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"The Dance of the Knife." Ethnographic Reflections on Neurosurgical Experience and Agential Materialism

> "A good butcher changes cleavers every year because of damage, a mediocre butcher changes cleavers every month because of breakage. I've had this cleaver for nineteen years now, and it has cut up thousands of oxen; yet its blade is as though it had newly come from the whetstone. . . . The joints have spaces in between, whereas the edge of the cleaver blade has no thickness. When that which has no thickness is put into that which has no space, there is ample room for moving the blade. This is why the edge of my cleaver is still as sharp as if it had newly come from the whetstone. . . . Even so, whenever I come to a knot, I see the difficulty to doing it. I am careful to remain alert, with my gaze steady. Moving slowly, I exert a very slight force, and the knot has come apart, like earth crumbling into the ground. Then I stand there with my cleaver, looking all around and pausing over the satisfaction in this. Then I clean off the cleaver and put it away."
> The king said, "Excellent! Having heard the words of a butcher, I have found the way to nurture life."[1]

Introduction

Observing a neurosurgical team at work, I watch with the resident the tip of an instrument cutting out a tumor from a human brain.[2] The screen of the microscope is crisp, and the action is lively—the knife is moving within a microscopic site, with staggering stakes for the patient under the surgical covers, for the person holding the tool, for the team, and the institution around them. New to this field, my ethnographic mind is focused on the action, translating it to the movement of my own inscription devices. I have been hired to investigate the activity of the material pertaining to the practices of cutting in a neurosurgical context, at a world-class clinical research department. As I see the delicate nervous tissues in vivid colors being pushed around and aside speedily, I wonder at the number of human hours and human lives it took to get things moving so smoothly. The masterful healing cut brings to my mind a Taoist tale from a

1 Thomas F. Cleary, ed. and trans., *The Essential Tao: An Initiation into the Heart of Taoism through the Authentic Tao Te Ching and the Inner Teachings of Chuang-Tzu* (Edison, New Jersey: Castle Books, 1998), 48.

2 I would like to thank Joe Dumit, Laurence Douny and Yoonha Kim for their insightful remarks on this chapter, as well as Elisabeth Obermeier for her relentless editorial management. I am indebted to Joe in particular for steering me toward a deeper understanding to the work of Karen Barad. I am also grateful to Aaron Bogart for his thorough proofreading and reviewing work, and to Sabine Marienberg for coming to my rescue on a technical point during the revision. Thank you also to the team at Charité—Universitätsmedizin Berlin and especially for the warm welcome of Peter Vajkoczy, Thomas Picht, Anna L. Roethe, and Janett Grimm without whom this fieldwork would not have been the same.

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book I like to read at night when I can't sleep. One of the stories of Chuang-Tzu, in part quoted above in the epigraph, introduces a master butcher whose instrument never gets blunt, as they have learned to cut around and with the bodies, throughout and alongside their lines. The knife is "dancing" within the animal body and the master is following it. The point of the story is hinting at a way of life which has merged with nature itself—it means in that context a life imbued with non-action, a way of life that doesn't impede the cycles and flows of the universe.[3] If the atmosphere in the operation room is quite relaxed, which is a cue to an arguably harmonious cosmic relation of the practitioner with the universe, the rest of the setup seems far from natural, and the heavy intervention that is happening would probably make a Taoist cringe. Or would it? The neurosurgeon at work, Peter Vajkoczy, likes to speak of humility in the neurosurgical practice. When he discusses and transmits his practice to others, he articulates action and nonaction in skillful ways: when there is a possibility of saving a patient with an intervention, deciding against the intervention is also an intervention. Stretching senses of the possible and bending the statistics of success is the baseline of his neurosurgical research. Vajkoczy is an influential proponent of considering neurosurgery as a dynamic and therefore daring field of investigation. Bringing the patient on-board is an act that requires charisma and a leap of faith, something that isn't purely medical skill. Or is it? Vajkoczy speaks of attracting talents to his team —and he knows the kind of teamwork that is necessary to take people to higher places. When people start speaking of a scientific practice as an art, we are at the limit of a delimited and theorized practice and we enter into an open area of reworlding and mystique.

Back on the fieldwork scene, I'm trying to gain critical distance facing the awe provoked by the surgical act; I survey the environing stage of the microscopic performance. Science and technology are everywhere I look: neatly ordered in category and procedures, the products and devices embed a hundred years of biomedical innovations, they are the infrastructures of what Byron J. Good has described as a reframing device for an emotional and human situation to be converted into a rational stage for biomedical operations.[4] The decision to operate on that patient was supported by a grid of criteria based on a review of studies with blind controls, itself published into a renowned peer-reviewed journal, tidying up a messy clinical reality into a workable decision process. A team of highly specialized professionals is at work, supporting a single person, and a single human hand, as the main channel of their definitive action. The sociologist Stefan Hirschauer argued that surgeons are sculpting the material to conform it to anatomical models.[5] Rachel Prentice complemented this view in the most elegant (ethnographic) manner: a lifetime of practice forms the hand of the sur-

3 I have to thank my colleague Shang Jing from the University of Tongji for this insightful remark.
4 Byron J. Good, *Medicine, Rationality, and Experience: An Anthropological Perspective*, The Lewis Henry Morgan Lectures 1990 (Cambridge ; New York: Cambridge University Press, 1994), 85.
5 Stefan Hirschauer, "The Manufacture of Bodies in Surgery," *Social Studies of Science* 21, no. 2 (May 1, 1991): 279 – 319, https://doi.org/10.1177/030631291021002005.

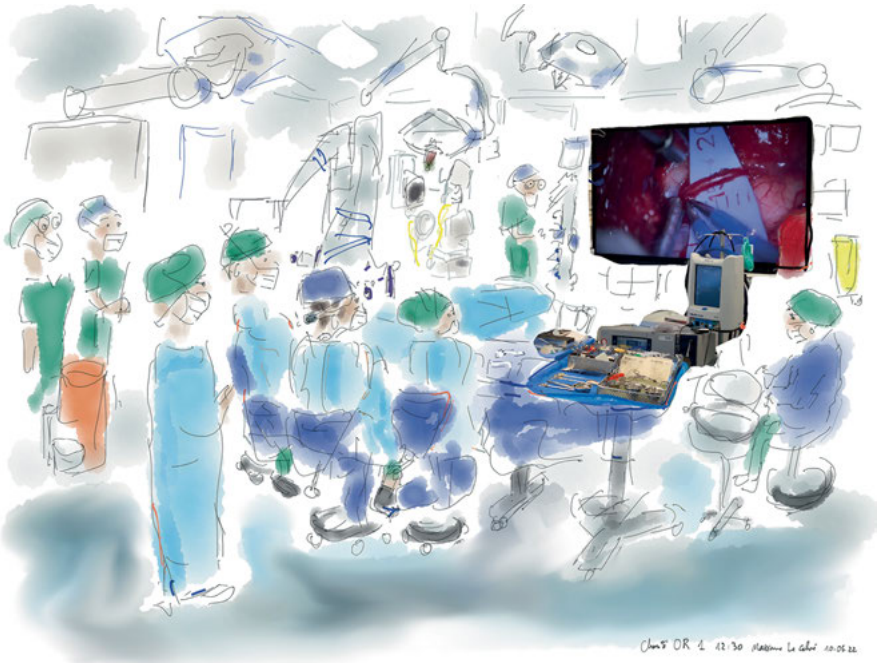

Fig 1: Peter Vajkoczy conducting vascular bypass surgery at Charité. Digital drawings by Maxime Le Calvé.

