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POSITRON EMISSION TOMOGRAPHY IN THE MONTREAL
NEUROLOGICAL INSTITUTE & HOSPITAL.
A Case Study of a Frontier Technology

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February 1995

A Thesis submitted to the Faculty of Graduate Studies and
Research in partial fulfillment of the requirements of
the degree of Master of Arts

c Zlatko Anguelov, 1995



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*We dance round in a ring and suppose
But the Secret sits in the middle and knows.*

Robert Frost

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**Positron Emission Tomography in the Montreal Neurological
Institute & Hospital. A Case Study of a Frontier
Technology**

Abstract

This thesis is an exploratory study of the factors that account for the construction of a local social world around a frontier medical technology. The analysis is based on participant-centred accounts of the structuring of a PET world in the MNI&H. According to local actors, the following factors can be identified to have played a role in the birth, promotion, structuring, and maintenance of the local PET world: *the personalities; the institution; the resulting tradition; the assessment of PET; the sense of quality; the size of the local PET world and of the institution; elements of the environment such as cost, funding sources, and manufacturers.* The data show that the structuration of the PET world in this elitist research cum hospital institution cannot serve as a model for the diffusion of this frontier technology, although the demarcated pattern exhibits some characteristics common with those described in the literature for similar innovations.

La Tomographie d'Emission de Positrons dans l'Institut et
Hôpital Neurologiques de Montréal. Etude de cas d'une
technologie avancée.

Sommaire

Cette thèse représente une étude préliminaire des facteurs et des processus ayant joué un rôle dans la construction d'un monde social local centré sur une technologie médicale avancée. L'analyse est fondée sur les représentations des participants concernant la construction du monde de la TEP dans l'IHNM. D'après les acteurs qui ont participé au développement et à l'utilisation de la TEP dans cette institution, les facteurs suivants sont responsables de la naissance, de la promotion, de la structuration et du maintien du monde local de la TEP: les *personnalités*; *l'institution*; *la tradition qui en résulte*; *l'évaluation de la TEP*; *la perception de la qualité*; *les dimensions du monde local et de l'institution*; ainsi que des *éléments de l'environnement tels le coût, les sources de financement et les manufacturiers d'équipement*. Les données démontrent que la voie suivie par la TEP dans cette institution d'élite combinant la recherche avec l'hôpital ne peut être généralisée comme model de diffusion d'une technologie médicale avancée, malgré qu'elle exhibe certains traits communs avec ceux décrits dans la littérature pour des innovations semblables.

ABBREVIATIONS USED IN THIS THESIS:

BI - Brain Imaging;
BIC - Brain Imaging Centre;
CEA - cost-effectiveness analysis
CNS - Central Nervous System
CON - Certificate of Need
CT - Computer Tomography;
EEG - electro-encephalography
fMRI - Functional Magnetic Resonance Imaging;
FNI - Functional Neuro-Imaging;
FOI - Function Of Interest
MNI - Montreal Neurological Institute (up to 1984);
MNI&H - Montreal Neurological Institute & Hospital (from 1984 on);
MRI - Magnetic Resonance Imaging;
MRS - Magnetic Resonance Spectroscopy;
NIL - Neuro-Imaging Laboratory;
OTA - Office of Technological Assessment
PET - Positron Emission Tomography;
ROI - Region Of Interest;
SPECT - Single Photon Emission Computed Tomography;

CHAPTER I.

THE SOCIAL WORLD OF BRAIN IMAGING

"The road to hell is paved with good intentions."

1. Making a Choice

Brain imaging (BI) is an activity whose goal is to obtain a comprehensive picture of a brain in action using a constellation of visualizing techniques. While some of these techniques can be used in isolation, more often than not it is the constellation, and not the single technique, that characterizes BI as an activity: each technique reconstructs an aspect (image) of the brain's spatial and temporal characteristics so that only the cumulative effect of the various images provides the anticipated picture of a brain.

In this chapter I will identify the characteristics, the human and non-human actors, and the applications of BI. I will also present the principles underlying the different techniques of BI in order to convey an understanding that they are sequential but not interchangeable links of the ambitious intellectual project of visualizing the brain in action. In so doing, I will deliberately place the emphasis on the machines and their interactions, since, in my opinion, BI equipment is the structuring factor of the BI activity.

On the other hand, BI equipment would be idle unless an activity of BI is performed. This dual meaning of BI - as equipment and as activity, i.e., as structure and function -

lies at the base of the sociological interest in how BI activity is associated with the actors who constitute the local social world of PET.

PET is the latest development in BI, which involves new machines, new interactions, and new types of activities. Hence, the study of PET can provide new insight in the social processes that structure a new local world around a frontier technology. This was a key consideration for choosing PET as the object of this study.

The identification of the technological and social elements that interact to promote the career of PET is, however, a prerequisite to addressing the main sociological question of this study: why and how a frontier medical technology can be studied in terms of the construction of a local social world?

In the available sociology literature PET has not been analyzed in such a context. In addition to that, the identifiable social factors which contribute, according to the local participants, to the structuring of a local social world, might reveal actors' choices and decisions as crucial for the career of a technology. Even more so, the PET social world emerging in the institution which has generated this technique and advocated its diffusion will retrieve features of a model of a social world construction around a technology. Although such a model may not be general enough to account for all occurrences of PET worlds in "elitist" institutions, it will provide enough prognostic clues as to the patterns of diffusion

of this technology, especially within research settings.

2. Main Characteristics

BI is an activity carried out in medicine, but which attracts paramedical and extramedical explorers as well. If we imagine BI as a cross-point, the roads leading to it traverse the domains of neurosciences, the neurological and neurosurgery clinics, nuclear medicine, and computer technologies. The roads taking start out of it - still short and not ideally paved - go into brain physiology, pathophysiology and the treatment of brain diseases, cognition (by a variety of disciplines grouped under the label of cognitive sciences), and computer modelling. To put it otherwise, the image of a brain is produced by a multidisciplinary effort, and the interpretation of this image fuels the momentum of another constellation of activities with undisputable social implications. On the other hand, the division of BI people into runners (people who manage, run, and ameliorate the equipment and the technique as well as carry out research on the PET technique) and users (people who use PET in biomedical research) is helpful for the sociological vantage point, from which I will provide a narrative about this particular social world¹. Thus, the first characteristic of BI is that it may well be identified as a multidisciplinary, multisocial, and multifaceted enterprise.

Yet, the cross-point is a picture. For the runners the picture is an end. For the users the picture is a starter. The

more accessible the meaning of the picture is, the more powerful are the discourses and actions generated on its basis. Therefore, the unifying interest of both runners and users is to improve the quality and the veracity of the picture, since the existence and the welfare of this hybrid world depends on the promotion of high status for the meaning of this picture among the medical profession and the public at large. Thus, a second characteristic of BI is that its outreach resides in its product, the picture.

The third characteristic of BI is that, at the present moment, it assembles research and clinical work under the same roof. BI is described by people who have linked their career to it as a world which drains people with different ambitions, all of whom are opportunity-seekers. Neurologists and neurosurgeons seek the opportunity to refine diagnosis and achieve cure or, at least, better treatment for the neurological patient. Physicists (such as biophysicists, instrumentation physicists, etc.) and engineers endeavour to manage radioactivity, to manufacture devices and to measure biological function. Chemists and pharmacists strive to generate radiochemicals and radiopharmaceuticals with a large spectrum of applications. Linguists seek to locate the language 'apparatus' in well-defined parts of the brain. Neuropsychologists believe they may be able to visualize thinking and behaviour. Biochemists expect BI to provide new data about the metabolism of the neurons and the non-neuronal cells of the brain. Bioscientists of the

'basic' kind explore opportunities to understand and model fundamental cellular and genetic mechanisms as they all are represented in the cytoarchitectonics of the brain. *Mathematicians, statisticians, and computer engineers* are tempted to find clear and easily reproducible algorithms for the computerization of the signals coming from or induced in the brain; modelling simultaneously brain anatomy and brain physiology is a challenge for them, but also an anticipation that artificial intelligence may help elevating our knowledge of the mind.

Both basic research and clinical work are prestigious activities, concurring in their goals but also competing for social recognition. Fuelled by both of them, BI seems to be prestigious as well, but at the same time imbued with internal tensions as it is built - and especially funded - on the common land between medical research and patient care. The transition of newly introduced BI technologies from their experimental (research) phase to their routine (clinical) use is loaded with conflicts of interests and, in addition, is questioned for its cost. At this period of after-birth life of BI technologies another group of powerful actors has entered the stage: the commercial manufacturers of technologies. It is only natural that their interest is closer to profit than to philanthropy. Thus, a fourth characteristic of BI is its high cost.

It would not be an exaggeration to say that the cost of BI technologies is a Gordian knot, in which the social complexity

of BI is plainly manifested. The academic world where new technologies are conceived and created is ambivalent to the aspirations of the manufacturers to patent and monopolize the production and distribution of these technologies. The world of clinical practice, in its turn, is dependent on the funds society allocates for the purchase of new technologies and on the ability of researchers to demonstrate efficiency, effectiveness, and safety of each newly emerging technology, the three of which are a justification for funding. Although there are many examples of joint ventures between researchers and clinicians, a general formula of their relations has hardly been found. We should clearly distinguish between two cases: a/ BI is developed in a research institute (hence, funded as research) and its modalities become accessible to the hospital(s) administratively and/or territorially linked to the institute; b/ BI is built from scratch as an institutional or a multi-institutional enterprise in order to provide patient care for a community (hence, funded as a health-care activity). The first case can be exemplified more or less by the MNI&H. The second case is described by Frick et al. (1992) and Prezio & Ackerhalt (1992) and discussed with real cost estimates in Conti et al. (1994).

Finally, a fifth characteristic of BI is that, because it is designed to visualize the *human* brain and to help solving issues regarding the *human* brain's normal and diseased functions, BI is regarded as bound to become part of the health-

care system. No matter how long the experimental period may last, time comes when technologies change their career and acquire new social environments; at least, such was the fate of many major equipment-embodied medical technologies such as, for example, X-rays and ultrasound; CT-scanning entered the clinic bypassing research, and MRI is already appropriated by the hospitals in North America. In the case of BI, the process of transition from research to the clinic is driven by the pressure BI researchers exert over the hospitals to check and implement innovations that would justify the usefulness of their research, but also by the fact that the health-care system is far from being saturated with technology. The transition process is slowed down, on the other hand, by the conservative nature of the political and fiscal levers in society. But puzzles and risks concern society only until an innovation is integrated in the system. Once absorbed, the innovation becomes routine and, as a rule, concerns become history (Reiser, 1978).

For those involved in the process, however, the diffusion of an innovation is not a matter of course; and this attitude is shared by social scientists. Indeed, the social sciences manifest a genuine interest in medical technologies (Banta et al., 1981; Jennet, 1986; Roth & Ruzek, 1986). Sociologists have their own motives to join the multidisciplinary chorus that explores BI, for instance, by claiming that biomedical researchers alone are not able to guarantee a smooth transition of BI from the institutes into the hospitals, let alone to

tackle the practical problems surrounding its incorporation in the health-care system.

3. Why PET

While this thesis' specific focus is on the latest among BI's technologies, namely PET, it cannot help addressing BI as a whole. BI's underlying technology is not homogeneous. Three distinct techniques, each having a specific equipment embodiment, and several subvariants of them are used to scan the brain: CT, MRI, and PET².

The common principle shared by all of them is that the image is digitally constructed from signals coming from inside the body, which are detected by computer-linked devices. Each signal is measured as to its place in space and time, and the set of measurements is mathematically processed to form an image; thus, the image matches the set of signals emitted by the scanned region. In CT and MRI these signals come from the structural constituents of the brain, while in PET they are sent by mobile compounds which take part in the functional activity of the brain.

The techniques differ in the type of energy applied to induce the signals.

CT uses X-rays: highly focused X-ray beams traverse a targeted cross-section of the body, whereby different tissues absorb varying amounts of their energy. Detectors positioned at the exit of the beams record X-ray signals with different

intensities and the computer program reconstructs an anatomical image of this body section (Raichle, 1994).

MRI uses a static magnetic field coupled with radiofrequency pulses: both are addressed toward the region of interest (ROI), thus inducing an excitation state of all atomic nuclei (consisting of protons and neutrons) aligned in resonance with the magnetic field. When returning from excitation to the equilibrium state (relaxation), the protons emit a signal which is detected by the computer system. Different protons emit signals with different intensity according to the type of atoms they are in and the dynamics of their relaxation, thus giving the necessary information to the computer to reconstruct a high-resolution anatomical image of the ROI (Prichard & Brass, 1992; Raichle, 1994).

PET uses radioisotopes: when short-living radioisotopes decay, they emit positrons (positively charged beta-particles) that travel shortly and hit nearby electrons. Each of the resulting annihilation events emits two gamma-particles that go in opposite directions. When the radioisotope incorporated in organic molecules, such as water or glucose, or in a drug is introduced in the body, paired detectors positioned around the ROI record the emitted photon signals and the computer recognizes the places of the tracer molecules, thus reconstructing an image of the pathway the tracer follows in the ROI. This image can be assessed qualitatively and quantitatively, but it is not an anatomical image. It is read

as a functional, or physiological, image. PET is the first visualizing technique that provides an image of a biochemical process - metabolism or receptor topography - or of a physiological event - blood flow (Phelps, 1991; Powers et al., 1991; Raichle, 1994).

It should be clear from the above schematized descriptions that PET is a technique different from its precursors³. On the other hand, PET is only in rare cases used alone, since it is not the function per se that is of interest to scientists and clinicians, but the localization of the function in the brain. Therefore, PET images (which visualize a function of interest, FOI) are coupled with MRI images (which visualize a ROI). This coupling requires more refined approaches to the very scanning of subjects and also convenient algorithms to achieve the anatomo-physiological match that is idiosyncratic for each subject (for specialized information on the anatomo-functional correlations in BI cf. Proceedings of the PET Data Analysis Workshop, 1991, and in particular Rapoport, 1991; Evans et al., 1991; and Levy et al., 1991).

There should be no doubt that PET is at the cutting edge of technoscience, and, to be more precise, of bioimaging and of the neurosciences (Posner, 1993; Raichle, 1994). But PET, its long incubation period notwithstanding, is not yet at the cutting edge of clinical medicine (Mullani, 1992; Wagner, 1992; Koh et al., 1994;). And it is exactly this dynamics of PET, present in the local world of the MNI&H, that evokes social

concern. But before exploring this issue in chapter III, I have to explain why, while choosing PET as a focus of technological innovation in a neurological environment, I cannot ignore the other BI techniques. This, in return, will give the reader an idea of why PET instead of the whole BI was chosen as the central subject of this study.

In the first place, given its nature, PET is part of a technological trend whereby virtual communities, i.e., communities in which computing systems (non-human actors) are used by human actors to process and analyze information, advance new techniques for acquiring knowledge. This trend was inaugurated by the CT, introduced by Hounsfield in 1972⁴, and it shortly became the bedrock of various visualizing technologies. The goal to see what is going on in the living organism by non-invasive techniques - an old dream of medicine's - began to look achievable when computer systems were given the task to construct the corresponding pictures. The power of the computer to measure signals and to transform measurements into comprehensive images seems unlimited (Koeppel & Hutchins, 1992). As one PET runner from the MNI&H put it, "it's the physics, not the computer science, which is the limiting factor" (interview, March 1st, 1994) for the resolution power of the imaging instruments. So, all BI techniques rely on the computer. What is changing is the nature of the detectable signals. Although MRI does not precede PET as to the time of its development, I would call both CT and MRI precursors of PET: they embody

consecutive steps in the development of energy sources able to extract information about the living structure in a detectable form. PET, which processes information about the in vivo function is just the last and most complicated invention in a sequel (Rockstroh, 1990; Ter-Pogossian, 1992; Croll, 1994; Raichle, 1994).

Secondly, PET images cannot be interpreted in isolation. No matter how they are obtained, PET images must be correlated with either CT or MRI images. But since MRI outranks CT in quality, sensitivity, and resolution and CT is now being applied for routine body-scans predominantly, in BI MRI-PET is the usual correlation (Evans et al., 1991). On the other hand, PET instrumentation as a rule is conceived, purchased and installed in centres that already have CT and MRI units. Thus, in every respect, PET is something that comes after or is built upon the preceding imaging techniques (Freeman & Blaufax, 1992; Ter-Pogossian, 1993; Raichle, 1994). In this sense, in BI MRI serves as a referent to PET. The underlying reason, I propose, resides in the fact that biological structure and function are not only the two sides of a coin, but they exist in a mixed form in the thinking of PET people (Anguelov, 1994). The exciting feature of PET is that it 'shows' function, but nobody contends that this 'show' has a meaning without being correlated, matched or referred to the anatomical picture of the same region, section, volume, and time.

And in the third place, a PET unit (or a PET centre)

includes MRI (and its sub-versions like MRS and fMRI). On the one hand, a PET unit cannot be fully dissociated from clinical work, and since MRI is already routinized as a clinical tool and its use is independent from the use of PET, it provides most of the clinical information required. But on the other hand, MRI's independent use in research is limited, since no competitive research project restricts itself to structural data when functional neuro-imaging (FNI) is at hand (PET researchers: interviews, May 9th, Dec. 12th, Dec. 21st 1994). For instance, the imaging technologies used for research in the MNI&H, as we shall see later, are administered as a Brain Imaging Centre (BIC), but their work is coordinated by a separate, PET-centred unit, called Neuro-Imaging Lab (NIL), "which is dedicated to the integration of information obtained with the various imaging modalities" (Annual report, 1990). Thus, PET is inseparable from the preceding imaging techniques, but, more significantly, the older techniques are not rendered obsolete because of PET. PET does not replace outmoded techniques (and this has cognitive, but also considerable financial and organizational implications), it supplements their power with a radically new insight in the brain in action.

Still, PET is classified as a medical technology, i.e., one which would potentially be used in clinical work; hence, it may be analyzed in the context of patient care and the health-care system (medical sociology) in addition to the context of the sociology of knowledge.

Summing up, the reasons why the PET social world was chosen as the topic for the present sociological analysis are the following: 1/ PET is a frontier technology, i.e., several PET-related issues, technological as well as sociological, are still in a transitional stage and thus likely to exhibit a peculiar social dynamics, which is often black-boxed after the technology becomes routine; 2/ PET is not simply a new technology emulating existing principles; it is based on different principles and produces essentially new products the meaning of which is not yet definitely determined. Thus, once again, it lends itself to the study of the social dynamics underlying the shift of meanings; 3/ though the transition of PET from research into the clinic is under way, it is being also largely questioned, constrained, or simply not encouraged (PET Panel, 1988a-d; Powers et al., 1989; PET runner, interview Dec. 21st, 1994); and 4/ PET precursors have been studied as innovations and as diffused technologies (Banta et al., 1987; Blume, 1991; Barley, 1988), while PET is not yet in the centre of the sociological interest in medical high technologies.

