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On Vision and Seeing

Seeing is believing.

Neuroscientists describe vision in terms of the processes that unfold when light falls onto the retina. Between the retina and the visual cortex, there are many transformations that the original (retinal) stimulus undergoes. In humans (as in all mammalian species), there are the photoreceptors in the retina, ganglion cells, ganglion cell axons (optic nerve), and synaptic transitions. At higher levels following the optical tract, neural activation is set in motion by the original stimulus that passes through the superior colliculus, lateral geniculate nucleus, and optic radiations before reaching the visual cortex. However, vision does not only involve activation that travels from the retina to the visual cortex ('afferent' movement); rather, activation also travels in the opposite way ('efferent' movement) so that higher-level processes directly affect the photoreceptors.

Everyday understanding of visual perception and its psychological equivalent take the visual cortex to be something like a panoramic internal screen from which the conscious (Cartesian) 'I' extracts or constructs the patterns of a given world. That is, the visual cortex is taken as the 'mirror of nature' that underlies some epistemologies. Such a view is implemented in almost all current cognitive models of learning from visual contact with the world. For example, the cells in the visual areas are treated as feature detectors that extract from a visual array ('raw primal sketch') propositions like 'there is an edge with coordinates (112,39), orientation 128°, contrast 82, and width 4' (Anderson 1985: 31). More recently, researchers also use artificial neural networks to perform feature extraction and use gestalt principles to scan a visual buffer for structure and form. But these newer models still presuppose the existence of features that are immediately given to the conscious mind. From this perspective, then, students extract the patterns from the visual spectacles presented to them (e.g., in a demonstration) that create some patterns on their retinas. If students do not see what they are supposed to see, the problems are attributed to deficits in their minds.

Recent research in the neurosciences puts such conceptualizations into relief, by and large questioning the existence of the Cartesian observer who extracts patterns that can be represented in propositional terms. Thus, the very process of perception of objects appears to change with experience, though the role of experience in human perception has yet to be fully understood. There is mounting neuroscientific evidence that much of our perceptual apparatus is affected by learning. Seeing is hypothesized to be a way of learning how the world *is* from the individual's immediate apprehension of how the world *looks*. There is increasing evidence that perceptual and motor systems are highly correlated; this evidence supports the hypothesis that the invariant structures of reality unfold in and through active exploration of appearances. In this, neuroscientific research is consistent with views (and explicitly linked to previously developed insights) that have been analytically developed by phenomenological philosophers such as the late Ludwig Wittgenstein and Maurice Merleau-Ponty.

Phenomenological philosophers point out that we always perceive from a first-person perspective: from the inside so to speak. Research in the cognitive neurosciences, too, show that perception is not merely embedded in an abstract world full of constraints; perception actively contributes to the forthcoming of a world through the movements of the person. This world, for the individual, is not the world measured and explained by scientists. Rather, perception is situated so that '[w]hat the world *is* to the organism depends on what the organism is doing and might do next' (Clancey 1997: 257), and, most importantly, what it has done in the past. At the same time, we do not have to reconstruct objects from first principles based on visible appearance; our knowledgeable interactions with things are facilitated by their functionally significant perceptual properties or *gestalts*. How this works is largely unknown – but it would be a mistake to assume a simple context-independent mapping between perceptual features of the world and the things we perceive.

One of the most important findings of phenomenological inquiry is the vagueness, blurredness, indeterminacy, and indistinctness of the visual field: there are no such things as visual images of precisely 24 or 25 pencil marks, 100-gons and circles, or gaggles of 100 geese (Wittgenstein 1975). This vagueness, blurredness, indeterminacy, and indistinctness of the perceptual field, rather than being a problem, has to be taken as an irreducible and a priori feature of perception; it has to be taken as a positive phenomenon. This phenomenon has been the focus of research in phenomenological studies of perception: building on Gestalt psychological principles, this research articulates perception in terms of the dialectical unit of figure and ground. The simplest perceptual entity is not a sensation but a relatively precise figure floating over a more indistinct ground. The figure-ground structure of perceptual experience is an invariant of perception, known to be such prior to phenomenological reflection.

