The space inside the skull: digital representations, brain mapping and cognitive neuroscience in the decade of the brain

Beaulieu, J.A.

Citation for published version (APA):

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Chapter 1 New Views of the Mind-in-the-Brain

The last decade has been marked by great changes in the fields of psychology and neuroscience, and these changes have been highlighted by the declaration of the nineties as the Decade of the Brain in a number of countries, and the instigation of the Human Brain Project in the U.S. During this period, new views of mind and brain have been formed through the development of new technologies and new strategies for relating the mind and the brain. The objects of study of various disciplines and specialties have shifted in ways that have affected the greater cultural context, as well as institutional arrangements that rely on mind/brain distinctions, also implicated in these shifts in research. For example, through the use of brain imaging technologies, which show new aspects of mind and brain, rationality, responsibility and intent as key concepts in legal settings are being redefined (Kevles, 1997; Kulynych, 1996). Our own understandings of our subjectivity is also changing as we come to think of mental illness or learning disorders as having primarily a physical basis (Dumit, 1995). This thesis aims to trace these changes by focusing on a core project that arose between the mid-seventies and late eighties, and was consolidated during the nineties, namely ‘brain mapping’.

**Brain Mapping and Representations**

Brain mapping is a very heterogeneous research endeavour. One reviewer noted that the textbook ‘Brain Mapping: the Methods’ failed to provide a definition of what this is, leaving the reader to figure out, by default, that brain mapping refers to the diverse contents of the book. Even the label for this work has been the object of discussion: functional imaging, brain mapping and imaging neuroscience have variously been used to describe the stream of work that will be traced in this thesis. Significantly, arguments for particular labels are often formulated in terms of the need to associate or distance research from the technologies used. Functional imaging\(^1\) has indeed grown around a number of technologies constructed in the seventies, and relies to a large extent on the development of digital technologies. Among these many tools, positron emission tomography (PET) is often called the workhorse of functional imaging. PET’s development is typically presented by participants as bringing together research streams from physics, chemistry

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\(^1\) I will use alternately brain mapping and functional imaging: both are meant to evoke the bringing together of brain and mind, but I take to have a slightly different emphasis: mapping highlights the labelling the brain in terms of its functions, while functional imaging stresses the technological possibilities of this particular type of scanning, especially in contrast to anatomical imaging.
and mathematical research\(^2\). The following events are often mentioned: the first PET conference was held in 1978 at the Montreal Neurological Institute (Canada); a clinically-applicable ‘early’ PET was built around 1975 inspired by the work on CT scanner; ‘mature’ PET and the first commercially produced PET with cyclotrons were available by the mid-eighties.\(^3\)

While currently closely associated with neuroscience and cognitive psychology, PET was developed in nuclear medicine and neurology contexts (Kennedy, 1991; Kevles, 1997). It was first applied to measure cerebral blood flow and metabolic abnormalities in the brain (such as high-energy consuming tumours) in the early eighties. It was also used for pre-surgical evaluation of epileptic patients, a clinical practice in which a different type of mapping was often performed during surgery.\(^4\) Later used in combination with other imaging technologies, PET studies in brain mapping research allow the localisation of cognitive functions to particular areas or groups of areas in the brain. The experimental methods for localising cognitive activity with PET were developed in a series of studies in the course of the eighties (See Figure 1, on page 3). These developments will be discussed in detail a subsequent chapter.

\(^2\) Depending on whether they emphasise technology or brain mapping, researchers will trace the history of radioactive substances and their detection, or that of using blood flow to measure metabolic activity. See Ter-Pogossian, 1992; Phelps, 1991; Kennedy, 1991 for first, Raichle and Posner, 1997 for emphasis on second. Another element in the history of PET which would deserve further investigation is the link to national nuclear research programs and government support of this research as a peaceful application. See Kevles, 1997, especially pages 208-11, and Paul Cho. "U.S. DOE Programme of Support for PET and Nuclear Medicine", 1992.

\(^3\) The first commercially built tomograph was produced by EG&E, Oak Ridge Tennessee in 1978. One reviewer places the beginnings of PET “shortly after the moment of creation, the Big Bang...From this boiling sea of nuclear reactions emerged positrons, electrons and the annihilation radiation signal used by today’s PET systems (Rich, 1997).

\(^4\) A number of factors distinguish clinical, presurgical mapping and “cognitive” types of study, such as a focus on the ‘normal’ as opposed to diseased brain, and the involvement of non-clinical psychologists. These types of mapping have a times been pursued entirely separately, though some institutional arrangements fostered cooperation, for example where a tradition of clinically-based research in brain mapping existed. Certain projects under the aegis of the HBP also aim to foster such cooperation, though up to now one or the other view tends to dominate (compare for example Ojemann et al and Mazziotta et al in Neuroinformatics). Some areas of brain mapping are endeavouring to make their tools clinically significant.
This is the psychologist’s rendering of brain mapping. The space of the brain is clearly present, the outline marks the space in which function occurs, but the most prominent aspect are the floating rainbows, which, though anchored in the brain, most dramatically depict function against function. In the same way that the nineteenth century physiologist Marey’s visual measurements removed depth, and all other elements not involved in motion and temporality, so this image, which became the emblem of mapping, shows the cognitive brain. The rainbow acquires an iconic role in showing activity, while structure is depicted as white outline (as above) or in the grey scale of x-ray tradition, with some variations to other (single-tone) scales, such as ‘hot metal’.

But PET is not the only tool involved. Since about 1992, the development of functional magnetic resonance imaging technology, (fMRI, the use of an MRI scanner to measure ‘function’) has also changed the above picture. fMRI scanners are more common than PET scanners, since they are more widely used for clinical imaging, and less expensive to run. The possibility of doing brain mapping studies has therefore been extended to many more centres, leading to a new kind of competition in the field. Some PET users have expressed fears of a band-wagon of imaging studies done by non-experts in functional imaging, while the ‘death of PET’ was also pronounced--fMRI does not require a cyclotron, and is considered less invasive than PET scanners which require the administration of radioactive substances to subjects. Other technologies have been brought under the label of brain mapping technologies since the mid-nineties; the latest Human Brain Mapping Conference Brain Mapping course dedicated time to fMRI, PET, trans-cranial magnetic stimulation, MEG and EEG, and ‘anatomy’ as key components of the brain mapping armamentarium. A common motif in the use of these many technologies is that they are variously coupled to provide representations of both activity and structure, as maps of function in the space of the brain. The results of multiple tools
are therefore combined to produce a complex object—the map of activity in the brain, from merging types of data.