geon as much as the bodies of their patients.[6] And so does ethnographic practice: while I am sketching the scene, as I routinely do to capture the moment as an atmospheric note, the dancing tip of my digital brush catches my attention. The pen moves hectically as if by itself, like the knife of the surgeon, which brings me closer to the micro-scene broadcast on a big screen. I see no big consequences here for a wrong stroke, and certainly not the same kind of virtuosity at play, yet an improvised movement of note taking that has shaped me as much as it has shaped my work. It strikes me how the "middle voice" that arises in practice—not active, not passive, right in the middle—is bringing new dimensions of truth to light, and how making and knowing sometimes seem to flow.

With this text, I am sketching a direction for a larger project with an ethnographic study of the daily labor in the operation room. I attempt to pursue, in an essayistic mode, the idea of "cutting" as a micro-mystical practice: How do neurosurgeons stretch their senses and their sense of the world as they follow the cues of the material? I funnel the material through the lens of the practice of cutting as defined in two sources that I already mentioned above, one of Chinese origin and one from the Greeks, which I conceptually compare. I will also evoke the work of a number of scholars

6 Rachel Prentice, *Bodies in Formation: An Ethnography of Anatomy and Surgery Education*, Experimental Futures (Durham, NC: Duke University Press, 2013), 229–31.

who have written on the relation between the craftperson and the material—starting with Gilles Deleuze and Félix Guattari, over to Tim Ingold, Trevor Marchand, Lambros Malafouris and Don Idhe—on craft and on the interaction between the craftsperson and the stuff they are engaging with, as well as the extension of one's senses that happens through a technical device. I will use the notion that can be found in the new materialism literature and coined by Karen Barad in the context of her research on the history of experimental physics, that of "cutting together/apart." Language is tricky: it separates things into categories. Science has been caught in this trickiness, which extends through experimental apparatuses and discourses.[7] As the first section of this paper will show with a reading of two ancient parables, this seemingly antithetical notion of the cut, which bring things together, echoes far older reflections on the relation between subject and object. Insights into human embodied knowledge emerging from practices of cutting animal bodies can be found in the writing of two iconic authors from antiquity, one Chinese, Chuang-Tzu, and one Greek, Plato. The separation and the bond between them can be wonderfully emphasized when the link between them is the sharpness of a tool. Dichotomies are conceptual cuts that allow the classification of things into distinct categories.[8] They are central to modern scientific epistemology, which separates natural species, as Plato wrote, "carving nature at its joints," as one cuts a roasted chicken. As the French anthropologist André Haudricourt has noted, the way we handle animals and plants says a great deal about our relation to the world and to our fellow human beings.[9] Both Chuang-Tzu and Plato take on the same image of "cutting at the joints" of the animal body as a metaphor for the exemplary way of knowing. And yet, as we will see, their approaches are stunningly different. In a second step, I present a few graphic fieldnotes, sketches from my ethnographic survey of the neurosurgical cut, to illustrate some of the insights gained during my observation at the Charité Hospital among the neurosurgeons. The evocation of the fine skills of the craftsperson incites me to further the notion of skillful gesture as analytic in the context of digital mediations—exploring the premises of what I will call a 'stretching' of the master cutter's senses through training, scientific knowledge, institutions, and instruments.

7 Karen Barad, "Diffracting Diffraction: Cutting Together-Apart," *Parallax* 20, no. 3 (2014): 168–87, https://doi.org/10.1080/13534645.2014.927623.

8 As Joe Dumit pointed judiciously out to me, we should ask first if things are there before any cuts/dichotomies/categories. Are humans the originators/senders of categories, or via Barad, is cutting together/apart a way of worlding worlds?

9 André-Georges Haudricourt, "Domestication des animaux, culture des plantes et traitement d'autrui," *Homme* 2, no. 1 (1962): 40–50, https://doi.org/10.3406/hom.1962.366448.

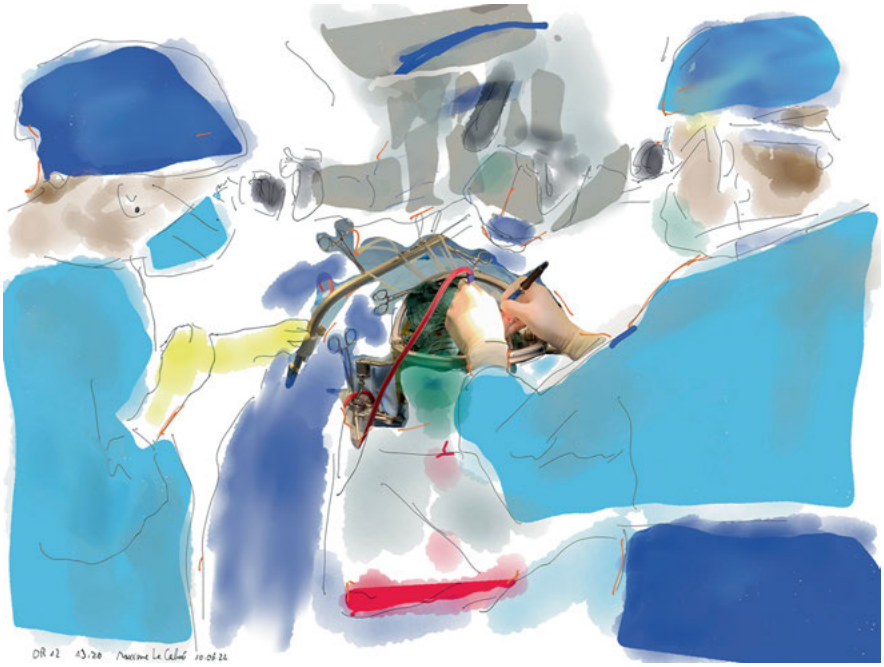

Fig 2: Surgeon operating with a resident at the binoculars.

