normal perception. From this they could also reflect on what is meant by normality and to what extent our notions of the norm are socially-constructed. In order to compare norms, a variety of images from hand-drawn (e.g., Clock Face Drawing Tests) to the technological (e.g., fMRI recordings) were analysed. My conclusion was that one could not rely on any single diagnostic by which to set norms and adjudicate ADHD. Conversely that does not mean that multiple diagnostic tests in combination with other indicators are without value. Because no definitive test exits for diagnosing ADHD, both images

i Fan et al., 2002 developed ways to test predictions of various *attentional* processes.

and imaging play active roles in ADHD research, diagnosis, and treatment. The public could greatly benefit by understanding the basis for gauging the values and limitations of imaging and other diagnostic tests in similar contexts by having access to more visual literacy. As chapter four also suggested, variations of objectivity and interpretation with regard to images and imaging have, at times, helped to create unsupported perceptions of what constitutes the norms of behaviour in children with regard to diagnoses of ADHD. For example, I questioned the basis on which normal controls were selected in psychological trials and challenged some tests with regard to their selectivity and specificity.

By providing examples of artworks that dealt with the individual's place in society and the roles of schools and providers of health care, I was also concerned with the behaviours stemming from *attention* disorders with roots in socio-economics. Unfortunately, I found limited literature specifically pertaining to the intersection of social activism, images, economics, and *attention*. By bringing examples of this intersection together, this thesis has added to the relevant literature and attempted to obtain a deeper transdisciplinary perspective. For example, I explored how the artists Biggs and Buck[ii] have adapted some of the images associated with pathology to probe society's values and public policies, the context in which medical discoveries are commercialised.

Chapter five was also critical of the trend of increased medicalisation and of rigid definitions of pathology. My findings from this chapter were that ethical and political dimensions are involved in classification schemes and that artists can raise awareness of these factors through their interpretations. For example, the DSM is influenced by numerous social and ideological issues. By providing examples of data visualisation (chapter five), incentives within the educational, industrial, and social systems could be disclosed, bearing on medical decisions regarding ADHD. Patent citation methodology was adapted from the field of economics to shed light on the relationships between recent medical technology (e.g., isomeric separation) and the marketing of medicine (e.g., methylphenidate as treatment for ADHD). I concluded that the USPTO can yield valuable information and source material for the social activist artist.

Artists and neuroscientists can offer each other concrete benefits with respect to understanding the attentional system

Art and neuroscience enable complementary observations to be made about the *attentional* system. Kosslyn (1999a) once asked a paradoxical question: "If neuroimaging is the answer, what is the question?" I now ask a similar question: What issues can science resolve about *attention*? Throughout this thesis I have considered how each of these distinct disciplines of art and neuroscience can legitimately advance knowledge about *attentional* processes. Neuroscience can best answer questions that involve imaging technologies since these technologies largely indicate which processes and structures in the brain confer the ability to recognise objects

ii Janet Biggs and Robert Buck's artworks are discussed in chapter four.

or to form visual mental images. In chapters one, four, and five, I discussed how imaging technologies like fMRI have established the organisational structure of the *attention* networks and how *attention* tasks are processed in the brain. Scientists often infer the function of a particular structure or *attentional* process on the basis of specific brain activation (e.g., EEG). However, one cannot necessarily assume that neuroimaging provides causal evidence of ADHD pathology. For example, I noted circumstances (see chapter four) when the interpretation of neuroimaging data may not be straightforward due to the lack of sufficient data about age-appropriate norms of behaviour.

Moreover, neuroscientific imaging has been unable to make a link between medical imaging and the person as a totality. In chapter six I concluded that medical imaging is unable to exteriorise our inner, psychological selves and that art suggests connections within these realms that neuroscience cannot.

On the other hand I now ask: What issues can art resolve about *attention* that neuroscience cannot? Art can suggest certain links regarding *attention* and *attentional* pathology but not generally provide evidence unless controls have been provided and a strict methodology of quantification has taken place. I demonstrated that art can construct and stage *attentional* phenomena (e.g., inattention blindness), allowing participants to experience the limits of perception (chapter two). As the phenomenon of inattention blindness demonstrated, we tend to register only images to which we explicitly attend. By staging inattention blindness within a gallery context, a public forum was created, allowing visitors to engage with the phenomenon and consider how their own *attention*-set might be changed. I also provided other examples of art that allowed participants to experience aspects of their *attentional* system (chapter three). Some of the knowledge held in art includes visceral response, and this experience can be made accessible to viewers who engage with the art. In general, I examined how viewers can empathetically share in the emotions and situations presented by the art experience.