We live in worlds that come forth from our actions; we learn as a function of the events and our encounters with the objects in these worlds rather than in scientific, third-person worlds. To understand learning as it arises from individual, subjective experience, we need systematic phenomenological inquiry; the results of such inquiries can then be correlated with those from neuroscientific research. At present, however, scientific (psychological) approaches to learning (science, mathematics)

almost always take third-person perspectives. One of the reasons for the reluctance to adopt a first-person perspective lies in the fact that phenomenological inquiry is charged with being ‘introspective’, ‘fluffy stuff’, and ‘extremely subjective’. This, however, is an inappropriate view. The real aim of classical phenomenological, first-person inquiry is the articulation of experience in terms of concrete *universals*, which manifest themselves in the particularities of all members *without* exception. First-person (subject-centered) approaches therefore develop (psychological) concepts that are concretely applicable to every single human being.

In the following section, I provide a first example. Readers are invited to experience the structure of the method first hand. Stop your reading at the places indicated and engage in the inquiry described prior to reading on. In the second part of this chapter, I provide a description of the method designed to inquire into what it might mean to learn something not already known. While staying at the *Hanse Institute for Advanced Sciences* (as a fellow in the cognitive division), I conducted studies of physics students in the process of learning about electricity. I wanted to better understand their learning processes, and therefore engaged in first-person investigations of perception.

Fundamentals of Visual Perception

One of my own first experiments of this kind involved a classical image used in Gestalt psychology (Fig. 2.1).¹ What do you see? Are there different things you can see? If you can see several things, what do you have to do to go from seeing one thing to seeing the other thing? That is, what are the conditions for seeing one thing and how do the conditions have to be changed to see another? Attempt to find answers to these questions by engaging with the figure prior to reading on.

In the introduction to this book (chapter 1) I note that *epoché* has an initial phase during which experiences are systematically produced. In the preceding paragraph, I invite the reader to varying the perceptual experience without requiring any systematicity. During this phase, first-person researchers suspend their beliefs about the entity, here the drawing denoted by the term ‘Maltese cross’.² The intent of this phase is to bring about a conversion from the content to the process of seeing. That is, during this conversion, the attention is changed from the content of experience – the *what* of seeing – to the process of experience – the *how* of experience. During this phase, there is no judgment. We accept all experience without

¹ I find it useful to regenerate such images on the computer and then look at them against a completely white background. Working with a graphical software package, such as Adobe Illustrator, I have conducted experiments, such as the one described here, on the airplane. The advantage of using a software package is that one can *systematically* vary or change the image under investigation.

² It is actually possible to see many other things than the Maltese cross. It is possible to see the figure as a square circus tent from above, a cross of the German Order, a cross of the Teutonic Order, a simile of the cross of St. Benedict. We limit our present inquiry to the Maltese cross, even though one might design experiments concerning variations of the cross and the conditions to perceive it as an instance of one or the other crosses that might be perceived.

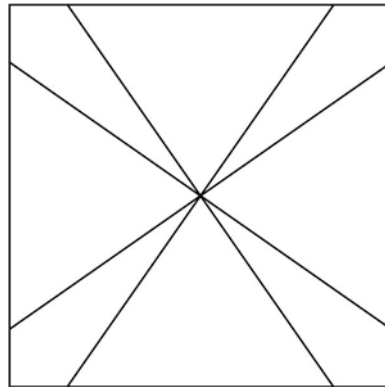


Fig. 2.1 This figure, which is known as the Maltese cross, has been used in Gestalt psychological research concerning perception.

particularly paying attention to or preference for one or the other. That is, this first stage of the first-person inquiry requires an unprejudiced openness to the details of experience. Up to this point, in your first attempt, you may have simply noted the two crosses that can be seen: although there is but one material configuration – the ink dots on the white page that make Fig. 2.1 – there are at least two figures that can be seen easily against (or as floating over) a diffuse ground. (Go to the appendix A1, p. 249, if you require some assistance with identifying the two crosses I am referring to here.) Gestalt theorists have explained the phenomenon in terms of the law of proximity, according to which items that are closer together in physical space are grouped preferentially. In the present situation, the cross that is oriented along the diagonals tends to be perceived preferentially – that is, as an average across persons – rather than the upright, broad-leafed Maltese cross. Can you see the second cross stand out against everything else as ground?