I Philosophical Butchery

Let’s start by reviewing and confronting two positions on cutting bodies from antique sources and their statement on the relation between knowledge and the cutting gesture. Both have to do with the idea of following lines in the structure of the body, therefore complying with a certain agency contained within them: a “sense” (direction) of the material that has to be acknowledged and “sensed” (perceived) by the cutter. Those two positions, however, differ starkly on the epistemic effect of the cutting action. On the one hand, a precursor to modern thought, Plato considers that dichotomies (meaning binary cuts) operated through language are justified by the preexistence of a structure of things in nature: the realist will “carve nature at its joints” to classify objects into categories according to certain characteristic behaviors or features, including their shape. On the other hand, the tale of the master butcher told by Chuang-Tzu speaks to the same action of cutting along the lines of the body, but with a very different conclusion: it is the sense of nature itself that is sharpened, rather than the knowledge or categories of the resulting pieces. The symptom of this progress is that the blade of the master will never go blunt, as the master butcher guides it or lets himself be guided by the knife in a sort of dance, always finding space within the tissues and, again, carving effortlessly at the joints. On the one hand, we have the philosophical

butchery of cutting out species from each other. On the other hand, the unifying and integrating effect of mastering the technical gesture brings the subject and the object together in a state of inter-being and inter-becoming. Both texts agree on the fundamental idea of following the lines of the material. Their conclusions, however, couldn't be more different.

Plato speaks precisely of cutting nature at its joints. In the introduction to a book of 2011 bearing this quote as subtitle, the philosophers of science Matthew Slater and Andrea Borghoni start with the Taoist tale of the butcher who never sharpens his blade and juxtapose it with Plato's statement.[10] They are interested in scientific classification, which they compare to "scientific butchery," and the way these classifications are constructed as "discoveries" coming directly from nature. They tell us how the theory of Plato has been put into the service of a modernist ideal of science:

> Plato famously employed this "carving" metaphor as an analogy for the reality of Forms (Phaedrus 265e): like an animal, the world comes to us predivided. Ideally, our best theories will be those which "carve nature at its joints." While Plato employed this metaphor to convey his view about the reality of Forms, its most common contemporary use involves the success of science —particularly, its success in identifying distinct kinds of things.[11]

In the ensuing paper, they write at length on the paradigm of "discovery" as opposed to that of "invention": modern scientists have the ambition to "cut the chicken" (nature) in the most efficient way, which should be dictated by the chicken itself, as there aren't many ways of cutting it into distinguishable parts. The first example they take comes from ornithology: Ernst Mayr, long-time authority on the question of species, claimed that all people of the world recognize species of nature "as a western scientist."[12] While philosophers are trying to enforce the "skeletal structure" of nature, historians and philosophers of science are challenging the "naturalness" of natural kinds.[13] Indeed, when analytical philosophy takes over, the Taoist tale's insight is lost for good in the exploration of properties, categories, and essences of things and of what Slater and

10 Matthew H. Slater and Andrea Borghini, "Introduction: Lessons from the Scientific Butchery," in *Carving Nature at Its Joints*, ed. Joseph Keim Campbell, Michael O'Rourke, and Matthew H. Slater (Cambridge, MA: MIT Press, 2011), 1–3, https://doi.org/10.7551/mitpress/9780262015936.003.0001.

11 Slater and Borghini, "Introduction," 1.

12 Things are getting more complicated with the recent breach of speciation genomics, now that "the molecular basis of the splitting process" is within reach of the researchers, see Jochen B. W. Wolf, Johan Lindell, and Niclas Backström, "Speciation Genetics: Current Status and Evolving Approaches," *Philosophical Transactions of the Royal Society of London: Series B, Biological Sciences* 365, no. 1547 (2010): 1717–33, https://doi.org/10.1098/rstb.2010.0023.

13 Slater and Borghini, "Introduction," 2. See in particular David L. Hull, *Science as a Process: An Evolutionary Account of the Social and Conceptual Development of Science*, (Chicago: University of Chicago Press, 1990); Geoffrey C. Bowker and Susan Leigh Star, *Sorting Things Out: Classification and Its Consequences* (Cambridge, MA: MIT Press, 2008), 8.

Borghini call the "sortal" tradition—the modern scientific custom of separating things and species into distinct categories, which they consider a rebirth of essentialism.[14]

Fig. 3: Excerpt from fieldwork journal at the neurosurgery department: preparing an unconscious patient.

Returning to the scientific butchery essay of Slater and Borghoni with the Taoist story in mind, I couldn't rid myself of the impression that there is so much more to learn from the Chinese tale than just a quick parallel with the metaphor of Plato. What about the actual cutting and carving that scientists practice in their everyday work to make dichotomies and advance their knowledge? The "dance of the knife" that is captured so vividly in a few sentences by Chuang-Tzu points in other directions: What does it mean to follow the practical lines of the materials, so that our blade never becomes blunt, and the activity of the material, its resistance, reactions, immediate and in the longer term, are taken into account in the description and experience of the cutter? Moreover, the continuity existing along the line traced by the edge of the knife implies a relation between the cut, the cutter, and the hand/tool in between: the Taoist story highlights the fact that they are becoming one. This relation contrasts with the idealist notion that the different characters of the scene and the form that is being discovered have always existed and will keep on existing as essences whose "joints" would simply have to be distinguished. The parable of the master butcher is not

14 Slater and Borghini, "Introduction," 7.

about the dichotomy practice, which traces a line between already existing territories. To take the example of the neurosurgeon, this would be the ideal of an intervention planned on screen, with a 3D visual of the tumor appearing in its non-tumorous surroundings. The actual intervention, both in the case of the butcher and the neurosurgeon (and perhaps that of the ethnographer), is rather about letting the boundaries appear through a path and a practice. This is a process of co-constitution of the cut and the cutter, building on a consistently minded encounter that changes both parties. The Taoist Chuang-Tzu repeats it throughout his work: the practitioners get closer to nature itself as they advance on this path.

Because we can't productively embrace the Taoist practical philosophy of nature in the frame of this essay, I am appealing to Barad as an unlikely mediator. Physicist and philosopher, they have turned to the quantum physicist Niels Bohr to derive from his work a full-fledged process philosophy, advocating for a new understanding of nature and the process of knowing things.