4. PET as a Technology

A PET-unit requires the functional assemblance of four facilities: a cyclotron, a radiochemical laboratory, a PET-camera (scanner, tomograph), and a data-processing and display system.

The cyclotron is a miniature nuclear reactor, which

produces radioisotopes with a short half-life. The radioisotopes routinely used in PET are: oxygen (^{15}O) with 2 minutes of half-life; nitrogen (^{13}N) with 10 minutes of half-life; carbon (^{11}C) with 20 minutes of half-life; and fluorine (^{18}F) with 110 minutes of half-life. In the absence of a cyclotron a cheap radionuclide generator can provide small quantities of rubidium (^{82}Rb)-chloride with 76 seconds of half-life (Gardner et al., 1992). Short-living isotopes are a necessity because they emit only positrons, their radiation potential for the patient is negligible, and the collimation of the emitted pairs of photons allows the reconstruction of a high-resolution image.

Short-living isotopes are particularly convenient for BI, because they allow for the shortening of the time during which the experimental subject keeps performing the same cognitive task that is visualized by the change of blood flow in the activated brain regions⁵. However, short-living isotopes cannot be transported and stored, therefore, they must be produced on the spot and used in due time. This makes PET cyclotron dependent. Recently, hospital organizational designs have been proposed and attempted, whereby several PET labs are built around a single cyclotron (Prezio & Ackerhalt, 1992).

It is in the radiochemistry division of the PET unit where the radioisotopes are incorporated into biological compounds: either metabolic substances or substrate analogues. Carbon, oxygen, and nitrogen are part of the compounds of the human body and of most drugs, and fluorine can substitute for hydrogen.

These labelled compounds demonstrate convenient chemical properties (Ter-Pogossian, 1992) and can be introduced in the body where they presumably follow the physiological pathway typical for each of them. According to the radiochemical used, PET can visualize blood flow, metabolism, or drug receptors. ^{15}O -labelled water is used as a blood flow imaging agent, ^{18}F -fluorodeoxyglucose is the most used glucose metabolism imaging agent, and drugs are labelled mainly with ^{11}C (Fowler & Wolf, 1990; PET Panel, 1988b).

The PET camera, or the tomograph, is the data acquiring site. It consists of crystal detectors designed circularly to catch paired photon signals around a transverse section of the brain or the body. The first such camera for detecting brain tumours was built at the Brookhaven National Labs (Upton, NY) in the early 1960s, but it was unable to produce an image of the brain since computers were not yet coupled with it. The first positron tomographs that functioned on a practical level, that is, to make an image of the tracers' dynamics within the brain⁶, were developed at Washington University in St-Louis, Missouri (Koeppel & Hutchins, 1992) and at the MNI&H (interviews, Nov. 23rd and Dec. 12th, 1994) in the mid-1970s. The first commercially built primitive transverse section tomograph was manufactured by EG&G Ortec, Oak Ridge, Tennessee in 1978. The MNI&H also built the first camera using BGI (Bismuth Germanate) crystals, that have the highest known density and are currently largely used in commercially produced PET tomographs (Thompson

et al., 1978). According to Koeppe & Hutchins (1992), positron emission tomographs are manufactured nowadays by Siemens Gammasonics, Inc. in Hoffman Estates, Illinois; General Electric Medical Systems in Milwaukee, Wisconsin; Scanditronix AB in Uppsala, Sweden; Positron Corporation in Houston, Texas; and UGH Medical Systems in Philadelphia, Pennsylvania. As a matter of fact, all PET-tomograph producers are affiliated with three big companies (interview, Dec. 12th): Siemens and General Electric in the US, and Shimadzu in Japan. But research to design improved generations of tomographs is going on in Japan (National Institute of Radiological Sciences in Chiba and Research Institute of Brain & Blood Vessels in Akita in Tokyo), France (Laboratoire d'Electronique et de Technologie de l'Informatique in Grenoble), the United States (Donner Laboratories in Berkeley, California and Massachusetts General Hospital Physics Research Lab in Boston, Massachusetts), and Sweden (Karolinska Institute and the University of Stockholm) (Koeppe & Hutchins, 1992). The perfectioning of a positron tomograph refers to: density (which is a function of the crystals), resolution (which is a function of the size and arrangement of the crystals), number of planes (or slices) that can be scanned simultaneously, ability to re-construct tri-dimensional images, and to increase signal-to-noise ratio (which is a statistically manageable problem) (Mullani & Volkow, 1992; PET Panel, 1988a).

Computer systems. Once the camera has acquired the data,

all measurements are sent as an input to the data processing hardware and software (a schematic configuration of this system is given in Koeppe & Hutchins, 1992). The data processing consists of qualification (an image display and analysis workstation) and quantification (a data display and analysis workstation) of the radioactivity detected in the ROI. The quality of this part of PET is assessed on speed, volume, long-term storage of data, easy access to data, sophisticated extraction of quantitative information from images, co-registration of a multiple image sets, and manipulation of images as to space and time. It is here, using the software of the data processing and display system, that different experimental designs to test hypotheses can be accommodated, and room exists for the increase of precision and flexibility in localizing and quantifying biochemical processes performed in very small quantities by the living brain. Finally, the software enables the imaging team to co-register (correlate, match) the FOI with the ROI, thus acquiring knowledge about the structure-function relationship in every individual brain.

What the above description of PET technology implies is that: 1/ several research fields have contributed to the emergence of functional neuroimaging (FNI); 2/ accordingly, several research fields have benefited from the challenge to develop this new kind of imaging; 3/ PET imaging is a team enterprise involving people from various disciplines; 4/ PET is high technology, whose management and coordination is a

sophisticated and competitive task; 5/ PET technology exists in a strongly competitive environment and, thus, may survive only as a high quality⁷ activity; 6/ high quality in modern FNI requires considerable money and human resources; 7/ PET imaging is attractive for corporations that manufacture and market high technology.

5. Applications of PET

One way to get an idea of the utility of PET is by collecting information about the domains and the extent of its applications. PET people feel that this information is a strong argument in their hands to promote the high social status of the technique. Interestingly, the majority of a sample of 1980s' articles, surveyed for this study, emphasized the research applications of PET, while after 1988 major interest was paid to its clinical utilization. This shift signals the tension between laboratory and clinic that, as I will show later, is at the core of the social dynamics of PET.

Brain research. FNI is currently applied to study neuromediating and drug receptors of the cells of the central nervous system (PET Panel 1988c, Phelps 1991), glucose metabolism of brain tumour cells (Herholtz et al., 1990; Koh et al., 1994), and cerebral blood flow as a tool to localize brain functions (Prichard & Brass, 1992; Heiss et al., 1992; Posner, 1993). Cerebral blood flow measurement in the so-called activation studies is at the base of the tri-dimensional brain

mapping, that is, in fact, the most recent re-evaluation of the brain functional topography initiated in the 19th century by Broca and Wernicke (Rapoport, 1991; Evans et al., 1991; Levy et al., 1991; Phelps, 1991; Neil, 1993; Chen, 1993; Raichle, 1994).

The general trend in the research performed with the help of PET is to understand brain physiology at the molecular level (Wagner, 1992). In his optimistic review Wagner (1992) claims that "the invention of radiotracers moved medicine further along the pathway from anatomy to physiology to biochemistry. [...] Nuclear medicine can be defined as 'in vivo molecular medicine'" (p. 286). If such a molecular world is visualized and a commonly recognized brain map is achieved, researchers believe this will radically alter the clinical assessment and treatment of brain pathology.

Clinical research and diagnosis. PET utilization in direct clinical research or diagnostic process is still rather limited. The overviews on the clinical utilization of PET are written predominantly in a future tense (Freeman & Blaufax, 1992 and 1994; Masey & Jeffery, 1991).

PET is used on a limited scale in the clinical management of: epilepsy (Masey & Jeffery, 1991; Sperling, 1993); circulation brain disorders (Alavi & Hirsch, 1991; Baron, 1993); brain tumours (Herholz et al., 1990; TTAS-AAN, 1991); movement disorders like Huntington's disease (TTAS-AAN, 1991) and Parkinson's disease (Masey & Jeffery, 1991; Alavi & Hirsch, 1991); psychiatry, namely for Dementia and Alzheimer's disease

(Masey & Jeffery, 1991), Schizophrenia (PET Panel, 1988c, Alavi & Hirsch, 1991), Depression (Cummings, 1993), Mood disorders (Alavi & Hirsch, 1991), Alcoholism (Alavi & Hirsch, 1991); pain (Chen, 1993); head trauma (Alavi & Hirsch, 1991). The non-brain clinical applications of PET are in cancer (PET Panel, 1988a; NCI Workshop Statement, 1988; Koh et al., 1994) and heart diseases (PET Panel, 1988b; Bonow et al., 1991).

6. Runners and Users

Despite the complexity of the world of PET imaging, we may distinguish two categories of people according to their orientations. One is the community of those who run, ameliorate, purchase, and coordinate the different technological blocks until satisfactory images are produced. They also work on projects aimed at improving the technique itself. I call them runners. The other is the community of those who need the images and the quantitative data for testing the hypotheses they generate to study the normal and the diseased brain, or simply to make a clinical diagnosis. I call them users.⁸

Runners are: biophysicists, instrumentation physicists, radiologists, radiochemists, radiopharmacists, engineers, electroengineers, computer engineers and technicians, mathematicians, statisticians, physicians, and institute or hospital managers. They all perceive themselves as collaborators and pretend that the hierarchical positions, i.e, coordinator or director of a unit, are of negligible importance to their

mutual relationships. What matters is that they are anchored to the PET world so that they are almost constant, immobile members of this world; they are the core of the positron imaging.

Users are: basic researchers in neurosciences, clinical scientists (mainly physicians), neurologists, neurosurgeons, neuropsychologists, psychiatrists, linguists, and cognitive scientists. Users dwell at the site of PET only when they employ the technique for research or diagnosis. But despite their interim status, they are legitimate members of the PET world who generate biomedical hypotheses and also contribute to the dynamic of this world.

These two communities (heterogeneous within themselves) interact on different levels and in different settings when the imaging techniques are utilized to produce knowledge. They interact when hypotheses are generated, when new techniques are generated or existing techniques are modified, and when images are interpreted in the context of an experimental or pathological condition. But they differ in that the runners produce the images and, thus, are responsible for their quality, while the users consume the images and, hence, are responsible for the quality of the underlying experimental design.

While runners' activity centres on the imaging technology, the users will treat it as one of the tools available to test hypotheses or to be applied for a more refined diagnosis. With respect to these different attitudes, both groups will defend different projects as to institutional approval, social

acceptance, and funding. Thus, the interaction between runners and users is an essential element of the BI world and will be discussed with regard to the position of the PET world within the MNI&H.

Notes:

1. As I will explain in more detail in Chapter 2, in this thesis I will use the notion of social world as formulated and promoted in the sociological literature by Strauss (1978) and further developed by Kling & Gerson (1978), Gerson (1983), Strauss (1984) and Clarke (1990). I think that it describes more adequately the designated entity than community, group, setting and the like. Wherever the notion of negotiation occurs, it is again used in the sense of Strauss (1978).
2. Of course, all three of them are also utilized to scan different parts of the body, but I will describe them in the context of BI exclusively, since the social world I am interested in is engaged in studies of the human brain and the human nervous system.
3. An alternative to PET is the Single Photon Emission Computed Tomography (SPECT). In contrast with PET, SPECT uses longer living radioisotopes whose nuclei emit a cluster of photons with energies considerably lower than the gamma-particles in PET. In addition, each photon is singular and the detecting collimators are designed accordingly. The lower sensitivity and resolution of SPECT compared with PET is contrasted with its lower price and the easy provision of radioisotopes (no cyclotron needed). Some authors plead in favour of SPECT (Weinberger, 1993; Reba, 1993), but there is a general recognition that it has limited applications compared with PET, which is unanimously acknowledged as a revolutionary technique, even by the advocates

of SPECT (Wagner, 1992; Ter-Pogossian, 1992; Sperling, 1993; and many others). SPECT is not used in the MNI&H; therefore, I will limit my attention to it to this footnote.

4. He shared the Nobel Prize for physiology & medicine with Cormack in 1979.

5. For example, the subject is asked to move his eyeballs in darkness or by following a moving object in front of him for only 1 minute, since the radioactive oxygen used as a tracer will emit the maximum positrons during this minute. Should PET use long living isotopes, in order to detect enough emitted radioactivity, the same task would have to be performed for a much longer time, which is inconvenient for the patient, if at all practically possible.

6. Feindel & Yamamoto (1978) have used in the title of their presentation to the First Symposium on PET the qualification "Physiological Tomography".

7. I don't feel obliged to define 'high quality' or to argue how 'quality' is assessed by people who run PET systems. The quality of PET will be discussed in chapters III on the basis of my data. And yet, there is a tacit sense of quality which conveniently determines people's attitude toward comparable objects, systems, and events.

8. Kling & Gerson (1977), who have studied the structure of the computing world, demarcate 14 major orientations of the people and groups constituting it. In the case of MNI&H, it suffices to define these two major orientations, without caring to segment them into suborientations. Those two groups of PET people will be differently positioned with respect to the processes which structure the PET world.

CHAPTER II

THE SOCIOLOGICAL APPROACH TO PET

"A model is by definition that in which nothing has to be changed, that which works perfectly whereas reality, as we see clearly, does not work and constantly falls to piece; so we must force it, more or less roughly, to assume the form of a model."

Italo Calvino
Mr. Palomar, 1983

1. Introduction

In the preceding chapter equipment, activity, and actors were identified, the three of them staged in the laboratory. What is of sociological interest, however, is not their isolated, 'ivory tower' community, but the interface between the laboratory and the outside world. This interface is a dynamic interaction of individuals, worlds, interests, values, and policies. The study of this interface may help conceptualizing a social reality for practical purposes as well as within social theory.

This study, which has by rule a limited scope, was designed as a *participant-centred* account about the construction of a social world around a frontier BI technology that occurred in a local institution. The objective of the study was defined as: the story of PET in the Montreal Neurological Institute & Hospital, why here? why now? The MNI&H was considered to be a good case for getting information about the social processes which accompany and the social factors which contribute to the

construction of a local PET world: this institution both participates in the R & D of PET and is a host and an advocate for its diffusion in research and patient care. The features of the local structuring processes are, in principle, generalizable to the extent that such a construction occurs in all other places where this high technology becomes available. Then, the model can be used to prognosticate social factors and processes that will legitimize or delegitimize the diffusion of the technology within its typical environment.

Indeed, the story of PET in the MNI&H, as viewed and assessed by the participants, provided significant data about how a frontier technology gives birth, promotes, structures, and maintains a particular social world within its typical environment.

At the same time, the very availability of PET high technology for the medical profession is pregnant with medical issues which are of great concern to the medical researchers and practitioners throughout the world. In this respect, the data about the social world constructed around a technology provide also an analytical basis for studying the interaction between the medical issues and the social issues characterizing the career of this high medical technology.

2. Sociological Perspectives.

a) **Analytical framework.** The basic notion of social world was defined by Strauss (1978) and further developed by Gerson

(1983), Strauss (1984) and Clarke (1990). The appeal and strength of this notion is that, following the Chicago interactionist tradition, it provides an anti-deterministic analytical framework implying change, communication and inexhaustible dynamics of the social systems. In addition, the notion of social world has been developed by Strauss on the basis of his research in a hospital environment, and used thereafter by several sociologists to study hospital settings. The social studies of technologies, and of medical technologies in particular, are often framed within the social world analytical perspective.

A social world "consists of a set of common or joint activities or concerns bound together by a network of communication" (Kling & Gerson, 1978; p. 26). Strauss (1978) warns that in addition to seeing the social worlds as universes of discourse, we must also consider activities, memberships, sites, technologies, and organizations as typical constituents (thus; dynamic factors) of a particular social world. One distinct property of social worlds is that they intersect and segment. *Intersection processes* govern the manner in which worlds interact with one another, while *segmentation processes* divide worlds into subworlds organized around more specialized kinds of activity. Finally, *legitimation processes* occur, whereby the various lines of action are evaluated and accepted or rejected (Gerson, 1983). Strauss (1978) focuses on processes as central to the study of social worlds. Clarke (1990) goes

further in formalizing this approach: she distinguishes *social domains* as "loosely-bounded collections of social worlds", which are committed to a particular social area, *social arenas* within a given domain, which are restricted to a "focal area of action", and, finally, *social worlds*, which interact within an arena for a certain period of time. She describes the dynamics in time as follows:

Each social world within a particular domain may participate in several arenas within that domain with varying degrees of frequency and intensity. The social world may additionally participate in other domains and their arenas. In each chosen domain of action, the social world may select arenas, within which to act routinely, arenas to monitor for possible action, and so on. (Clarke, 1990)

It is clear that, according to this perspective, the social world is viewed as a fundamental structural-functional unity of the dynamic social organization, while the other sets seem to complete the societal picture on a comprehensive level. Social worlds may encompass both the group of people linked by an activity at large or the group of people performing this activity in a defined local setting. In this study the analysis refers to the local social world of BI activities within a neurological institution.

The characteristic symbolic interactionist approach to social structures led Strauss in the late 1950s to formulate the idea of negotiated order (Strauss, 1978) as a theoretical approach to the analysis of social structuring. In his 1978 book on negotiations Strauss admitted that the early development of the negotiated-order approach overlooked actors' theories of negotiation, the accompanying or alternating subprocesses, and the structural contexts and the negotiation contexts. These are

now regarded as key elements of the negotiated-order theory.

Since the approach of this study is centred on actors' interpretations of the construction of the PET local world, it fits within Strauss's theoretical framework. Negotiated-order theory is a particularly apt analytical framework for this case study because its objective is to examine how a not-yet-existing order is created/negotiated around a new piece of technology. In addition, the negotiated-order perspective was successfully used by Barley (1986, 1988) to study the structuring of a world around another imaging technology, CT-scanning. Thus, this study's analytical approach takes as its starting point both Strauss's general considerations and Barley's research strategy to interpret empirical data, similar to the ones in this study, from the negotiated-order structuring perspective.

b/ Sociological interpretations. From an administrative point of view, medical technologies are usually defined as "the drugs, devices, and medical and surgical procedures used in medical care, and the organizational and supportive systems within which such care is provided" (Banta et al., 1981; p.5). This practical definition is utilized or implied when sociological interpretations of medical technologies' careers are undertaken. Following this definition, medical technologies are classified according to medical purpose and physical nature (Banta et al., 1981). According to the medical purpose, medical technologies will be: diagnostic, preventive, therapeutic, rehabilitative, organizational (administrative), and supportive.

The first five categories are self-explanatory; the last one refers to technologies which provide patients, especially inpatients, with services like beds and food. According to the physical nature, medical technologies may fall into three categories: drugs, devices, and procedures.