It seems that measurements of biological pathology (e.g., clockface drawings in scientific research and medical visualisation techniques) could be unreliable. Art therapy drawings cannot readily serve as “evidence” of a state of health or illness, but artists can often successfully incorporate such images and drawings in their art for their affective potentials. Artists also make data visualisations based on sources outside the arts. I concluded that the data present in patents and patent drawings could provide evidence of market forces at work in society, reflecting the growth and influence of pharmaceutical industries that are developing technologies of *attention*. The growth of ADHD drugs has been spurred in large measure from a confluence of social and economic factors. This has led to market incentives resulting in pharma seeking patent approval for new applications of isomeric separation and drug delivery. Art can open these complex factors to public scrutiny.

In considering other issues that art can resolve about attention, one realizes that, of course, art can offer a great deal of evidence about our aesthetic choices over time. These choices are signified by human preferences for particular kinds of *attentional* patterns as noted by most art historians. Art history is a record of what has survived into the present from the past, with the assumption that these objects are what the art public has most valued.

Art and science together suggest ways to bridge private and public cultural domains

Culture attempts to provide individuals in a community with a supply of common ideas and images for understanding and communicating their experiences. Such models might make it possible for members to share meanings. Religion once accomplished this, and art and philosophy have now assumed some of the role of establishing a shared intersubjectivity. Several chapters showed how both disciplines would be enriched by combining their insights. At its best, art embodies memorable meditations on emotion, lived experience, and reflections about time that permit one to comprehend the world and oneself in new ways. Science could, in turn, offer insights into some of the interplay of dynamic forces that underlie our existence and consciousness.

Because the body affects perception, I concluded that artworks based on neurocognitive understanding could explain some personally-experienced phenomena as commonly-shared aspects of our physiology and cognition. In many parts of this thesis I have shown that artists and scientists are most alike in their experimental and observational practices (e.g., the *attentional* demands of the art form of flicker films and their resemblance to rapid serial visual presentation tasks). Both art and science are part of culture; artists, however, tend to embed social, emotional, and political factors within their artwork, whereas scientists prove their hypotheses through measurement and validation of results. The increased ability for scientists to explore how emotion modulates *attention* suggests ways for science to investigate more of life's personal dimensions as well as universal impulses.

In chapter six I briefly explored how the translation of meanings between different cultures and between people within the same culture takes place. I examined some research on metaphor, which has supplied important insights about cross-cultural influences. Artists have an enormous role to play in individualising shared conventions as well as the converse: in demonstrating how personal experiences become conventionalised. It seems that in order to understand *attention* in all its fullness the contributions of neuroscientists, philosophers, and artists may be required. However, what one culture views as art might not be considered art in other cultures. Art offers a handle on the topic of subjectivity and of differences among cultures, which remain elusive to scientific scrutiny despite a search for their neural correlatives.

Establishing a shared language (e.g., a taxonomy) may help encourage neuroscientists to combine insights and methods with art professionals

My conclusion is that these separate areas of art and neuroscience offer a fuller sense of meaning when observations of both art and science are considered. I believe their boundaries should be respected but insights about each of them should be merged. But it has been difficult to span these disciplines, which have often been considered incommensurate. Neuroscience offers artists a way to expand their methods and methodologies (i.e., new tools and imaging techniques). I found that art offered neuroscience important insights in areas of sensory perception, emotion, and the staging of experience. Although seldom acknowledged, it is almost impossible to separate notions of art from the study, control, construction, and differentiation of *attentional* patterns. Creating these patterns and making viewers responsive to them heightens an awareness of the *attentional* network among both the artists and participants. In all legitimacy, it seems that art can be re-conceived as the study of *attention* in its fullest sense.

The first three chapters showed that, to the extent that natural phenomena and simulations are “staged” within exhibition settings, they come to resemble interactive science experiments and encourage observation in similar ways. This dissertation posited that the knowledge of images, imaging, emotional states, and social context that is deeply embedded in art practice can supplement neuroscience’s understanding of *attention* and its disorders. The taxonomy of visual references that I have created in this thesis sets a preliminary shared language in place, and it becomes possible to imagine that neuroscience could adapt some of these art experiments to further its own experiments. The converse is also true; artists could conceivably expand their range by being informed of methods involved in scientific testing.