There are actually two issues that we have to research. First, we see a cross. That is, we see a figure that has a particular internal structure. In the case of the broad-leafed Maltese cross we see four leaves along the vertical and horizontal axes. Second, we see a cross against some ground. How is it that we see the cross *as* cross? And how is it that we see this figure (cross) in the first place? That is, there are two aspects to our perception, one leading to the perception of the *internal* structure, the other one leading to perception of the overall structure to everything else *outside* of it.

With some practice, you notice the upright, *broad*-leafed Maltese cross as a figure with the remainder of the square as diffuse ground. Or, if this was the cross that first stood out in your perception, practice until you can see the other, *narrow*-leafed cross to stand out. You want to arrive at a point that you can, at will, see one or the other. Remember, our goal is to vary this experience so that we can investigate the conditions for seeing one or the other. We are not interested in the fact that we do see the broad-leafed or the narrow-leafed Maltese cross. We are about to investigate what the conditions are for seeing one or the other.

At this point you should be at ease with seeing one or the other cross. Do not continue until you can switch back and forth between the two images.

Before reading on, think about this. You may have noticed already that you always see a *figure*; but you do not attend to the ground. That is, when the broad-leafed Maltese cross stands out, this is what you see against everything else, which is rather indeterminate. You do not see the broad-leafed cross against a narrow-leafed cross. This is so because there is always something constituting a figure; but the figure always is against a ground. You do not attend to the ground, which is precisely why the ground is ground. If you attend to that aspect of the display, *it* will come to be the figure against everything else as ground. Figure and ground constitute each other. I therefore write the pair dialectically: figure | ground. This notation is meant to make salient that each term depends on the other. We cannot have figure without ground, and ground is ground precisely because it is not figure. For any particular something that is figure, everything else is the ground. In fact, there are not two phenomena that work together, one figure, the other one ground. There is one diastatic³ figure | ground phenomenon. We see below the work that the eyes do to accomplish a figure standing against the ground. Once we understand this work from our inquiry, we also know why figure | ground is one phenomenon rather than a combination of two phenomena.

Now we move to the next stage in our exploration. Remember, this kind of research is not about having *this* experience. It is about exploring *the conditions* of having this experience as compared to other possible experiences. We want to know more about the conditions for seeing one rather than the other cross. This means that we have to systematically move between the two figures so that we can explore the process that brings about the change in figuration. Gaze at the image and make it switch back and forth between the two configurations. You may look at one of the figures, let us say a broad-leafed Maltese cross, and then close the eyes. Open the eyes again but with the intent to see the other cross. Practice so that you can produce a switch between the two as fast as you can flicker with the eyes. Once you can easily switch between the two figure | ground configurations, we attempt to understand *what* makes you see the broad-leafed cross in one instance and the narrow-leafed cross in the other? What are you doing without being conscious thereof that brings about the switch between the two ways of perceiving?

Your inquiry will show that the figure | ground reversal, which here is a figure to ground and ground to figure transformation, is associated with a shift of your focal point. If you have not yet seen it on your own then return to the image. Place your perceptual focus on a point about one-third of the distance between the center and the outside border and in the center of the vertical leaf. You will see the cross to which this leaf belongs: the broad-leafed Maltese cross. Now move the focus to a point near the diagonal axis, again about one-third of the distance between the center and the corner of the square. You notice that the narrow-leafed cross comes to be the figure.⁴ Move back to the first focal point; then return to the second. You notice the switch between the two crosses. That is, moving back and forth between

³ *Diastasis* means separation. The phenomenon therefore is one shifted with respect to itself: it is non-self-identical.