The notion of high technology gained popularity without being strictly defined, but it refers generally to technologies which are based on a sophisticated design, expensive construction, and the use of specially trained personnel. As a result of these characteristics, high technology is by definition expensive and thus questionable by patients, politicians, sociologists, and various interest groups.

The technologies, the implementation of which depends on specially constructed machines, are referred to as *equipment embodied technologies* (National Research Council, 1979), i.e., they are neither drugs, nor intervention procedures that can be performed by medical professionals without the use of machines. In this sense, they operate as intermediaries between the professional and the patient, allowing information about the patient's condition to be acquired from a distance. Imaging technologies, hence, are *diagnostic equipment-embodied high technologies* and they are emblematic for the problems routinely discussed by sociologists.

One group of authors regards them as knowledge acquiring systems that promote changes in the medical ideology (e.g., Reiser, 1981 and 1993; Pasveer, 1989 and 1993; Marks, 1993;

Delkeskamp-Heyes & Cutter, 1993). The general concern of this trend is with the dehumanizing nature of technologies (see for example Taylor's 1979 book entitled: "Medicine Out of Control: The Anatomy of a Malignant Technology"), but not with their diagnostic strength or social impact.

Another group of authors describes its interest in medical technologies as a concern about the social impact of high technology medicine (Roth & Ruzek, 1986). The main questions deriving from this concern can be summarized as: high tech diverts resources from primary (mass) medical care and accessible social services, thus, it is genuinely elitist; high tech approaches have not always or not yet proved their effectiveness in terms of reducing mortality and improving diagnosis and treatment; there are indications that high tech reduces the control that consumers and practitioners may exercise over medical services; cost concerns tend to minimize the role of the social context in high tech adoption.

In this vein Susan Bell (1986) criticizes the attempt to define the stages in the career of a technology, which she calls 'a sequential approach', as being blind to the interests of the communities involved in technology adoption. In contrast, on the basis of her study on diethylstilbestrol (DES) adoption, she offers an 'interactive model' of adoption, which, she claims, takes into account the conflicting interests of communities affected by a technological innovation and, thus, can better explain the political and economic context in which technologies

expand. Ost & Antweiler (1986) interpret the medical technology innovation in the case of CT-scanning as interlocks between corporations, universities, and communities' interests (the so-called CUCI). "The decision to adopt CAT-scanners was essentially a power struggle between competing elites or class factions", contend these authors and conclude that the introduction of CAT-scanners exposes clashes between the innovation processes and patient needs (p. 83). Alternatively, Budrys (1986) and Greer (1986) point out the dominant role of physicians, which determines to a considerable degree the expansion of a medical technology. In the book of Brearley et al. (1978) health care policies, including those concerning technological innovation, are viewed as being shaped by the rise of health expectations in society, which in turn leads to an increasing demand on the health services. As a consequence it seems "no longer politically or economically feasible to equate demand with need and attempt to increase provision to keep pace" (p. 57). Assessment of technology is thereby shifted toward the imbalance between demand and need in an attempt to maintain a reasonable balance. This largely politico-economical approach is mostly irrelevant to the scope of this study, which focuses on the structuring processes that occur in a local world. The macrosocial impact of the adopted imaging technologies is of limited concern to the local participants.

A great part of the literature on medical technologies deals with technology assessment. Following the premises of

classic diffusion theory (Greer, 1977), according to which the adoption of innovations is explained by the role of single individuals and by the character of the information these individuals pass on, technology assessment literature (e.g., Banta 1980, 1986, 1987; Anderson & Jay 1985; Banta et al. 1981, 1983; Rogers, 1987) provides concepts about the diffusion of a technological innovation on the organizational and inter-organizational level.

The ultimate benefit from a technology, these authors state, is the increased ability to control disease (Banta et al., 1981). Their operational concepts are efficacy, effectiveness, and safety. *Efficacy* of a medical technology refers to "the degree of positive health outcome received by individuals in a defined population under optimum conditions" (Goldman, 1979; p. 9). *Effectiveness* means "the benefit under conditions of actual use" (Goldman, 1979; p.9). And safety is "a judgement of the acceptability of risk in specified conditions" (Banta et al., 1981; p. 98). The terms 'assessment' and 'evaluation' are used interchangeably in the literature.

The idea underlying technology assessment is to rationalize the use of health technology. In this respect, this type of literature discusses R & D, the adoption process, factors affecting the use of technology, social values, and the quality of patient care. These authors try to respond not only to the concerns about the possible violation of social values by high technology adoption in medicine (the adoption being generally

recognized as a humanistic activity), but also to counter the opposite concern, raised by the medical profession: what does society lose if the health care systems resist and/or fail to adopt an available technology. By taking this balancing role, the technology assessment trend is practically rather than theoretically oriented. As Cambrosio & Limoges (1991) point out, its focus is on the development and adaptation of methodologies and procedures, which would be able to identify and measure the impacts of high technologies and to investigate the consequences of the options available to decision makers (Stocking, 1988; Banta et al., 1981; Banta & Vondeling, 1994; Drummond, 1994; Drummond et al., 1994).

The largest number of articles about medical high technology, however, are dedicated to cost-effectiveness analysis (CEA). Various aspects of the rising costs of technology in patient care are addressed by this kind of literature: the role of government (Iglehart, 1977; Rutten & Bonsel, 1992); the role of the biomedical research community (Iglehart, 1977); the role of physicians (Banta, 1987; Stocking, 1988); the role of the bureaucracy (Littrel, 1989); the voice of the consumers (Stocking, 1988); the role of the industry (Stocking, 1988; Rutten & Bonsel, 1992); the role of the justice system (Littrel, 1989; James et al., 1991); the failure of public policies in the case of CT-scanners adoption and diffusion (Banta, 1980); guidelines for clinical (Guyatt et al., 1986) and economic (Guyatt et al., 1986; Jönsson, 1993)

evaluation of health care technologies; the impact of technologies on the rationing of health care (Aaron & Schwartz, 1990); and the role of the reimbursement scenario (Jackson, 1990). All these aspects may fall under the rubric of tentative policies for the regulation of health care technology diffusion; thus, CEA is an approach that provides useful information to policy makers.

The underlying meaning of CEA was summarized by Phillips & Lille (1976), as cited by Iglehart (1977; p. 35): "balancing institutional demands versus budget on one hand, and community needs versus restrictions on the other". Thus, CEA continues to be a top priority topic in the medical technology literature; for instance, out of a set of 67 articles focused on imaging technologies, retrieved from the 1990-1994 database 'Sociofile', 37 dealt with CEA. But criticism for its unsatisfactory status is often expressed (James et al., 1991):

The financial implications in terms of human value are difficult to quantify. Patients given free choice have traditionally selected the most technological and, thus, the most expensive form of health care. Patients want access to this type of machine, but would they if they had the necessary data to understand the financial implications? (p. 153)

Even in his sociohistorical approach to health care technology Blume (1992) cannot pretend to ignore the above problem, although he puts it in a slightly modified wording:

Rationing access to the latest technology is an unacceptable denial to some patients of the potential benefits of medical progress. (p. 4)

He examines the non-rational and un-measured reaction to new medical technologies in the context of medical progress. Instruments, he claims, are viewed as an embodiment of science-

in-medicine, so that they transform the face of medicine in becoming a standard for clinical routine. Blume's cases in the book, including the history of the CT-scanner and the MRI, prove indeed that instruments are still transforming the face of medicine, because, the author asserts, they reflect social changes on a broader scale like specialization of Western medicine, the nature of people's expectations from medicine, and the rise of life insurance. This is, in fact, a reformulation of Brearley et al.'s (1978) dilemma of demand vs. need in the context of rising (or changing the nature of) health expectations.

This brief review of the main trends in the sociological interpretations of medical technologies demonstrates a dispersion of objectives and approaches, which might invite criticism but also recognition that medical technologies represent a topic of sociological interest and concern. A centre of the sociological analysis, however, has not yet been found. The choice to study the structuring factors of the local social world of PET, which is an expensive, sophisticated, and still not diffused innovation in BI, by using participant-centred accounts within Strauss's negotiated-order theory, implies the understanding that actors' choices and decisions are a possible focus to explain the career and social behaviour of high technologies. In this particular case, the professional considerations for such choices and decisions are of ultimate importance; therefore, the professional evaluation of BI

technologies is of crucial relevance to this analysis¹.

c) **The professional debate.** The neurosurgeon Bryan Jennett (1986) synthesizes the medical practitioners' attitudes towards technologies in the following way: high medical technologies are complex and expensive, hence restricted in availability. The consequences are that high technologies must be under the control of specialist staff, and that, because the demand for their use exceeds supply, they have to be rationed. The strong argument of the profession is that high technologies facilitate the medical task to assure a positive outcome for the patient by intervening in diagnosis, prognosis, decisions, and management (in Jennett's terms this includes patient care, treatment, and cure). But the question "is high technology worth the money?" remains unanswerable. The professional rationale for answering yes to it is to use only those techniques which are effective and to use them only when they are really needed. Regrettably, the relationship between the use of high tech and the benefit to patients is seldom straightforward. Although Jennett's 1986 monograph is looking for the balance between "benefits and burdens" of high tech, he tries also to balance the professional with the social assessment, and the result is a good inventory of the issues but not a clear perspective for addressing them.

A spontaneous professional assessment of PET is occurring through publications of research data obtained by using this technique alone or modified or coupled with other BI techniques.

Most of these publications assign high reliability to PET as a research method. As an example, during the period 1990-1994 two of the leaders of research teams at the BIC in the MNI&H have published 38 and 45 articles respectively with only 4 overlaps (where both leaders are co-authors) in leading biomedical journals such as *Science*, *Journal of Neuroscience*, *Journal of Computer Assisted Tomography*, *Journal of Cerebral Blood Flow & Metabolism*, *PNAS*, *Brain Research*, *Journal of Neurochemistry*, *New England Journal of Medicine*, etc. These publications augment both the authority of PET and the prestige of the MNI&H.

A purposeful assessment of PET and the related BI techniques in the US specialized literature occurred during the years 1988-1991. From April to November 1988 the Journal of the American Medical Association (JAMA) published five reports of a specially set PET Panel (1988a-1988e) under the cover of the Council on Scientific Affairs, and two editorials (Sheps, 1988 and Chalmers, 1988). The reports of the Panel, based on the scientific literature as of February 1987, were submitted to the House of Delegates of the American Medical Association at the 1987 Annual Meeting as informational reports. The members of the Panel were all physicians or biological scientists. In addition to that, in April 1988 JAMA published the summary of a Consensus Conference convened in October 1987 by the Warren Grant Magnuson Clinical Centre and the Office of Medical Applications of Research of the National Institutes of Health (NIH, Bethesda, MD) "to resolve issues regarding safety and efficacy" of MRI

(Consensus Conference, 1988). In June 1988 professional concerns about the poor quality of early evaluations of MRI (Cooper et al., 1988) were again voiced in JAMA. They were followed in the November 11 issue by a set of disgruntled letters to the editor (Berk et al., 1988). In that same issue an editorial by Chalmers (1988) summarized the whole JAMA campaign about imaging technologies. In the same year *Annals of Internal Medicine* published a meticulous study by Kent & Larson (1988) on the clinical efficacy of MRI.

Although no one dared formulate definite conclusions, the whole debate delineated the advantages and flaws of these frontier imaging techniques, which could be identified at the time, with regard to clinical efficacy, safety, and future potential. Cost was mentioned only as a caution but was not discussed with any accurate data. Before going into details, let me point out two things. On the one hand, MRI and PET, although assessed separately, were put into the same perspective regarding: a/ the concerns that prompted the evaluations; b/ the techniques and standards of evaluation; c/ the complementary (or substitutive) nature of the technologies in the clinical context; d/ the feeling of both their increasing efficacy and increasing cost. On the other hand, for the second time after the mid-1970s when a heated debate followed the CT-scanners' uncontrollable boom in the US (Shapiro & Wyman, 1976; Banta, 1976; Iglehart, 1977; Culliton, 1978; Blume, 1992) an organized attempt was made by leading professional associations and

individual scientists to set down the 'benefits and burdens' of an imaging technology.

What everyone reports to have happened in the CT case in 1972 is that it was welcomed with "wild enthusiasm" (Blume, 1992) by clinicians and, thus, successfully marketed by EMI in the US prior to any evaluation. According to Blume (1992) the dynamics of CT diffusion was the result of expectations of physicians for more information and more accurate information, market pressure (availability of CT on the market), and policy of cost containment. This dynamics was marked by an increase of purchases up to 1977, corresponding to the period when professional evaluation was highly positive, then a plateau of about two years was observed, which was followed by a clear decline of the interest. The plateau and the decline, according to Mullani (1992), were due to the legislation introducing the Certificate of Need (CON), which obliged hospitals to file an application to the state governments prior to the purchase of a CT. So, CT became a notorious example of arbitrary governmental cost containment measures aimed at reducing cost of medical care by limiting the use of new imaging devices, independently of the fact that they had been assessed as unquestionably useful by the professional community. The debate about PET and MRI seems to have reflected intuitive fears, based on this precedent, that factors other than the professional ones would intervene in the diffusion process.

But the history reiterates itself with an amazing

consistency: although the professional community skews the assessment process toward the benefits, and various non-medical interest groups voice concerns about the increasing financial burden, a diffusion of the technique, nevertheless, occurs. It is only in the face of increased expenditures that the health care system reacts by imposing financial restrictions on the diffusion. Evaluation of the technology is praised by almost everyone as a panacea against such an uncontrolled dynamics. In 1988 Chalmers plainly admitted that:

CT scans and MRIs are now an *integral part of patient care*, but they have become billion-dollar industries without the kind of scientific determination of efficacy and effectiveness that one might expect when so much money is being spent. (p. 2713; emphasis added)

According to him, PET scans cost 3-5 times as much as MRI and the cost of the MRI is roughly 3 times the cost of CT. It becomes more and more evident that the imaging technologies follow a career pattern, which neglects the process of clinical evaluation and also, to a considerable extent, the process of CEA (see previous section of this chapter).

Methodologically speaking, the evaluation of MRI is in a more advanced stage than the evaluation of PET. MRI was launched in the medical market in 1980. In 1984 it had already spread to the extent that concerns about the justifications for its further diffusion replaced initial enthusiasm and tacit tolerance (Blume, 1992). But it was only in 1988 that two comprehensive overviews tried to summarize the authentic value of this technique in clinical practice (Kent & Larson, 1988; Cooper et al., 1988). Both articles studied the literature

published by researchers using MRI. Kent & Larson (1988) referred to 386 articles published before January 1987 on MRI of the brain and spine only, and Cooper et al. (1988) assessed 54 articles published in the MRI field between 1980 and 1984. Kent & Larson (1988) found that very few studies addressed issues of therapeutic or outcome efficacy related to MRI and that virtually all studies were affected by bias. Their conclusion was that published evidence did not show that the clinical efficacy of MR imaging was generally superior to that of existing imaging modalities such as computed tomography.

Cooper et al. (1988) applied 10 assessment criteria "valuable in converting a clinical experience into an experiment that will supply useful data about the reliability of the procedure". Again, the conclusion was that each of the 54 articles was written "to illustrate the diagnostic usefulness of the procedure" and, thus, health care professionals who pay for expensive diagnostic technology "should demand better research of diagnostic efficacy" (p. 3277). Cooper et al. (1988) summarized their motives to make the study as "a need for proper evaluation from the beginning if time and money were not to be lost with the introduction of new technology" (p. 3279).

The response of the professionals (among them the editors of the two major journals, *Radiology* and *American Journal of Roentgenology*, where 34 out of the 54 articles analyzed by Cooper et al. were published), reveals the belligerent style, with which they justify their evaluation approach. "Lack of

appreciation by the authors of the unique nature and complexity of anatomical/ spatial information and the importance of anatomical diagnosis" and "hospital administrators who are no longer willing to subsidize research" are among the mildest formulations in the letters to the editor of *JAMA* (Berk et al., 1988; p. 2662) exposing the indignation of the MRI community against the 'bias' of the assessors of their articles.

Thomas Chalmers, who is a co-author of the Cooper et al. (1988) evaluation article, summarized the consequences of this situation in his editorial in *JAMA* (1988) as follows:

The editors of the *American Journal of Roentgenology and Radiology* [...] defend the poor quality of early evaluations of MRI by pointing out that there is currently no way to pay the costs of exemplary studies. They have put their fingers on the crux of the problem. Radiologists may have been forgiven for doing what they are paid for and recounting their experiences in the classic case-report way. But the costs of medical care have risen too high to allow that to continue to replace adequate technology assessment. The situation is becoming worse rather than better because the third parties have begun to refuse to pay for new and expensive technologies until they are established as useful. Both CT scans and MRI achieved that status by a very slow process, and the fact that early trials had to be "bootlegged" is reflected by their poor quality. But that same poor quality is responsible for wasteful duplications in the use of modern imaging procedures.

Evidence that the above statement is not an exaggeration and that PET follows the same vicious pattern² are two major reviews on PET published in 1991 (Alavi & Hirsch) and 1994 (Koh et al.). There again, the professional assessment is uncritically biased in favour of PET and the conclusion (Koh et al., 1994; p. 323) is the same cliché:

While further clinical validation is required, PET promises to provide vital information complementary to present anatomical imaging modalities that will aid oncologists in optimal management of their patients.

3. Collection of Data.

Qualitative sociological research offers a lot of freedom

in collecting data, but requires a lot of intellectual discipline in interpreting them. In an attempt to avoid a mismatch between these two aspects of the adopted ethnographic strategy within the limited scope of this thesis, only the following data sources were used: non-participant observation, analysis of documents available at the MNI&H library, and interviews.

a) *Observation*: In the Spring and Summer of 1994 I attended two thematic seminars organized by the PET group for the institute's research and clinical staff, and three open lecture series with invited speakers from the US and Europe. From May to September I was also auditing the special Brain Mapping Seminar, which is a permanent forum for discussing research problems among the different projects using PET in this institute. In November 1994 I followed the discussions organized on the occasion of the 60th anniversary of the MNI&H in the form of an open house and a two-days scientific session. In the role of an experimental subject I spent four days observing the operation of PET and MRI equipment and I had several hourly visits to observe the computer interpretation of recent and stored data. Regrettably, an unexpected accident with one of the PET staff members barred me from attending the Monday working meetings of the Neuro-Imaging Lab (NIL) as well as from having access to the grant applications of the PET unit. During the period when I actively visited the MNI&H (January-December 1994) at least 3 times a week, I have had a number of informal

conversations and discussions with PET people and managers which helped me a lot in structuring my interviews and provided me with 'unofficial' information about the local social worlds.

b) *Documents*: In the library of the MNI&H I found the annual reports of the institute from 1979 to 1994, historic publications about the development of technologies, including BI technologies, in the MNI&H, minutes of a Retreat held in the Fall of 1992, the preliminary and the final reports of the Panel for the feasibility study for the McGill University hospital centre, where the MNI&H is included, and the legacy in print of Dr. Penfield.

c) *Interviews*: I started my interviews in March but the majority of them occurred during November and December 1994. I use here data from 7 interviews and 1 exchange of letters with staff ranging from PET researchers to hospital administrators. My access to people was not easy mainly because of their busy schedule, but only in two cases was I refused an appointment. The interviews lasted about 2 hours each and were tape-recorded.

