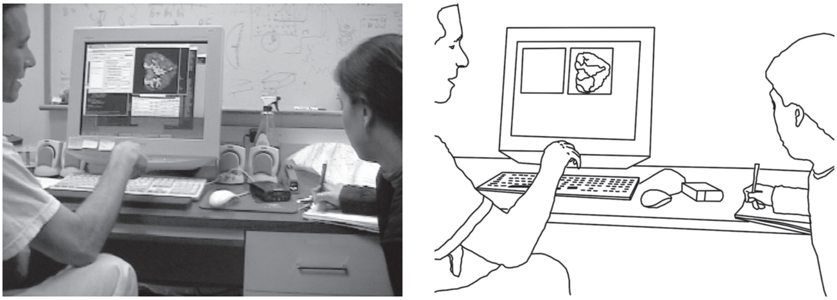
1 In the fMRI Laboratory

It is 2002, and we are in a cognitive neuroscience laboratory at the University of California, San Diego. There, we encounter two researchers seated in front of a computer screen (figure 1.1). One of them, the laboratory director, Paul (a professor with a distinguished record of publishing and teaching in the field of cognitive neuroscience), is talking with a graduate student named Jane (a promising Ph.D. candidate in cognitive science) seated next to him (featured on the right in figure 1.1). The two researchers are engaged in the practice of *functional magnetic resonance imaging* (fMRI).

fMRI, together with its forerunner, *MRI*, is a key modern digital imaging technology used for medical and scientific purposes. The goal of MRI is to provide detailed static renderings of the anatomic structure of internal body parts, such as the brain. This technique uses radiofrequency, magnetic fields, and computers to create visual renderings ("visuals") based on the varying local environments of water molecules in the body. To obtain such visuals, a person (or, in fMRI practitioners' jargon, an *experimental subject* or a *subject*) is scanned. During a brain MRI scanning session, hydrogen protons in brain tissues are magnetically induced to emit a signal that is detected by the computer. Such signals, represented as numerical data, are then converted into visuals of the brain as the brain anatomy of the experimental subject is imaged.

The mapping of human brain *function* by use of fMRI represents a new dimension in the acquisition of physiologic and biochemical information with MRI. The technique is used to observe dynamic processes in the brain that are demonstrated by visualization of the local changes in magnetic field properties occurring in the brain as a result of changes in blood oxygenation. The role of fMRI visuals is, thus, to display the degree of activity



(a) (b)

Figure 1.1
fMRI researchers working on a laboratory computer.

in various areas of the brain; if the experimental data are obtained while a subject is engaged in a particular cognitive task, the visual can indicate which parts of the brain are most active during that task.

To show these results, however, fMRI visuals require extensive analysis in the laboratory. During analysis sessions, such as the one in which Jane and Paul are involved, fMRI practitioners use computers to engage their data, shaping the appearance of fMRI visuals. The engagement with digital material allows the practitioners to enhance their understanding of the imaged biological matter. This means that observation by an fMRI practitioner is *multimodal* and *cyborg-like*; it is accomplished by coordinating the eyes with digital technology, an array of instruments, graphical inscriptions, and actions of the hands.[1] Rather than passively gazing at static visual images, fMRI researchers interact with each other and the technology, engaging their experiential and semiotic bodies. They manipulate, listen to, and touch computers and other instruments, and they also talk, gesture, interactionally engage their heads, necks, and torsos as they attend to each other in the work of cognitive neuroscience.

One of the ways practitioners can engage digital material to enhance their understanding is to flatten computationally the imaged cerebral cortex to see not only what is shown on its ridges (or *gyri*) but also what otherwise would be hidden in the fissures (or *sulci*) that surround such ridges. This is exactly what Jane and Paul are doing when we join their data analysis session. Because Jane still needs to acquire skills in data analysis, Paul, while talking about the brain visuals displayed on the computer screen, shows Jane how to use fMRI software to generate visuals that appear flattened. When the computer screen displays a set of data as an “inflated surface,” Paul identifies portions of the imaged visual cortex: “That’s the center of the gaze and that’s that other thing that I said don’t look at it. That’s up, right there.” As he points out a section that does not look like he thinks it should, Paul chuckles while jokingly warning Jane not to pay attention to it. During the entire sequence, as Paul holds the computer mouse in his right hand and skillfully directs the changes of the displayed visuals, he indicates specific brain areas by using the cursor and pointing with his left hand. While attentively listening, Jane takes notes and shows her understanding by nodding.

When Paul begins to explain how laboratory members look at the imaged visual cortex, his description invokes physical actions: “Usually how we look at it is, we put a cut down there and another cut over here, and then we flatten the whole thing out.” To make their *seeing* (as the capacity to discern the cortical organization) more powerful, laboratory members perform the actions of “cutting” and “flattening” of the digital matter. When the screen displays the desired view, Paul says: “So you made a cut right here then like spread that out.” Just before saying “spread that out,” he gets closer to the screen and carefully places both hands over it; his palms face the screen while the right hand is tilted slightly to the right (figure 1.2a). As he utters “spread that out,” Paul stretches the hands apart (see figure 1.2b, c), generating a clearly marked but patiently performed gesture. To conclude the action, he turns toward Jane and says, “That’s actually how you are looking at it when you look at it flattened.”