⁴ If this does not happen right away, then the problem is of the kind that we explore below (chapter 12): the separation of a description of an action, a recipe, and the action itself. Once you have produced the intended action, the description will be obvious.

the two focal points switches between the two figures and, equivalently, switches between the two grounds. In fact, what is figure in one situation is ground in the other. We now know more about what makes something a figure and everything else the ground; and we can use this knowledge intentionally to reverse figure and ground. This figure | ground structure is in fact an invariant of perceptual experience, whereby the ground becomes increasingly indeterminate whereas the figure comes to be increasingly determinate (Thompson et al. 1999).

We therefore have arrived at a first result of our inquiry. *We can intentionally move from one figure to another by choosing a particular focal point.* Now, we have to ask immediately: Is it the focal point that determines what we see? How is it then that we see what I loosely call internal and external structure? What would happen if we were not moving the eyes at all?

It is not easy to get the eyes to stop moving so that the figure we look at falls onto the same place on the retina for an extended period of time. Psychologists actually have devices for fixing the image onto the retina. With such a device it would be easy to study what happens if the effects of eye movement on perception are eliminated. But, with some practice, we can get to that point.⁵ I find it easiest to do this experiment with one eye only. Return to the Maltese cross (Fig. 2.1) and focus on the intersection. Try keeping the focus without letting the eye slip. You may soon notice that at first some of the lines begin to turn into a light grey. With more practice, you will experience the entire visual field turning into a continuous grey. Under strictly controlled experimental conditions, this extinguishing of the figure occurs within 1–3 seconds (Yarbus 1967). Because it will take a while to get to that point, you may want to read on and take my description on faith for the moment and return to practice the experiment at some other time.

We therefore have arrived at a second result of our inquiry. *When there is no movement of the image on the retina, such as when the eye is focused onto the same spot, then the image will disappear and we see nothing but a constant grey.*

We can now stop and move to the second stage of epoché, which may lead us to results or hypotheses that can be investigated by means of further experimentation. In this second stage of the process involves, as I point out in the introduction, a systematic analysis of the results obtained during the first stage. I have already begun this second phase by stating the first and second results of the experimental phase: (a) what I see as figure depends on the focal point and (b) no eye movement, or rather, no movement of the retinal image implies no figure at all. We can generate some further results or hypotheses if we think about the implications of these two results.

The first result shows that the movement of the eye to a new focal point produces a shift in the figure | ground configuration. I know that in each of these posi-

⁵ The effect was first described already in 1804 by Ignaz Paul Vital Troxler and known under the name of Troxler's effect or Troxler's fading. Nowadays, various means are used to achieve it. The image can be projected by means of a contact lens onto the retina, where it will stay even if the eye moves. The object movement also may be adjusted to the eye movement so that the former cancels the latter and the image remains stable. Finally, the image may be projected via flash, which creates an afterimage. As readers will have experienced, any after image will fade within a few seconds. *Eye Movements and Vision* (Yarbus, 1967) provides a good introduction to the general topic of perception.

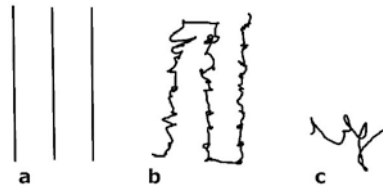


Fig. 2.2 If a person is asked, in an eye tracking experiment, to follow the three straight lines (a), the eye does not move straight, as the person might intend to do, but involves small involuntary and unconscious sideward saccadic movements (b). When the person is asked to count the same lines, we see slight movements following the line from down to upward, sideward movements to change to another line, and sideward saccades (c). (See Yarbus, 1967, for such experiments.)