Around this research, a recently formed community shows some of the earliest traditional signs of ‘professionalization’ or discipline formation. The International Conference on Functional Mapping of the Human Brain has been held since 1995, when the first conference was organised as a satellite meeting of the Society for Cerebral Blood Flow and Metabolism. The annual meetings attracted about 1000 researchers. Two journals have been set up and oriented to publishing brain mapping research: Human Brain Mapping (1993) and NeuroImage (1992). The publications of monographs and textbooks on brain mapping is also quite recent. Besides Images of Mind, published as a Scientific American Paperback (1994, 1997), and addressed to “a broad audience”, other textbooks on brain mapping appeared in the nineties.

Yet, a great amount of diversity remains in many aspects of this research, and up to the late nineties, the Association has been deliberately ‘conservative’ in its activities, concentrating on organising the yearly meeting and course. Disciplinarily, almost no one has been ‘trained’ in this ‘field’ (Fox, 1993), and large interdisciplinary teams are involved in running experiments—motley crews of physicists, statisticians, psychologists, neurologists, etc. Such diversity can also be observed in terms of scanners and software used. Even before other technologies were included in mapping, throughout the eighties PET scanners could be considered ‘little big science’, with no two scanners and cyclotrons being the same, and until the release of a ‘package’ for data analysis, the software used was also quite diverse. As well, PET is usually used in combination with other imaging technologies (CT or MRI), and combinations may differ per institution. Furthermore, because of the costs and complexity of purchasing and running the scanners (Frick et al., 1992), alliances with several research and clinical groups have been the rule, so that no two centres have had similar overall research agendas.

Brain mapping has been amply discussed, praised and contested by researchers in terms of its results and of its contributions to understanding the mind/brain dichotomy. In reaction to claims of being able to ‘see the mind’, brain imaging has sometimes been (pejoratively) presented as positivistic, an endeavour limited by researchers’ failure to address the meaningful content of what they are imaging:

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1 The 1999 meeting in Dusseldorf attracted 1093 abstracts, and the electronic mailing list of the organization contained 830 email addresses.
2 A few publications on brain metabolism and PET came out in the eighties, generally directed to clinical application. Textbooks oriented to brain mapping appeared in the nineties: Brain Mapping: the Methods, 1996; Neuroinformatics, 1997; Human Brain Function, 1997. These books were only just appearing as my own project was unfolding. The lack of these types of materials at the beginning of the project, as well as lack of ‘secondary’ sources, were strong motivations for going into the field. Having to deal with scientific articles directly sometimes felt like I was doing things the hard way, though the feeling of being on the cutting edge also kept me ploughing through the material. I am particularly grateful to Joe Dumit who shared some of his work on PET while I was considering pursuing this project.
3 Arguments have been made in the ‘town meetings’ of yearly conference for the need to have a strong organisation which would counter the molecular biology lobby (Boston 1996), and to stimulate and possibly enforce the use of standard ‘spaces’ and nomenclatures for reporting results to increase the ‘coherence’ of research (Dussendorff, 1999).
"One must think about what it means to the brain to be part of a human subject paid to lie in some machine while performing more or less stupid tasks (and most of the paradigms studied in the actual brain function/cognition projects with imaging are so simple that the brain will never be confronted with them in real life) (Schmitt, 1995)."

In this view, mind is the meaning of brain processes, and this remains outside reach of these imaging experiments. For others, the successes of imaging are at best marginal, exploring only what is at the edges of mind. A reviewer states that while the authors of the popular book on functional brain imaging, entitled *Images of Mind*,

"seem to have gone out of their way to make the results of PET scans seem humanly and psychologically meaningful, ... this effort can most generously be called a limited success. PET scans have indeed provided us with ‘images of mind’, but only of very few simple aspects that, by and large, really do not tell us very much about how the mind as a whole behaves (Goertzel, 1995)."

This reviewer further hesitates as to what these results address, and goes on to say that “at present, however, the scans...feel more like ‘images of brain’ than ‘images of mind’ (though the latter is also a perfectly accurate description) (Goertzel, 1995).” While the imaging technologies have not yet delivered, and though they leave the reviewer unsure as to the status of the object they show, (mind or brain or are these both the same), the promise of these experiments does not leave him indifferent, as becomes apparent from the rest of his review. Indeed few have remained unmoved by brain mapping, reacting to its claims, costs or vivid images.\(^8\)

In more enthusiastic evaluations, research using brain imaging technologies has been widely presented as an exploration of mind in scientific (because material) terms. ‘Consciousness research,’ often labelled the hardest question in cognitive science research, is said to be making a comeback; the contribution of imaging research makes it into an empirical discipline.\(^9\) Many discussions setting out research agendas have defined mind and brain, subsuming the former to the latter:

"Another term for this complex of cognitive processes that are in many ways uniquely human is ‘mind’, which is not to be taken as some mystical entity but rather as a description of the functional properties of our brains that render us human. Thus the study of human cognition and perception is in a very real sense*

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\(^8\) See Tom Wolf (1997) “Sorry but your soul just died”, and Fodor’s ‘diary’ in the *London Review of Books* (1999), for two particularly colourful commentaries. I thank Michael Lynch and Stuart Blume for bringing these to my attention.

\(^9\) The point has been made in reviews (Russo, 1999) keynote speeches (Tulving, 1997 Conference (fieldnotes) and interviews (Schulman, 1996), and a number of popular science books (Dennet, 1991; Rose, 1999). Gregory and Miller (1998) point to this wave of books about consciousness as an example of how science marks certain new domains of research as properly scientific.
the study of the functional properties of the human brain... One aspect of the study of human cognition and perception is the use of various non-invasive techniques, such as PET, MRI, ERP, and MEG to discover the neural correlates of human cognitive and perceptual activity (NSF. 1991)."

The scare quotes around the word mind, and the prescriptive formulation warning against mystical views, are indicative of tensions in brain mapping research (which will return in the course of this thesis), between a materialistic philosophy of experimentation and dualistic notions limiting what can be known about the mind. Indeed the healing of a Cartesian breach has been a recurring trope in discussions of functional imaging technologies: these scientific experiments move from brain to mind as though the philosopher’s division had never existed.10 Taking an even stronger view, some have announced the death of the mind:

"The time has come where brain function, from emotion to mentation, imagery, intention and so on is definable, in the relatively crude terms that we can define it now, in the substance, the material substance of the brain. So things like soul and mind and so on become useless, no longer of any use in scientific discourse (Senior Researcher, trained as a physician)."

During the same period, there have been appeals to scientists to accept that the brain has "dimensions", along which it can be studied, though some are "repelled by a reductionistic approach which has proved so successful in understanding other organs of our bodies (Koshland, 1992)."

The working brain, visible in a PET scan, is therefore presented by researchers, in turn, as touching the hard core, or as (literally) mindless reductionism--with less extreme versions of each view in between. The notions of mind and brain are important concepts for researchers in psychology and neuroscience, which determine what can legitimately be claimed, questioned and investigated in the course of research, as well as delineating who is qualified to pursue these investigations. The few arguments presented above provide a glimpse of a partial reconfiguration of the mind and brain dichotomy through brain mapping research. The consolidation of the biological basis of mind in relation to brain mapping is especially of interest here.