What just happened—Paul’s stretching his hands over the digital display while talking about physical actions and changing the appearance of the brain visuals—is not treated as an extraordinary event. Quite to the contrary, after the completion of Paul’s action, the two researchers continue with their discussion as if nothing unusual had happened. Paul’s animating of the visual matter by selecting computer commands, gesturing, and talking about physical actions is an ordinary and frequently encountered feature of laboratory work and communication. Scientists routinely engage their hands by typing commands on keyboards and touching the computer screen while gesturing in front of brain visuals. Does this mean that such acts are of no particular importance? Is the engagement of hands with

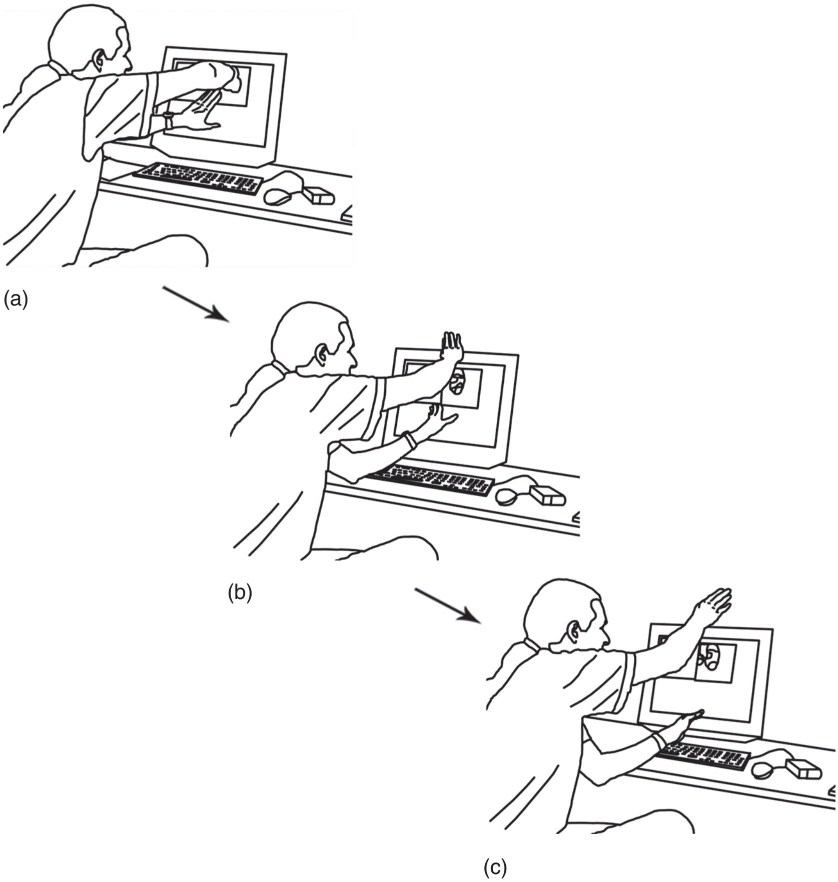


Figure 1.2
fMRI researcher coordinates his gesture and talk with a brain visual.

digital visual matter not of interest for an understanding of scientific practice?

In this book, I argue that these routine and ubiquitous interactional enactments deserve attention. To illustrate how the interactional events constitute scientific work and generate understanding of scientific data, this book focuses on scientific visuals—a topic that has been extensively discussed in social studies of science and technology (e.g., Cartwright, 1995; Daston & Galison, 2007; Knorr-Cetina & Amann, 1990; Latour, 1995; Lynch, 1985b, 1990; Lynch & Woolgar, 1990; Rheinberger, 1998; Rudwick, 1976). In attending to the articulation of fMRI brain visuals in the laboratory, I am interested in how digital scientific visuals achieve meaning through the engagement of hands. As seen in the interaction between Paul and Jane, fMRI practitioners operating computers often gesture over screens to communicate with each other and make sense of the visual data with which they are dealing. These multimodal engagements with the digital matter are central for turning experimental material into what can be seen and understood. Rather than being only a contextual scene for the digital visuals, they are their essential component.

The participation of the hands in work and multimodal semiotic interaction illustrates the specific ways in which scientific practice is rooted in the body. Michael Lynch distinguishes two orders of laboratory "space," *opticism* and *digitality*: "The paradigm for the former is the lensed instrument and the scrutinizing eye, while the latter is embodied by the play of fingers (digits) on a keyboard instrument" (Lynch, 1991: 56). Lynch points out that digitality does not displace opticism; rather, the two orders coexist and overlap with each other across historical periods. I deal with the interplay between opticism and digitality at the level of multimodal action and interaction. As exemplified by the interactional moment in Paul's laboratory, cognitive neuroscientists, in the age of computers (e.g., Mindell, 2002, 2008), gesture, talk, orient their bodies, and gaze to accomplish their work. These actions not only show how they understand the objects of their inquiry but also allow for discussing the assumptions behind fMRI.

fMRI technology implies a model of the mind and embodiment where the mind is confined to the internal workings of an individual, and embodiment concerns the grounding of the mind in the brain. Conversely, the subtle and skillful handling of the digital substance in the laboratory suggests that the mind in action cannot be solely understood in terms of the brain without taking into account the entire body and the sociocultural world that such a body experiences. In the context of laboratory work, fMRI scientists think by bringing together their lived semiotic bodies with digital screens.