tions, vision would disappear if the image were to be fixed on the retina. Thus, movement is required to see anything at all. But what is it that allows me to see a narrow-leafed rather than a broad-leafed Maltese cross? There has to be something that distinguishes the two perceptions. Or, to sharpen the point I am driving at: What is it that allows us to see a cross rather than a line or a triangle? It is not a simple apperception of the thing – e.g., it has been suggested that ‘we can perceive a whole geometric figure . . . we can perceive a whole line as simultaneous’ (Piaget 1970: 61) – but rather, even the simplest thing such as a line is the result of eye movement that distinguishes a straight line from a curve. The eye movement in each case is not the same. Thus, we are led to the realization that two movements are required, one that produces the figure | ground distinction and the other that produces the particulars of the figure as this rather than another figure. Or rather, we could state this as a hypothesis and then engage in subsequent investigations to find out about the eye movements that allow us to view a straight line rather than a curved one, a rectangle or square rather than a triangle or circle. At this point, I do not intend pursuing this line of work but simply refer readers to some experiments. Thus, recent physiological studies show that the intensity of the figure | ground distinction is a function of saccades, that is, the slight, unconscious eye movements that shift the image on the retina (Supèr 2006). In the book I refer to above, readers can see what the eye does when there is a more complex displays, for example, one involving a square, a triangle, a circle and two sets of straight lines, one oriented vertically the other one horizontally (Yarbus 1967). One observes that even when the eye follows a line – these are the movements that produce the line as line – there are saccadic sideward movements – these stabilize the line against the ground. As a result, if there is an array of three vertical lines (Fig. 2.2a), the instruction to follow the lines will lead to a corresponding recorded eye movement (Fig. 2.2b); and the instruction to count the number of straight lines will also reproduce the lines and the sideward movement (Fig. 2.2c).

There are some tremendous implications that derive from this investigation for my understanding of cognition. *If visual perception requires the movement of my auto-sensing body, and if it requires sensing, then whatever I see as an object independent of myself actually involves my flesh. What appears to me in my percep-*

tion appears as it does because of the specificity of my, specifically human movements and sensibility to be affected. The world and I are intertwined!

In this section, I engage the reader in an exploration of visual perception. At this point, we have arrived at some basic understanding of what happens when we see something. In doing what I ask you to do, you actually did the experiment on your own. This comes with two advantages, one with respect to method the other with respect to the findings. In both instances, we can learn something more than we have done so far. By doing the experiment, you have *lived* rather than *read about* the method. You have enacted the method, and therefore practiced it. You have, in and through your investigation, done what you need to do when you engage in a first-person inquiry. In this way, method is not just something you read about in a book but is something that you actually do. This is what I had in mind when I created this series for Sense Publishers, concerned as it is with the *praxis* of research method rather than some *account* of research method. That is, once you will have done such inquiries sufficiently often, you will be *competent in* the practice rather than just *knowing about* it. The latter might involve being able to describe and talk about it, as sports journalists comment on professional athletes and games, which they can do without actually being professional athletes themselves – though, in a very strong sense, they do not know with their bodies the phenomenon (i.e., *what*) that they are talking about. Having done first-person inquiry gives you a real understanding, one that is engrained in your doing, in your dispositions, rather than one that you have to think hard about to make it work.

The other aspect of this way of working is that some result that natural scientists already have researched or will be researching in the future, are known to you in and through your personal, pre-reflexive experience. In the present case, I refer to the earliest accounts of visual experiments in the early 19th century, and subsequent work published in the 1960s. Other work – such as the findings of the relation between figure | ground strength and the saccadic movements – however, has been published only recently. In this same vein, a study published 1997 in the flagship journal of the natural sciences, *Science*, about the way in which we perceive spatial objects, suggests that their results had been anticipated by the philosopher Maurice Merleau-Ponty (1945) in his book about the phenomenology of perception. For me, personally, coming to such results that are confirmed by third-person research is of utter gratification, as it provides me with the sense of a true understanding, something that has become apparent to me in and through my lived experience, rather than something that I know and master symbolically. Such symbolic mastery is not mastery of the real thing. It is superficial, in a way. We do not feel it. Experience, on the other hand, is essentially pathic. Because I have experienced what happens in perception, I can also experience *sympathy* and *empathy*, which I cannot truly do when something I know is not related to pathos.