> [T]he heart of the lesson of quantum physics (is that) we are a part of that nature that we seek to understand. Bohr argues that scientific practices must therefore be understood as interactions among component parts of nature and that our ability to understand the world hinges on our taking account of the fact that our knowledge making practices are social-material enactments that contribute to, and are a part of, the phenomena we describe.[15]

Barad has developed renewed attention to the effect of material-discursive practices in epistemic work. "Agential cuts" are operated by scientists as they construct categories and embed them into their apparatus. Inspired by the foundational reflections of Niels Bohr on the impossibility of separating scientific fact from scientific devices, the physicist-philosopher insists on the idea that we are always "meeting the universe halfway." In a move that the butcher of Chuang-Tzu would approve of, they read into this phenomenon "an invitation that is written into the very matter of all being and becoming."[16] The intensity of this encounter can be more or less sharp according to the practice and experience that is put into the technical gesture. Whereas Plato and the moderns do not let any sort of moral leak into their cutting story—although it is intensely moral as it polices expertise—this is not the case with the Taoist story, for which mastery stands for knowledge, practical wisdom, and inspiration for a way of life. The act of knowing relies on the production of a difference that is, as such, a "cutting together/apart," which is firstly engendered by the devices and the discourses that are embedding the practice.

15 Karen Barad, *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning* (Durham, NC: Duke University Press, 2007), 12.
16 Ibid., 12.

> Apparatuses enact agential cuts that produce determinate boundaries and properties of "entities" within phenomena, where "phenomena" are the ontological inseparability of agentially intra-acting components. That is, agential cuts are at once ontic and semantic.[17]

Barad calls this knowledge process a "mattering process." [18] This expression is a double entendre, hinting at the fact that this process is both giving matter its conceptual consistency and driving our sense of importance to a new, specific pole of what will matter to us in this newly forged circumstance. They describe the process of the production of knowledge in laboratories and elsewhere as a specific form of their "dance"—to quote them again: "Meaning and matter are more like interacting excitations of nonlinear fields—a dynamic, shifting dance we call science."[19]

These remarks on cutting will, hopefully, help me to explicate certain tensions that I have found in my ethnographic observations of the practice of neurosurgery: a cohabitation between the protocols and requirements of scientific experimentation, creativity, improvisation, and the attunement between the neurosurgical body and that of its patients. As they get their senses stretched by the practice, their relationship to the contingencies of the world is reshuffled and becomes unrecognizable—not in an exceptional event but in the daily grinding and drilling of clinical work.[20]

II Driving a Tipping Point through the Brains

The neurosurgical cut sits at the pinnacle of modern physiological science. The case of neurosurgical skill is extreme in many respects. Let us swiftly go through a review of a few ethnographic insights gained during fieldwork at the Department of Neurosurgery of the Charité Hospital in Berlin.[21] First, the "material" the surgeons are cutting is the flesh of a person: each central nervous system is embedded in an "ecology of relations," as Thomas Fuchs, and Gregory Bateson before him, have called it.[22] A mistake can have disastrous consequences on the life of that human being. While they are operating, they are aware of almost constantly standing at a tipping point between heal-

17 Ibid., 148.

18 Ibid., 141.

19 Ibid., 188.

20 Although exceptional events also occur and are sometimes reported in the literature, see the opening scene of James R. Doty, *Into the Magic Shop: A Neurosurgeon's Quest to Discover the Mysteries of the Brain and the Secrets of the Heart* (New York: Avery, 2016).

21 My fieldwork focuses mostly on the perspective of the Image Guidance Lab, which gave me an overview of the current research on neurosurgical imaging and planning practices at this hospital. During this time, I could also observe several interventions, document experimental training, and shadow several members of the clinic, drawing graphic field notes.

22 Thomas Fuchs, *Ecology of the Brain: The Phenomenology and Biology of the Embodied Mind* (Oxford: Oxford University Press, 2018); Gregory Bateson, *Steps to an Ecology of Mind: Collected Essays in Anthropology, Psychiatry, Evolution, and Epistemology* (Northvale, N.J: Aronson, 1987).

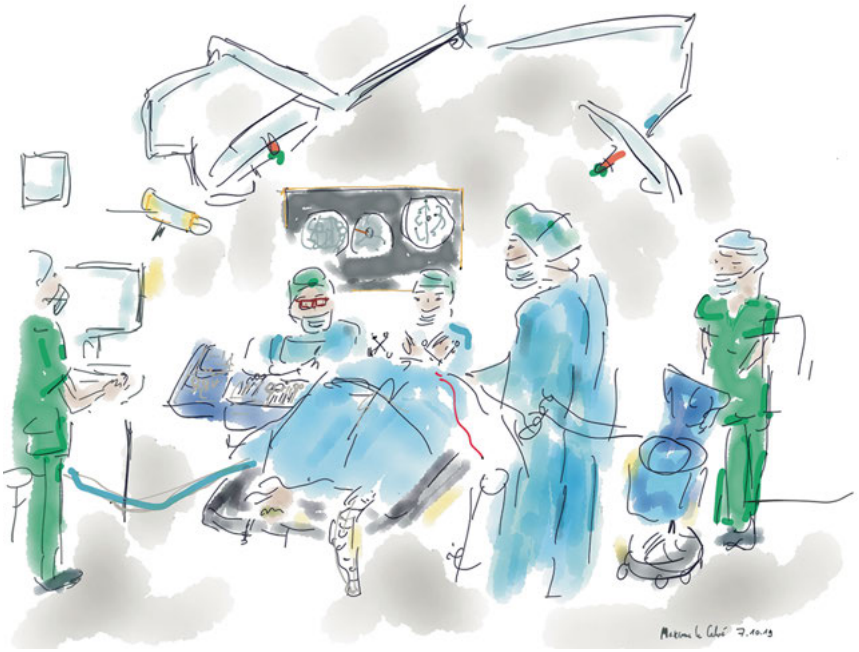

Fig. 4: Excerpt from fieldwork journal at the neurosurgery department: preparing an unconscious patient.

ing and harming, handling it with a delicate balance of caution and courage. Second, contrary to what I believed in the beginning (as well as most laypeople I present my research to), most neurosurgical operations are conducted by hand. The noninvasive techniques of robot-assisted surgery have, at the time of writing this chapter, very limited application in this domain, because of multiple difficulties related to the terrain itself. Brains are an instable and sometimes explosive material for the surgeons: The "brain shift" that occurs at the moment of opening the skull shuffles the tissues because of the difference of pressure. This scrambling is further aggravated as the operation moves on. It makes imaging devices incapable of rendering a precise cartography of the area of intervention, since things will move as the surgeon reaches the target. Imaging possibilities during the operation are making progress, but it requires interrupting the operation for a moment and to wheel out the patient in a machine, or to wheel in the machine to the patient. Handheld technologies are on their way, using ultrasounds, but real-time picturing seems to be out of reach.[23] Another cause