The interviews were structured around three themes: 1/ what accounts for the fact that "a strong movement to gain approval for [PET] use as a clinical tool" is being unleashed in the neuroscientific community (Freeman & Blaufax, 1992)? 2/ what has made the MNI&H into a promoter and host of a leading edge BI technology such as PET? 3/ what characterizes the social actors and the material resources that made it possible for the MNI&H to keep its leading position in neurosciences, the treatment of

neural diseases and BI?

I have formulated my questions so that they evoke a spontaneous assessment of PET by the people who have dedicated their careers to its career, either as runners of the modality or as its users. Not surprisingly, to a third category of people, the hospital managers, PET seemed to be of less interest, although they have demonstrated deep insight into the problems of BI and new technologies.

I obtained multiple answers related to everyday activities, concerns, expectations, experiences, and opinions, which animate the local BI world and which demarcate the basic level of existence of this world within its natural arena: the neurosciences and the care of the neurologic patient.

On a second, more abstract level, the discussions of these themes revealed how people cope with these realities, translated into values such as prestige, authority, research demands, research ambitions, research ethics, patient care, rules and regulations, etc. The coping process exposes the local characteristics of BI and the BI world, the views and attitudes of the local actors toward BI, the dynamics of their personal and group interactions, the properties of the negotiation process that drives this dynamics forth, and some of the interactions of this world with similar or functionally related worlds outside the MNI&H.

One general characteristic of the personal accounts is their unanimity: I could not single out any major contradictory,

conflicting or controversial statements either between the different interviewees' opinions or in the claims of any single informant. This shows the high degree of integration and homogeneity of the local PET world, in spite of the heterogeneity of the disciplines involved in its performance.

Another notable feature of these interview data refers to the activity with which every interviewee is associated. As a matter of fact, I tried to cover the whole spectrum of institutional activities which may be reduced to variables between two extremes: researchers (one manager defined them as people "who will never look at a patient") and hospital managers (who, for instance, say "I don't have anything to do with the running or funding of PET"). In-between them there are people who combine research and managerial functions. The point is that one may trace a clear correlation between the judgements about PET/BI and the location of the person within this spectrum. The more one is close to the research pole the less concerns are expressed about the clinical utilization and cost of the procedure and, on the other hand, the more one is embedded in the hospital management reality the more pragmatic and closer to the cost/quality aspects of patient care are one's preoccupations.

4. Limitations of the Method.

I will analyze the story of imaging related to the introduction and adoption of PET in the MNI&H on the basis of

the interviews, my notes taken during the attended events, the documentation at my disposal, and the publications of local PET researchers. Thus, it is important to stress that my analysis is based on the actors' perceptions of this story rather than on my considerations about the processes and the factors that played a role in the construction of the local PET world.

Barley (1990) distinguishes three vantage points in similar research conditions: synchronic, diachronic, and parallel. The synchronic analysis looks for comparisons between the social world under investigation and the surrounding social worlds during the time of observation. The diachronic analysis aims at contrasting the different periods of the development of a single social world. The parallel analysis juxtaposes identical social worlds but acting in different institutional or national environment.

As mine is a case study I did not attempt to collect data for a parallel analysis. The impossibility to apply a full participant observation excluded to a large extent the synchronic approach as well. Thus, my data collection pattern enabled me to make a diachronic analysis, which is

most comparable with a symbolic interactionist notion of a negotiated order: the idea that social structures sediment out of a stream of ongoing actions, interactions, and interpretations that gradually define the contours of tasks, roles, and relationships as well as a *technology's identity as a social object*. (Barley, 1990; p. 223; emphasis added)

Of course, the scope of the master's thesis restrains ambitions of similar complexity, and I am well aware that my data are just an introduction to a full-fledged diachronic picture of the PET local subworld. Nevertheless, even in an introduction one can

convey a good sense of the field, delineate the contours of the specified arena, and provide arguments for the possible tracks to follow with a successful research strategy, both epistemologically and within a chosen theoretical paradigm.

Notes:

1. "Professional evaluation" is the assessment carried out by all interested parties involved in and concerned with the so-called expert opinion which bears on both the performance of a new technology and the decisions shaping its career. As far as this study (and all sociological studies, for that matter) has nothing to do with any interested party, it might appear that the features of the professional evaluation have no bearing on it. After closer examination, however, the bearing is to be found in terms of the context in which the participants' interpretations about PET are situated. The assumption runs that the very people from whom an expert opinion is sought are highly interested in the diffusion of every new piece of technology and, hence, a priori biased; and this is perhaps the problem with the CEA. Evidence pro or con such an assumption is not provided by this study, but the reader must keep in mind that the participants' accounts are embedded in a everyday reality highly sensitive to the CEA, no matter if it is done scientifically or by a mouth to mouth way. For the purpose of clarity, I dedicated a separate section on the professional debate about PET and MRI in this chapter, while providing a discussion of the assessment data collected in this study in the corresponding section 4 of chapter III (pp. 79-93).

2. To buy and implement imaging technologies, the hospital managers need data about their efficacy and safety. However, in order to get reliable, unbiased data about efficacy and safety, research has to be done in clinical environments, which is

virtually impossible if the equipment is not already purchased and run appropriately. In practice, practitioners and clinical researchers in the richest institutions press the administrators to acquire the new technology while it is still in its research phase. This preliminary use provides enough data to convince manufacturers that the technology can be marketable and they begin to offer it at a high price. Once in the market, the technology seems to acquire a life of its own, which is almost independent of assessment considerations.

CHAPTER III

THE PET WORLD OF THE MNI

"We are all one family."

MNI&H manager

1. Introductory Remarks

As was suggested in the first chapter of this thesis, the PET world (as the latest subworld of BI) can be regarded as a cross-point. It can be reached by following its history in the MNI&H, where part of it is encoded. It can be traced along through the different places around the world, where another part of it will be uncovered. It can be told from the perspective of the medical industry, where a third stage for its development was set up. It can be walked through from the standpoint of the wealthy donor, who is pushed by fundraisers to provide financial support for its building and running, and this will be a complementary side of the story. There is also the pathway that medical practitioners are expected to climb up to begin using PET and sending patients to be tested with it. Still another alternative to approach PET is the optic of the manager, who is preoccupied to fit it into the budget and to arrange a good schedule for its practical use. All these lines of activities are interacting and negotiating among them, and at the same time they are keeping their features as distinct social worlds.

The perspective of the MNI&H chosen for this study will be presented diachronically: PET is a world which developed in time

by obeying certain rules as well as by interacting with a changing environment. The assumption is that this particular institution will demonstrate essential features of the genesis and career of a frontier technology. In other words, it may give clues as to how a local social world is constructed around a frontier technology.

The approach used in this study is the analysis of participant-centred accounts. This approach focuses on local actors' perceptions of the dynamics of their micro world and the interactions it establishes with the macro worlds of brain research, health care, health education, health industry, and health policies. From the collected empirical data, the following factors/processes can be identified to have played a role in the construction of the local PET world: contribution of personalities; the institution; tradition; assessment of PET; sense of quality; size of the emerging world and of its local environment; key elements of the environment such as cost, funding agencies, and manufacturers.

Intertwined with these factors are participants' opinions about questions discussed or neglected by the literature about medical technologies, such as: does research or clinical use, or both determine the future utilization of the technology? does this technology trigger changes in the pattern of care for the neurological patient? and is the quality of patient care an argument in the assessing strategy of the new technology?

Banta & Vondeling's (1994) article on assessment strategies

of health care technology focuses on the choice of the right moment for evaluation with regard to the decisions enhancing or impairing technology diffusion. These authors are, in fact, emblematic for a group of health technology assessors endorsing effectiveness as a key concept in evaluation. Yet, effectiveness is used by this group of authors as a self-explanatory concept, whereby health needs, health status effects, health care effects are ranked on the same level as social consequences, policy relevance, and R & D consequences, but the issue of quality of patient care is not addressed specifically.

Another, rather contrasting stance is the one of Rosch & Kerney (1985), whereby technological evolution, viewed as the "evil" side, is opposed to the holistic health movement in an attempt to re-define the doctor/patient relationship in such a dynamic environment. Again, the quality of patient care is only tacitly implied.

In both cases the structuring role of new technology is grossly defined, if not almost taken for granted, and consequences or modulating strategies are addressed. In both cases, also, considerations of research use are excluded a priori from the analysis.

An earlier article of Mechanic (1977) discusses the role of hospital bureaucracy in rationing health services in terms of "how changing technology and organization affect not only the provision of medical care, but also the underlying assumptions of practitioners and patients" (p. 6). Although a claim is made

about the provision of medical care, the author's focus is on the conflicting interests between hospital managers and physicians with regard to technology utilization, but not on the very technology as a cause for structuration. Littrel (1989) argues that new technology acts as a strategic resource for bureaucrats in the struggle between hospital managers and physicians to control medical services, but fails to address the seminal issue of possible changes in the very pattern of the medical service. Such changes might indeed influence the adoption and diffusion of a given technology beyond any strategy of CEA or bureaucracy/physicians divergences. In this context, a case study of a research cum hospital institution such as MNI&H might be able to effectively highlight factors of structuring of a local world around a technology, which might prove useful for any assessment strategy carried out on a larger scale.

A stance which fails to address the 'micro' questions of research vs. clinical use and of change in the pattern of care toward an amelioration of quality of patient care is the one adopted by a Houston PET researcher (Mullani, 1992). This author claims that in the era of cost containment of health care delivery the main concern of the actors in the health technology arena should be to assess how the available and newly emerging imaging modalities improve the accuracy of diagnosis¹. It is between these two issues - quality of patient care and cost containing social environment - that the local participants

located their opinions about the factors which have played a role in the structuring of the highly competitive local social world of PET.

2. Historic Facts

The Montreal Neurological Institute (casually called 'the Neuro') was inaugurated in 1934. It began its existence as a derivation from the Royal Victoria Hospital, but as an institution it has always been administratively related to McGill University. Its founder and Director until 1959 was Dr. Wilder Penfield.

In 1937-38 an EEG Department was opened in the Neuro to become an axis for the management of epileptic patients and the brain research during the Second World War and up to the 1970s when the variety of BI techniques were introduced. Neurosurgery was the core clinical activity of the MNI since the very beginning (Dr. Penfield himself was a neurosurgeon), and neurophysiology and neuropsychology developed here as the core research activities for studying the brain. Herbert Jasper, the Director of the EEG Department, embodied the neurophysiological orientation, aided by Penfield himself, by Dr. Boris Babkin, a Russian and a follower of I. Pavlov, as well as by eminent visiting neurophysiologists from the US. Donald Hebb, the father of neuropsychology, chaired the Department of Psychology at McGill from 1947 until 1958 and after him Brenda Milner came to command in the clinical research program in neuropsychology at

the MNI. The neurosurgeons trained by and successors of Penfield are Theodore Rasmussen and William Feindel: Rasmussen became Director in 1959 and in 1972 Feindel took the leadership from him to exercise it until 1984. All the above mentioned persons, except the deceased Penfield and Hebb, still keep offices and labs in the MNI&H.

In 1972 the first CT-scanner was purchased with support from the Webster fund and the Quebec Ministry of Social Affairs. In 1975 the first trials with PET began with a revised camera on loan from the Brookhaven National Laboratory (Upton, NY). In the same year Canada's first whole body CT-scanner was installed here.

In 1978 staff physicist Chris Thompson and Dr. Lucas Yamamoto, who moved to Montreal from Brookhaven in 1973, built a PET camera for imaging the brain using for the first time in the world bismuth germanate crystal detectors and original software design for the construction of images. In 1981 the first medical cyclotron in Canada was installed in the Neuro, so that a full PET unit was organized composed of the cyclotron, the radioisotope lab and the PET camera. The abundant clinical contingent of the Neuro was meant to provide cases for basic and clinically related research projects. And it actually did so, and still does.

In 1984 MRI equipment was purchased. It was replaced 10 years later by the latest market version of a Siemens MRI-scanner, which now operates in the MNI&H.

As to the PET story, the camera built in this place in 1978, called Positome II, was used here until 1989 when it was phased out and sold to the University of Leipzig, Germany. Meanwhile an improvement of its design led to the version called Positome III, which was the prototype camera built by AECL in 1982 and installed the same year in the MNI. However, AECL failed to become a successful manufacturer of PET cameras. The Positome III was sold to Rigshospitaliteet in Copenhagen, Denmark, prior to the acquisition in 1989 of a new Swedish PET camera, the Scanditronix PC-2048-15B, purchased with financial support from the McConnell Family Fund. A big 4-year grant from the McDonnell-Pew Foundation was given for neuropsychology studies with PET, and basic PET projects were funded by the Medical Research Council of Canada (MRC), Natural Sciences and Engineering Research Council of Canada (NSERC), and several pharmaceutical companies.

In 1986 the availability of equipment for three BI techniques prompted the establishment of the McConnell BIC. This was an organizational unit set up to coordinate and carry out basic and clinical research using PET, MRI and the PET/MRI combined imagery. In 1988 the BIC was structured into four subunits: PET, MRI, MRS and neuro-imaging laboratory (NIL). The NIL and the PET lab concentrated researchers who run the PET unit and conduct research based on PET imaging, which from its very onset was called *functional neuroimaging*. The BIC is currently coordinated by a physicist, whose career started in

1979 with AECL as the person in charge of the Therascan to be installed in the MNI in 1982. He switched position in 1984 to research with PET and gradually became the leading runner of the PET modality in the MNI&H.

An important event with a long-term impact on the organizational structure of MNI was the imposing upon it of an administrative split of the management into research management and hospital management: in 1984 the Penfield's Neuro was effectively separated into institute and hospital, but they remained as one institution. It became, to use the words of one of its managers (interview, Nov. 23rd, 1994), 'institute *cum* hospital'. Or, because the buildings are owned by McGill University, the institute stood as the lessor and the hospital stood as the lessee. Two general directors have been appointed: one for the institute and one for the hospital. This separation has some controversial budgetary and organizational consequences which will be discussed later in this chapter.

3. Role of Tradition

Amateur historians, and many elite doctors among them, like heroes and are usually proud to name those who have clearly contributed to an important event. Sociologists, on the contrary, prefer anonymity and use confidentiality as a condition for objectivity. In the case of the MNI&H, where the institution is overtly identified, I long agonized over this dilemma before deciding to take a middle position: to name those

who are unanimously recognized as important contributors to its history and to keep the informants' names anonymous. This decision came after the realization that the participants of this local world seized every opportunity to point out the contribution of certain personalities and expressed often their perception that what in sociology is called interaction and negotiation is "to some extent subjective" (interview, Dec. 12th, 1994).²

So, beyond naming actors, there is the problem of whether this 'some extent' is measurable. One may find a relevant discussion about the structuring role of actors' behaviour in Barley (1986). He juxtaposes the view of those students of technology who portray structure in a technology setting as a template for action to the contrasting view of others who treat structure as deriving from human behaviour. His dissatisfaction seems to be that this alternate conception of structure has not yet seriously permeated the study of technology, since, in his opinion, a full account of structural change - and in the case of the construction of a PET world in the MNI&H we have exactly this - requires a synthetic view of structure as both a constraint on and a product of human behaviour. Goffman (1983) has observed, in this respect, that actors in everyday life are simultaneously the marks and the shills of social order.

Following Strauss's (1978) tradition for conceptualizing the structuring role of the subjective factor on the basis of everyday life events (negotiated-order theory), Barley has

studied how the institutional realm and the realm of action configure each other. It is interesting, therefore, to see how MNI&H actors themselves perceive both their own behaviour as 'producing' structure and the institutional establishment as a factor formatting their endeavours.

a/ **Contribution of personalities.** It looks only very natural to begin the narrative about the BI people in the MNI&H by a statement, which two of them made in 1978: "The great attraction of positron imaging is that it can show us not only how the brain looks *but how it works*." (Feindel & Yamamoto, 1978; p. 637). To discover how the brain works has been a dream since the time the neurosciences were founded. But to claim that this dream might be fulfilled just by a newly introduced imaging technique speaks a lot more about the people who dared utter the claim than about the technique itself. Who are these people? And how did they arrive at such confidence in a piece of equipment?

There is no historic account that omits to relate the date of the opening of the MNI to Dr. Wilder Penfield. Feindel (1992) points out that the genesis of Penfield's project was fertilized by the exposure of Penfield to Charles Sherrington's course in physiology at Oxford³, by his 6 years of neurosurgical work at the Royal Victoria Hospital in Montreal, and by his exploratory visits to many major medical centres in Europe prior to the opening of the institute. Under Penfield's direction the MNI became the generator, promoter, or host of several trends in modern neurosciences, such as neuropsychology, experimental

neurophysiology, the study of neuromediators, the localization and the surgical treatment of epileptic seizures, and the mapping of brain functions. It also became the place where new technologies have been introduced and developed. There must be no doubt that in terms of the latter a successful pattern was set up in the MNI from the very beginning.

The original example of this pattern is electroencephalography (EEG). Penfield's core clinical interest was epilepsy and the technique of recording the brain's electric activity seemed to be the tool of choice for examining epileptic patients. Penfield himself admitted that until 1937 he "did not know that there was such a thing" (Penfield, 1972; p. 9), but when in the early 1937 he was invited to talk at Brown University in Providence, Rhode Island, he met there Dr. Jasper, the American who had introduced EEG in the US in 1935. Jasper persuaded Penfield to operate in Montreal upon some of the patients that had already EEG-records, and the operations happened to be successful. After months of commuting between Providence and Montreal, Jasper was permanently transferred to Montreal, where he is still working. Jasper's account of his settling in Montreal tells us *inter alia* (Jasper, 1991; p. 534):

My move to Montreal was made possible by Penfield's friendship with Alan Gregg, then in charge of medical sciences in the Rockefeller Foundation. He was able to get my operating grant transferred from Brown to McGill, with additional matching funds for building an addition to the MNI to make room for our laboratories which had not been considered in the original plans of the Institute. Matching funds were also raised by Penfield through the generosity of private donors and the City of Montreal.

The EEG diffusion is described by the actual Director of the EEG Department, Luis-Felipe Quesney, as "the first properly

planned clinical and research EEG unit anywhere."