My own research is concerned with the study of knowing and learning related to mathematics and science. The present method and results have assisted me in understanding demonstrations that high school science teachers or professors use as part of their lectures. Thus, if students do not already know what is to be seen or what is relevant in a demonstration, the results of the current investigations allow us to anticipate that there will be differences in what students perceive. But these differences are not the result of conscious ‘constructions’; rather, they are the re-

sults of non-conscious processes: where the eyes focus and what they do thereafter. There are implications, however, to making different observations. Thus, if these differences among students and between students and teachers/professors do not come to the fore, then the lecturing individuals might assume that the students had seen something that allows them to make sense of the theory taught when in fact the students have seen something else. It then will make absolutely no sense to the students what the lecture is about; or alternatively, they will produce a fit between what they hear and what they have seen not realizing that there are grave inconsistencies. In one research project conducted in an Australian high school, I could show precisely this (Roth et al. 1997). Some 18 students saw motion in a demonstration and five did not. To make sense of the lecture, however, one had to have seen motion. When the 18 students provided explanations, these could not make sense because the teacher assumed no motion had occurred and required answers that explained no motion rather than answers that explained the motion. What is it that made some students see motion where others did not see it?

We can extend our thinking about the results of this investigation, and this leads us into the third stage of *epoché*. This third stage requires us to ‘sit still’ and let the results work upon us. The true impact of some findings will become evident to us only later. We may suddenly have an insight or wake up at night and know, all of a sudden and without having intended it, what our findings really mean or imply. For example, I did not immediately realize that the present results also show us that perception is not a matter of ‘interpretation’. It is not that I see *something* that I then interpret to be a Maltese cross. My eyes work on their own, based on my (their) immanent knowing how to move; they do not require the conscious mind to follow movement trajectories that allow me to see what I see. What is there to be seen then is given to me in my perception. Their (my) movements are engrained, so to speak; these movement forms constitute kinetic melodies that my eyes recall on their own without requiring my consciousness. It is during a time of non-attention that I have come to accept new understandings that emerge in my conscious awareness. It is during such moments of non-attention that I have developed the insights about perception described here. In fact, this third stage of the phenomenological *epoché* is of sufficient importance to be investigated as a phenomenon in its own right: Knowing as something pathic, *being given* (to us), as a recent book title suggests (Marion 1997), rather than as something intended. We encounter this aspect throughout the present book, but especially in chapter 9 devoted to investigating the passions.

One way in which readers may want to pursue the present inquiry is by systematically varying the cross itself. Again, this is easily done using a graphics program that affords changing the relative angles of the two crosses, which may produce further changes of interest to us. That is, we can always extend some inquiry and thereby produce new variations that allow us to better understand the conditions for having *this* rather than *that* (perceptual) experience. I have produced one such change using the Maltese cross (Fig. 2.3). But for a true inquiry, I would produce many crosses if the purpose of my investigation were to understand the role of proximity of adjacent lines on salience of a particular figure. Thus, for example, the investigator may ask in which configuration the vertical cross rather than the diagonal one will be dominant, that is, will be the one that springs first into the

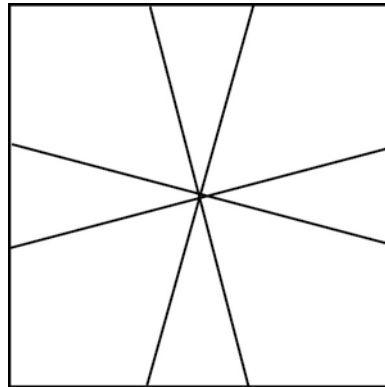


Fig. 2.3 One variation of the basic figure known as the Maltese cross.

eye. What are the relative angles when the dominance shifts from one to the other cross?