23 R. M. Comeau et al., "Intraoperative Ultrasound for Guidance and Tissue Shift Correction in Image-Guided Neurosurgery," *Medical Physics* 27, no. 4 (April 2000): 787–800, https://doi.org/10.1118/1.598942; David G. Gobbi et al., "Correlation of Pre-Operative MRI and Intra-Operative 3D Ultrasound to Measure Brain Tissue Shift," SPIE Proceedings: Medical Imaging 2000: Ultrasonic Imaging and Signal Processing 3982 (April 2000): 77–84, https://doi.org/10.1117/12.382260; Sean Jy-Shyang Chen et al., "Validation of a Hybrid Doppler Ultrasound Vessel-Based Registration Algorithm for Neurosurgery," *International Journal*

for the general use of noninvasive technologies in neurosurgery is the disastrous effect of bleedings—countermeasures to interrupt them in the delicate tissues are themselves a risky operation and make for the most stressful, tedious, and repetitive tasks of all. Third, the microscopic scale of the operation site is a miracle of human dexterity. These surgeons operate with the help of microscopes, which they fluidly pilot as prosthetics of their ocular organs. The precision of the tissue removal is of sub-millimeter accuracy when approaching the most critical areas, in particular during tumor resection within "eloquence areas." To access the operation site, they take "streets" that they have determined in advance, finding their way through the meanderings of the cerebral matter. And when they have to go through a part of the neocortex to access a tumor, they use a mini brain blaster device operating with ultrasound. Using the clinical equivalent of a vacuum cleaner, the assistant casually sucks out a person's liquified brain, and a wrong move at the wrong moment would have, again, calamitous consequences on the life of the patient, and on the career of the assistant. Fourth, they are engaged in teams that are enabling their tiny moves at the current limit of the hand-eye sensing scale, ensuring the stability of the life signals of the patient, the flawlessness of the aseptic environment, the continuous motion of instruments and products circulating around the room, the reanimation of the patients from earlier in the day, and the preparation of the patients next in line, while the surgeon remains steadily focused on the task, often at the workbench for more than ten hours in a row.[24] Fifth, they are inheriting and pushing forward their predecessors' tradition and experience that is incorporated in their training, in the way they frame anatomical problems, react to the unexpected, and in the way they hold their instruments.[25] Neurosurgery is a medical science on the move. The neurosurgeons of the team are researching as they are conducting their surgical practice, pushing the limits of the operable, and if they argue—controversy is the motor of any modern science —, clinical success will settle any discussion. They are pursuing that tipping point, chasing the next level of the possible cut, endlessly training and growing to the task. This slow and collective process of building up and stretching of the senses, generation after generation, brings them to find their bearings and to

of Computer Assisted Radiology and Surgery 7, no. 5 (September 2012): 667–85, https://doi.org/10.1007/s11548–012–0680-y.

24 In his recent biography, Peter Vajkoczy compares the process of resecting a veinous malformation to a legendary battle of man and fish, never quite over until it's over, "*Fisch raus, Fisch rein*." *Kopfarbeit: ein Gehirnchirurg über den schmalen Grat zwischen Leben und Tod* (Munich: Droemer, 2022). The sociologist Hirschauer has delivered an unmatched account of the distribution of tasks and attention in the surgical moment: Stefan Hirschauer, "The Manufacture of Bodies in Surgery," *Social Studies of Science* 21, no. 2 (1991): 279–319, https://doi.org/10.1177/030631291021002005.

25 The "Penfield dissector," for example, is an instrument that looks like a hook with a scoop, which was invented and named after one of the pioneers of the discipline, giving its descendants direct access to his gestural innovations incorporated into the tool. See Morenikeji Buraimoh et al., "Origins of Eponymous Instruments in Spine Surgery," *Journal of Neurosurgery: Spine* 29, no. 6 (2018): 696–703, http://doi.org/10.3171/2018.5.SPINE17981.

dealing with the increasing level of contingency that comes along with deeper, more complex, and invasive interventions into the brain material.

Fig. 5: Excerpt from fieldwork journal at the neurosurgery department: preparing an unconscious patient.

The evocation of the fine skills in the craftsperson's gesture leads me to refer to the contribution of Tim Ingold and other authors who have examined the question of thought in action, doing, and thinking, taking the notion of "skillful" gesture as analytic. Taking inspiration from archaeology, this literature focuses exclusively on low-tech environments, making them difficult to use as an exclusive framework to describe that sort of distributed skill.[26] I will refer to other thinkers in the field of technology studies, to comprehend this high-tech environment as a setup that is "stretching the senses": an extension of the human perception and intervention to more-than-human scales. My intention is to embrace elements of the literature considering technologies as prosthetics—including imaging and modeling—while keeping up with a phenomenological account of the neurosurgical practice. The hybrid digital/analog apparatus thus comes together in a single sensory experience as both the cutter and the cut are growing down

26 See also Lambros Malafouris, *How Things Shape the Mind: A Theory of Material Engagement* (Cambridge, MA: MIT Press, 2016). On the articulation between postphenomenology and the theory of material engagement, see Don Ihde and Lambros Malafouris, "Homo Faber Revisited: Postphenomenology and Material Engagement Theory," *Philosophy & Technology* 32, no. 2 (2019): 195–214, https://doi.org/10.1007/s13347–018–0321–7.

the scaling, reaching a state of micro-alertness to the contingencies of the environment.[27] This state is best grasped by conferring to the knife the status of an extension of both of the surgeon and the body. Thus, the touching is also touched within this device.[28] The knife is "dancing" the dance of the knife, following the impulses of both the material and the neurosurgeon. Perception is stretched, impulses are reverberated in the sensors of the magnetic resonance imaging devices, in the graphic processors, the architecture of the room, and the whole building. The many probings, trials and errors, multiple disciplines and design studios, the generations of medical specialists, and the career of each individual practitioner all are present within the encounter of the tool and the living tissue. None of them would exist without that instance. Cutting brings all these people and things together. Cutting is relating because the hand and the material become one at that precise moment: matter and activity are coproduced.[29]

III Stretching the Senses

Learning to dance with the knife is a matter of securing and fastening all possibilities, yet it is also a matter of embracing the instability as a fundamental element of this relation, and to ride it until mastery is achieved. This achievement is a tipping point. Another world becomes navigable and makes sense, not only in the visual domain but with all the senses. In the work of the anthropologist Tim Ingold, this sort of dance

27 This amplification of and coming-closer-to the object of attention is a learning process, a growing rather than a reducing (and reduction is what modern science would label it); on this point see in particular the anthropological argumentation of Hallam and Ingold in the introduction to Elizabeth Hallam and Tim Ingold, *Making and Growing: Anthropological Studies of Organisms and Artefacts* (London: Routledge, 2016), https://doi.org/10.4324/9781315593258.