Embodiment and the Body

Since the 1990s—famously named the "decade of the brain"[2]—cognitive neuroscience has occupied the central stage in the scientific study of the human mind: Human mental processes are to be studied in terms of brain processes. This grounding of the mind in neuronal activity places cognitive neuroscience apart from earlier efforts in the study of human cognition. The approaches that typically fell under the umbrella of *cognitivism* were based on the analogy between the mind and the computer program, where the mind was seen in terms of the manipulation of symbols defined independently of the material substrate in which such manipulation is instantiated (or, *on which the program runs*). This implied a disregard for the details of the biological underpinning of cognition; the mind was considered to be a logical rather than biological machine.

In contrast with the approaches grounded in Cartesian modernism (e.g., Damasio, 1994), the availability of imaging technologies—particularly fMRI—has allowed biological processes to become the focal point. By visualizing brain processes, fMRI is framed as a technique for the study of the mind that concerns the human body. Consequently, the turn to embodiment, shaped by the availability and constraints of fMRI technology, presupposes an equation between the brain and the body; when talking about embodiment, cognitive neuroscience refers to the brain.

Feminist and *postphenomenological studies of science and technology*, on the other hand, conceptualize embodiment and the body in a somewhat different manner. Embodiment is not only about the brain but also the lived body immersed in the complexities of the sociocultural and technology-mediated world. These approaches, rooted in Foucault's (1977)discussion of surveillance and self-surveillance, Lacanian psychoanalysis (Lacan, 1977, 1982), and the phenomenological writings of Heidegger (1962, 1977, 1982) and Merleau-Ponty (1962, 1968), argue against restricting our understanding of the body to naturalistic and scientific modes of explanation. Feminist scholars (e.g., Butler, 1993; Grosz, 1987, 1994; Irigaray, 1985; Marshall, 1996), thus, see the body as a *fluid site of potential*.

> The body is neither—while also being both—the private or the public, self or other, natural or cultural, psychical or social, instinctive or learned, genetically or environmentally determined. In the face of social constructionism, the body's tangibility, its matter, its (quasi) nature may be invoked; but in opposition to essentialism, biologism, and naturalism, it is the body as cultural product that must be stressed. (Grosz, 1994: 23–24)

In focusing on the developments of new scientific instruments and information technologies, feminist scholars have shown that once the relationship between the body and technology are brought to the surface, the idea of the body as a self-contained biological object that obeys mathematical-causal laws is irreversibly disrupted (e.g., Barad, 2003, 2007; Cartwright, 2008; Haraway, 1988, 1991; Hartouni, 1991; Mol, 2002; Sobchack, 2004; Suchman, 2007; Wilson, 2004). Similarly, postphenomenology, in indicating how technologies allow us to see what would otherwise be invisible, explores how the experience and sense of the body are affected by such an engagement (e.g., Ihde, 1990, 1993, 1998, 2002). In science, the early use of optical technologies—telescopes and microscopes, for example—transformed what was seen, enhancing features of the observed object while reducing the visual field to which that object belongs.

The current book draws upon these theoretical developments to explore how scientists experience their bodies while interfacing with digital computers, other imaging technologies, their colleagues, and the imaged bodies. I describe the complexities of the thinking body in cognitive neuroscience by specifically focusing on the digital visuals and interactional organization of everyday scientific activity. How do fMRI practitioners gesture, coordinate their talk, and orient to each other and to their computers? How do they touch the objects that surround them and how do they sense their bodies as they accomplish their work? Dealing with these questions is a way to discuss how fMRI technology implies, constrains, and enables the body in cognitive neuroscience. Whereas the technology and the theoretical positions associated with it assume that a thinking body can be reduced to the brain, I focus on the dynamics of interaction in fMRI practice to talk about the constitutive outside, questioning the proper distinction between brain and body, the scientists and the sociomaterial world of their practice.

Studying Multimodal Interactional Organization of Scientific Practice

To capture embodied interaction in scientific practice, I draw from *ethnomethodology* (Garfinkel, 2002) and *conversation analysis* (CA; Jefferson, 2004; Sacks, 1995; Sacks, Schegloff, & Jefferson, 1974). In particular, I ground my approach in a recent research trend aimed at recovering fine details of the multimodal interactional organization of everyday practices (e.g., Goodwin, 1994, 2000b; Heath & Hindmarsh, 2002; LeBaron, 2007; Koschmann et al., 2007; Mondada, 2007; Ochs, Gonzales, & Jacoby, 1996; Streeck, 2009; Suchman, 2000).[3] Similar to *ordinary language* philosophy (Austin, 1962;

Wittgenstein, 1973) and the approaches in *semiotics* (Benveniste, 1971; Peirce, *Collected Papers* [C.P.]), these studies point out that talk, as well as bodily conduct and the engagement with material elements of the setting, participate in the practical accomplishment of social activities. When we coordinate our talk with gestures and bodily conduct, we accomplish actions. These actions are *situated* (Suchman, 1987)—always realized, moment by moment, with respect to the environment in which they are lodged, while they constitute the local context.

