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CHAPTER 1

The intellectual background: two millennia of Western ideas about spatial thinking

Spatial thinking is crucial to almost every aspect of our lives. We consult our spatial memories constantly as we find our way across town, give route directions, search for lost keys, try to find a passage in a book, grope our way to the bathroom in the night, and so on. The intricacy and importance of all this becomes apparent when it goes wrong. I recently saw a man reduced to near insanity because he had 'lost' his car in a huge airport parking lot (really, of course, he had lost himself). The Balinese, whose system of spatial description requires compass-like orientation, consider loss of cardinal orientation a sign of madness ('Not to know "where north is" is to be crazy', Geertz 1972: 446, cited in Wassmann and Dasen 1998: 693). The neuroscience literature is replete with exotic syndromes, where lesions in specific areas of the brain induce specific spatial inabilities, as in the following description of a patient with topographical amnesia:

> Whenever he left his room in the hospital, he had trouble finding his way back, because at any chosen point of the route he did not know whether to go right, left, downstairs or upstairs . . . when he eventually arrived in front of his own room, he did not recognize it unless he chanced to see some distinguishing feature, such as the black beard of his roommate . . . (de Renzi 1982: 213)

Spatial competence involves many different abilities, from shape recognition to a sense of where the parts of our body are with respect to one another, from navigation to control of the arm in reaching for something, and so on. The evidence from human brain lesions and from animal studies is that these abilities are based on a myriad of distinct neurophysiological systems, all of which converge to give us a coherent subjective sense of space.[1] Our conscious apprehension of space can also be dissected analytically into component parts – for example, the characteristic shapes of objects, their spatial relation to our bodies as we point to them, the sense of where we are with respect to our larger surroundings, and so forth. No single book could do justice to all we now know about this fundamental domain of human experience.

This book takes up just one strand of this complex cloth, albeit a subject that has a central importance for spatial abilities, namely the coordinate systems that underlie spatial memory and classification. For example, when I think that I must have left my glasses in front of the TV, I am using a different kind of coordinate system than when I think I must have lost my keys in the grass to the left of the tree over there. The first makes crucial use of the sidedness of objects like television sets, while the second makes essential use of my bodily coordinates. Understanding the difference between such ways of specifying where things are is one of the central tasks of this book. Another major aim is understanding the similarity and difference between *thinking* 'I must have lost my keys in the grass to the left of that tree' and *saying* it. Put that way, it seems that the thought and the sentence meaning must be identical. But for all sorts of reasons that cannot be right – there is a metric precision and visual detail in our thoughts that is not present in language. In addition, and here is a startling fact, in many languages there is no way to express *that* specific thought at all! For many languages do not provide the linguistic means to express an egocentric coordinate system of the sort implied by the English expression *left of*. Speakers of languages without such a coordinate system must either have different thoughts, or thinking and language must be dissociated and thus potentially work on different lines. It turns out – and much of this book is devoted to showing this – that in fact language and thought closely parallel one another, and thus linguistic diversity is reflected in cognitive diversity. Cross-linguistic variation therefore provides us with new empirical insights into old philosophical conundrums about the relationship between language and thought.

Why is this rather specific theme – coordinate systems or frames of reference in language and thought – of general interest? First, it concerns the very heart of complex spatial thinking. There are simple spatial notions, like the proposition that object X is at named place Y, which do not directly invoke anything as complex as a coordinate system. But as soon as object X and landmark Y are substantially separated in space, it becomes important to think about X as *in some specific direction* from Y – some kind of angular specification becomes relevant, and a coordinate system is necessary to provide that.[2] Coordinate systems or frames of reference thus play a crucial role in many kinds of human thought and activity, from navigation to the design of our cultural environment, from moving our eyes or limbs to scientific models of the universe. A better understanding of naïve spatial thought – the kind reflected in everyday language or action – can contribute fundamentally to all the sciences concerned with our use of space, from archaeology or geography to neuroscience.