Bounding the brain and studying it according to its 'dimensions' requires a number of shifts and innovations in social and technological arrangements, which are all the more complex, as the brain becomes the place from which to study the mind. Brain mapping research is often discussed in terms of a 'window onto the brain', through which

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10 See chapter 3 for discussion. The dichotomy is addressed particularly intensely in an issue of Behavioural and Brain Sciences, dedicated to imaging research. Brain and Behaviour is a journal dedicated to the discussion of particular themes through peer comments from a wide range of prominent researchers in psychology and related fields, and the sheer number of peer comments which address brain mapping as a mind/brain issue is impressive. See among these “Tough Times for Dualists” and other articles in Posner and Raichle (1995).
the workings of the brain termed the mind can be observed. The assumed transparency of the technology participates in important ways in the discourse of collapsing mind into brain. Accessing the mind is presented as a matter of developing a technology to look at the brain, to penetrate the space inside the skull. But technologies do not render nature in any self-evident way. And when they seem to do so, it is the result of complex processes. These processes are all the more multi-dimensional when, as mentioned, a number of technologies and disciplines are involved, as is the case with brain mapping.

Rather than showing the development of brain mapping as the desirable or harmful evacuation of one term of a mind/brain dichotomy through technologically-mediated discoveries, I will show how these objects are recast. By asking ‘what is the brain’ and ‘what is the mind’ being investigated through these technologies, it becomes clear how traditional boundaries come to be blurred, and how these objects come to be superimposed onto a map. I will argue that in the course of developing a mapping practice, a different object, the mind-in-the-brain, is constituted.11 Recasting the question in these terms not only de-essentializes scientific categories, but it also points to the importance of processes of institutionalisation and technologies in the constitution of these objects. This thesis addresses the development of scientific knowledge and the very contents of a new stream of research, as shaped by intertwined processes of biologisation and digitalisation. It does so by considering brain mapping as a new arrangement for seeing, an emerging techno-scientific project in which representational practices play a key role.

It is difficult to speak of functional imaging research as a speciality or discipline, or to trace its development according to a single technology or research area. The object it examines is also contested. A thread linking various developments can be found, however, by considering these developments as the constitution of brain mapping as a representing practice. The importance of building and sharing representations can be seen at many levels of functional imaging work and its importance stressed by participants. For example, the growth of this stream of research was recently evaluated using citation-analysis, which takes a shared representational convention as an indicator of work done in the field. (See Figure 2). From the point of view of the editor of Human Brain Mapping, having a reference to Talairach atlases means working on the topic of brain mapping.12

11 I offer this neologism as a way of underlining the translations and transformations performed (especially by cognitive neuroscientists) in order to form their object of study. It also highlights how these scientists present the specificity of their claims in addressing the neural correlates of cognition. The term arises in a context where many scientists are rejecting the word ‘mind’, while still invoking the wonder of what makes us human. Hence my own need to have these terms of mind, brain, and mind-in-the-brain, in order to analyse how the subsuming of mind to brain is still actively discussed, and made into a special claim in relation to a pre-existing tradition where the terms and concepts are separate.

12 This marker was also used in documents of the International Consortium for Brain Mapping (ICBM), in an editorial for Human Brain Mapping (Fox, 1997) and in communications with and publications of the Human Brain Project.
Figure 2 Talairach as shared convention in the field.

Reproduced from ICBM (1997).

In terms of the work performed in the lab (‘what functional imagers work with’) Annex 1 contains my account of discovering the importance of representations through fieldwork. There is very little ‘wet’ work in brain imaging: human subjects appear briefly, for a few hours at specific times, and the manipulation, analysis and interpretation of representations form the overwhelming majority of the work performed in the lab.

Another sign of the importance of representations can be found in discussions and reviews of journals in which functional imaging research is to be disseminated. The editor of *Neurolmage* promises attention to representations:

“The care we give to reviewing, typesetting, and producing the manuscripts will be surpassed only by our commitment to visual integrity of the illustrations (Toga, 1992).”

In the same vein, reviewers of journals evaluate the ability of journals to carry the representations produced in this research—whether colour images can be reproduced, whether authors are charged for these and what the quality of representations are (Cohen, 1997, reviewing *Neurolmage*). For reviewers, the claims of brain mappers are best supported when journals can render colour maps, the representations in which these claims are embedded:

“The large format and high-quality reproduction allow the dramatic colour images—a hallmark of the field—to be shown to magnificent effect (Haxby, 1995, reviewing *Human Brain Mapping*).”

The corollary of this alignment between a material support that accommodates the elaborate representations and brain mapping research also holds. When the production
values praised above are not included in a journal’s profile, then this is taken to exclude brain mapping investigations. A reviewer of a new journal on “laterality” assumes that the journal will favour the “phenomenology of laterality” and “speculations about its neurobiological underpinnings”, rather than clinical work and imaging studies:

“This inclination is reflected in the small format of the journal (which precludes the large glossy figures that are now routine for imaging studies) (Purves and White, 1995)”

Representations are therefore acknowledged as important for the field itself, in terms of making and sharing its object(s) of research. The importance of developing representations and conventions for making and interpreting them will be shown in detail in subsequent chapters. Undoubtedly, representations permeate all scientific work (Latour, 1990; Lynch, 1990); a focus on representations and inscriptions in science studies purports to make visible the dynamics of Western scientific work and its successes. The argument I am making here takes representations as a starting point in a slightly different way; it takes representations to be important for understanding brain mapping work in particular. In a community-in-formation, where the material and institutional conditions vary, where various disciplines interact, and where the scope of the common project of ‘mapping the mind’ is far from settled, researchers recognise each other’s work in terms of the representations produced, and they evaluate their own successes in terms of their ability to produce maps and to have their results circulate in terms of representations in journal and databases.

Representation will be examined as a communal activity, not primarily as a cognitive one. Looking at representations is a way to get insight into the conventions of a group: into its “instruments, graphic inscriptions and inscriptional processes” (Lynch, 1990). Representations form the empirical materials obtained through imaging technologies (scans), the experimental strategies and knowledge claims (maps), define the epistemics of functional imagers (their view of what they do) and are part of strategies for establishing brain mapping as important in neuroscience and its clinical applications (atlases).