In exploring these methodological positioning in the context of *science and technology studies* (STS), I transcribe videotaped instances of the work in fMRI laboratories to focus on the choreography between hands, eyes, and ears in the ongoing social interaction between practitioners of fMRI. These aspects of conduct characterize practitioners' involvement with the materiality of the laboratory setting and are enacted as a part of doing cognitive neuroscience; they indicate how the imaged body is known through multimodal action in the laboratory.

Thus, to talk about the body and embodiment in neuroscience, I turn my STS gaze toward gestures, details of talk, movements of hands, and nodding of heads in the work of science. Rooting the approach in the videotaped records of such actions in the laboratory, I examine how the body is experienced and how it generates meaning as it interacts with the imaging technology. Importantly, I do not use videotaped record to document and represent fMRI practice, but I treat it as an analytical resource (e.g., Heath, 1997: 190; Heath & Hindmarsh, 2002: 104) to discuss how fMRI practitioners engage their bodies with computer screens in learning about imaged brains.

Examining Videotaped Work of Science

During my study, I videotaped fMRI scientists as they interacted with each other during work sessions and apprenticeship practices. As the videotapes indicate how fMRI practitioners gesture in front of and touch digital screens while working and communicating with their colleagues, they shaped the study, affording access to the interface between the body and technology. Despite the interest in the visual, video recordings are still not widely applied by STS scholars as a methodological tool to study scientific practices. However, if we accept that scientists accomplish their work through tactile interaction with technology and visible semiotic comportment, we must examine such acts. As we go beyond the linguistic aspects of communication (such as talk and writing), our intuition and memory are not reliable sources with which to document the complexities that characterize multimodal interaction. Furthermore, people are often unable to provide accurate accounts of their own conduct, especially when their use of multimodal communication is in question.

Gesture, for example, is very dynamic and largely unnoticed. As such, its articulation in the environment of practice cannot be either fully reported in an interview or accurately remembered by an observer. A scientist who was involved in the work when a gesture took place can just have tacit knowledge of how that was done, and an ethnographer who saw the gesture is only at a loss when trying to represent its temporal unfolding and coordination with other elements of the semiotic action. The problem is not only the gesture taken in isolation but also its fine embeddedness in the complexities of the moment of practice. The gesture is contingent upon the local and spatial organization of the setting, and is produced in relation to the ongoing talk and the actions of the co-participants. To access multimodal semiotic aspects of working hands in the laboratory, video recordings of everyday interactions are crucial. With all their insufficiencies and their inevitably incomplete output, video recordings are currently our best mode to record the dynamicity of the setting in which work and multimodal interaction take place (Goodwin, 2000a).

In video recording the scientists, I was particularly interested in the scientists' communication with each other, their use of instruments, their ad hoc creation of drawings, and their engagement with computer screens. To capture—as much as is possible—the richness that characterizes such acts, I typically positioned myself with the camera behind the practitioners, facing toward the computer they were looking at (as exemplified by figure 1.1). Sometimes I placed additional recording devices in front of the practitioners (e.g., the small recorder seen to the right of the computer in figure 1.1). In such a way, I documented how scientists orient toward each other, how they manipulate things placed on the desk in front of them, how they construct new objects (such as the ad hoc drawings), and how they work on the computers (e.g., how they use mouse and keyboard commands). It cannot be denied that the presence of an ethnographer with a video camera distorts some of the "naturalness" of the recorded scene. In my experience, however, practitioners busy with the tasks at hand tend to pay little attention to the prolonged presence of the video camera behind them.

By scrutinizing the audiovisual record on multiple occasions, slowing it down, and transcribing it, I observed how fMRI practitioners accomplish minute yet vital details of their everyday practice. I analyzed how they engage brain atlases to inscribe landmarks on the scans, how they change the appearance of such scans, and how they point and gesture to enact features of the scans.

To warrant my analytic claims, I paid particular attention to how practitioners themselves deal with the specific actions of others (Garfinkel, 2002). I looked at whether practitioners orient toward certain events and whether they treat such events as relevant components of the activities they are engaged in. If, for example, my video record shows that a practitioner treats a shoulder movement of the other scientist as indicating what has happened during a previous scanning session, then I considered such movement to be a communicative act rather than a motion of the body without semiotic import.

The videotapes also provided me with an opportunity to share my insights with other researchers and discuss my analysis with fMRI practitioners. During my study, I did conduct interviews with practitioners, but these interviews were mostly done in the beginning of the study to supply general knowledge about the practices. When I conducted interviews in the later stages, they were often organized as discussions of previously video-recorded activities. These occasions (articulated around the videotaped record) not only solidified rapport but also improved the study, as the practitioners, while often unaware of the interactional details through which they organize their conduct, helped clarify specialized vocabulary, use of technology, and understanding of local procedures (Heath & Hindmarsh, 2002: 103).

Once I identified the excerpts that were most informative of the practical methods scientists use in making fMRI visuals intelligible, I transcribed them, specifying features of *talk-in-interaction* (Schegloff, 1987). This included elements such as the length of silences and pauses, onset and overlaps in talk, as well as the aspects of speech delivery and intonation.

Such transcripts are useful in deciphering how practitioners produce action with regard to the conduct of others and how they deal with meanings accomplished through the ongoing interaction.