It turns out that sometimes one investigation will lead us to something unsuspected so that we learn about something else. Thus, in the next section, I engage readers in an inquiry that goes, among psychologists, under the name of Müller-Lyer illusion. When I first investigated it I wanted to find out why two lines appeared to have different lengths even though I knew they were of the same length (I had merely copied and pasted the second one). That is, on the surface, this might look like an investigation that belongs into this section, where we produce simple perceptual experiences, such as the perception of a straight line. It turns out that the results have taught me something about the relation between perceptual depth and its effect on the perception of line length.

The Perception of Depth

My interest in the relation between perception and the three-dimensional nature of the world arose for me in the context of doing a study on young children's learning of geometry. I was especially interested in understanding what the second-grade students I was following already brought with them in terms of experiences and competencies that were presupposed by the lessons and that are part of the fundamental experiences of being in this world. The basic things that the children were working with included objects standing for cubes, cylinders, rectangular prisms, pyramids, spheres, and so on.⁶ While writing a chapter with a graduate student, we asked the question that also became part of the title: 'What makes a cube a cube?' We begin the chapter with a drawing (like Fig. 2.4) but then, because of the book's

⁶ The practical things we encounter in the world are only approximations of the things that geometry deals in, which are ideal objects with properties that real objects can have only in a limit case.

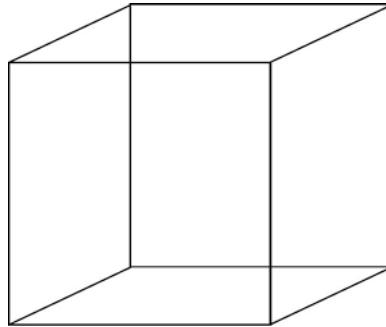


Fig. 2.4 The Necker cube serves us for a first-person experiment in spatial perception from two-dimensional drawings.

focus on the interface between body and culture, go on to relate children's bodily experiences in cultural settings. But in pondering the question subsequently, while looking at the figure again, I began to investigate why we see the line drawing on a flat page *as a cube* and not as some assembly of straight lines in a two-dimensional plane. 'What makes this drawing', I began to ask, 'appear as something three-dimensional?' I asked in particular because I could not buy into the constructivist answer that the perceivers 'construct' what they see. Clearly, constructivists confuse what appears on the retina with some inner representation that is subsequently interpreted by the conscious mind. This means that the lines would be on something like an internal mirror. Some inner mind would then look at this image and interpret the combination of lines in this or that way, thereby constructing it as one or another cube, a combination of lines, or still something else. The preceding investigation with the Maltese cross shows that prior to any rational conception and interpretation, the eyes are engaged in movements that make us see something. We may liken what we see to other experiences, for example, see Fig. 2.1 or 2.3 as instances of the Maltese cross, or a cross of the German Order, and so on. But by the time there is something that can be likened to something else or given a name, other events have happened. These events are not apparent to consciousness but can be, nevertheless, investigated using first-person methods.

The figure is known in the psychological research as the Necker cube (Fig. 2.4). Although there are but a few black lines on a two-dimensional sheet of paper, most research participants report something like 'I see a (three-dimensional) cube', 'I see a cube from below that extends from front right to back left', or 'I see a cube from the top that extends from the front left to the back right'. When asked further, participants may outline, moving their fingers along the lines, where they see the different surfaces of the particular cube they see. In their statements – which may be provided verbally alone or communicated using a range of semiotic resources – they provide *accounts* or reports of experience. What they have not provided us with is access to the actual lived work that is obliquely referred to in the account/report.

To find out more about perception, we need to set up an experiment, which begins with epoché and its three phases: generation of experience, reflection, and

passive acceptance of new understanding. We begin with the generation of experience.