A second major source of interest is that there are significant cross-linguistic differences in this domain. Much of this book revolves around the difference between languages with predominant 'relative' frames of reference, versus those with predominant 'absolute' frames of reference. The first is familiar enough – it is the kind involved in the earlier-mentioned reading of *The cat is behind the truck* as 'The truck is between the speaker and the cat' (this is often, erroneously, called the 'deictic' frame of reference). The second is less familiar – on the horizontal plane it can be illustrated with a sentence of the form *The cat is north of the truck*. Interestingly, there are languages where this is the main or only form of coordinate system in spatial language. Since such systems are exotic, examples are described in some detail in the chapters below. This opposition between language types turns out to have quite deep cognitive consequences for users of the two types of language. This is shown below in a series of experiments, and in observational studies of wayfinding and gesturing. The end result is a clear and quite surprising finding: the choice of a predominant frame of reference in language correlates with, and probably determines, many other aspects of cognition, from memory, to inference, to navigation, to gesture and beyond.

Some of the reasons why this finding is so unexpected lie in a web of preconceptions about the nature of naïve human spatial conception which has been woven into two millennia of Western thinking. Many of these preconceptions have arisen in the history of Western philosophy, from which many of our scientific concepts of space have been borrowed. Later some of these speculations passed into the new discipline of psychology, and, more recently, into the wider circle of the cognitive sciences. This chapter sketches just a little of this background, focussing on concepts important for appreciating the findings described later in the book – naturally it cannot pretend to do justice to a domain as important to the history of physics as it is to psychology. Let us first begin with a glimpse of the new facts that will prove problematic for the preconceptions about naïve human spatial conception that have such a long ancestry in our intellectual tradition.

1.1 THE GREAT EYE OPENER – DIFFERENCES IN SPATIAL RECKONING

This book focusses on variation in spatial language and cognition that our long Western tradition about human spatial thinking has led some researchers to think unlikely or impossible. The following anecdotes may help to convey the sense of surprise. Scientific research is not about anecdotes, but small, wayward observations can often be where it all starts. Some, often chance, experience has to alert the researcher that there is something wrong with the existing paradigms. This book is an attempt to at least shift the paradigm of the study of human spatial thinking a little, and although many scholars have contributed to this new perspective, here are some of the small experiences that drove home to me personally the simple message that human spatial cognition is not fixed, but culturally variable:

1. Old Tulo, Guugu Yimithirr poet and painter, whom I am trying to film telling a traditional myth in Cape York, Australia, tells me to stop and look out for that big army ant just north of my foot.

2. Slus, a Mayan speaker of the language Tzeltal, says to her husband, facing an unfamiliar contraption: 'Is the hot water in the uphill tap?' It is night, and we have just arrived at an alien hotel in a distant, unfamiliar city out of the hills. What does she mean? She means, it turns out, 'Is the hot water in the tap that would lie in the uphill (southerly) direction if I were at home?'

3. Roger, another Guugu Yimithirr speaker (and last speaker of Barrow Point language), tells me that I am wrong – in a store 45 km away there are indeed frozen fish, and it's here, 'on this side' he says, gesturing to his right with two flicks of the hand. What does he mean – not it turns out what I thought, namely that standing at the entrance to the store, it would be to my right. No, what he means is that it would be to my left. So how to explain the gesture? He gestured north-east, and he expected me to remember that, and look in the north-east corner of the store. This makes me realize just how much information I am missing each time he says anything.

4. Xpet, a Tzeltal-speaking teenager, is looking at two photos that are identical except that they depict mirror-image arrangements. My wife Penny has put them in her hands, because Xpet has failed to distinguish them in a communication task, and Penny is asking her what the difference is between the two photos. Xpet stares, looking first at the

one, then the other. Her brow furrows. 'They're the same' she says, adding 'but this one has a dirty finger-print on it'. Nothing can shake her out of the apparent conviction that they are two tokens of the same photo.

5. We've been searching for ancient cave paintings deep in the bush, following instructions from various old hands. Dan, a Guugu Yimithirr speaker, is thrilled to find them after a day-long bush trip through dense and difficult forest. We are sitting in the cave entrance, and disoriented myself, I ask him to point back to base. He does so without hesitation, right through the hillside we are sitting on. I check with an accurate prismatic compass, and ask him for other locations. Checking later on maps, it turns out that he is spot on – absolutely dead accurate, as far as my compass can discriminate.