Chapter one also showed that it is no longer adequate to describe art in more general terms as involved with questions of perception. The field of art, like that of neuroscience, has many subdivisions, and the separate art experiments included in the taxonomy are differentiated. They encompass traditional artistic practises as well as conceptual, site-specific, electronic media, installation and interactive art, and bioart. It seems that, to be mutually communicative, experts in each field require knowledge of prior work conducted in both fields. A kind of coding is apparent to those versed in art’s history, and it is this knowledge that enables the determination of the artists’ intentions. Science similarly has its own history and methods, which must be learned by artists who want to contribute their expertise to scientists. Just as scientists can greatly expand upon their reservoir of images, artists can also benefit from looking at the variety of methods scientists use to represent structures that they cannot see and introduce different kinds of approaches to their installations. *Attention* cannot be owned by a single discipline like science since it is essential to most others, particularly art. Therefore both fields derive benefit from sharing their information, but this can only take place if bridges between them are erected and discourses opened that go deep into analysis.

Furthermore, a great deal of the art analysed in this thesis may force the general public to examine some of the assumptions of social and political neutrality that are presumed to govern science. In addition, one cannot blindly accept the common assumption that art eschews measurement and methodological rigor. Since the 1960s, new principles have replaced formalism, and new technologies have been developed, some shared by artists and neuroscientists. Changing definitions of creativity are also involved in bridging these disciplines. Typically it was considered that artists are defined by exceptional manual skills whereas scientists require formal knowledge in order to design and implement experiments. Clearly, this is no longer the rule. It is now recognised that the conduct of art and science both entail creative approaches to the design of new experiments. Some artists participate in both artistic and scientific discourses and work in laboratories. Conversely, some scientists present their work within the context of art. All such works defy disciplinary boundaries and explore gray areas of experimentation, within which it is more likely that a shared language would be developed and utilised.

Summation

This thesis explored similarities and differences of art and neuroscience with respect to their experimental and observational practices. Chapter one summarised views (Hacking, 1983) that many kinds of relationships exist between theory and experiment and that the scientific enterprise will ideally be less dominated by theory and more by the complexities of observation and experimentation. From my research, I believe that art can contribute to the understanding of *attention*, and it is likely that insights from art will be most useful in the realm of experimentation. In some instances, artworks will even generate data that can contribute to quantifiable scientific investigations, and, in a smaller subset, artists will analyse the data themselves, serving as both artists and scientists. One of the major reasons art and science are generally considered incommensurate is that it is hard to reconcile intuitions with rigorous scientific analysis. Art historian Kemp has contributed greatly to their mutual understanding (Kemp, 2006). As qualia have become more amenable to analysis (see chapter six), new syntheses between art and neuroscience have become possible.

Most art experts would agree that art is involved with states of consciousness. *Attention* and consciousness are closely related, but not identical, concepts. The term "*attention*" is most accurately applied to selective operations, while "consciousness" is applied to events that humans can report (Baars, 1998, p. 59). As Posner stated, "an understanding of consciousness must rest on an appreciation of the brain networks that subserve *attention* in much the same way as a scientific analysis of life without consideration of the structure of DNA would seem vacuous" (Posner, 1994b, p. 7398). It seems to me that a theory of art would need to account for consciousness in all of its cultural fullness and, at this point in time, despite attempts, neuroscience seems yet unable do so. We saw in chapter six that Kandel, Zeki, and others have identified the task as involving an understanding of the biological basis of aesthetic judgment. It was also noted that we must take into account the fact that both science and art take place within a distributed cognitive network that constitutes culture (Donald, 2006). I conclude that insights from art are necessary (if not sufficient) to shed light on these difficulties. Unfortunately both contemporary art and neurobiology are not easily accessible to the general public, a limitation that often impedes the knowledge that these disciplines can share.

The examples supplied in this thesis illustrate how art can offer new insights about the neurobiology of *attention* and stimulate public and scientific debate about its disorders, and it seems that pooling information from art and neuroscience may provide a way to enhance discovery in these important areas. In conclusion, a broad perspective is actually essential to understanding *attention* since its phenomenon and pathology can be more fully rendered by uniting insights from multiple disciplines. Consequently this thesis might add to the growing interchange of art and neuroscience in the future.

* * * END * * *

SUPPLEMENT:

TAXONOMY: ARTLINKS TO NEUROSCIENCE

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