The few markers of development of this community discussed above point to the large investments in representational techniques that provide brain mappers with their object. But, to recast Hacking’s (1983) terms, researchers do not want to be seen to be only ‘representing’, in the sense of passively observing, but as also ‘intervening’, experimenting with the brain and mind. Their object of study, being so powerfully visually representational, is the source of anxiety. A search for ways to overcome this, by highlighting the search for principles of brain organisation rather than maps as

13 Not only representation but also vision can be considered in professional terms. The socially negotiated nature of perception has been analysed in settings where proper visual perception is taught (a biology or haematology lab or an archaeological field) or where participants must co-operate in order to see anything at all (for example marine explorations where boat, camera and marine life have to be aligned). See Lynch (1985) Atkinson (1995), Goodwin (1994) and Goodwin (1995) respectively for each of these studies.
representations, is a growing concern in recent brain mapping research (Friston, 1998). Furthermore, the central role of representations in this work underlies an important tension in brain mapping research, which will be addressed in detail in a later chapter.

Representations in Brain Mapping: Physical Minds and Virtual Brains

Brain mapping, as a new high tech arrangement for seeing inside the body, is involved in two entwined processes, namely biologisation and digitalisation. Brain mapping inscribes notions of mind onto the body, but does so through the mobilisation of a set of technologies and manipulations involving complex digital spaces. Each process will be discussed here separately, in terms of the intellectual traditions which have construed them as categories for analysis, but will be discussed as interacting in subsequent chapters.

Self, Embodiment and Biologisation

Many scholars have analysed the ways in which the body is explored and marked, and made into the locus of power in modern and post-modern culture. Complex interactions between the creation of new objects of scientific study, new institutional arrangements and new modes of ‘governmentality’ often revolve around the constitution of representations. Brain mapping, as a new stream of research, seems to be constitutive of new representations, recasting the terms in which not only the social and the somatic, but also the mental and the physical are understood. Phrases used to describe brain mapping research, like “mapping thoughts”, “the mind in action”, or “the biology of madness” point to brain-based conceptions of mind and its diseases—arguably, formulations which contrast with the more psycho-dynamic views which were dominant two or three decades ago. The emphasis on finding new physical traces of the mind inscribes brain mapping in a process of biologisation. Notions of self and of mental illness have long been tied to the concept of the mind. When mind is linked to the brain, this object of study is accompanied by shifts in notions of self and mental illness. As the mind comes to be known through the body in novel ways, then a different configuration of the self arises, with a different relation to systems of knowledge and power.

Analyses which address the recasting of social relations in terms of the body have been inspired by Foucault’s work on the relation between knowledge and institutions for (clinical) medicine, the penal and military systems or the management of insanity (Foucault, 1975; 1976a; 1976b). A common theme in this body of work (again, following a Foucauldian theme) has been to analyse the move to embodiment. This can mean inscribing onto the body the regimens of health, hygiene, military discipline, morality, as well as dysfunctional opposites: disease, insanity and inefficiency. Measurements of heights, strengths, weights, temperatures, speeds, and shapes of large numbers of conscripts, workers or patients have led to particular understandings of normality and abnormality. Thus, the argument goes, difference came to be a mark of the body at the end of the 19th century, “the somatic territorializing of deviance” as Urla and Terry (1995)
have coined it. Such critiques sometimes posit embodiment as essentially problematic (more on that below). But for the purpose of this thesis, the strength of this approach is in highlighting the link between the body and the social, between the individual and populations, through the constitution of representations:

“...what we know to be bodies are always representations; what matters is that scientific and popular modes of representing bodies are never innocent but always tie bodies to larger systems of knowledge production and indeed, to material and social inequality (Terry and Urla, 1995).”

The way in which representations circulate and tie the body to these systems of knowledge will be discussed in the next section. The argument has also been made that these large systems of knowledge are actually getting larger, increasing the extent to which the biological as the domain of life is used to define relations in social systems (van Dijck, 1995; Rabinow, 1992). The Human Genome Project and molecular biology have been analysed as the source of geneticization as a particular kind of biologisation, the trend towards the attribution of a genetic definition of conditions (Lippman, 1992). This trend transforms not only social relations in terms of biological definitions but also generates modes of social interaction based on biology, what Rabinow has termed bi-sociality. In this context, there is a partial

“move away from face-to-face surveillance of individuals and groups known to be dangerous or ill,... toward projecting risk factors that deconstruct and reconstruct the individual or group subject. This new mode anticipates possible loci of dangerous irruptions through the identification of sites statistically locatable in relation to norms and means (Rabinow, 1992).”

The use of formal and bureaucratic tools (surveys, files, tests) are an important component of this process, which is “non-subjective in a double sense: it is objectively arrived at, and does not apply to, a subject in anything like the older sense of the word (that is, the suffering, meaningfully situated integrator of social, historical and bodily experiences (Rabinow, 1992). “ This has been termed the “technocratic administration of difference” (Castel, 1981), which focuses on sets of factors which it represents and finds in/significant. Castel, perhaps more than Rabinow, aim to explore but also to critique these changes in scientific and medical arrangements.  

14 Within this category of biologisation, Catel’s notion of the “technocratic administration of difference” further qualifies the process, though this label too can be further defined in terms of, for example, a digital, database-reliant mode of administration. Amsterdamska has demonstrated that this process varies between settings in terms of cognitive models and experimental strategies (Amsterdamska, 1998). The argument is further spelled out here:

“It has often been said that the modern biomedical sciences are reductionistic and that the chemical understanding of physiology and pathology has become dominant in 20th century bio-medicine. It is questionable, however, whether we can speak of a single reductionism rather than a variety of potentially incompatible reductionist analytical frameworks. It is one thing, for example, to reduce disease to a failure in the functioning in the immunological system, quite another to see it in terms
While having blossomed into a large area of academic inquiry, the theoretical and analytical moves which point to changes in notions of ‘the embodied subject’ seem to lead to a conundrum. Not that odd juxtapositions do not have their place in end-of-millennium theorising; purity is no longer a criterion. But, coherence, if not purity, might be a reasonable goal; paradoxes may still be preferable to contradictions. The question can then be posed as follows: How does one perform a critique of such a move to post-disciplinary or post-modern notions of the body, if bodies in modern society are said to be properly understood as representations? Constructivism, because it rejects the possibility of an un-represented body, has often been accused of being incapable of such evaluative assessments. How is it possible to make the constructivist point that bodies are made and unmade as representations, while also maintaining a sense of what is gained and what is lost in the various configurations of modes of representation? In other words, how can a notion of the body or of the self (on which such a critique would rely) be maintained, without appealing to unmediated versions of these, which would imply finding the body outside representation and technology… Van der Ploeg (1998) suggests a metaphor to understand the relation between these registers. Modernists notions of self and post-modernists moves towards multiplicity, diffuseness and a breakdown of boundaries (human/animal, biological/material, etc) can be seen as two sides of a coin. The notions of normal bodies can be then critiqued as having served to maintain Subjective Western Man, and never having existed in nature to start with. The way deviance from this model is established can also be shown to marginalize and disenfranchise ‘others’ from full participation in the state as citizens, in the market as labourers or owners, or as possessing a fully-fledged autonomous self in the case of living wills and pregnant women (Davis, 1994).