28 From the perspective of the material engagement theory, see Lambros Malafouris and Maria-Danae Koukouti, "Where the Touching Is Touched: The Role of Haptic Attentive Unity in the Dialogue between Maker and Material," *Multimodality & Society* 2, no. 3 (September 1, 2022): 265–87, https://doi.org/10.1177/26349795221109231; and from the perspective of quantum physics and queer studies: Karen Barad, "On Touching—the Inhuman That Therefore I Am," *Differences* 23, no. 3 (December 1, 2012): 206–23, https://doi.org/10.1215/10407391–1892943.

29 Prehistorians have attributed to cutting and the making of cutting tools one of the major first steps of humans out of their animal condition, by entering the realm of the symbolic (chipping stones through systematic action), and hence developing frameworks of knowledge of trade and transmission. The production of cutting tools has also created an edge over other species with the introduction of tools in general. With the surplus that could be taken from the environment, specialization and further ensued, in a process that we used to call "civilization." Modern technologies and ecological disaster shouldn't be too easily lumped together however; from the perspective of quantum physics, see Karen Barad, "On Touching—the Inhuman That Therefore I Am," *Differences* 23, no. 3 (December 1, 2012): 206–23, https://doi.org/10.1215/10407391–1892943; and from the perspective of the material engagement theory in the field of anthropology, Lambros Malafouris and Maria-Danae Koukouti, "Where the Touching Is Touched: The Role of Haptic Attentive Unity in the Dialogue between Maker and Material," *Multimodality & Society* 2, no. 3 (September 1, 2022): 265–87, https://doi.org/10.1177/26349795221109231.

of "making" is a recurrent topic. In one of his most famous texts, he speaks of the act of weaving a basket as a way of feeling and *doing* with the willow branches, their resistance.[30] A correspondence with the world is established during this activity, as one understands in the most practical way that the basket is an assembly of forces, holding together because of the strength accumulated in the stems in a self-contained winding motion through the rhythmical action of the weaving hands. Ingold elaborates on this when he moves on to a description of another hands-on activity conducted with his students during his anthropology seminars: when making and flying a kite, one becomes slowly aware that the wind and the entire atmosphere is part of what we are composing and playing with, part of a perceivable and knowable world that the human senses have grown in correspondence with.[31] The kite becomes then an extension of the sensing self. More recently, as he was making and flying kites again in the company of Jennifer Clarke, Ingold reportedly went on to utter another brilliant remark: "[W]hen you are flying a kite, you are also flying in a way, although not like in a plane."[32] Feeling and sensing the air stream and its rhythms, the kite flyer extends and stretches their senses inward and upward, feeling through the wind streams and the intricacies of their moving boundaries.

The tool as a sensorial extension of the body is a theme that has been explored by many thinkers, such as Niels Bohr, Gregory Bateson, Maurice Merleau-Ponty, or Jean-Pierre Warnier. The most common figure to jam around this theme is the walking blind person.[33] Dis/ability studies scholars and blind phenomenologists have contested the use of this figure of the "blind man," which stands for a commonplace ability to synthetize the world through the tools we use.[34] As Niels Bohr noticed, the stick suddenly disappears as an object—a phenomenon that helped him to convey his understanding of the scientific apparatus and of the way the knower and their knowing devices, as well as the known, are intrinsically entangled. Stretching their canes in front of them, the blind sense the floor through the relation they establish along the staff,

30 Tim Ingold, *Making: Anthropology, Archaeology, Art and Architecture* (London: Routledge, 2013).

31 See among the many occurrences of the kite narrative in Ingold's oeuvre: Tim Ingold, "The Textility of Making," *Cambridge Journal of Economics* 34, no. 1 (2010): 95–96, https://doi.org/10.1093/cje/bep042; and Ingold, *Making*, 98–100.

32 Personal communication with Jennifer Clarke, November 2021.

33 Warnier and his working group "Matière à Penser" have conducted a vast number of studies on the relation between thinking and doing, often referring to the first thorough investigation of the body image authored by P. Schilder, *The Image and Appearance of the Human Body* (Oxford: Kegan Paul, 1935). See Urmila Mohan and Laurence Douny, ed., *The Material Subject: Rethinking Bodies and Objects in Motion* (York: Routledge, 2021).

34 Here, I take cues from a forthcoming paper by Asaf Bachrach and Joe Dumit, which Joe Dumit generously sent me along with his insightful comments: see Joel Michael Reynolds, "Merleau-Ponty, World-Creating Blindness, and the Phenomenology of Non-Normate Bodies," *Chiasmi International: Trilingual Studies Concerning Merleau-Ponty's Thought* 19 (2017): 419–34, https://doi.org/10.5840/chiasmi20171934; Jesse Workman, "Phenomenology and Blindness: Merleau-Ponty, Levinas, and an Alternative Metaphysical Vision," PhD diss. (University of Denver, 2016), https://digitalcommons.du.edu/etd/1210.

with swift movements that are prescient of the potential trajectories of their bodies, which "expresses the power we have of dilating our being in the world, or of altering our existence through incorporating new instruments."[35]

The American philosopher of technology Don Ihde has wrapped his mind around the problem of sensing and experiencing through technological devices for decades. One of the first and simplest examples that he has provided is a clinical examination tool.[36] The dental probe, which we all intimately know from the inquisitive metallic touch on the enamel of our teeth, does not only extend the fingers of the dentist to inaccessible corners of the buccal cavity, it also amplifies the sensation at the surface of the tooth. Through the sharpness and hardness of the metal and their quick probing actions, practitioners acquire a precise haptic image of the tooth, including texture, resistance, shape, and depth of cavities, all dimensions that are only made possible through this equipment. Just like the surgical blade, the dental probe is a historical artifact in which the dental knowledge comes together with the immanent senses of the dentist to produce her diagnostic and set her on a course of action. In this case, the senses aren't expanded in all directions, but rather, they are stretched into a precise direction, following the "pathway" of the handle. Moreover, senses become other, non-correspondent even, in enabling new forms of worlding to arise.[37] Does the sensitivity stop at the surface of the tooth, or does it go deeper? Like the kite flyers, the dentists and their probes are "becoming one" with the material, with its current dynamic state, they sense the internal structure of the dentin and the way it may degrade if the cavity lurks further. And so are the neurosurgeons as they build prosthetic scaffoldings around a fragilized spine, working with special alloy plates and screws, drilling into bones and preserving marrows.