6. Jack Bambi, Guugu Yimithirr master story-teller, talking about a man who used to live nearby points directly at himself – no, there's no connection to himself, he's pointing south-east, to where the man used to live, through his body as if it was invisible. Years later, I have the same immediate misinterpretations looking at Tzeltal speakers, and realize this is the same phenomenon: in some striking way, the ego has been reduced to an abstract point in space.

7. I film this same Jack Bambi telling the story about how he was shipwrecked and swam miles to shore through the sharks. Watching my film, John Haviland realizes that he filmed Jack telling the same story two years before, and he goes and compares the films frame by frame. Despite the fact that Jack is facing west on the first telling and north on the second, the linguistic and gestural details of how the boat turned over, who jumped out where, where the big shark was and so on, match exactly in cardinal directions, not egocentric ones – the events are directionally anchored in all their detail in Jack's memory.[3]

By the time this book comes to an end, I promise some scientific evidence that shows that these anecdotes are symptoms of systematic differences between human groups, differences that specialists in spatial language and cognition never thought could exist. But the reason why we did not expect them needs a little exposition, because they lie deep in the history of the field. This chapter tries to provide a sketch of this background, concentrating on frames of reference in the history of ideas and in recent theory in the cognitive sciences.

1.2 IDEAS ABOUT SPATIAL COGNITION IN THE WESTERN TRADITION

1.2.1 *Place and space, absolute and relative, in Western philosophy*

I do not define time, space, place and motion, as being well known to all.
Isaac Newton (in the Scholium to the *Principia*, 1687)

Many commentators have pointed out how slowly and laboriously an abstract notion of space was evolved in Western thought. It is worth reviewing some of this history, because the developing ideas have been built on naïve concepts, often enshrined in language. Early Greek thought was preoccupied with discussions about whether space should be thought of materially (as in the school of Parmenides and Melissus) or as a void (as argued by the Epicurean atomists) – the one school arguing that it was impossible for nothing to have extent, and the other that, however big the extent of space was, it was always possible to throw a javelin beyond it, requiring an empty infinity (Jammer 1954: Chapter 1, Sorabji 1988: Chapter 8). Plato held a material view of space (viewing air as a substance with geometrical properties), so allowing a general identification of tridimensionality and matter that was to play a central role in medieval thought, and indeed in Descartes' ideas (Sorabji 1988: 38, Casey 1997: Chapter 7). (This view has played some role in recent linguistic theorizing about the nature of naïve spatial thought, where it has been supposed that dimensional expressions in language might form the heart of spatial cognition – see Lang 1989, Bierwisch and Lang 1989).

A material view of place was easily ridiculed by Zeno – if everything is in a place, and place is something, place itself is in something, but what? Aristotle's solution was to view place, not as the displacement volume of, e.g., air by a body, but as the adjacent or inner boundary of the matter containing the object. Aristotle therefore viewed space as a nested series of places, up to the outer sphere containing the universe. This reduction of space to place, and the denial of empty space or the possibility of a vacuum, sets Aristotle outside the slow but triumphant emancipation of a space concept in line with the development of physics. But the emphasis on place remains close to naïve reasoning – most languages probably have locutions for 'place' (i.e. the location where things are or belong), but few have expressions for 'space'.[4] Aristotle tried to stay close to the phenomenology, and he came to worry about what we today call 'frames of reference'. First, if a boat is moored in a flowing river, is the place always changing, since the containing fluid is? If we take the water as reference point, the answer seems to be counter-intuitively 'yes', so Aristotle chose the banks of the river, arguing that its place is the nearest containing surface that is immobile (for the millennia of puzzlement this caused, see Sorabji 1988: 188–92, Jammer 1954: 68–72). These ideas introduce the notion of a reference point, landmark or 'ground', which plays an important part in naïve spatial language. Secondly, Aristotle held that space/place had six phenomenological dimensions:

> These are the parts and kinds of place: above, below, and the rest of the six dimensions. These are not just relative to us, they – above, below, left, right – are not always the same, but come to be in relation to our position, according as we turn ourselves about, which is why, often, right and left are the same, and above and below, and ahead and behind. But in nature each is distinct and separate. (*Physics*, book 4, cited in Casey 1997: 53)

The directions 'up' and 'down' in particular he viewed as special, and part of nature, 'up' anchored to the celestial spheres and 'down' to the centre of the earth (Casey 1997: 360, n. 14). The discussion implies that Aristotle recognized that directions can be set both relatively, in terms of the orientation of the human frame, and absolutely, in terms of the cosmos.

Classical Greek thought left behind certain inconsistencies – Euclid's geometry of the plane, Aristotle's concept of place, Ptolemy's celestial projections – that seem to have inhibited the development of a rectangular coordinate system right up until the seventeenth century. Much of the medieval discussion of space revolved around the incoherencies in Aristotelian dogma (Duhem 1985). It was not until the Renaissance, with the rediscovery of the ancient atomists, and connection to the Arabic, Jewish and late classical traditions, that space began to be thought about again as an infinite three-dimensional void, as in the work of Patritius, Bruno or Gassendi (Jammer 1954: 83–92). Newton built on this tradition in his celebrated distinction between relative and absolute space: 'Absolute space in its own nature, without relation to anything external, remains similar and immovable. Relative space is some moveable dimension or measure of the absolute spaces' (*Principiae*, quoted in Jammer 1954: 97). Newton (ibid.) goes on to explain that because we cannot sense absolute space, therefore 'from the positions and distances of things from any body considered as immovable, we define all places . . . And so instead of absolute places and motions, we use relative ones; and that without any inconvenience in common affairs.'

Leibniz, in his correspondence with Newton's champion Clark, attacked the Newtonian concept of absolute space as unnecessary metaphysics: space is no more than the relative locations of things – a mere network of places, and when we ascribe motion to one body rather than its reference point, this is an arbitrary convenience. This relational quality of locations – as things located with respect to other things – is fundamentally reflected in much ordinary spatial language, as we shall see. Leibniz was thus on the threshold of a theory of relativity, but Newton's concept of absolute space was to rule up till the end of the nineteenth century. By 1769, Kant thought he had found incontestable proof of the reality of Newton's absolute space in the distinction between **enantiomorphs**, or three-dimensional objects that differ in handedness, like a left vs. a right shoe (he called them 'incongruent counterparts'). Suppose, he said, the universe consisted of a giant hand – it would have to be a right hand or a left hand, and yet that would not be determinable from the set of internal relations between its parts – the thumb would remain a set distance from the fingers in either hand. Only in a yet larger spatial framework, absolute space, could the handedness be determined (see Van Cleve and Frederick 1991 for modern discussion). Kant had found what was missing in Leibnizian space – namely direction (about which, more will be said below). In later work, Kant attributed absolute space to intuition, an *a priori* conceptual form that organizes our perception of space – it is thus an intuition utterly independent of the ensemble of concrete relations that Leibniz thought space could be reduced to. Kant's nativist ideas, his psychologizing of space, played an important role in the early history of psychology, for example in Helmholtz's psychophysics (Hatfield 1990), and similar ideas pervade modern American psychology in the nativist tradition. Incidentally, the terms 'absolute' vs. 'relative', as applied to frames of reference, will come to have a slightly different meaning in this book, but one sanctioned by the history of thought (see Chapter 2).

This brief review cannot do justice to what has proved one of the most central themes of philosophical and scientific discourse. Such an outline only gives us the line of thought that proved congenial to classical mechanics, but there were many other currents, many of them theological (indeed Newton's absolute space was partly motivated as further evidence of the divine). But enough has been said to give us some conceptual pegs, and to illustrate a number of important themes that will recur below: naïve human spatial reasoning tends to be couched in terms of place rather than space, in terms of relative locations to other objects rather than to abstract location in a spatial envelope, and yet seems to presuppose larger spatial schemas of the kind indicated by Aristotle's six directions or Kant's intuitions about space.