Jasper applied the EEG to the greatly improved selection of epileptic patients for surgical treatment, cortiography began to provide important clues on the initiation and propagation of electrical discharges in the human brain and [...] the EEG laboratory sparked off a vigorous productivity in experimental neurophysiology that has continued at the Institute over the years. (Quesney & Feindel, 1991; p. v:)

In this publication and elsewhere (for instance, cf. Feindel & Yamamoto, 1978; Feindel, 1991) another track of local tradition is singled out as vital for the local affinity toward imaging technologies based on radioisotopes. It is from McGill University that Earnest Rutherford and Frank Soddy (who first coined the term 'isotope') reported in 1902 their studies on the nature and cause of radioactivity⁴. Dr. Robert Bell, Rutherford Professor of Physics at McGill, reviewed in a personal account to Dr. Feindel the connection between the positron in physics and the application to PET, concluding that "the number of scientific laws and concepts involved in the successful use of PET is remarkable" (Feindel, 1991). It is McGill's Department of Physics' cyclotron which provided the isotopes for the first local attempts to scan the brain with the loaned PET camera in 1975 and further on until a medical cyclotron was purchased by the MNI in 1981. This link between the Department of Physics of McGill and the MNI was stressed as vital also by many of the informants in this study.

The participants in the birth of Neuro's traditions unanimously claim that the vision and the will of one man created an institution (a complex social system, indeed) to fulfil two interrelated tasks: to treat brain diseases and to

study the brain⁵. Unquestioned authority, close links to the fund givers, and a talent to appropriate the needed people according to the priorities of his agenda characterize the leader of this enterprise. In the words of the first Director of the EEG Department, Dr. Jasper, this reads (Jasper, 1991,; p. 535):

We were all inspired by Dr. Penfield's dream of a truly multidisciplinary neuroscience Institute, combining basic research laboratories in neuropathology, neurophysiology, neurochemistry, neuropsychology, neuroradiology with clinical neurology, and neurosurgery, working together as a team. It was the achievement of this dream that attracted fellows from all over the world for research and training.

A hospital manager, whose background is medicine, related the MNI mission and actual status to Penfield as well. Showing an architectural sketch of a cross-section of the original MNI building, he explained (interview, Nov. 23rd, 1994):

For many people around the world there is the MNI, which in the way Penfield organized it was: three floors of patient activities, another floor for laboratories that were mainly for clinical activities, including radiology, and on that same floor the operating room suits, and then three floors above that were for research laboratories dealing with the various kinds of problems the patients came to us with. So, the whole principle of the bench-to-the-bedside which is the essence of any major teaching hospital really was developed here from the ground up.

There is no hesitation in those words that it was Penfield who set up the structure of the institution. In contrast to Barley's (1986) observation of techno-centred social worlds, where personal contributions are sunk into some routine repetitive interaction with and around a machine, it is not the anonymous role of human behaviour that is advanced here, but the leading, authoritarian impact of one personality.

Dr. Penfield's personality and his vision emerge in another hospital manager's view in the context of the appointment in

1992 of a new director of the MNI&H ("the first who came not from the family"):

"Dr. Penfield, he used to be very charismatic, powerful brilliant man and the whole situation was different... He ran this place, he didn't have to ask anybody for permission or authority to anything he wanted. If Dr. Penfield needed money he picked up the phone to his great friend Duplessis, who was the premier of the province, and he was great and close friend with John McConnell, one of the wealthiest foundations in Canada, and so... no problem. And he ran this like a very tight ship, people were either devoted to him or not so devoted to him... but if you came here, and it was a great privilege to come here, and I think it still is, but you played the game by Dr. Penfield's rules. They happened to be, you know, because he was world famous and so the rules were pretty good and worked. But this is still so, even after he retired, with Dr. Rasmussen who worked with him, and even with Dr. Feindel who had worked with him and was trained by him. So it was, I remember the Dean telling me that the Neuro ran like a private club. And it did! Well, then... It was successful. (interview, Dec. 1st, 1994)

The implications of the above narrative are: to be sure, changes of persons are important, and also, changes in persons tend to modify the original vision about the whole institution, but the charismatic figure of its founder has left a lasting imprint on the institution.

Dr. William Feindel, who was to become the director of the MNI in 1972 and to hold this position up to 1984 (the years of flourishing of BI in the world and in the MNI), reported in 1962 of his own contour brain scanning with radioisotopes (Feindel, 1962). In 1975 he brought the emerging idea of positron imaging here, because he was personally involved in brain imaging studies and he had information about the experiments with positron imaging going on in the US. But still before the notion of positron imaging had appeared and long before he became director, he knew a man, who used to work with radioisotopes and brain tumors in Brookhaven and invited him to work in Montreal; this man was a neurosurgeon with special love for nuclear medicine (interview, Nov. 25th, 1995).

Lucas Yamamoto is the person who everyone in the field (including he himself, personal interview) recognizes as the inventor in 1966 of the circular array unit used in Brookhaven for scanning the brain. He and the camera were later transferred to Montreal to become the basis of the 1978 PET camera built by Chris Thompson with bismuth-germanate scintillators (personal interview). At this time Thompson was a staff computer physicist interested in instrumentation.

Dr. Feindel also forecast that if the CT-scanner was so quick to invade the medical establishment in 1972-73, another kind of tomography based on a different signal-producing principle would soon be born.

It was these three men's cooperation, fertilized by the general vision of one of them and the creative talent of the other two, that actually planted the seed of the emerging PET world. Had it not been for the three of them to join their personal qualities, the story of PET in the MNI would have been quite different. Everyone here recognizes that the difference between having participated in the design of a new technique and having just bought an apparatus with somebody's donor money is not a trivial one. A participant in this pioneer enterprise points on the difference:

Hounsfield built CT-machine for commercial purposes, and we bought it totally from outside. But before this, he came to Brookhaven to look at the work there. PET is built initially here, [in the MNI,] we built it, and then in 1978 we had the First International Symposium on positron imaging here. At that time our bismuth detector was the only one in the world. And Hounsfield came to see us then. (interview, Dec. 25th, 1994)

The PET camera was built with the ambition to demonstrate

its usefulness to the scientific community at the First International Symposium on positron imaging held in Montreal in 1978. A specific flavour about the atmosphere at the time provided one of the participants in these early events (interview, Dec. 12th, 1994). In this account several structuring factors are mentioned in the way they interplay in everyday life: personal contacts, money, the casualness of interaction, the intuitive assessment of the new technology, and the size of the group. So, after the Brookhaven machine worked for 18 months in Montreal, the people running it heard about a new kind of detector, the bismuth germanate crystals, six of which the director was able to purchase immediately for trial. After successful experiments were performed,

I had a discussion one day with Dr. Feindel, it was actually the end of October 1977, and he said to me: 'what you are going to do with these measurements that you've got? It looks very promising. Where are you going to go from here?' And I said: 'Oh, I think, based on that, it would be, it looks as though it will be very worthwhile to actually build a system, a machine that is based on those'. And then he more or less said: 'How long it will take and how much it will cost? How long it would take to build?' You know, just, I mean, we were standing outside the washroom, discussing this, it wasn't a formal meeting, it hadn't been something like today was the day I was going to present these things, it was just a very... sort of, in the corridor, I don't remember where it took place. But it could have been anywhere, there was not any particular reason for us to meet at that particular time.

After this discussion, the Director had no problem to find the money for purchasing 64 crystals and he set the task to the physicist to build a machine within the 8 months remaining till the June 1978 Symposium. The machine was built, proper images were made, and a successful presentation at the Symposium took place. As the constructor put it, "the machine actually became not only used, it became useful". An interesting remark concluded this story:

You know, to put that into a perspective, last year I applied for a grant to build a PET-imaging system that is going to be used for detecting breast cancer. It took longer to review that grant than to actually build this machine.

One very important circumstance in those years when PET was conceived was emphasized by him: he had never had any concern about how much it was going to cost. The director was able to come up with the money. Dr. Feindel "was great... he was fantastic for thinking ahead, you know, for seeing how useful something like this can become" (ibid.).

In 1978 Feindel & Yamamoto were aware of the limitations of this technique (p. 637):

Positron tomography, since it is almost cyclotron-dependent, will necessarily be limited to a relatively small number of medical centres in the first instance. But the history of radionuclide scanning and of computed tomography indicates that wider acceptance of this promising clinical tool is an eventuality.

These two cautious phrases are quoted in a historical review of PET (Croll, 1994) as prophetic. Feindel & Yamamoto (1978) finished their report with a paragraph, which Feindel quotes in his 1991 chapter of the history of PET (Diksic & Reba, 1991). It will be quoted here, first, because it appears in two different contexts (one being the year of euphoria accompanying the successful building of a new PET camera, the other being a moment of re-thinking the years that followed this same first achievement), and second, to point out that its author's confidence in PET has not decreased during the 13 years which separate the two publications in spite of the controversial assessments of PET clinical utility (the underlined part is quoted in Diksic & Reba, 1991; p. 6): "Computed tomography has given us splendid still-life pictures of the brain. Despite its

remarkable contribution to neurological diagnosis, it has not so far led to any new therapeutic inroads on neurological disease. The great attraction of positron imaging is that it can show us not only how the brain looks but how it works. We can reasonably expect that this technique will yield treatment for some of the many unsolved neurological disorders that affect the human brain and mind."

A PET runner said that he supports the vision that Penfield set up for the MNI "to have first rate tertiary care, neurological treatment of patients but alongside fundamental research". In the early 1980s this was extended by "Bill Feindel who wanted to introduce an imaging program, which was in many ways an update of the same vision, but with modern technology, with PET, in particular" (interview, Dec. 21st, 1994). This researcher views his task in following "in the same footsteps to develop imaging as a way of studying the brain on a system level. And that's because I think that Penfield's vision was a very simple one" (ibid.)

The other aspect of the subjective factor in the interactive process is usually advanced as a perception:

I think, it is to some extent subjective, and I think a lot of the things that have been done in choosing one technique over the other or one machine over the other do tend to be quite subjective. There is also the perception: is this something that's going to last for a long time?... And I have been involved in a number of these decisions, that I think there is an aspect, particularly if you're buying a piece of equipment, which is the first one or the second one, there is a leap of faith required,... (interview, Dec. 12th, 1994)

The subjective nature of the decisions is also underlined when interactions between researchers and clinicians are explained, for instance, how clinicians have to be persuaded of the

usefulness of positron imaging (interview, Nov. 25th, 1994). The recruitment process is also perceived to legitimately occur on the interpersonal level, although obeying institutional rules and criteria. The role of the subjective factor was, in addition, acknowledged in an oblique way, when BI annual reports got structured according to the leading researchers of projects as opposed to the initial thematic structuring.

An ongoing event allowed me to grasp still another aspect of the role attributed by my informants to personality in structuring the local PET world. I was reminded that if the original vision about the enterprise (in this case, the MNI&H) was not shared by a new leader, but was instead substituted by his/her own vision, two camps would emerge: those who stick to the first vision try to do their best to keep it working, and those who are adepts of the visions of the new leader(s) oppose or dissociate from such strategies. Basically, three crucial changes occurred in the period after Penfield: a hospital was incorporated within the institute; an imaging program using high technology was launched and carried out for two decades; and a director with another vision (the first who was not a physician, but a basic bioresearcher) came in to head "the family". These changes concerned every actor and every group and world, so that their repercussions were constantly negotiated and renegotiated on each level of the vertical hierarchy (among directors, among members of boards, among researchers, among physicians, among technicians), but they affected also the interaction between

worlds and subworlds on a horizontal level. It is essential to keep in mind that the two structural changes were effectuated under external pressure, while the functional change (a high tech-based BI project) was worked out on internal incentive and consensus. And the real problem, implied in the opinions of all my informants, is that this functional change, judged unanimously to be favourable for the objectives and the status of the institution, was put in jeopardy by the structural changes, especially by the replacement of the director.

This whole dynamics speaks, on one hand, for the strong role attributed to the director in this kind of institution, where the professionals' and technologies' careers are directly dependent on his/her will and ability to attract funds and social approval. But on the other hand, I will provide evidence below of the strength the professionals, structured in worlds, subworlds, and interest groups possess to renegotiate their functional priorities.

A researcher, who is an important figure among the PET runners, expressed his concerns in the following way:

I think there is not much doubt about it that the current director is not particularly excited about imaging. I mean, he certainly hasn't done anything to degrade it, but he is more supportive of the sort of things that he is interested in (molecular biology). I think, we were very fortunate to work under Dr. Feindel who was extremely interested in emerging technologies, and also we were proposing these things and put them together. [The new Director] thinks it's very expensive. He came with his own agenda which is incompatible with some of the things we want to do. (interview, Dec. 12th, 1994)

One of his colleagues, a PET runner, avoids such a direct criticism by proposing a sound formula for the same kind of leader/group interaction, stipulating that this is only a

general statement:

Any group is only as successful as the leader can be. And the leader has to be able to coopt the group into a vision, which they can become part of. The best leaders are the ones who have a clear vision and can articulate that vision to the people in the group to the point that the people of the group identify with the vision. (interview, Dec. 21st, 1994)

This general statement implies, in fact, a trust that a director "who came with his own agenda" is bound to fail in the local conditions, whereby this leading PET runner views himself as part of the group which supports the vision set by Penfield and Feindel for the MNI.

Accounts of the episode with the director came, in fact, uninvited: this was the only topic the interviewed people spoke about without being asked. Juxtaposed to their accounts about the past leaders of the Neuro, it seems to have a significance larger than if it was just an episode, and that justifies why I include it in this section. This episode actually speaks of a mood of threat and tension in all relationships in the MNI&H. And it might be considered as negative evidence for the importance the leader of such an institution has for the maintenance of its structure. On the other hand, I imply that the result of this rising antagonism between the leader and the social organism will indicate whether the Neuro's neurosciences arena has indeed embedded in its structure the vision set up by the first directors, as my informants suggested.⁶

b/ Contribution of MNI&H. Vision is what some personalities have and creative talent is what others perform to materialize this vision. The social structure resulting from the interactions of visionaries and performers - in the present case



this structure is the MNI&H - stands as an autonomous factor of change and stability. If we follow Barley's (1986) narrative, the negotiated order of this institution might be driven by actors' interpretations of events, by access to resources, and by moral frameworks that legitimate this order, but it might be, on the other hand, constrained or enforced by technological innovation and economic change. It is, therefore, important to report actors' interpretations in an attempt to assess how they perceive the role of the institution, which is the cradle of their careers, in the construction of the peculiar PET world. In this same line of thought, they have acknowledged the interference of the changing economic environment as a factor of constraint.

Feindel (1992) says that at the day of its opening the MNI was a "hybrid, unique in its time, a 50-bed hospital for patients with neurological disorders combined with a research centre for the scientific study of the nervous system" (p.176). As to the money, it was the Rockefeller Foundation that provided the initial and the continuing funding for the MNI, following a tradition established in 1921 to award grants to McGill University for biomedical research and clinical development.

In Penfield's proposal, underwritten by McGill University, the goal of the project was defined as (after Feindel, 1992; p. 176):

to provide a centre for neurological thought that would serve the whole continent and where clinical neurology and neurosurgery would be carried on in the same building that contained up to date laboratories for neuropathology, neurophysiology, and the anatomy and psychology relating to the nervous system.

It is not surprising that, in this vein, MNI&H was among the first clients of the British Electrical and Musical Instruments (EMI) firm to purchase in the middle of 1972 its newly launched CT-scanner. The British physician who first proved in 1972 the utility of this device in clinical trials at Atkinson Morley's Hospital in Wimbledon, England, Dr. J. Ambrose, was invited to report on it in a Thomas Willis lecture in December of that same year at the MNI. The First International Symposium on CT-scanning was held at the MNI in May 1973 and here a consensus was reached that the name 'CT-scanning' be coined on this new visualizing technology combining X-rays with a computerized construction of an image.

From 1978 on the process progressed: the MNI began to look for people to ameliorate the camera and the technique itself and at the same time to build up the infrastructure for a full-fledged PET unit. In 1979 AECL established a partnership with the MNI⁷, but withdrew short of eventual market success, while PET hosted by the MNI was doomed to flourish. After the acquisition of a cyclotron (1981), an improved Positome III (or Therascan) PET camera (1982) and an MRI modality (1984), the Neuro seemed to be technologically equipped for large-scale imaging projects.

The actors involved in this dynamics are almost unanimous that "the environment in this place has been remarkably open, remarkably multidisciplinary in its nature. The field [of PET] demands it. Imaging program requires that you be able to

interact with many different types of scientists or physicians, neuroscientists as well as basic physical scientists. And I find the environment here as being very conducive to doing that." (interview, Dec, 21st, 1994) To put it in another terminology, the local arena of neurosciences is favourable for the thriving and growing of the BI world, of which PET is the forefront. In a more concrete light, the interaction between people from different areas of expertise is described by a physicist working in a biomedical setting in these terms:

Q.: Do you feel that this is a kind of limitation that you are not a doctor in your endeavour to study the brain?

A.: I think that you could say that, but you have to say it in the context that everybody has strengths and weaknesses and some people are not able to understand what imaging techniques can do, they are forever condemned to work with the instrumentation through other people. On the other hand, the instrumentation, the methodology of imaging itself shouldn't be seen as an end, it should be seen as a mechanism for promoting biological research in a setting like this. We're not a university engineering laboratory inside the neuroscience, neurology and neurosurgery setting. So, I think that it's important that both sides recognize the importance of the other. (ibid.)

A researcher, who definitely linked his career to the MNI&H, thinks that the specialness of this place boils down to the historical mandate to study the brain, do basic science research on the brain in a clinical setting. He stresses the tradition that MNI&H has in doing system's level brain research in in vivo subjects: normal people and people with various brain dysfunctions. Thus, he claims, MNI&H becomes a natural setting for an imaging program to do brain research.

An interesting evaluation of the role MNI&H plays in imaging is expressed by a hospital manager, who claims to share Penfield's vision entirely. This hospital manager is not concerned with the problems of PET, but with the quality of

patient care delivered by the hospital. Her reasoning, therefore, is that although seeking persons who will contribute to research, any director will not underestimate the excellency of clinical work as an equal criterion for recruiting personnel. And this is so because the standard of clinical care "is what attracts patients to the Neuro and impresses the public and private donors, as opposed to other similar institutions where the research is the only impressive activity" (interview, Dec. 12th, 1994). In addition, she points out, MRI is acquired with hospital funds, it belongs to and is run by the hospital, and the hospital complies with the research needs to make its schedule most effective.

In the 1992 Retreat BI was not envisioned specifically, but in the group discussing research priorities a special recommendation was made: "to continue to develop, strengthen and capitalize on an already strong program of collaboration between Neuroimaging and other basic and clinical departments". The same group advanced that "the Neuro is a unique place where through interaction across groups and individuals with different specialties and expertise, a fundamental understanding of major integrating principles of brain and behaviour could be gleaned". Basically, all groups maintained traditional values established and well worked out in this 60-year old "family" in order to support the maintenance of the mission of the MNI&H and the structure corresponding to this mission.