At the same time, it is also possible to view post-modernity as a co-existing, alternative discourse, in which there may be powerful positions. These are appearing ‘kitty corner’ from regular bodies which we sometimes only too happily inhabit, as the institutions that sustained and were sustained by Man are pulled, bent and otherwise exploded out of their original shape by the new configurations of world economies, cyberculture, coalition politics and enhanced bodies that go from substandard (‘handicapped’) to better than most (Haraway, 1991). In such a world, flexible bodily boundaries, inchoate personhood and multiple alignments may be better ways to gain access and exercise power than the proper correspondence to the norm. But, from a pragmatically political perspective, Van der Ploeg (1998) makes the powerful point that if only those traditionally excluded from notions of personhood take up the labels of post-modernism, this may not challenge the categories used by those currently in power and simply dissolve any political action that was arising at the margins.

of a vitamin deficiency and a different one yet to understand it in terms of genetic defects
(Amsterdamska and Hiddinga, 2000)."
The analysis developed in this these focuses on the interactions of biologisation and digitalisation, as a particular configuration of bio-techno-power.
15 Mol, Annemarie. Personal communication, WTM C Winterschool 1998
Again, the question posed here is then how to avoid the conundrum of oppositional discourse which appeals to a romantic notion of the natural body in order to critique an institutionalised one. Van der Ploeg provides a philosophical answer: Post-modernism can serve as a powerful stance to highlight what and who is excluded. And while the contingency of representations of the body itself cannot be critiqued, categories of modernism are not powerless because contingent, she reminds us. We are, most of the time, (still) predominantly interpellated by institutions on the basis of modern bodies. From an anthropological point of view, Rayna Rapp (1997) proposes two empirical strategies to solve a similar conundrum in her study of ultrasound: to explore the meanings attached to new technologies by a variety of subjects, and to try to open up the context in which debates are pursued, shifting these debates from medical/scientific framework to a wider cultural/social framework.

The first strategy has been applied to brain mapping in a few studies. Dumit has explored what it means for the category of person to be partly constituted through novel digital imaging of the brain. This analysis reminds us that the stakes are indeed high, when the basis of the self is addressed. Dumit offers this declaration of a biological psychiatrist, whose review of PET research begins with the following words:

“In the 1970s, the anti-psychiatry movement almost had us… but now we have proof (quoted in Dumit, 1997).”

With the “proof” provided by PET, biological psychiatry puts anti-psychiatry on trial, and it puts scans of brain function in the witness box. Dumit goes on to note that even in cases when non-biological therapies are valued, they are meaningful in terms of the brain, in the same way pharmaceutical treatments are understood:

“the brain remains the bearer of mental illness, but has now become an intersection for social and biological influences (Dumit, 1997).”

The brain is indeed an intersection for therapeutic interventions, and an obligatory point of passage, through which the physiological effects of drugs as well as social and cultural phenomena are to be translated. Also in a psychiatric context, Dumit notes that patients and their families may find that brain scans enable them to destigmatize their condition, and to posit a potentially healthy self, afflicted with a sick brain. Other work on the contextual meaning of these images of brain function show a great deal of hope invested in PET scanning, likely means of ‘testing’, and offering the possibility of distinguishing normality from abnormality. The desire for an objective answer to health and disease is focused on the body, and on the ability of technology to provide particularly objective answers (Dumit, 1993; Beaulieu, 2000). Other meanings of brain scanning, particularly those of cognitive psychologists, neurologists and neuroscientists will be encountered in the course of this thesis (especially in chapter 4).

16 This also happens literally. See Dumit (1997), and Kulynych (1996).
But mainly, this thesis will further follow the second strategy suggested by Rapp in order to discuss techno-science and embodiment. Rapp, as mentioned above, proposes the recasting of debates about technology from a medical/scientific context to include a more cultural/social one. Some of her efforts at doing so address debates about the use of ultra-sound technology, but present this technology as black-boxed, the object of a factual description, so that technology is not explicitly brought into the debate she wishes to broaden. My own attempt to recast debates about brain mapping will closely follow how various uses of technologies and the knowledge they bring are developed. This contrast in approaches is perhaps most typical of the kinds of moves specific to science studies, which open up the boxes of knowledge and technologies left closed by other disciplines such as gender studies or medical anthropology.

I also wish to note here that such concerns are not totally foreign to the preoccupations of brain mappers, though they tend to remain very marginal, in terms of time, and effort invested in dealing with them, besides simply flagging them. For example, in a special issue on biomedical imaging, the following issues were noted: the growth of imaging in biomedicine increases the role of computers, opens up new fields of study and creates new responsibilities for researchers. Deploiring that images seem dangerously transparent and require vigilance;

“Counterign these dangers means an increased awareness that images are constructs that include just as much ‘noise’ and require just as much care as any other technique (Crease, 1993).”

But besides occasionally noting that imaging is especially likely to lead to epistemically irresponsible behaviour, development of these techniques is labelled progress, and little is made of these pious remarks. These themes are brought centre stage in this thesis.

**Digitalisation**

Having sketched the approach to discussing the representation of bodies, another aspect of brain mapping can be addressed. The particular biologisation of the mind involved in brain mapping is entwined with the development of a relatively new context for making representations: the use of digital tools. If new representations are powerful in reconfiguring key dichotomies and interventions in mind and brain, this power is constituted in large part by the possibility of making and circulating these representations. The development of brain mapping intersects with the growth of digital media. The dynamics of the constitution and use of new media constitutes the kind of topic traditionally significant for science studies, not only because it becomes a new support for scientific knowledge, but also because of new possibilities it offers in research. The ‘digital’ furthermore reorganises physical spaces in which scientific work
takes place (See Annex 1 for some of the material consequences for lab work of a focus on the digital). The consequences of the ensemble of practices, technologies and institutions which can be loosely labelled ‘digital’ will be discussed theoretically here, with emphasis on the consequences for representations. Two main aspects are of interest: new objects built in digital contexts, and new modes of circulation of digital representations, often mutually constitutive aspects.

Digitalism offers a particular configuration of epistemology, representation, and laboratory work, which become visible when contrasted to an optical form of these, as demonstrated in Michael Lynch’s work on topical spaces (1991). A topical space is both a symbolic and physically constituted space which is articulated in relation to technological organisation. Such an analysis ties an epistemological framework to a particular topical space. In other words, by being able to analyse a particular site of knowledge production, in its symbolic and physical features (which are affected by the technological organisation of the site), the very knowledge that emerges can be characterised.