Because of my interest in the semiotic and "non-symbolic practical, instrumental routines of the hands" (Haviland, 2005: 213; Streeck, 2009) developed through everyday activities,[4] I also annotated occurrences of multimodal semiotic modalities, such as gesture, gaze, facial expression, and body orientation (Goodwin, 2000a). In doing so, my aim was not to describe any one semiotic mean (gesture, for example) in isolation. Rather, I wanted to capture the coordination of multimodal semiotic means. In doing so, I looked at the exact moments of their production, their embeddedness in the instrumental and collaborative sequences of action, their coordination with technological objects, and their situatedness in the laboratory space.

Following Goodwin's (2000a) technique of transcribing visual phenomena, I turned still photographs (retrieved from the video) into line drawings (see figure 1.1b). Using software programs, I delineated the contours of scientists' bodies and relevant elements of the setting by working directly on the photographs (as seen by comparing figure 1.1a with figure 1.1b). These renderings were enriched with arrows and other signs to indicate relationships between rendered acts (see figure 1.2). In providing such transcripts, my goal was to let the reader see as much as I saw while indicating elements of the practice that the scientists were treating as relevant in their work and interaction.

For example, the whiteboard visible behind the computer screen in figure 1.1a is not rendered in figure 1.1b. Even though use of the whiteboard is a crucial component of work and learning in an fMRI laboratory, during the entire sequence of work from which the still image (translated into the line drawing) was taken, the practitioners did not draw on, refer to, or attend to the whiteboard. Because the goal of the transcription of the embodied activity is not only to preserve as much complexity of the video record as possible but also to communicate relevant events as clearly and vividly as possible (Goodwin, 2000a: 161), the whiteboard was not shown in figure 1.1b.

Video records, however, neither fully capture nor provide direct access to the meaningful activities in the laboratory. To understand the relevant patterns in the analyzed data[5] as part of scientific practice, I interpreted the transcribed excerpt in light of the knowledge derived from my long-term ethnographic work (e.g., Cicourel, 1987; Lynch, 1993).

Ethnographic Study of fMRI

The first videotape from this study dates back to summer 2002, when some of the leading scientists and administrators at the University of California, San Diego (UCSD) gathered to inaugurate the new Center for fMRI. UCSD and the nearby Salk Institute are renowned for their research in medicine, neuroscience, and cognitive science, and the $13.5 million center was announced as "the largest brain imaging facility dedicated to research in the Western United States."[6]

The speakers at the opening ceremony, among them Edward W. Holmes, chancellor for Health Sciences and dean of the School of Medicine at UCSD, and Roderic Pettigrew, director of the National Institute of Biomedical Imaging and Bioengineering, frequently mentioned the partnership between institutions, research fields, and individuals. Edward W. Holmes, for example, said:

> With this dedication we announce the availability of this powerful imaging facility that will serve a wide variety of investigators: neurologists, psychiatrists, cognitive scientists, radiologists, engineers, biologists, and chemists.

The initial goal of my ethnographic study was to observe scientific work at the newly opened facility, focusing on how fMRI technology features in collaborations among scientists from multiple fields, and how this technology both generates and is shaped by broader societal phenomena.[7] Captivated by the scanner—a monumental and expensive machine—and the large-scale collaboration that it requires, I wanted to see how the distributed work of science, organized around this technology, develops and what it entails.

As the project progressed, however, my focus gradually shifted from the fMRI center, where scientists conduct their scanning sessions, to individual laboratories, where the data collected in the scanner go through an extensive process of interpretation before they are turned into the colorful brain visuals usually seen in scientific journals or mass media outlets. Following scientists in their daily work (Latour, 1987), I most often found myself in the laboratory, where practitioners spend long hours working on experimental data. Whereas a scanning session generally takes only a couple of hours, the data analysis may span months, typically involving a much larger group of collaborators. Similarly, graduate students are able to obtain proficiency in operating the scanning machine after a couple of hours of training, but they tend to dedicate their Ph.D. studies to mastering fMRI data analysis.

To make sense of what I was observing in the laboratories, I took advantage of my dual positioning in the field: a semiotician trained in cognitive science. During the study, I was a doctoral student in the Department of Cognitive Science at UCSD and hence a member of the research field—at once an insider and an outsider (Mol, 2002). Given this position, the everyday activities of a doctoral student—attending talks, taking classes, presenting and discussing research results—were not easily discernible from my ethnographic work. As I was taking part in the activities of the community, I was observing its dynamics with the goal of generating what Geertz (1973)—borrowing from Gilbert Ryle—calls *thick descriptions*.[8] Being embedded in the community allowed me to spend long periods of time with its members and to capture some of the details that constitute the everyday practices of fMRI.

The three laboratories that I studied focus their research on human cognitive processes through the employment of fMRI. Two of these laboratories were located at the UCSD campus and the other at the Salk Institute. One of the two UCSD laboratories researches brain development in the patient population, whereas the other two laboratories specialize in the study of visual processes in healthy adults. My ethnographic observations encompassed the work of principal investigators, researchers, and students in cognitive science, psychology, and neuroscience at the graduate and undergraduate levels and lasted for 3 years. During the study, in addition to the usual participation in the cognitive science community, I attended working sessions and laboratory training activities, carried out interviews, and gathered documents that ranged from e-mail correspondences and architectural plans to scientific reports.