A manager calls the entity symbiotic: the research aspect,

he says, was always considered to be just as strong and dependent upon the clinical side and the latter was considered itself to be very strong, but dependent on the research side. His metaphor for the actual status of the Neuro is "Siamese twins": two heads, two directors that is, but trying to keep in on one body, in which in the past "you had this very close interaction between the scientists working in the institute and the clinicians, looking after the patients. And very often this was the same people." (interview, Nov. 23rd, 1994)

But what is at stake here is not the quality of the people or of their interactions, which no one judged as insufficient, but the orientation of their work. I will quote now a PET user who reveals his feelings about how the MNI&H is conducive to a creative interaction within the structure of the PET world:

There is a very close relationship between, let's say, the neuroimaging group and neuropsychology... there was a mutually positive relationship. Because the neuropsychology groups would be coming up with very interesting scientific questions about the brain/behaviour relationship thus pushing for some innovations and on the other hand, the PET group was able not only to accommodate these kinds of modifications but was able also to anticipate and develop new tools for better analysis of the images and so forth. [The runners] generate experiments of their own. There are many experiments they would be carrying out related to modelling, kinetic modelling of the distribution of tracers. Though they don't make brain/behaviour research, they study problems pertinent to the physiology of the brain. That's clearly their own research and they have their own scientific questions that are related to brain physiology, to the pathology of the brain in different conditions such as Parkinson's disease, schizophrenia... it's hard to say who is contributing more in mapping of the human brain. (interview, May 9th, 1994)

The inverse side of the process, namely what the role of the PET world is for the MNI&H, was noted by a PET runner:

I think it's one of the things that has been developed here, has been refined, some of the innovations in the area of imaging come from here. [The cost of the equipment and running it] is definitely less to us. Because we can, and we have on, I think, on just about every major purchase that I've been involved with, been able to say: "look, if you put one of these in our place, we have the patient population, we have the surgeons that are working on this particular disease, they are going to publish papers, you are going to get free advertising on this, so that a lot of people are coming through". I think that everyone who

works here milks [the complex institution] for everything that it's worth and this would apply to our relationships in which we've applied MRI systems, angiographic systems, all kinds of things. (interview, Dec. 12th, 1994)

In summing up, we need to realize that local people trust their priorities, their cooperativeness, the established relationships, the big import of big personalities, and the joy of working together. A hospital manager drew the conclusion that in the changing conditions and the changing internal relationships support prevails over constraint. To be sure, my informants' opinions suggest the following features of the MNI&H as a home for BI: 1) MNI&H is the product of the vision of one man, extended by his followers; 2) MNI&H is an unique integration of research and patient care under the same roof; multidisciplinary activities are carried out here to provide high level neurological care to patients on the basis of fundamental research; 3) the proportion of research and patient care is balanced and efforts are constantly carried out to keep this balance; 4) MNI&H exists in its present form in spite of ongoing environmental changes, which in some instances, e.g. the arrival of an outside director, are not regarded as favourable for its mission.

These and also other similar accounts of the role of tradition demonstrate that local actors feel comfortable with the institution and try to emulate existing patterns of action when 'exogenous shocks', such as the arrival (or the creation *in situ*) of a new technology is encountered (Barley, 1986). On the other hand, they turn their backs on another 'exogenous

shock' such as the arrival of a new director who threatens to change the well established and worked out patterns. It seems that local actors determine or inherit their priorities and use the same structure (in the form of patterns of action) either to accommodate or to encapsulate the new structuring element.

However, what is peculiar in this case is that on the level of initiation, that is, when actors have begun to interact among themselves to create the structure, they had to create new patterns to serve their dreams and goals. And one may interpret their further interactions as a recreation of the structure they have built to act in. This recreation of the structure within a changing environment is, in fact, what one calls tradition. In this sense, personalities and institution (or actors and structure) that are initially regarded as factors for the construction of a social world, are in the course of time welded to become cohesive elements of this world. So, tradition becomes a process whereby structure is negotiated and renegotiated in everyday life, an interpretation which fits the negotiated-order theory (Strauss, 1978).

4. Assessment of PET by Local Participants

Another key factor, which according to the people in the MNI&H has a considerable impact on the promotion and maintenance of the PET world, is the meaning of PET within the value system that reigns over this place. The legitimation of this meaning is achieved by them through an assessment of PET on two levels:

one is PET as embedded in medical practice and research, i.e., as it is presented on conferences, in the literature, and by the actors' personal experience with the performance of the technology with regard to the purposes of its utilization; in other words, PET as a biomedical field. The other is PET as a local technique, i.e., how PET as equipment, cost, degree of sophistication, efficacy, necessity or luxury is perceived to behave in its local niche and when matched with the local conditions. On the first level the actual object of assessment are PET products and PET applications in general, while on the second one the very PET technology is evaluated as an actor in the local virtual community.

Not surprisingly, the opinions about PET as a field tend to be almost without exception on the positive side. But when things come to PET in the specific local environment, opinions and attitudes do not simply turn more subtle and more engaged; they also become indicative of the concrete, definable social world that arose because of PET. A clear borderline cannot be traced, of course, between these two situations. On the contrary, opinions related to both interact and allow judgements about this social world: the difference is that PET's general role is indirectly related to the individual careers and the health of the local community, while PET's status within the MNI&H is vital to the interests of those who run it, use it, or compete with it for research priorities and funds.

a/ **Assessment of PET as a field.** The main tenets of the

assessment strategy set up in the MNI&H to evaluate BI technologies is best exemplified by one of the pioneers of PET in this institution. When in 1975 the MNI purchased Canada's first whole body CT-scanner, a concise but for the perspective of this study very significant evaluation of head and body scanning by computer tomography was published by the Director of the MNI (Feindel, 1975). The professional part of this evaluation contains two claims: firstly, simplicity, speed, safety, and the possibility "to see anatomic and pathologic details in the living brain that before could only be detected by postmortem examination" are reviewed as main advantages of the technique itself; and secondly, "a complete change in our approach to diagnosis and management of intracranial lesions has been taking place over the past 3 years as a result of the use of the EMI scanner". Obviously, the Director was convinced still in those early years that the CT technique promoted a change in the pattern of care for the neurological patient. Such a conclusion is supported by several specifics: in Feindel (1975) CT scanning is depicted as "an ideal means for screening patients" and it is claimed that "the results of therapy can be determined and the natural evolution of acute brain disorders [...] can be followed". It is important to note his use of the verb 'to see' without quotation marks as a key-word to designate essential advantages of the new technology as well as the 'numerical' claim that the CT images "provide 100 times more information than the usual x-ray film".

Still more interestingly, Dr. Feindel went further in making a CEA of the new technique, asserting that "the initial high cost of the scanner and the somewhat stringent terms of payment arranged by the company are offset by the cost-effectiveness of the method". He pointed at three factors which increase the effectiveness: a) "examination can be made on an outpatient basis"; b) "further reduction of hospital stay because the diagnosis in patients who are admitted has already been made with a high degree of certainty from the CT scan; hence, they are treated with less delay"; and c) "decrease in performance of air studies⁸ with the increased use of CT scanning". The cost-decreasing factor was to be found in a reduction of personnel: "the CT scan, carried out by a single radiologic technician, is a far less costly staff operation than an air study or an angiogram, which requires a specialist, a nurse [...] and often an anaesthetist" (p. 274). According to Dr. Feindel, conservative estimates showed that a cost reduction could run from half a million to over a million dollars per year. But he also warned against an overexpansion of CT scanners, which should be confined to an all-round neurologic centre, because "it seems difficult to justify placing these devices in areas without the neurologic and neurosurgical expertise to manage patients' special problems" (p. 274). Thus, an explicit link was made by a director of a research institute to connect a diffusing diagnostic technology to the management of patients. Moreover, the use of technology was linked to the

availability of a specific range of professional skills, concentrated in the MNI as a clinical setting.

In a personal note to me Dr. Feindel summarized an important part of the above evaluation with respect to PET:

Part of the social history in this field has been the economic factor: cost of equipment/large savings because of shift from in-patient to out-patient procedures, higher quality detection of operable and treatable lesions and increased efficiency of use of patient facilities. (Nov. 24th, 1994)

In this statement two things are worth emphasizing: the awareness of the economic factor and the use of the notion of quality as something intrinsic to technology dynamics. It also reflects the patterned actions of local participants in constructing a world around every next new technology.

The first local evaluation of PET appeared publicly at the First International Symposium, held in Montreal on June 2-3, 1978 (Feindel & Yamamoto, 1978; p. 637):

The advantages of measuring blood flow by this avenue are substantial in that the method is non-invasive, provides an anatomical map on a horizontal plane and facilitates comparison with CT scanning.

A PET researcher is convinced that "because CT and MRI look at anatomy, you look at the picture and if you see pathology, you can immediately act. But with PET you are involved in the theory, for instance, of glucose metabolism and to understand your findings you have to know the physiology, certain tracers' physiology, and also the principle involved in this stuff." (interview, Nov. 25th, 1994)

In the 1985-86 annual report the Director of professional services, referring to MRI, pointed out that neuroimaging "continue[s] to play a central role [...] not only because of

the extraordinary contributions it makes to patient care, but also because of its impressive appetite for funds to acquire and maintain equipment". Note that the hospital administrator placed the accent on patient care and appetite for funds, while second-rating the research importance of neuroimaging.

Another opinion about PET was based on its usefulness and availability. The question was: "Why does it take so long for PET to become a routine procedure and it is still not in the clinic?" This person who as a PET runner was involved from the very beginning in the improvement of PET technology, answered that there is nothing of a diagnostic nature that PET does, which can't be done with something else.

Maybe in some ways PET does them better but the infrastructure required to instal PET in an institution is significant compared with these other imaging modalities. And so, MRI for instance is extremely versatile. And PET is versatile, too, but it's mainly in the research. You can do things with another technique which is less expensive and more available. So, cost is a factor. And I think, a lot of people regard PET as something that will answer a question as to whether a particular technique is diagnostically useful. But once that's been shown, then, it's going to be useful on a great variety of patients and so, you would better make it more available. (interview, Dec. 12th, 1994)

To sum up: cost, usefulness, and availability are explicit assessment criteria. But there are others, related to the technical advantages provided by PET; and they can only be measured as part of the overall values sustaining the medical field. Canguilhem (1988) has argued that the development of modern medicine is characterized by a shift of focus, on the one hand, from the patient to the organ to the cell to the molecule, and on the other hand, from the qualitative observation to the quantitative measurement, for the purpose of which measuring instruments are invented and developed. Among the second set of

values, quantification of physiology is a major element.

The local actors in the PET world are no exception to the above trend. Thus, a PET runner is persuaded that the primary contribution of PET as a field to the development of imaging is to be found in its accent on quantification:

Although you can look at the data that come from the PET machines in terms of visual properties where you can diagnose diseases on the basis of the images themselves, PET is being focused increasingly on quantitative results. (interview, Dec. 21st, 1994)⁹

The biggest strengths of PET, according to him, have always been that, because of the ability to produce ^{11}C , ^{13}N , and ^{15}O which can be incorporated into an infinite variety of physiological tracers, there is an almost infinite capability of PET to look at biochemistry of the brain in a way that no other technique can. While fMRI is going to be an important tool in the near future for studies of hemodynamics and cognitive activation of blood flow, it is not going to be able to do quantitative neurochemistry with the sophisticated radioligand tracers that are produced with the PET cyclotron and are counted in PET. Basically, PET and MRI are complementary, not competitive modalities. MRI (and CT) are true cameras, he contends: you take a picture of the brain, which is traditional radiological imaging, and therefore, they are immediately brought on line as clinical machines. Research use was secondary to the obvious immediate clinical benefit. But PET is quite different: it started out as a research field, it provides measurements of physiological compounds in vivo, it is very expensive, and images as well as its application in clinic are not its *raison*

d'être.

A hospital manager related PET to another value of contemporary medicine (Canguilhem's first "shift"): its molecular (some would say reductionist) paradigm. PET is unique among all imaging tools, he believes, because it brings you down to the molecule. In addition, if the research does not at least potentially inform the medical community a little better as to the basic mechanisms of certain disease states, than it has nothing to do in this building.

I asked a hospital manager with a medical background whether he had noticed a change in the pattern of patient care provision due to the utilization of new imaging technologies preceding PET. The answer was: "to an enormous degree". The example he provided was CT-scanning, which, he said, sent pneumoencephalography in the history books. Prior to CT, this procedure was the only way to visualize some conditions of the brain by injecting air in the subarachnoidal space. Although it was a routine procedure, it caused great suffering to patients, "it would have been delightful to the Spanish inquisitors". And the visualizing capabilities of a CT-scan are many times larger than the best performed pneumoencephalography could ever provide. MRI, he thinks, is quite a different technology and has not outlined CT. The "terrific advantage" of MRI is that anatomical structures can be seen more clearly than on an anatomical preparation on the table in front of you. In terms of management of patients, these technologies have promoted

'revolutionary' changes', comparable to anaesthesia in surgery. He made a last notable point about the future of PET on the basis of what we already know about the preceding techniques:

I wouldn't say within 5 years we would do PET instead of an MRI or CT-scan. And one of the factors that makes all this kind of thing a little difficult is the rapidity with which the technology advances. An MRI picture 5 years from now will make our current pictures look rather primitive. And there are certain things that PET will always be able to do and MRI will never be able to do. (interview, Nov. 23rd, 1994)

Before going on with the assessment of the local PET world, it is worth summing up the general PET characteristics as presented here by people acting in the local arena: 1/ PET is an exciting research technology to visualize neurochemistry; 2/ a view, which is not yet popular in the literature, asserts that, in addition to this, PET is a unique tool to quantify neurochemistry, whereby quantification outranks imaging; 3/ PET is complementary to the other BI techniques; 4/ PET involves many highly sophisticated people in a team effort; 5/ PET is expensive and not affordable on an average basis; 6/ PET requires highly trained specialists to be run and further developed; 7/ PET can set standards of usefulness and availability of similar techniques.

b/ Assessment of PET as a local world. The Montreal camera was named Positome II and the status of positron imaging prior to it is described by its creators: "low efficiency and low spatial resolution meant that we were always working at the limit of the machine's ability" (Thompson et al., 1978; p. 650). It is a general wisdom of the field that it is in a permanent state of working at the limit of the machine's ability. Yet,

optimism and vision are used to argue for a continuing effort to improve the technique, to expand its utilization, and to enrol (in the sense of Law, 1983) other researchers to put trust in its unexplored potential. The question "is there anyone here who would doubt the results?" was ridiculed by a PET user with the ironic answer "no one that I remember of" (interview, May 9th, 1994). Certainly, it is not a blind trust (ibid.):

There might be, of course, certain aspects of the results that people may not agree on. We are questioning them. The technique is not absolute, there is a limitation in the time course. But we are aware of those limitations.

In other words, limitations are not used as arguments against the use of PET, but rather as a starting point for further development.

One of the limitations is the lack of anatomical information in the PET images. This requires PET to be combined with MRI. The 'matching' between PET and MRI images (a technical issue) has a double impact. In institutional terms, the BIC in the Neuro is organized as a coordinating unit of joint research efforts to achieve combined anatomo-physiological BI¹⁰. In terms of research opportunities which blend technical and economic factors, however, the drive of PET is to reach the status of high quality pictures, large clinical applications, and the lower cost that MRI is currently enjoying. A typical medical assessment of BI is published by a group of surgeons from the Neuro (Feindel et al., 1991; Palmini et al., 1991; p. 586):

CT and especially MRI have greatly expanded the role of imaging in the understanding of patients with intractable epilepsy. The advent of [MRI] not only permitted early diagnosis of [neuronal migration disorders that are usually

accompanied by epilepsy during life; it has also set the stage for the delineation of an anatomically or radiologically defined classification of neuronal migration disorders.

Such type of assessment articles about PET has not yet been published by the local PET people and the reason for this resides perhaps in another opinion about the role of PET, expressed by a local PET runner. He believes that everybody in the MNI&H is aware that PET is primarily a research tool. The future of PET, according to him, is "predominantly research". There will be occasional applications which can be brought to the clinic, but PET cannot be regarded to be like SPECT, MRI, or a CT machine. As to the place of the PET unit within the MNI he has no hesitations:

This is probably the best environment for a PET centre to be in existence. It's not a nuclear medicine radiology setting, it's a direct link with neuroscience, neurology and neurosurgery. So, it's not used as a service centre, it's used as a research domain, and it's all right. I wouldn't say there is a raging demand for clinical applications of PET here, mostly because we haven't encouraged clinical use of the machine. Because PET is not a SPECT machine. We do not want to have lots of people using the PET research environment, to whistle up a PET scan, it's I think an incorrect use of the capabilities of PET. If you want to do that, you must use a SPECT machine. (interview, Dec. 21st, 1994)

In addition, he thinks that PET can do clinical work - and it does so 20 percent of the time in the MNI&H, but even so it is in the form mainly of clinical research; to use it solely for clinical work seems to him not justified. There are many PET centres out there you never hear from, he contends, and it is because, instead of doing quantitative studies to any significant degree, they use PET as a clinical machine. In other words, there is a certain tension between research and clinic, and it is not a matter of shifting from one to the other; rather, a precipitous stress on patient care use of PET risks

to jeopardize the research projects that are currently pursued to extend the unexplored measurements that PET can offer.

A hospital manager who gave an extensive account of the clinical potential of PET, nevertheless, said that unless the patients fit into a clinical protocol that is being run to study the efficacy of PET, almost no one orders PET-scanning for patients admitted for treatment in the hospital. He added:

If we were just a community hospital, I would be the very first to say we should not be putting our resources on PET. If all the money had to be coming from clinically dedicated monies, it is definitely not worth it. It hasn't yet evolved to the level of being an all-demand clinical test. But as far as putting the research money into it, researchers are pretty hard headed people when it comes to investment of money, now, PET technology does open doors that no other technology can. It does help us understand certain aspects of functioning of the brain that no other technology ever can (interview, Nov. 23rd, 1944).

An important appreciation of the specific local conditions was given by a PET runner (cited on p. 76) who thinks that the cost of PET equipment to the MNI is definitely less than to other institutions because this 'thing' has been developed and refined in this place.

It is also notable that the acquisition of MRI was due mainly to the newly established hospital management, while the BIC coordinator was particularly concerned with the local leading, competitive position of the PET group. In this context, a good deal of time and effort in 1986 and 1987 went to preparing and defending a major request to the MRC for the acquisition of a new state-of-the art PET camera. The request was granted and clinical projects on cerebrovascular disease, epilepsy, brain tumors, neuroanesthesia, and neurodegenerative disorders were planned for the coming years. The other areas of

planned research were itemized under: basic science projects, namely in radiochemistry, basic neurology, PET methodology, and PET instrumentation. Neuropsychology projects were strikingly summarized in the clinical section. It is difficult to evaluate the proportion between basic and clinical projects at that time as well as to perceive the specific problems and failures that the imaging group experienced. What is evident, however, is that PET is in the centre of research imaging and MRI is focused on the diagnostics.