At the risk of stretching my concept of stretching senses a bit far, I would like to include another means of accessing invisible and inaccessible realities. What about the magnetic resonance imaging devices used by the neurosurgeons to plan their navigation within the brain?[38] The technological development I traced during my early fieldwork at the university hospital is the translation of a technique used in neuroscience into a surgical planning method. Tractography is a practice that delineates the neural network. The team of Thomas Picht at Charité focused on speech-related tracks, in order to integrate the spatial information of the "fiber bundles" of the

35 Maurice Merleau-Ponty, *Phenomenology of Perception*, trans. Donald Landes (New York: Routledge, 2013), quoted by Dumit and Baschraff, forthcoming.

36 Don Ihde, *Experimental Phenomenology: Multistabilities*, 2nd ed. (Albany: State University of New York Press, 2012), 102–03.

37 See Workman, "Phenomenology and Blindness" and again my gratitude goes to Joe Dumit for his invaluable suggestions and hints for further developments.

38 Things become even more tricky when we look at the modeling practices, imported from linguistic computational neurosciences, that are now making their entrance into the domain of neurosurgical planning, putting sci-fi-grade claims to absolute control of the consequence of the cut, e.g., Friedemann Pulvermüller et al., "Biological Constraints on Neural Network Models of Cognitive Function," *Nature Reviews Neuroscience* 22, no. 8 (2021): 488–502, https://doi.org/10.1038/s41583–021–00473–5.

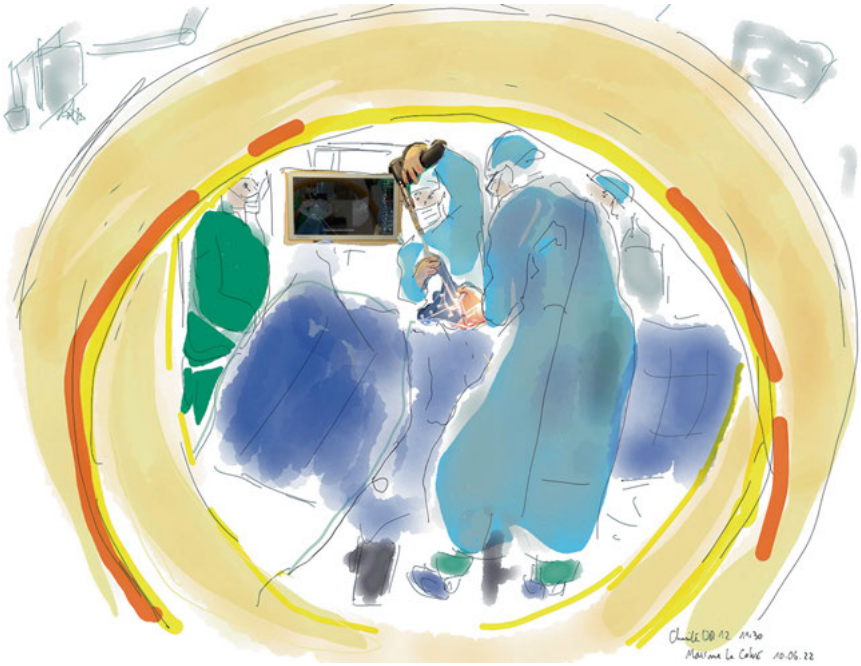

Fig. 6: Image-guided vertebra drilling as seen through intraoperative scanner.

brain into the navigation data.[39] The "tracks" and "hubs" they form outline a set of critical zones for the neurosurgeons: the brain can compensate for many disruptions, but the functions will "travel" to other places in the brain if, and only if, these pathways are preserved. The drama of a patient that can't move a limb or can't speak a word is a daunting threat in the daily job of the neurosurgeon, and the worst nightmare of the neurosurgical patient. This is why the novel technique of tractography is currently spreading, as one more factor that surgeons can be aware of—if they make themselves attentive to it. I want to claim that the new tractographic practices are a stretching of the senses as well.[40] Again, Don Ihde has provided some insight regarding what

39 Lucius Fekonja et al., "Manual for Clinical Language Tractography," *Acta Neurochirurgica* 161, no. 6 (June 2019): 1125–37, https://doi.org/10.1007/s00701–019–03899–0; Lucius S. Fekonja et al., "Detecting Corticospinal Tract Impairment in Tumor Patients with Fiber Density and Tensor-Based Metrics," *MedRxiv* (November 3, 2020), https://doi.org/10.1101/2020.10.28.20220293; Mehmet Salih Tuncer et al., "Towards a Tractography-Based Risk Stratification Model for Language Area Associated Gliomas," *NeuroImage: Clinical* 29 (January 1, 2021): 102541, https://doi.org/10.1016/j.nicl.2020.102541; for an ethnographic portrait of the principal map maker of this project, see Maxime Le Calvé, "Intersecting Cartographic Imperatives. Map-Making Practices of a Medical Artist in the Wake of the Computational Brain," *Kunstlicht* 41, nos. 2–3 (2020): 81–90.

40 The digital twin as a model from the engineering world stands for an all-encompassing simulation environment; the "discontents" of Sherry Turkle are appearing in the most splendid way. Sherry Turkle, ed., *Simulation and Its Discontents* (Cambridge, MA: MIT Press, 2009).

he called the "the understanding of science as an embodied technoscience, the instrument-embodied science of the contemporary world."[41] The work of Ihde aims to bring into the picture of the interpretative activity of science the "sensory interpretative activity" of its practitioners, an interpretative activity that is not related to words but images: a "*thing interpretation* through imaging instruments."[42]

Fig. 7: Excerpt from fieldwork journal during a workshop on "eloquent tumors" at the Image Guidance Lab, Charité—Universitätsmedizin Berlin.

Under the umbrella concept of what they call "haptic creativity," anthropologists Natascha Myers and Joe Dumit have described a stream of experiments led by interdisciplinary teams of computer scientists, designers, and scientists to create a dynamic working environment into which geologists are invited to dive down into scalable models of their data.[43] Based on ideas developed by Myers, who worked on the embodied thinking of protein modelers, they show how the experience of data in virtual reality rep-

41 Don Ihde, *Expanding Hermeneutics: Visualism in Science* (Evanston, IL: Northwestern University Press, 1998), 4.

42 Ibid., 8, emphasis in the original.

43 Natasha Myers and Joe Dumit, "Haptics," in *A Companion to the Anthropology of the Body and Embodiment*, ed. Frances E. Mascia-Lees (Chichester & Malden: Wiley-Blackwell, 2011), 239–61, https://doi.org10.1002/9781444340488.ch13.