The shift of focus from the fMRI center to the laboratory had consequences for the shaping of this study. Once in the laboratory, my attention was absorbed by the ordinary methods (Garfinkel, 2002) that scientists use in their work with fMRI data. Particularly, I was fascinated by the manual engagement and interaction with technology that such work entails. By observing scientists at work, I had to notice that their encounters with the massive and expensive scanning machines were mediated by their gestures in front of brain visuals and their commands typed on ordinary personal computers. Intrigued by the space between scientists and their computers as the locus of the everyday action and interaction in the fMRI laboratory, I set out to describe aspects of its dynamics.

A Return to Laboratory Studies?

By attending to everyday features of scientific practice, my approach is a return to the expository style and interest of early *laboratory studies* (Knorr-Cetina, 1981; Latour & Woolgar, 1979; Lynch, 1985a, 1993; also Collins, 1985; Pinch, 1986; Traweek, 1988). Like the laboratory studies originating almost three decades ago, of importance are epistemological issues grounded in local research practices. The goal is to examine "the methodical way in which observations are experienced and organized so that sense can be made of them" (Latour & Woolgar, 1979: 37). However, different from earlier studies, I turn attention to the intricacies of multimodal semiotic interaction.

At their outset, laboratory studies were responding to a significant absence of knowledge about how scientists actually work. Bruno Latour and Steve Woolgar (1979:17), for example, noticed that an important effort had been dedicated to the study of science, yet the majority of such projects were primarily devoted to examinations of science on a larger scale. To fill this gap, early laboratory studies urged for detailed participant observations (aided by interviews and discourse analysis methods) to be conducted in places where scientists actually do their research. While engaging ideas from Wittgenstein's (1973) *Philosophical Investigations*, Kuhn's (1962) *The Structure of Scientific Revolutions*, European semiotics of the narratological stem (e.g., Greimas, 1987), ethnomethodology (Garfinkel, 2002), and pragmatics (e.g., Austin, 1962), these empirical relativist studies generated accounts of how scientists prepare experiments, collect data, and discuss and write scientific reports. The interest in how scientific activities actually take place allowed laboratory studies to disturb assumptions about science as a unique sphere of human cognition and to sharpen the awareness toward the local and contextual aspects of science (see also, e.g., Fujimura, 1996; Galison, 1987, 1997; Mindell, 2002, 2008; Pickering, 1995; Shapin & Shaffer, 1985).

Today, however, although important laboratory studies continue to be accomplished (e.g., Doing, 2004, 2009; Merz & Knorr-Cetina, 1997; Mody, 2001; Roth, 2005; Sims, 2005), the excitement and productivity that characterize the early ethnographies has waned (for a discussion, see Amsterdamska, 2008; Doing, 2008). Even though there is no doubt that the original studies provided a deep grounding for the contemporary STS, with the maturing of the field they have been frequently judged as naïve and too burdensome to conduct.[9] Since the 1990s, as the field gained institutional strength, the emphasis on the practical and local has been largely replaced by research more readily focused on scientific texts, larger communities, and societal phenomena. The attention has been turned to policy and governance in public and political institutions, emphasizing global and normative aspects in the practice of science and in extending its analysis to include scientists' relationships to media, courts, advertising, and funding (e.g., Epstein, 1996; Haraway, 1997; Jasanoff, 1995; Reardon, 2005).

This move from the local to larger social structures, though unquestionably productive, has, however, left significant portions of scientific practices still underexplored. Studies of brain imaging are one example. Important work has been done investigating the intersection between popular culture and neuroscience, using cultural criticism to frame the issues of how visual representations are used to explain biological processes, and how they, while generating powerful ideas about our health and identity, are embedded in larger social, political, and economic configurations (e.g., Beaulieu, 2002, 2004; Dumit, 2004; Joyce, 2005, 2008; Prasad, 2005a, 2005b).[10] Yet, when these studies target the practice of science, they remain somewhat removed from the details of individual episodes of real-time work with brain scans.[11] Their readers, therefore, do not learn much about the material status that *digital brains* may conserve or acquire during specific instances of laboratory work and interaction. To confront these issues we must reconsider laboratory studies.

In fact, despite the prevalence of interest in the large-scale phenomena that characterize the current moment in STS, recent scholarship shows signs of interest in the scientific laboratory. In his study of modern physics, Park Doing (2009), for example, has pointed out the need to investigate what is left unanswered by the early laboratory studies—that we still do not know much about the relationship between laboratory work and the status of the enduring facts that the laboratory has produced. Even though Doing's main preoccupation is to reengage laboratory studies and the now-established interest in the realm that goes beyond the laboratory, his agenda importantly disturbs the general sense that early laboratory studies, though being foundational for the field, should be considered an accomplished and closed chapter of STS:

> These days, few sessions at professional meetings, only a handful of journal articles, and even fewer new books are dedicated to the project of ethnographically exploring fact making in the laboratory. After all, why repeat a job that has already been done? Indeed, the job was apparently done so well that there are not even that many laboratory studies in total, despite their subsequent importance to the field. In spite of this unfolding of history, however, questions must be asked of laboratory studies in STS. Did the early lab studies really accomplish what they were purported to have accomplished? Did they, as Knorr Cetina said, show the "'make' and accomplished character or technical effects"? And, importantly, are what present studies there are now doing all that they can do? (Doing, 2008: 280–281)

Similarly, in the domain of the history of science, Robert E. Kohler, for example, has recently pointed out a noticeable absence of historical accounts of laboratories. Kohler observes that after a productive start in the 1980s, laboratory history is neglected today. He suggests bringing back the early trends in the "microhistory of laboratory practices" in the form of "macrosocial history of the laboratory" (Kohler, 2008: 1).