Lynch’s starting point is the context of knowledge: where is the lab? He notes how the scientists peering into instruments inhabit a world that does not make sense to him as observer, yet does not seem to them to be a world separate from the everyday world. How then is the space created where things are perceived that are not readily available to all, yet seem to be in continuity with the ordinary world? Lynch suggests a limited Foucauldian notion of the organisation of the locale of the lab, where language is not determinant but rather plays a participatory role. He states:

"it would be incorrect to say that any particular application of language creates a space of operations: rather, any such application participates in a contexture of activities in which a space is organised (Lynch, 1991). "

In order to elaborate on Merleau-Ponty, who does not consider historical of technological variations in this encounter between body and world, Lynch draws on Foucault’s articulation of how “embodied spatiality” is affected by technological and textual mediation of perception. Specifically, two orders of spaces are discussed by Lynch, opticism and digitalism. These are worth considering in some detail here, since they demonstrate how new technological possibilities and new representations might be linked to discuss the context of knowledge about the brain.

Opticism is a set of constructs used to describe perception (an image of the world is projected on the back of the eye) and which provides much of the vocabulary used in epistemology. The following features of opticism form the “’epistemic’ conditions of embodied action in particular technological complexes (Lynch, 1991):”

1. Ocular vision provides the paradigm of perception and observation.

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17 A question that also arose in my fieldwork, on a more pragmatic level (See Annex, page 191), when I tried to find the place of work. The spaces I consider are not only individual labs but also how such outposts of spaces are constructed to enable cascading to extent. See especially chapter 5.
2. Visual field and viewer's images are clearly distinguished along Cartesian lines. (there is an object out there and an internal image inside the observer).
3. The viewer's "eye" becomes a singular point or aperture toward which a field is oriented.
4. The field is framed by a window, often represented as the outer edge of the cone of the rays.
5. The relationship between eye and object is transacted through a converging arrangement of linear rays. This arrangement limits forms and axioms of Euclidean geometry with the mechanisms of vision.
6. A transparent lens and/or reflective mirror mediates the linear transfers of rays into...the eye's image.
7. A point by point correspondence obtains between image and object....
8. The model for vision supplies a vocabulary and sets of topics for a more general epistemology.

Figure 3 Mixed Opticism and Digitalism

This drawing wonderfully illustrates Lynch's definition of opticism (especially points 2-7). It is a reworking of a drawing of Descartes' theory of the formation of images on the retina (published 1622). A brain's outline has been added inside the head and a small image of the brain slice being 'seen' is drawn on back of the head. The drawing further illustrates a clumsy encounter of opticism and digitalism: the object of vision is presumably a digital fMRI scan on which visual activation is represented, a scan of the visual cortex' localisation appearing on the visual cortex. This visual pun further invokes the healing of Descartes' split discussed in the introduction: here the mind shown as the brain knows the mind, by seeing it represented on the brain.


Thus, opticism coordinates spaces and practices: optical instruments, representational technologies, a theory of optics (Lynch, 1991). All these are part of a way of organising, conceiving and articulating the relations between the subject and the object, which seem to be challenged by digitalism. Lynch is not interested so much in the epistemological essence of knowing, as in the scripts that may be embedded in opticism: "what it expresses is a set of instructions for performing actions in accord with the various optical knowledge-production machines; a disciplinary compliance on the part of the subjects in those systems (Lynch, 1991)."
Systems within opticism, it can be repeated, deal with the lensed instrument as paradigm. In contrast, digitalism focuses on the play of fingers on a keyboard instrument, in contrast, though not in contradiction to opticism; the two modes co-exist as shown in Figure 3. A digitalist version of perception describes it as the deciphering of a psychophysical code. Lynch draws up a list of features associated with digitalism:

1. Pixelated space: digital space is mathematized in terms of atomic details
2. Arbitrary code: the code does not resemble anything
3. Manipulable details: the elements of the keyboard have no inherent tie to an object; they are places for the fingers to strike in the course of an expressive action.
4. Diachronic organization: an order emerges from the play of signs in a series rather than from a point by point correspondence between an image and object.
5. An equivalence of ‘qualities’ and ‘quantities’: no distinction between form and content.

Thus, digitalism is an explicitly simulated or constructed space. Phenomena in a digital context are not in a particular representation: research scans do not have the status of snapshots in this digitised world, but are constantly recreated in the processing of electronic data. While ‘construction’ of representations may be more evident, this does not mean that any and all constructions are possible. Therefore, brain mapping evolves in a digital context, sometimes in opposition, sometimes in interaction with the optical mode, and the possibility of particular types of construction it enables. Digitalisation of the brain might have consequences not only in so far as it constitutes a way of knowing, but also as it is intertwined with a new view of the brain, a new research paradigm around it, and a new set of tools for applying this new knowledge.

In terms of digital representations specifically, much remains to be investigated about this relatively new mode. The comparison of opticism and digitalism seems fruitful, and points to the possibility of using the categories of representations from an optical topical space to contrast those of digital representations. A major effort in highlighting

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19 As Lynch also shows, this construction in digital imaging may be hidden in favour of appearing to offer an optician approach. In some instances, digital images are used to evoke photographic realism, an optical presentation of digital images. The astronomers also use the conventions of photographic realism to give a ‘qualitative’ appreciation to funding bodies or lay people (Lynch, 1991). They allow their images to stand as pictures, but do not spell out how the epistemological assumptions of digital representations might contrast with the optical understanding of the lay public.

“in contrast to the pointillist or impressionist artists, who topicalized the compositional elements of painting, thereby exploding the established conventions of pictorial realism, astronomers tend not to bring out fully digitality’s distinctive contexture. As a consequence they act as a community of the wise (Goffman, 1963), sharing a secret understanding of non-apparent qualities while putting on a front for the sake of prevailing standards of taste and decorum (Lynch, 1991).”

Much more can be said about the choices made by astronomers and how these serve to establish professional identities and reinforce boundaries between science and the public (see Chapter 4). 19 This strategy has been used in other analyses, by Cartwright (1997) to compare paper and digital anatomy, for example. While this approach is less likely to fall into the ‘hype’ of new media, its
the importance of representations in scientific practice has been the Latourian notion of inscriptions (Latour, 1985). It aims to provide a correlate to the efficacy of Western science and technology since the modern period. The powers of the “centres of calculations” that make up the nodes of networks significant for the shaping of Modern society (science, civil institutions, and medical systems to name but a few) can be explained by the manner in which they mobilise inscriptions. As Latour ties these effects to the possibilities offered by the technology of the printing press, it is therefore interesting to investigate empirically the relation of new technologies, such as computers and electronic networks, to these effects. New technologies may reshape these, making some more significant, or less relevant.

Inscriptions are particular in that they make ‘mobilisation’ possible. The features that make inscriptions mobilisable are worth considering, since they provide a way of linking practices, institutions and cognitive claims. Inscriptions, Latour argues, are not in and of themselves explanatory, but become so when considered as mobilisable allies, in the sense that they can convince someone to take up a statement, to make it more of a fact or to change one’s behaviours. In the Latourian understanding of inscriptions, two main concepts stand out. First, the inscriptions are the result of scientific activity as well as the basis for further work. Modern medicine then, is the shift from “small scale practice to large scale manipulation”, so that:

the same medical mind will generate totally different knowledge if applied to the bellies, fevers, throats and skins of a few successive patients, or if applied to well kept records of hundreds of written bellies, fevers, throats and skins, all coded in the same way and all synoptically present (Latour, 1990).