Additional details regarding the institutional assessments, in which priority is given to the medical problems of PET, are provided in the annual reports. These are the *par excellence* rhetorical tool for fundraising, as plainly admitted by one of the informants for this study. They contain, nevertheless, information about the restructuring of the BIC and its activities and the ongoing redefinition of the role of PET. Soon after 1984 the available funding permitted the re-organization and the enlargement of the BI within the MNI&H. For example, activities previously carried out within the Department of neuroradiology and the BIC were unified in a new organizational entity, called the Neuro-imaging laboratory (NIL). In the beginning the NIL received direct funding from a MRC maintenance grant, Phillips Medical Systems, Siemens Medical Systems, and General Electric¹¹. During the years 1985-1991 an entrenching of PET through overgrowth with so many users occurred: the number of collaborators in positron imaging, both institute

staff members and students, increased. Particularly notable was their increase in cognitive sciences, where many projects relating neuropsychologists to linguists to physiologists have been launched. This can be interpreted as a stabilization of the structure of the PET world.

Nowadays, the established structure is not questioned any more by the participants. Notably, this structure corresponds to the functional component of the PET world, namely, the biomedical arguments for the application of PET. In all accounts the biomedical arguments are inseparable from the social ones, and as a whole, they are prevailing in the assessment strategy. They can be summarized as: unique ability to visualize and also quantify neurochemistry; unexplored research potential; a standard to assess less sophisticated techniques which can be successfully used in the clinic; best technique for understanding how the brain works; an unexplored, but promising, diagnostic potential, to be used in the neurologic clinic for raising the quality of patient care.

In terms of PET's interactions in the MNI&H environment, the informants of this study advanced the following mechanisms: 1/ the future of PET is seen in its research potential rather than in its clinical applications; 2/ PET is part of the prestige of the MNI&H because it was designed and developed here; 3/ the same reason makes PET less expensive to this institution than it would be for anyone else; 4/ PET is commonly accepted as important part of the MNI&H, but not as the most

important; yet, no one questions its future, either from a structural or from a functional point of view; 5/ PET is money consuming and this incomparably more than all other BI techniques; but no one has cared much about its local cost-effectiveness; 6/ PET has not yet entered the clinic and, thus, had not altered the pattern of patient care with regard to any disease, but the possibility is not excluded that it may do so, if it follows the evolution of other BI techniques.

One strategic tool to negotiate the structure of the PET world was to insist on what peer reviewers and the general public perceive as prestigious aspects of medical practice. Medical science in its most elitist sense was prestigious in this environment in the 1980s and is still being perceived as prestigious nowadays, and it was tacitly equated to high technology equipment: the higher the technology, the better the science. This enabled the PET subworld in the MNI to overcome its embryonic state by satisfying its appetite for funds and thus successfully carrying out several research projects. There is hardly a mention of another arena of action of this subworld than the arena of research; while the determinant 'clinical' is stuck everywhere to 'research', even the diseases studied were viewed in the context of research only. Thus, one cannot draw conclusions about the impact which the routine clinical environment would have had on PET, except that it did not show any affinity for absorbing PET as an everyday diagnostic device (as it did for the MRI).

To sum up, local participants do not consider the very assessment of PET as a structuring factor; they praise the positive result of the assessment as a tool for negotiating high social status for their world. It is impossible for the sociologist to dissociate with precision the sheer rhetoric from the indisputable truth in such an assessment, which is, in fact, a set of opinions rather than a rigorous set of criteria applied by a neutral observer to evaluate the performance of PET. These opinions, embodied in grant applications, annual reports, scientific publications, and mouth to mouth talks, are used for negotiations on two levels: one is application for funds with organizations that subsidize research, the other is persuasion of local hospital managers that successful research has an irrefutable impact on the quality of patient care. On both levels the interactions are characterized by tension: researchers defend their right to explore the new technology either against the government policy of spending cuts or against the clinicians' jealousy that patient care is second-rated to research by the local management. Complaints about the increasingly cost containing environment are scattered among the answers of my informants on several occasions (for example, cf. p. 67, p. 82, p. 98). On the other hand, the main problem to handle in this institution is identified as a tension between institute and hospital, that is, between research and clinic, because of the subsidizing mechanisms that privilege the institute (see p. 107) as contrasted to the leading role of

patient care in maintaining social prestige for the whole institution (see footnote 12, p. 75, and p. 89). In both cases an assessment strategy, which combines assessment of the products of the technology in terms of excellence in research and patient care with the estimates about the cost of the equipment and the running of the technology, is used to negotiate for funds and priorities.

Positive assessment is a powerful argument used by the participants to legitimize their world. The local assessment's main goal, it should be pointed out, is not to provide 'the true' value of PET, but to maintain the prestigious status of the local world. In this sense, it is a legitimate negotiating tool to accommodate technological innovation and to oppose unfavourable economic change, thus attempting to preserve the stability of the whole structure (Barley, 1986). On the other hand, the assessment of local participants stands aloof from the professional debate, reported in the preceding chapter (pp. 34-41), because local actors adopt the vantage point of pioneers. Vision and mission are notions that circulate routinely in this local world. In this sense, their positive assessment preceded the promotion of PET. It was this assessment that planted the seed of the local world of BI and positron imaging respectively, and subsequently, was a factor in maintaining the status of this world.

5. Quality as a Structuring Factor

In the personal note of Dr. Feindel that I already quoted in another context (p. 82) he claimed, based on his own experience, that every new technology, including PET, allowed savings of funds because of its higher quality performance in the clinical settings. He did not care to define the notion of quality using it as a taken-for-granted element of the dynamics of technology.

In a chapter about the history of PET (Diksic & Reba, 1991), in a section on the "Scope and limitations of PET" Feindel made another significant claim: "the continuing improvements in methodology, camera design, spatial resolution, and imaging quality coupled with innovative radiochemical techniques have led to greatly improved results in PET research". Note, again, the use of quality in the context of 'continuing improvement' and that quality in this case is referred to research but not to patient care.

Since patient care and research are indeed the two key functions of the MNI&H, their association with 'quality' may be interpreted as a perception that quality (no matter how poorly it is defined in the literature) is a factor with a substantive role in the structuring of this institutional world, a factor, that is, which accounts for the satisfactory accomplishment of its main functions.

Among participants talk of quality often parallels talk of excellence. Thus, the sense of quality as a structuring factor was noted by a PET runner (interview, Dec. 21st, 1994):

Once you get off of the ground and you build up the infrastructure and the user community as well as the scientific community around the PET program, [to buy a] new machine, although it may be expensive in terms of capital cost, is easy compared to start such a program from scratch. It is extremely time consuming and expensive to attract people, to train them, to bring them to the level of excellence, where they can function at the leading edge of the field.

When asked to define quality, a researcher puts it as "significant biological import of the findings backed up by the methodological rigour and reproducibility of those results" (ibid.). His contention was that the standards are set by the peer review process:

We have to adhere to rules and regulations that are in the scientific field. And one of the strengths, I think, of PET as a field is that it is really trying very hard to introduce mathematical, physical rigour into biological problems. In terms of functional neuroanatomy of the human brain, [the quality of PET is] absolutely [superior to what precedes it]. There has been nothing like PET. I think the field is mature to the point where you can get and buy the scanners and you can buy the software tools that allow us to analyze data in a fairly standardized reproducible fashion all over the world. Any scientific field has to go through a peer review process and ultimately it is going to be reviewed by a bureaucracy that doesn't understand exactly the details of what one is doing. And the bureaucracy has to rely on the peer review process. (ibid.)

Another researcher's view of excellence addressed the perspective of local interactions. He claimed that the standards of quality within the BI world of MNI&H were assured by the many interactions going on within the Centre, whereby everybody would get comments on particular issues even before a given study would begin.

In all the above statements quality figures as a perception. But this is a perception with a powerful impact on attitudes and the fulfillment of the roles everyone plays in the MNI&H. These data demonstrate that in terms of quality PET is viewed by the two interacting communities - researchers and clinicians - as a technology with strong performance in research but still not sufficiently qualified to perform in patient care.

It is a truism in public health that cost containment strategies run the risk of downgrading the quality of patient care. The possible outcomes from such a cost-quality dependence in terms of PET utilization as a diagnostic tool were tackled differently by my informants, although with the common concern that care quality had to be maintained "high" whatever the price.

All the hospital managers I have talked to repeated what is regarded as the standard line, but tried, in addition, to assign new meaning to the cost-quality pressures. And they all confirmed that in this place the high standards of care were set by the high quality of research that is carried out¹². On the other hand, researchers, but not in all instances the management of the institute, are very well aware that the standard of research depends on the patient contingent, because what really impresses the public and governments alike is patient care. And the 'institute cum hospital' institution lives on this dialectic.

The conventional reasoning of the hospital manager sees no dangers because of the benefits from the technology:

In a general way, technical changes like that have had a major impact on which patients need to be admitted to the hospital and what can be done on an outpatient basis. Patients previously had to come in for angiography, because in the old days angiography was of a considerably higher risk than it is now, and the same is true for the pneumoencephalogram; now that same patient gets a CT-scan. And the CT-scan covers all of the information you got in a much better way. So that the patient doesn't have to come in. So, reducing the length of the time the patients stay in hospital, reducing the number of patients that have to come in, that kind of thing will, it may not yet have shown although it has to some extent, certainly will have a major impact on health cost. (interview, Nov. 23rd, 1994)

A closer view, however, depicts a different reality:

We've got to operate with the money that is provided. We've cut back on physiotherapy services for outpatients, we've closed senior management posts, we've closed the position of patient services. Now, we continue to cut... And at this point we haven't affected patient care. I think, the public to a certain extent has been protected by the hospitals, maybe because there was fat in the system and we were cutting it out and there is not much left. But we cut everywhere before we cut in an area that will actually affect patient care. My concern is quality of patient care. (interview, Dec. 1st, 1994)

So, not only is quality a structuring factor for a technological local world, these participants contend, but it is directly related to another controversial factor: the cost of the innovation and the innovation as a cost-saving tool.

Some may argue that the term quality is used by local participants in a commonsensical way, i.e., PET provides pictures that are clearer and richer in physiological information than the preceding BI technologies. There are at least two arguments supporting a more complex understanding of quality by the local participants. On the one hand, researchers express awareness that PET is still not an unambiguous, and easy to operate technology; thus, it does not yet qualify for routine clinical use. In addition, they do not view PET pictures as the ultimate characteristics of this technology and argue that measurements are a bigger advantage of PET, an element that has yet to be translated in terms of clinical usefulness. On the other hand, both researchers and hospital managers do care about the quality of the medical services and see patient care as the ultimate objective of their activities; however, a direct link between PET results and patient care cannot yet be shown. Consequently, quality plays a balancing role in the interactions between research and clinic, and thus is considered by local

participants as a factor maintaining the structure of their world.

6. Size as a Threshold

Another notion was spontaneously advanced by the local participants when asked to interpret the differences between the initial period of PET and today: this is the size of the place.

Speaking of the changes that occurred since the beginning of his career in the local PET world, a PET runner, not without a touch of nostalgia, related to me:

In 1978 the Institute was much smaller. It was much smaller. People knew each other. People knew who was good for what. People perhaps had more confidence in each other. You didn't have to write as much. And if you've got to stay ahead in this business it's really really difficult. (interview, Dec. 12th, 1994)

Here, the problem is both the size of the local PET world wherein there is small room for additional users (a PET researcher said "there are many more requests for time on the machine that can be accommodated"; May 9th, 1994) and the size of the whole arena which is overcrowded with new institutional units, the purpose of which is to regulate the interactions of an increasing number of research units.

I believe, in a smaller organization, where people knew each other, obstacles were easily or more easily overcome than they are now, where some of the sort of internal regulatory bodies or internal budget planning or whatever, those things are much more abundant now. (interview, Dec. 12th, 1994)

The social issue that emerges here is how to satisfy the increasing demands of an increasing number of other worlds to use PET for their proper functioning (for example, research projects with remote connection to neurosciences, the inpatient clinic, the outpatient population, other research institutions

within a national system of division of labour and limited funding, etc.) without downgrading the established smooth processes of interaction that requires constraints in the size of the system.

Indeed, smallness as an organizational feature leading to fruitful interactions was mentioned by other informants. A hospital manager, for instance, said (interview, Dec. 1st, 1994):

The other thing is, [the Neuro] is small. We know each other. I may not know everybody's name but I do know everybody in this building. I talk to everybody. And if we are dealing with potential conflicts and tensions with people, we have to enjoy working with people.

A PET user has the same feeling of an appropriate size:

Other places are either too big, or they are too specialized. Here it is relatively small, but at the same time you can find expertise for this brain mapping happening at different levels. (interview, May 9th, 1994)

On the one hand, some perceive the size of the MNI&H as soared above acceptable dimensions. On the other hand, some still think that the size is small enough not to impair proper functioning. This tells us that the size of the social world is a subjective perception and there exist no shared standards to evaluate its correct or optimal magnitude. But the other implication is that both perceptions imply a common feeling that an optimal size does indeed exist, thus, insisting that size is a factor maintaining the structure of the social world. Participants' interpretations are based on the perception that their cohesiveness might be disrupted if the size of their social world grows beyond a certain threshold of manageability. Thus, cohesiveness must be related to the presence of

organizational elements that by interacting and negotiating are able to maintain a coherent social world: there is an optimal size which allows sufficient interaction for informal solutions to many problems to take place. Hence, these data open an analytical slot to study the size of a social world as a threshold for structural stability.

Size, and time alike (in the sense of Strauss, 1978, and Barley 1990), are dimensions of the structure to which negotiated-order theory has not paid due attention. The diachronical approach of Barley (1990), might be an attempt to overcome this flaw with respect to time, but he stopped short of analyzing size as a structuring factor. The participant-centred account of this study has not dealt with the time factor either. But since size was advanced in actors' interpretations of the social dynamics as a structuring factor, it might be a good analytical tool to study structure under the conditions of social change.

7. Role of Key Environmental Elements

Three additional structuring factors were advanced in the participants' accounts of this study: cost of PET, funding sources, and manufacturers of imaging technologies. They complete the answer to how a local social world was born, promoted, structured, and maintained around a new technology.

a/ Cost and funding sources. As previously discussed, cost in medicine is a general argument related to effectiveness and

quality of patient care. However, it is worth returning to this topic in a different context, since the cost of PET is the major argument against the acquisition or modernization of this high technology all around the world.

Cost in itself would not be a problem, had inexhaustible funding resources been available: that is why I joined cost and funding sources in the same section. A problem related to cost is the interaction with manufacturers and market dealers, all the more so since the MNI&H has been attractive for the latter as a place where one of the first successful designs of a PET machine was achieved. And last, but not least, cost, as already discussed, is related to quality, since quality is viewed locally as a measure of viability and self-discipline (interview, Dec. 1st, 1994).

According to a PET runner, cost is a crucial characteristic of PET. For example, he is persuaded that PET's difficulties in entering the clinic are related to its dependence on the cyclotron.

Not many clinics can afford 2.5 million dollars for a cyclotron. This is high technology medicine and most places can't afford the infrastructural costs of supporting it. And you also need some sophisticated and highly trained people to run the programs. (interview, Dec. 21st, 1994)

But when I asked a hospital manager, "Is the public aware that research is so costly, and that they get this high standard of care because of the research?", the answer came:

I think this is an area that has been badly, sadly neglected as far as the public is concerned. And as far as the government is concerned, too. The government just wasn't interested. If the government wasn't aware of the role of research it wouldn't contribute to it at all. I think, there is a lot of education to be done. I'm very simplistic when I tell to people of my age group: you know, one day you will not have to worry about stroke. Or about Alzheimer's. And I'm convinced of that, as a result of the work that's going on, the quality

of life [will be more], and the cost for the public will be far less. The trouble is it is so long-term. But I really would prefer not to talk about PET because I don't have anything to do with the running or the funding of it. I know it's used clinically, but I don't want to mislead you. But I must recognize that 10 years ago I wouldn't have thought MRI could do what it's doing. (interview, Dec. 1st, 1994)

In another context, of infrastructure and cost, the prevailing opinion is that "the MNI at McGill is one of those places where PET can flourish"¹³. On the other hand, MNI&H differs from many analogous US institutions that have chosen to utilize PET in the clinic before a reliable assessment of its cost-effectiveness is done (Powers et al., 1991; Conti et al., 1994).

As already discussed in Chapter II, the current problems around PET in the US are: a/ its questionable clinical usefulness; b/ the high cost; c/ regulatory-reimbursement issues (McGivney, 1991; Coleman et al., 1992).¹⁴ Very briefly, these problems interact in the following way.

Major medical and university institutions strain to augment the number of clinical indications for the use of PET as a diagnostic tool (PET Panel, 1988a-e; Powers et al., 1991). Clinical indications are advanced as arguments to raise funds and to build PET infrastructure on an institutional (Frick et al., 1992) or multiinstitutional (Prezio & Ackerhalt, 1992) basis. High cost, but not insufficient clinical indications, is the granting and funding agencies' strong argument to refuse funds and insurance companies' motive to refuse reimbursement of charges. On the other hand, the argument about benefiting from the procedure is hurdled by the bureaucratic mechanisms

that impede the federal regulation of the reimbursement process and, hence, reimbursement is negotiated on an individual basis (Coleman et al., 1992; Conti et al., 1994).

A single PET scan carries an average price tag of US \$ 1500-2000 (Gardner et al., 1992; Conti et al., 1994). Capital expenses for a clinical PET facility are estimated at US \$ 5-7.25 million, and the annual operating expenses for a clinical PET unit (cyclotron and scanner) amount to US \$ 2.4 million (Conti et al., 1994). Annual revenue projections for a clinical PET facility, when an overall collection rate of 64 % of total billed charges is assumed, might be up to US \$ 2.8 million, if a maximum of 8 procedures are carried out per day; the total average charge per procedure is fixed at US \$ 2400: 1500 for the scan, 600 for the isotope and 300 for the professional interpretation (Conti et al., 1994).

The cost of PET is not a major concern for the MNI&H for two complementary reasons: a/ as already mentioned, PET was built here and MNI&H is famous for its PET program, which is based on a well established infrastructure and personal contacts with the manufacturers; b/ the MNI&H PET strategy is research-oriented, therefore, it attracts research money and is independent from the money circulating in the health care system.

The consequence of this situation is that the existence of PET is vitally dependent on the good relations with public and private donors and on the top performance of the BIC as a

research unit. For the scope of this study, this means that the local PET subworld is idiosyncratic with respect to other clinical settings and that its characteristics cannot thus be unconditionally generalized. In addition, it means that the self-perception of this world is that of an elitist community privileged among its peers.