1.2.2 The anthropocentric bias

'Man is the measure of all things' Protagoras (481–411 BC)

Spatial cognition has been intensively studied in the twentieth century by sciences as diverse as ethology, cognitive and behaviourist psychology, child development, neurology and the brain sciences generally. There is, for example, a wondrous literature on animal wayfinding and orientation (Schöne 1984, Waterman 1989, see also Chapter 6 below); and it is striking how much less is known about human (and more generally primate) spatial cognition and behaviour in the wild. Nevertheless, the information on human spatial abilities and their neurophysiological basis is enormous, and quite beyond review in a book of this scope.

But there is one element of this modern work that is contradicted by the findings in this book, and thus needs documentation and discussion in this section. This element is a consistent emphasis on the exclusive centrality of egocentric, anthropomorphic, relativistic spatial concepts and abilities, as opposed to allocentric, abstract, absolute spatial information. The attitude is summed up by Poincaré (1946: 257): 'Absolute space is nonsense, and it is necessary for us to begin by referring space to a system of axes invariably bound to the body.'[5]

Take as an example the study of how spatial information is handled in the primate brain. The picture that emerges is one of great complexity, with multiple systems of egocentric coordinates for each sensory mode (Paillard 1991). Thus, when we pick up a coffee cup, the visual system processes the two-dimensional retinal arrays to extract, partly by stereopsis, partly by the analysis of properties of the array itself, a model that includes partial depth information from a particular viewpoint (Marr 1982). Next we abstract and recognize three-dimensional objects, perhaps by matching them with an inventory of three-dimensional models, thus recognizing the cup and its orientation and placement in depth from the retina. This information then drives the reaching mechanism, first through shoulder-centred coordinates, and then (through different neural pathways) the hand-based coordinates that achieve a grasp on the object seen (Jeannerod 1997). How the retinal coordinates are translated into shoulder- and hand-based ones remains a matter of contention: perhaps information is translated into a general spatial model and then out again, or perhaps specialized dedicated translation processes are involved (Stein 1992). There seem to be two independent neural pathways involved in the perception of space, called the 'what' and 'where' systems, the one controlling, for example, our perception of what things are and the other their location in egocentric space (McCarthy 1993, Ungerleider and Mishkin 1982). Findings like this are potentially highly relevant to our topic of the language of space: Landau and Jackendoff (1993) have speculated that the what/where distinction shows up directly as a universal of language, giving us object-names specialized for shape on the one hand, and closed-class spatial morphemes (like our spatial prepositions) on the other (a view challenged below).[6] This general emphasis on egocentric, relativistic concepts of space has rarely been challenged – but most effectively by O'Keefe and Nadel (1978) who claim that absolute spatial concepts, mental maps of terrain, are encoded in the hippocampus (see also O'Keefe 1991, 1993, Burgess *et al.* 1999, Maguire *et al.* 2000).

Although the notion of 'mental maps' in psychology is half a century old (Tolman 1948), the same bias towards the study of egocentric spatial information and coordination is also to be found in psychology. Thus, for example, in the study of children's spatial abilities, it is suspected that allocentric behaviour is actually generated by operations on egocentric information (for a review, see Pick 1993). In the psychology of language, it has been repeatedly asserted that human spatial language is a direct reflection of our egocentric, anthropomorphic and relativistic spatial concepts (Clark 1973, Miller and Johnson-Laird 1976). Rooted in this tradition is the prediction that all languages use the planes through the human body to give us, as Kant (1991 [1768]) put it, our first grounds for intuitions about space, in terms of 'up' and 'down', 'left' and 'right', 'back' and 'front'. This prediction turns out to be false, as we shall see, and raises the possibility that this entire tradition partly reflects the linguistic prejudices of the Indo-European tongues.

Despite the large amount of work on the neuropsychology of human spatial cognition, when we come to language and conscious spatial thinking most of what we know comes from introspection and the inspection of our own European languages. This phenomenology has a long tradition, and it has repeatedly harped on a limited number of themes, among which are the following.

1. Human spatial thinking is always *relative* in character, not absolute (Miller and Johnson-Laird 1976).