This is the level of analysis where the efficacy argument is most potent, linking practices and achievements. It highlights how, for example, individual brain scans produced in a session can become increasingly significant (in all senses of the term) as they are “cascaded” with others, and once so assembled, can come to stand for a population. This set of cascaded representations accrues authority, so that it can in turn serve as a diagnostic tool, so that further individual scans will be made for comparison with this new standard. Alzheimer’s patients, or normal males or dyslexics could all be populations whose brains are averaged.

conservative bias may also make for a less sensitive approach to radically new possibilities arising in new contexts.

I take the term inscription to be very close to my own use of ‘representation’, though with a greater emphasis on the ‘writing’ process, and a focus in Latour’s discussions on inscriptions as the result of machines (Latour and Woolgar, 1986).

Latour cites Eisenstein (1979) at length.

Historians and some sociologists will be right (and quick!) to point out that “it is rarely the same medical mind”, highlighting the importance of historical contexts which also determine how a given mind will operate in making this argument.
A second main aspect of this theory of inscriptions is the semiotic nature of the circulation of inscriptions as "immutable mobiles." The term is paradoxical enough to point to the difficulties in its use: how can something be the same here and elsewhere, no matter where? This question need not be posed in extreme constructivist mode to leave the analyst perplexed. In that sense, a concept like Star's boundary objects, highly defined in local, individual use, and looser and more flexible in communal use, emphasises the need for more sensitivity to the contexts of inscriptions, while maintaining a focus on circulation (Star and Griesemer, 1989). Establishing communality or stability of meaning is work, an outcome, and not a given of modern inscriptions. This thesis is precisely an attempt at showing how the digitality of representations is given meaning as mapping practices develop, and how contexts are developed so that these representations do become mobile.

But even if inscriptions do not start out as immutable mobiles but rather sometimes end up that way, the features Latour identifies are useful as categories for an empirical analysis of a new, digital, kind of inscriptions. For example, the possibility of combining inscriptions is attributed to optical consistency. Yet, in the case of digitised imaging, it is not so much the straightforwardly geometric relationship of Renaissance perspectival drawing that determines the combinability of scans. With digital imaging, the

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23 See Chapter 5 for an empirical demonstration of this. Heath for example, seems to tend in the direction I am indicating, as her analysis moves from the immutable mobile explanation to discussion of how she follows slides from the lab to the conferences and describes their functioning as "mutably mobile" as their meaning changes (Heath, 1998).
visual becomes quantitative, and traditional notions of perspective based on the observer are exploded (Kember, 1998). While inscriptions encompasses image, number and text, it may be necessary to distinguish these aspects of representations to understand the development of brain mapping, since the circulation of particular types of knowledge claims may be shaped by the form of this knowledge in relation to the ‘speciality’ dimension in medical research (Hiddinga, 1995), or more generally, to the epistemic style of a given scientific culture (Knorr-Cetina, 1999).

Such distinctions in modes of representation of knowledge have been shown to arise during the birth of Modern science (Stafford, 1991). Stafford has traced how a hierarchy of modes of representations developed and affected the way visual evidence, in particular, was considered. Because of a distrust of sensory perception, specifically associated with the visual, images were denigrated and largely abandoned in favour of quantitative and textual modes of representation. In one of her recent works, where she addresses more contemporary phenomena, the neurosciences are pointed out as a field where visual information is ‘inundating’. She has hailed a new era in this stream of research where visualism is gaining acceptance. Not content to observe this phenomenon, she has issued a call on those with an understanding of images, art historians, to grasp a (renewed) mandate to explain images, since “understanding their significance is enhanced by knowing that they still reverberate with allusions developed in the early modern.” She sees the cross-sections of PET scans as neo-Albertian windows on mental operations, and worries about the potential for insurers, employers and other institutions to exclude individuals on the basis of such representations (Stafford, 1996). While there is indeed a neo-Albertian element to the understanding of brain scans, I will show that it does not constitute the dominant understanding of brain scans. The point does remains that inscriptions must sometimes further be specified because of their associations with literary, quantitative or visual registers, and the relative valuation of these in Modern Western science.

Indeed, the ‘visual’ is also not a single entity to be translated monolithically into new media. A culturally specified set of practices warrants visual apprehension by the (medical) researcher. Lisa Cartwright draws a contrast between two ‘gazes’, two arrangements for seeing:

The qualitative and empirical gaze of eighteenth- and nineteenth century anatomo-clinical perception that Foucault describes overlapped with and was ultimately challenged by the relentlessly analytical and quantitative gaze demonstrated in the cases considered in this volume, a mode of perception carefully incubated within the laboratories of physiologists and medical scientists and finding its expression in an unlikely range of institutions and practices, including the hospital, the popular cinema film, the scientific experiments and the modernist art work (Cartwright, 1995).

The medical gaze has indeed especially been the subject of analysis, in relation to Foucauldian notions of medical surveillance and bio-power. But whether for medical or
scientific purposes, "the expert's gaze [must] be 'clarified in order that the disease should give up its hidden secrets into the domain of the visual (Marshall 1990)' (Terry and UrJa, 1995)."

To return to the discussion of Latour's features, geometric perspective and optical consistency are also identified as key features of inscriptions. While indeed a dominant mode of representation, geometric perspective too is best problematized, in terms of the subject/object relations that this mode of representation implies. Albeit very significant, optical consistency is actually only one of many forms used to subvert realist claims in representations, as historians of science Lorraine Daston and Peter Galison (1992) have shown. While Latour replaces objectivity with 'optical consistency', I would argue that it is rather one form of visual objectivity. Objectivity is generally defined in contrast to subjectivity, and moreover, as the result of the removal of subjective influences (Daston, 1992). Using a range of atlases as a chronicle of changes in the concepts of objectivity, Daston and Galison show how the ideal of truth to nature can vary and be achieved by contrasting representational strategies. The representations featured in the atlases can be ideal, corresponding to the notion of what nature should be. The ideal representation is the product of aesthetic judgements so that the illustration can be free of accidents or idiosyncrasies. In turn, a characteristic member of a category might be chosen, and represented in minute detail. A third mode of objectivity arises in connection to the mechanical truth. Human subjectivity, unable to refrain from interpretation is to be bypassed, and the 'constitutive and symbolic functions of the machine blur, for the machine seems at once means to and symbol of, mechanical objectivity (Daston and Galison, 1992)."