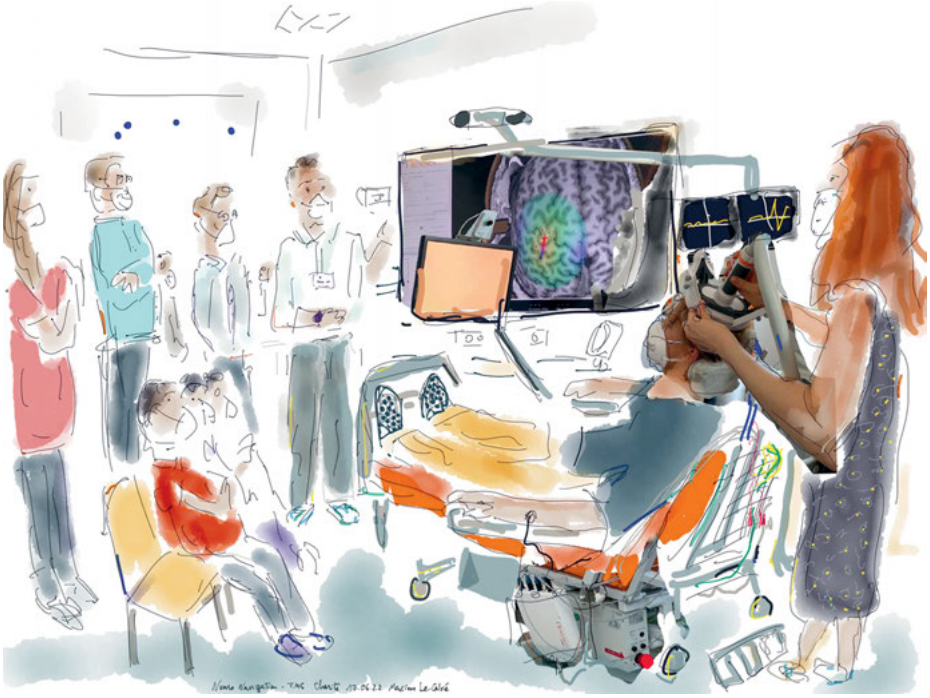

Fig. 8: Excerpt from fieldwork journal during a workshop on "eloquent tumors" at the Image Guidance Lab, Charité—Universitätsmedizin Berlin.

resentation changes the way scientists relate to the material, triggering new insights. The scientists started "dancing" with the material: "Modelers *transduce* these affects through their body-work and propagate these gestures through performative articulations that excite others into action."[44] Today, virtual reality can include the scientists' bodies in the model. However, the routine "fly through" into brain image data sets conducted by the neurosurgeons at work is already a way of coming into and becoming alongside with the material. The probe, in this case, is a gigantic magnet that defines a large number of measurements, saved and processed by a computer, and rendered into series of images arranged in three directions, which can be displayed simultaneously to provide a spatial representation of the neurosurgical site to the practitioner.[45] For a few years, a fourth representation showed the image in 3D, making more legible certain complex spatial information, such as the visualization of the ar-

44 Myers and Dumit, 240–41.

45 See Regula Valérie Burri, *Doing Images: Zur Praxis medizinischer Bilder* (Bielefeld: transcript Verlag, 2008), https://doi.org/10.14361/9783839408872; Silvia Casini, *Giving Bodies Back to Data: Image-Makers, Bricolage, and Reinvention in Magnetic Resonance Technology* (Cambridge, Massachusetts: The MIT Press, 2021).

rays of "tracks" running from distant parts of the brain through the white matter.[46] There are many ways to sense the lines of the material, and diverse equipment gives us access to different sets of boundary phenomena within the material. The master cutter's practical ideal—and ordeal—is to let the material guide the knife along its lines, tuning in to its demands, providing a balanced response to the question of the right form. This, in the light of Barad's thought, is how nature happens: a processual performance of knowledge that is intractably both representation and intervention, sensuous performance and bold invention.[47]

Conclusion

The idea of cutting along body lines can elicit two very different conclusions when translated to the metaphorical space offered by ancient philosophical tales: the idea of nature as a ready-to-discover ideal providing a set of "precut" facts, on the one hand, contrasts vividly with the phenomenological experience and the inherent perfectionism of its human practitioners on the other. The cutting scientist, like the Taoist butcher, experiences a form of growth as they move forward and contribute to their discipline and their team through their craft. This sensory and inventive process must be thought together with the rational aesthetics and the epistemic values of the field. Medical knowledge advances through a refinement of sensorial equipment, joining human bodies and metallic and magnetic instruments. Sustaining the form of elated working capacity of the neurosurgeon and of their teams, these dispositions and institutions are an interweaving of proprioceptive, technological, and social skills. Entering into a "mattering dance," they produce meaning and phenomena as a seamless unified working life-or-death experience for the physicians.

Through this reflection anchored in fieldwork, I attempted to challenge the common-sense modernist idea of the cut, and especially the breach introduced between the cutter and the thing being cut. I argue that the cut, as practiced in neurosurgery, can be considered as a response-able stretching of the senses toward materials and things, blending together elements of modeling, simulation, training, invention, and improvisation. The partitioners simultaneously cultivate the state of knowledge of the field and their relation to brains-as-material, and they grow individually and together, "becoming one" with a mattering process as they nervously sense their way through the nervous tissues. Through a lifelong process, the surgeon transmutes the nervous

46 Many attempts are being conducted (including by our team) to let the surgeons step in to the dataset using VR technologies: see the projects Brains Roads and TopoVox.

47 And certainly, also in the light of Alfred N. Whitehead, as in *The Concept of Nature*, see in particular *Thinking with Whitehead* by Isabelle Stengers for a comprehensive and generous guidance. Alfred North Whitehead, *The Concept of Nature* (Cambridge, UK: Cambridge at the University Press, 1920), http://archive.org/details/cu31924012068593; Isabelle Stengers, *Thinking with Whitehead: A Free and Wild Creation of Concepts*, trans. Michael Chase (Cambridge, MA: Harvard University Press, 2014).

flesh into a familiar landscape—a labyrinthic, deadly playground that becomes more plastic and trusted as the gestures become more automatic and yet more defined and nuanced, anticipating myriads of contingencies and reading the constellations of signs that bode well or unwell for navigation that day. However, whether any surgeon will find "the way to nurture life" within their practice, like the king following the Taoist butcher's teachings, is a question that remains to be elucidated.