Handling Digital Brains joins this trend. Yet, rather than broadening the perspective, it invites an even more detailed look at real-time work and interaction in the laboratory. It does so by focusing on what has been acknowledged by original laboratory studies but never thoroughly dealt with: multimodal aspects of scientific practice. Without aspiring to provide an exhaustive treatment of the brain mapping field, my interest is in showing actual instances of brain mapping practice to shed light on the embodied and experiential character of real-time work with digital technology. This is not to say that the laboratory, policies, and media do not coproduce each other; what goes on in the laboratory is always in respect to the broader social structures (and vice versa) (e.g., Latour, 1983). At stake, however, are kinds of entities and agencies that would remain invisible if we were not to look at multimodal semiotic interactions in the laboratory. Paying attention to the dynamic interface between scientists—their gesturing bodies—and the world of instruments and visual displays identifies the objects of scientific practice (our brains and our bodies) as constantly changing, distributed phenomena that dwell at once in multiple spaces.

Digital Scientific Visuals as Fields for Interaction

Proponents of laboratory studies have argued for the importance of embodied aspects of scientific work, pointing out the centrality of the knowledge that the ethnographer and scientists share (Lynch, 1993). This is particularly the case for those scholars who base their approach in ethnomethodology and phenomenological traditions, such as Michael Lynch, Karin Knorr-Cetina, and Klaus Amann. Knorr-Cetina and Amann, for example, argue that visual imaging (rather than literary inscriptions; Latour & Woolgar, 1979) is central in laboratory work:

> Images are objects on which work is performed in the laboratory; like other materials handled in the stream of laboratory activities, they are processed. The analysis contained in the data is not written in the image's face. It is brought to the fore by means of image analysis techniques that look behind the surface of the features displayed. Participants look at the display as one would look through a window that opens to a whole new environment of processes and events. (Knorr-Cetina & Amann, 1990: 262)

The question that remains to be answered is, how? How do scientists engage these visuals in real time? What are the techniques and practical details of such activities? And, specifically, how is this engagement accomplished with respect to the digital nature of the matter they are dealing with?

Once we refer to fMRI brain scans as digital and visual at the same time, they are not only "windows" to be "looked through" but also multimodal sites where work is importantly accomplished. In activities such as apprenticeship learning and data analysis, scientists *handle* brain scans. These practical engagements with a highly malleable substance indicate scientific visuals as *fields for interaction*. fMRI visuals are malleable fields because they are digital, but also because they can be altered in interaction through the involvement of gesturing hands. In this regard, the fields for interaction are also multimodal: To make sense of the visuals practitioners engage their eyes (and their thinking brains), but also their hands, ears, and the entire bodies. This active participation and embodied engagement of the scientists suggests that the visibility of digital visuals is relative to the circumstances of their practical and multimodal engagement.

The brain visuals, however, cannot be fully characterized as *socially constructed*. In the laboratory, the imaged bodies perform resistances by placing conditions on their scans. This, though, does not mean that the scans function as transparent conduits that unproblematically reveal the imaged bodies. Instead, the scans, by virtue of being at once visual and highly malleable objects, are involved in articulating digital brains. In other words, fMRI scans function as the center of action *with* which (not only *on* which) the work is performed. They allow the practitioners to deal with their experimental data in a manner that is somewhat analogous to our engagement with physical objects. Thus, when handled, fMRI visuals concern at once the material world, the digital reality, and the embodied, culturally shaped, and socially performed actions. They are the places where the scientists' interactional and experiential bodies are intertwined with the objects of their inquiry.

To face fMRI brain scans as sites for interaction that are at once visual and digital, I rely on the *interpretative semiotics* of Charles Sanders Peirce (1839–1914).[12] Semiotics has been an important influence for STS (e.g., Akirich & Latour, 1992; Haraway, 1991, 1992; Hayles, 1993; Latour, 1987, 1993; Latour & Woolgar, 1986; for discussion, see Høstaker, 2005; Lenoir, 1994). Yet, this influence has been primarily grounded in the *structural* semiotics of Ferdinand de Saussure (1983) and his follower Algirdas Julien Greimas (1987).

When referring to Saussure's semiotics, scholars interested in the material practices of science have suggested ways to overcome the relativism and distance from the material reality and the body characteristic of structural semiotics. For example, Latour (1993, 1999) has spoken about closing the gap between subjects and objects, nature and culture, and Haraway (1991) has proposed the feminist standpoint theory of *partial perspective*. This trend has, however, overlooked that, in contrast with the Saussurian model of the sign that *brackets the referent* (excluding from the domain of interest any reference to objects in the world), Peirce's conception includes what the sign stands for as its necessary part. Peirce's conception of the sign, with its concern for the materiality of the world, proves particularly valuable when multimodal sign systems and the digitality of the visuals are of interest.