![Figure 5 A probabilistic brain atlas](https://www.loni.ucla.edu/~thompson/disease_atlases.html)

The data from subjects is superimposed, and will enable the evaluation of the probability of a point being located in a particular region (33%, 66%, 0%). Such an atlas might be population based (i.e. schizophrenic brains, etc).

Reproduced from [http://www.loni.ucla.edu/~thompson/disease_atlases.html](http://www.loni.ucla.edu/~thompson/disease_atlases.html), courtesy of Paul Thompson, UCLA Dept of Neurology
Daston and Galison also reflect on what has been the role of the atlas itself: "the purpose of the atlas was and is to standardise the observing subjects and observed objects of the discipline by eliminating idiosyncrasies—not only those of individual observers but also those of individual phenomena (Daston and Galison, 1992)." The probabilistic atlas of the brain (see Figure 5) further broadens the role of the paper atlas, since in its electronic form, it is an automated tool developed to quantify the idiosyncrasies found in particular brains. To borrow a phrase, the subjectivity of the brain is 'cancelled out by dividing by the subject' in the constitution of a digital atlas. The constitution of brain atlases, for example, relies on a particular version of what makes an inscription objective.

Similarly, digital imaging and the tensions between the more common medical 2D scans and the new 3D world created for viewing the brain cannot be apprehended under the feature of flatness of Latour’s inscriptions—though flatness hints at an important aspect of representations (see Figure 6). Debates about how best to represent the cortex as a 'volume', as an unfolded, flat, map versus an idealised, inflated sphere (not shown) are not interchangeable, but rather represent different disciplinary traditions and tools within the neurosciences.

Neither can the scale of images be changed at will without changes in their internal proportions—another property attributed to immutable mobiles. When brains are aligned into similar spaces for comparison, the transformations must sacrifice in some measure the 'true' relations to different parts of the brain, thereby confounding the proportions (See Figure 7). In the brain imaging community, this is the source of a debate that has sometimes taken surprising turns: a template of a Japanese brain is currently in

Figure 6 The volumetric “canonical brain”, and the flattened cortex of the 2D brain.

Reproduced from the van Essen Lab homepage.
use, and Japanese researchers argue that it better maintains the proportions of the Japanese brain than the Western templates (Kanno et al, 1992). When approached empirically, Latour’s features of immutable mobiles therefore highlight significant points of debate in the developing representational practice that is brain mapping.

**Figure 7 Various aspects of one method for transforming brains to a standard space.**

The ICBM atlas transformations, which transform the brain to conform to a standard space.

Reproduced by permission from *Neuroinformatics*.

Therefore, the digitalisation of representations of the brain will be analysed, using Lynch’s ‘digitalism’ as a framework for understanding how a different order of work (ranging from the epistemological to representational) might arise in digital contexts, and Latour’s features of inscriptions as fruitful categories of empirical analysis.

**Dimensions of Representations**

“A new visual culture redefines both what it is to see and what there is to see (Latour, 1990).”

Representations in brain mapping will therefore be used to trace how experimental practices showing brain and mind develop and how the uses of technologies change in relation to these new representations. Representational practices evolve as the result of processes; interdisciplinary collaborations, the growth of digital technologies, and the visual aspects of these investigations will be shown to have particular impact on the new objects and practices that arise from this new stream of research. I will also highlight the particular contexts in which these representations have become ubiquitous and the constitution of frameworks in which mind and brain can be translated into powerful representations. Ultimately, my goal is to contribute to an understanding of ongoing shifts in systems (of healthcare, justice and education) that have relied on a different parcellation of what is meant by labels such as mind and brain, although addressing these in detail is beyond the scope of the present project.

Each chapter focuses on a particular kind of representation and on the issues of scientific knowledge and practice it raises. These can be take to correspond to ‘scans’ and the need to develop ways for nature to speak through technology; ‘maps’ and the question
of method for mind-brain correlations; the ‘visual as empirical basis’ and discipline formation; ‘atlases’ and normative interventions. If there is a direction of representations in this thesis, it is a social and technical one, like the movement of an assembly line (Lynch and Woolgar, 1990). Indeed, encounters with ‘originals’—the ‘optical’, the ‘patient’ in the flesh, the ‘real work’ of scientists—also spring up in chapter 5. Each chapter is therefore not to be read as a move further ‘away’ from an original, but to more complex manipulations and translations.

The next two chapters will address shifts in the understanding of brain and mind through the development of scanning and mapping conventions. These chapters specifically take up the interactions between digitalisation and biologisation, looking at how scans become meaningful traces, and come to stand as maps of the mind-in-the-brain. Chapter 2 contains a discussion of the many strategies used by different researchers, in the course of the eighties, to establish what can be learned from scans, focusing on the biological and digital contexts of reference used to ground the data provided by PET. Chapter 3 shows how mapping becomes both an experimental strategy and an organising metaphor for discovering the mind in a new space. The next chapter focuses on the development of a hybrid epistemic culture particular to brain mappers; the result of the integration of quantitative and visuo-spatial approaches to the brain and mind, constituting a quantitative visual culture. Chapter 5 considers how representations developed in brain mapping are cascaded in particular ways, constituting a new kind of mutable mobile. This enables brain mapping to occupy an increasingly significant place in neuroscience and a new normativity to develop around scanning and mapping. The concluding chapter contains reflections on the new features of knowledge developing around brain mapping, and how these might compare to other projects where biologisation and digitalisation figure prominently. Finally, the thesis ends with reflections on how to pursue further analyses of digitalisation as a growing representational mode in science.
An introduction for cognitive and neuro-scientists

Those who will have read Knorr-Cetina’s latest work will be familiar with her notion of epistemic cultures. I was delighted to find an echo of this concept while reading Daniel Dennett’s Consciousness Explained, where he puts forth the notion of epistemic curiosity as an important feature for understanding the brain. I reproduce a passage where this notion is introduced, early in the book:

“the only work that the brain must do is whatever it takes to assuage epistemic hunger—to satisfy “curiosity” in all its forms. If the victim is passive or incurious about topic x, if the victim doesn’t seek answers to any questions about the topic x, then no material about topic x needs be prepared. (where it doesn’t itch, don’t scratch) ....”

I ask readers not familiar with science studies and constructivism to try to use this concept to understand what will follow. What is discovered is what is sought, and in the course of discovery, nature is part of the contingencies, but not a determinant one in and of itself. The rest of this thesis argues that a dynamic similar to that of epistemic curiosity operates at the level of scientific activities, and that my own endeavour to learn (about) these activities has given me insight into it. Because my own epistemic curiosity contrasts with that of brain mappers, it can serve to highlight theirs. Ideally, if mappers’ curiosity can in turn be stimulated by what my own epistemic curiosity has yielded, this forms the opportunity to communicate, and shape perhaps a different kind of epistemic hunger. I cannot dream of a better beginning to opening up what is considered the relevant context of brain mapping, as this thesis aims to do.