The way in which MNI&H elaborated its strategy is based on the following rationale (annual report, 1987-88). The objective to understand the chemistry and physiology of the living human brain can be achieved by a number of scientists from different disciplines using sophisticated equipment. Such a high technology equipment is expensive. MNI&H must maintain its competitive position in the field by replacing this equipment periodically. Therefore, searching for research funds is a priority task. And every success in obtaining such funds is not only praised as a considerable achievement, but is used as an argument to request further funds.

The MRC was encouragingly responsive in the initial phase of large PET funding, followed by the NIH of the US, the Canadian and Quebec Heart Foundations, and the American Health Assistance Foundations. The first pharmaceutical company to launch a research project based on PET in the MNI was Ciba-Geigy, and this is regarded as part of the soaring academic-industrial collaboration. Several individual grants were also obtained during this period of re-organization and establishment of the BIC. By advancing to the foreground the tradition and the

central position in neurosciences of the MNI, the growing neuroimaging world has enforced old links and created new bridges with financial institutions and private donors. 'Brain', 'understanding the brain', 'seeing how the brain works', and 'to keep our leading position' have been the passwords opening key doors and consolidating money channels with a commendable lumen.

There is no ambiguity in this local world with regard to the dominant role of research use over clinical use of PET at this time. An ambiguity reigns, however, over the ratio of basic research vs. clinical research, which is not a PET related problem, but a general dilemma. A link supported by no direct evidence is assumed to exist between basic research and the management of disease, but, as pointed out in two interviews (Dec. 1st and Dec. 21st), the arguments in this respect change according to the judgement of the BIC people about the prevailing mood of the reviewers in the granting agency (annual reports 1985-1994).

What on the basis of these data seems generalizable is the dynamic and funds-dependent process of transition from research to clinic, which is believed to occur with every successful new technology initially generated for research. But more detailed studies than this one will be required to conceptualize this process, since it is generated through interactions and negotiations between research and clinical settings. Here, we have a combined institute cum hospital setting, that, precisely because of this hybrid status, could catalyse this process.

My data show that PET researchers are less, if at all, concerned with cost, while hospital managers single out cost as a priority concern. This discrepancy relates to the differing positions of both groups vis-a-vis the funding mechanisms and also vis-a-vis the expectations about the development of PET.

The incorporation of a hospital within the institute has created peculiar financial relationships between the two. The institute receives its money from McGill University and from research grants, privately donated as well as won through the peer review process from public funds-providing agencies. The hospital has its annual budget fixed by the Quebec Ministry of Health and Social Affairs (MHSA), about \$ 26 million per year, and no leeway is allowed. The government estimates that the hospital can earn an annual revenue for serving patients of about \$ 4 million and deducts this sum from the overall budget. It also deducts from it any money that might be contributed to the hospital by a grateful patient. Therefore, if patients and all other private donors want to donate to the hospital, they have to write their cheque to the institute instead. Thus, the institute serves as a foundation to the hospital, since, unlike other community hospitals, the MNH has not its own foundation. It is evident, then, that fair redistribution of money, whose main input is the institute, will depend on the balanced partnership between the two directors. This situation is explained by a hospital manager in the following terms:

We're not allowed to spend our money without permission from the institute. And the reason for that is that buying a piece of equipment may possibly impact on

the overall running expenses of the hospital. So, we have to declare that we will not require to employ a new technician to run this beautiful machine. An MRI machine costs 2 million dollars to buy but about 600 000 a year to run, so the fact that you get the money to buy it, who is going to give 600 000 a year to run it? That you will never get from donors. No one is going to give you money for your ongoing expenses, they don't mind giving it to you for equipment but the impact of that on the hospital budget has to be taken into consideration before we are given permission to buy it. In any event, we don't have a foundation separate from the institute. So, here is one constant source of discussion, shall we say, and at times conflict. There's tension. There is often a perception. (interview, Nov. 23rd, 1994)

There is a clear indication in this passage of all potential financial hurdles that PET must stumble upon, if a decision is made to put it into the clinical setting. And this may be one of the reasons why, on the one hand, researchers do not encourage this process, and, on the other hand, clinicians and especially hospital managers do not demonstrate any eagerness to have it under their control.

As to the Director's opinion on that matter, his argument is as follows (minutes of the Retreat, 1992):

I fully realize the Institute's obligation to support the MNH and the technology that is necessary to ensure patient care. However, issues need to be resolved for this to be done well. We need to continue efforts begun under [the previous] directorship to get the budget of the Institute under control and to reduce our annual deficit, which [...] is threatening our future. Doing so will liberate funds to meet the hospital's equipment needs and also to meet other institute priorities, including attracting and setting up faculty, supporting fellowships and studentships, and renovating and creating space.

Now, in these circumstances, PET is far from the headaches of the hospital management in terms of money, since the PET program is continuously funded by the MRC, FRSQ, and various specialized foundations. Even so, said one of my informants, "it is a high-tech expensive program, so we always need more money". He pointed out that the program was increasingly developing its links with the pharmaceutical industries: the special capabilities of PET "to look at picomolar and nanomolar

neurochemistry has an unique attraction" for the pharmaceutical companies. The answer to my question as to how PET researchers justify their grant applications was:

It's almost totally research oriented. 80 % of the laboratory funding, of its operating base is research. 80 % of our activities are research. And we dedicate approximately one day a week to do clinical PET studies and we have budget from the Quebec government to do that. And I think that works just fine, I think there is enough clinical uses of PET to justify that, backed on a research program. (interview, Dec. 21st, 1994)

This strong financial independence of PET explains to an extent why the approach of the latest director does not upset the PET managers as much as it does the hospital management and other newly developing imaging project groups.

And even as it is, PET is not an isolated paradise within a poor institution. The reasons for that are seen by my informants to reside in the tradition "particularly in the anglophone hospitals" to donate money "for worthy causes" and in the financial discipline of spending.

Even if my focus is imaging, there is no way to dissociate it from the complex institution, where "a lot of money comes [from former patients] because of the care they've received in the hospital. No question about it." (interview, Dec. 1st, 1994). This care, however, is maintained or improved also because of imaging; and again, MRI as opposed to PET is an example. As a largely clinical tool, MRI is cost-effective. And the hospital managers stress its local status in the same way as a PET runner praises PET. First of all, the cost of MRI is going down. Secondly, Siemens sold it to the MNI&H because "the company was very anxious to get state-of-the-art equipment in

here" (prestige-cost relationship). Thirdly, the company took back parts of the obsolete machine. And finally, the MNI saved on the service contract for the first 3-4 years because of the warranty for a new machine.

In terms of self-discipline, in times when to get money becomes "harder and harder", the management works on the principle "to do more with less". And it asks everybody not whether they can cut, but where to cut. But, a manager says, "we cut everywhere before we cut in an area that will actually affect patient care" (ibid.).

The above situation reflects a social order maintained through negotiations between two different positions: researchers, who expect PET to remain a predominantly research technology, and hospital managers, who expect, by analogy with previous BI techniques, that sooner or later PET will be accommodated in everyday clinical work. Existing tensions are leveled down by both sides finding arguments to maintain the high quality status quo which serves best the interests of researchers and clinicians. Each side expresses particular concerns and attitudes, but in the same time provides arguments of how differences may be smoothed away. Thus, it seems that in this local world negotiations have amounted to a strategy to maintain the structure against the unfavourable changes in the environment.

This summary of the financial environment, within which PET lives allows the conclusion that in the MNI&H the future of this

technology is safe, because of at least two things: its prestige as a successful research tool, and its potential to become a clinical tool in a high standard patient care setting.

b/ Manufacturers. The privileged position of the MNI&H and/or the BI and/or PET was already emphasized as a factor with a favourable effect upon the relationships with the manufacturers of imaging machines. Manufacturers play an important role in this business, as was pointed out in the first chapter of this study. In 1978 the PET group in the MNI presented a good opportunity to the Canadian Crown corporation AECL to become a competitive retailer of PET machines on the world market. AECL patented all possible segments of the Positome camera, which was originally invented and tested in the MNI&H and soon embarked on a project to build the prototype. Pushed by the local PET people, AECL was also involved in negotiations with Japan Steel Works to be a sales agent for the Japanese medical mini-cyclotron. Meanwhile US companies were working out their way to the market. One of my informants gave me the example of the UCLA PET program as a successful university-industry interaction (interview, Dec. 12th, 1994):

The people at UCLA worked with a company called Ortec, which make modules like you see on those racks. That company developed a spinoff which is now called CTA, and they used the designs that were designed between Ortec and UCLA and his has now been taken over by Siemens and that's the most successful PET system. That would be an example of an interaction between a company and an university group, which I think we probably had the same kind of opportunity to develop.

Unfortunately, AECL failed to persist with this project. "Failure of vision", says one of the participants in these events. Although at that time people from the now successful PET

manufacturer Siemens told him that they were concerned that AECL would become major competitor, the latter "haven't followed through. They didn't put the money for the program that was necessary. Because it didn't give an immediate, short-time profit, they pulled out of the program." (interview, Dec. 21st, 1994). Another explanation of this failure, which at a first glance seems contradictory to the previous one, was given by another participant in the process (ibid.):

That was one of the things I found quite frustrating because the people at AECL wanted to make a product... at one stage they were going to take over that technology and they were going to maybe adapt it, to commercialize it, but they didn't want continuous improvement that had to be integrated into their product, because otherwise they weren't going to be able to hand it out to individual people in terms of packages. But the machine was not a commercial success. And it wasn't a commercial success partly because the people involved in selling it were not skilled in selling to the people who wanted to buy it. I would say it's almost a personal kind of thing. My experience is that it's very much a personal kind of thing. Sure, the deals that are established between the universities and the companies as to protect the university's rights and to protect the companies' market share and make sure that you don't sell the same thing to two people, and that kind of thing, there are things like that... But I've been involved in several university-industry related things and, maybe it's just me, but I don't think so, but my impression is that a lot depends on how well you get on with the people and how adaptable, how flexible, how good people turn out to be working with one another and that has a lot to do with what makes things.

As a matter of fact, what the first informant calls corporate vision, the second one refers to as "personal kind of thing". It might worth investigating the university-industry relationships in the arena of the neurosciences, and especially at the level of the BI worlds. But this should certainly be a parallel study in the sense of Barley (1990). In this diachronic approach one may safely draw the conclusion that the development of PET in the MNI wasn't affected by the failure of the local industry to occupy a profitable market position.

Notes:

1. 'Accuracy of diagnosis' stands here for quality of patient care in its broad sense.
2. The unavoidable thing is, however, that some of my informants were quoted by others as being crucial contributors to the world of PET; hence, behind their anonymity a careful reader may recognize who they are.
3. Charles C. Sherrington is one of the founders of the modern neurosciences.
4. Rutherford became a Nobel laureate in 1908 for his research at McGill, summarized in his Silliman lectures in 1905.
5. In the 1992 Retreat the mission of the MNI&H was defined as: "The MNI&H is a research institute and a teaching hospital of McGill University".
6. It is not my judgement, but the participants' own assessment that the arrival of an outside director demonstrates the importance of "personality" and "subjectivity". In trying to present a neutral picture of the PET world, we have to admit that within this world PET is not at stake. What is at stake is the legitimacy of everyone or everything that dares question the necessity and validity of PET. This is the world for which PET has proven its importance, and no one here questions PET any more. In contrast, everyone questions those who do not express fascination about PET. If, however, one assumes that the social role of every director is to provide leadership in concert with the visions and goals that have created the particular local world - and in the case of MNI&H there is no hesitation that Penfield's successors' social role was exactly this - every director who departs from this role will be doomed to clash with the world he was elected to lead. This clash is about to happen in the MNI&H, according to my informants, and they identify the situation as filled with tension. It is not my task to forecast the outcome of this tension, but there is tension out there, and this is one more argument in favour of applying the notions of

negotiations and negotiated-order to the analysis of this case of a frontier technology. A frontier technology is by definition something that creates tension, so that even those who are reluctant to admit that negotiations occur in social worlds void of tension, might agree that in the present case to speak of negotiations is not just to resort to a fashionable sociological term.

7. A curious anecdote was referred to me in order to underline the role of the personal connections: A steel producer in Japan, called Japan Steel Works (JSW), was interested in producing cyclotrons for medical purposes. It so happened that JSW had its premises near the home town of one of the builders of the Montreal camera and this occasioned the purchase of a cheap baby-cyclotron by the MNI in 1981 from Japan Steel Works. MNI used, on the other hand, to act as a go-between in the negotiations between JSW and AECL to create a PET package (camera & cyclotron) to be marketed in North America. AECL failed to pursue this enterprise and interrupted the project after selling its prototype to the MNI in 1984. JSW still sells cyclotrons.

8. Pneumoencephalography = administration of air into the brain cavities, which allows to visualize their contours and thus to identify whether there are pathological changes in the brain substance.

9. Although PET is largely identified as 'imaging' technique, the fact of the matter is that the first step in PET is to collect quantitative data: every single positron emission is measured in a tri-dimensional space (and recently time has been added as a fourth dimension by the front PET researchers). It is at the next step that the bulk of measurements is digitally transformed into an image by the computer. But nothing can constrain researchers from using the data as measurements, i.e., in a statistical way. This trend is now gaining ground, and PET

researchers from the MNI are at its leading edge. As a matter of fact, one of the leading PET runners was critical to the whole PET field that it still sticks to the images instead of providing more rigorous results from quantitative data only (interview, Dec. 21st, 1994).

10. There are several research projects designed to exploit this matching to its limits (Evans et al., 1991; the tri-di atlas of the normal variability of the human brain; the 3-di stereoscopic display system for brain surgery; etc.).

11. The last two monopolize the world PET market nowadays.

12. But it is an ambiguous situation. "We don't turn patients away because they don't fit in the research protocols", said a hospital manager in an effort to convey her discord with my suggestion that research is a priority in the MNI&H. (interview, Dec. 1st, 1994)

13. This is because: a) MNI&H has always been well subsidized; and b) PET was partly developed in this place and the cost of PET for this institute is smaller than in places where it starts from scratch. The latter situation will be discussed later in this section.

14. PET is not yet discussed in Canada. There are four university-based PET centres in this country (Montreal, Toronto, Vancouver, and Hamilton), and a fifth centre is being organized in Ottawa.

CHAPTER IV.

SUMMARY AND CONCLUSIONS

"Quis custodiat custodes ipsos?"

If we assume that PET was correctly assessed as a powerful physiology quantifying technology and that this assessment is going to be confirmed by the medical community, and if we also assume that cost-quality considerations will be exercising pressures favouring the diffusion of PET, even if only in biomedical and clinical research, then one might expect that the construction of PET-centred local worlds in various institutional contexts will continue and expand. Since the history of medical technologies indicates that these two assumptions have proven correct for the preceding BI technologies, and the projection seems plausible, then the data analysis of this study might be a good start to address from a sociological vantage point the dynamics of the factors which structure and maintain a local world around a high technology.

The above implies two characteristics of this study: it is exploratory and it is rather idiosyncratic in its approach. The first means that the conclusions are based on a limited amount of data, and therefore, need further empirical support. The second means that the design of this study tried to avoid the traditional approaches to investigate the social impact of high technologies, discussed in chapter II, such as the science and technology studies approach, the technology assessment trend,

CEA, social history, and socio-political analysis.

The analytical approach of this study is centred on the experiences of the local participants with this particular new high technology, because of the assumption that the social career of a technology is shaped by the choices and decisions of people accountable for its conception, promotion, and maintenance. This assumption is supported by the argument provided by Barley (1988). The usual way people make sense of technologies, he asserts, is by acquiring knowledge about them: so long as technical knowledge is available, it is assumed that it is influential enough to account for the meaning of the technology. But, argues Barley, "since knowing is a social as well as an epistemological matter, what is epistemologically possible may be sociologically unlikely" (p. 497). So, to study the sociological likelihood of a technology career is a challenge for the sociologist.

The practical results from such a study are not less significant than the theoretical implications. From the participants' interpretations, the contours of a model emerge which can point at possible outcomes for PET in terms of its transition from research to clinic and its diffusion in the patient care environment at large. Again, a warning made by Barley (1986) on the basis of his study of CT-scanners in different radiology departments has to be kept in mind with respect to the applied aspects of the chosen sociological perspective. The warning is as follows: "identical technologies

can occasion similar dynamics and yet lead to different structural outcomes" (p. 108).

In summing up, as a result of all these considerations, the study presented in this thesis provides preliminary data about how the technology of positron imaging has initiated, promoted, structured and maintained a PET social world in the MNI&H. On the basis of the elicited experience of the local participants, several factors seem to have interplayed in this process.

Tradition was the factor that seemed to be ranked by local people as the most important one for the career of PET in an institution where brain research is an ultimate goal and care for the brain diseased is the central clinical task. Tradition was spelled out as a welding of extraordinary personalities with a formidable institutional environment. However, while relating about the institution as a factor, actors from the MNI&H were more secure in explaining the role of personalities than the import of the institutional organization.

Another factor, seminal for the prestige and the resulting support PET enjoys in this institution, is the meaning of PET within the value system which impregnates the structural organization of the MNI&H. This meaning is defined and redefined through a dynamic assessment of PET, tacitly or purposefully carried out by local participants. The combined assessment of PET as a field, both research and clinical, with PET as a local realm amounts to a full legitimation of the technology, since this evaluation is made mostly in terms of epistemological

possibilities and only in an accessory way in terms of social acceptability. The methodology of the assessment is, thus, biased on the basis of a professional value system which ranks research at the highest level with the awareness that the high social status of the institution and of each of its local worlds depends on the legitimation of the meaning of their activities.

In this context quality was advanced by local people as another structuring factor of the PET world. Quality is viewed as a perception, not as a measurable category. On the one hand, quality is an ongoing concern, and as a concern it is directly linked to the cost-containing health care environment. On the other hand, quality is perceived as a standard characterizing this institution; in the opinion of the participants, a new technology like PET is posed to maintain rather than to affect this institutional standard.

Cost as a structuring factor was discussed less in the context of quality, however, and more in the context of funding sources: the perception of achieved and only-to-be-maintained quality raised small concerns, while the relations with the fund givers seemed problematic and requiring sensitivity as to the risks. In this context the relations with the commercial manufacturers of PET equipment were unanimously assessed as a favourable factor for the maintenance of the PET local world.

The only factor that raised some degree of anxiety was the increasing size of both the local PET world and the institution as a whole. Participants assumed that the cohesiveness of their

world could become problematic when the size rises over an intuitively defined threshold of manageability and easy interactions.

Further studies are needed to explore the significance of those factors, to possibly add other factors, and to provide more robust arguments for the theory of structuring. This is not just a matter of collecting more data. It rather requires shifting from participant-centred toward an analytical-centred approach, choosing different institutional and health care contexts, and also triangulating data from synchronic, diachronic and parallel projects.

In terms of applied sociology, such studies might contribute to shape coherent health policies, decision making and market opportunities regarding new technologies in the context of dynamic national medical changes and international medical exchanges.

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