As the digitality is seen as a space for embodied engagement, I show how gestural actions and manual handling of the digital matter constitute thinking. Peirce's semiotic approach—pragmatic and antipsychological—is again of importance as it addresses the issues of the mind without reducing it to an individual's brain. Instead, the mind is a semiotic process that is dialogic and dynamic. For Peirce, thinking is the operation of signs that regards a communicative agent and comprises language as well as tools and instruments.

By embracing Peirce's semiotics, my taking on of laboratory studies is thus not a fateful return to the original approach, but a proposal of how to deal with the epistemological preoccupations typical of the early approaches while analyzing multimodal action and interaction that characterize local research practices in the computerized age. Inspired by Peirce's semiotics and turning the gaze toward digital screens (Manovich, 2001) means reconsidering how we understand ourselves and the world in which we live. When cognitive neuroscientists handle digital brains, they also think with their hands while engaging objects of their practice as hybrid phenomena enacted at the junction between the world of technology and the world of corporeal action.

At the Opening Ceremony

The organization of the chapters of this book follows the movement of fMRI experimental data as they are collected in the scanning facilities (chapter 3), undergo transformations in the laboratory (chapters 3–6), and finally leave the laboratory to be published in professional journals (chapter 7). At the same time, I discuss the status of digital visuals in science (chapter 2), arguing that their boundaries need to be reconceptualized once multimodal aspects of real-time scientific action and interaction are taken into account. The grounding of the discussion in concepts from Peirce's semiotics and the methodological approaches of ethnomethodology and conversation analysis are my way to join a recent trend in the study of scientific practice exemplified by the work of Annemarie Mol. As

Mol points out, a *praxiographic* approach no longer captures "a gaze that tries to see objects but instead follows objects while they are being enacted in practice. So, the emphasis shifts. Instead of the observer's eyes, the practitioner's hands become the focus point of theorizing" (Mol, 2002: 152). I look at hands in fMRI through the lens of their real-time, multimodal engagements in the laboratory.

Once such a grounding has been established, the text describes scientific apprenticeship and the problem of the body and embodiment from the angle of multimodal interaction (chapters 3–5). This perspective leads me to investigate how scientists conceptualize the object of their practice when they access it in terms of digital data (chapters 4 and 6). While highlighting the digital character of fMRI brain scans, I, nevertheless, reassert their visual status (chapter 7).

The fecundity of an approach attentive to multimodal enactments shows not only in its capacity to ground an exploration of digital visuals and the objects with which scientists deal but also in its aptitude to allow a critical dialogue between the ethnographer and the field of her study. By focusing on how scientists use their hands to *see*, and thus understand, what is displayed on the digital screen, *Handling Digital Brains* reflects upon the problem of the human mind and embodiment, the questions of central interest to cognitive neuroscience (chapter 5).

Whereas fMRI technology presupposes that our cognitive processes can be reduced to the workings of an individual's brain, I argue for a view of cognition that is distributed between people and rooted not only in mental processes and computational inferences but also in a culturally shaped and socially enacted world (e.g., Cole, 2003; Engeström & Middleton, 1996; Hayles, 1999; Hutchins, 1995; Lave, 1988; Middleton & Edwards, 1990; Mukerji, 2009; Neisser, 1982; Norman, 1988; Rogoff & Lave, 1984; Suchman, 1987). The book develops this line of thinking by turning attention toward the body, digital screens, and the processes that are often performative and dynamic in character.

As recorded during the aforementioned opening ceremony of the UCSD fMRI brain imaging center, Edward W. Holmes remarked:

> This state-of-the-art resource will accelerate the pace of discovery in the studies of the brain and its function. Armed with this technology we can address the fundamental questions about what is arguably the most fascinating organ in the body—our minds.

In a similar tone, Roderic Pettigrew added:

> We can now visualize the mind in imaging the brain. With this kind of resolution we are now able to attach the intangibles to tangibles to see the mind in the brain. Memory, forgetfulness, truth, lies, happiness, sadness can be visualized and thereby studied.

The event was conceived as the beginning of a new era for research at UCSD, as the presence of fMRI technology framed the future of scientific endeavors. The speakers talked about the ways in which fMRI technology rearticulates the possibilities for research by allowing scientists to acquire new capabilities for vision. “Armed with the technology,” scientists will be able to *see the mind* as a process of the human brain.

I listened to these statements with a somewhat divided stance. Like the speakers, I saw the promise in the scientific study of human cognition. On the other hand, I felt somewhat uneasy. I could not help but think about the ways in which this technological framing, while generating new possibilities for research, constrains how we understand ourselves as human beings. If “memory, forgetfulness, truth, lies, happiness, sadness” can be studied by analyzing recordings of physiologic changes in the human brain, where does this leave the rest of our bodies, engaged in the sociocultural world we live in? In other words, could our conception of technology and the results it generates preclude us from understanding the mind as a distributed and situated phenomenon where (just like for Jane and Paul at the beginning of this chapter) our thinking emerges through the interaction of our brains with our hands, eyes, ears, and tongues as we engage in the everyday activities, gesturing, seeing, listening, speaking, and interacting with each other and the world of our practice?

To deal with these questions, and thus take part in conversation with the field of science under scrutiny, I invite the reader to pay close attention to the role of multimodal interaction in the work of fMRI brain imaging. The practical and semiotic engagement with digital brains in the laboratory problematizes assumptions behind fMRI technology and its associated practices; it suggests that human meaning-making and learning importantly concern our *hands*.