So what is the lived work underlying the report of seeing this or that cube? The drawing (Fig. 2.4) allows us to investigate the *process* of perception and how we come to see in depth what we see in depth, that is, the *object* of perception. Upon first sight, you may see a cube, if you see a cube at all, from slightly above extending from the front left to the back and right. But, if you see a cube, you might actually see one from below and extending from front right to the left back. If you do not see one or the other, stop here and try. (You may verify what you perceive with the two drawings in the appendix A2, p. 249.) These two perceptions are the two spatial configurations that are seen in psychological experiments, where they are categorized as ‘cognitive illusions’. I know from lectures when presenting this drawing that many people initially will see only one of the two cubes; but as soon as audience members have seen the second one, they will be able to see them over and again – which means that they (their eyes) now have learned how to see the second cube. Rather than wondering about illusions, let us engage in the analysis of the lived work of perception to find out what is at the origin of the perception of the cube in one or the other way (i.e., from below or from above). We may do so by, for example, by exploring how to quickly switch back and forth from the cube seen slightly from above to the other one seen from below.

To begin with, look at the figure (Fig. 2.4) and allow the first cube to appear, for example, the one that you see from below and extending into the back toward the left; then intend seeing the other one until you see it. Move back to see the first; return to the second. You might also do this: look at the first cube, the one seen from the bottom and extending toward the back and left. Close your eyes – but intend to see the other cube upon opening the eyes again. Practice until you can switch between the two with the rapid flicker of the eyelids. Once you achieve this, focus on and observe what is happening with your eyes during the flicker. That is, how do you (intentionally) generate *this* or *that* experience voluntarily?

You may notice that if you place your eyes to the lower left corner that appears inside the set of lines and then move toward a non-present vanishing point to the left (‘along the surface’) – this may be along the edge leading from the ‘front’ vertex toward the back left – then the cube-seen-from-below becomes instantly apparent. Similarly, focusing on the equivalent vertex further up and to the right and then moving along the edge ‘backward’ to a non-existing vanishing point allow you to see a cube-from-above. That is, unbeknownst to your intellectual consciousness, the *movement* of the eye from one of the two vertices toward a non-existing vanishing point in the back to the left or right of the diagram creates one or the other perceptual experience. This, therefore, is a statement about how the work of seeing produces the cube even if we do not consciously attend to it. If the eyes do not make these movements, then the cubes do not appear and the lines remain on a flat surface.

As a first result of reflective analysis, we note that this experiment shows us that the cube is not (intentionally) constructed because when you looked at the figure for the first time, the cubes appeared, you did not intentionally construct it. And for the very first time you looked at the figure, you might have not seen any cube at all or only one and not the other.

This result generates new questions. How do the eyes know to move like this to make the cube appear? A first clue comes from our experience itself, especially when you were seeing initially only one cube or no cube at all. But as soon as you have been able to see one or the other or both cubes for a few times, you can easily see it (them) again when returning to the figure. This shows us that our knowing emerges from initially uncoordinated movements during which the flesh auto-affects itself such that it develops the capacity to move and develops an *immanent* memory of this capacity. We know that it is not reflective a reflective kind of memory, because we do not intentionally have to place our focal point and intentionally move the eyes. I (my eyes) *immanently* know what to do and do again to see the cube. In other words, during first random movements and before I have seen a cube for the first time, corporeal-kinetic movement forms (archetypes) emerge that would be more ancient, more basic than any ‘image schemas’ or ‘sensorimotor schemas’. Our perceptual ways *are given to us in an initial event of donation*.

In the third phase of the inquiry, we may realize that one of the upshots of this investigation is this: We do not just see or recognize a cube because its mirror image is produced on the retina. Rather, our eyes have to do work; and associated with this work there are changes on the retina. Based on the changing images, and based on prior experience, we have learned to see cubes. We can see cubes because our eyes (we) know what they (we) have to do to make a cube appear. It is in the non-perceived movement of the eye that the distension and dehiscence between the cubical figure and the ground occurs and that the former comes to detach itself from the latter. But we should not think of the image as something standing before the ground, as if projected against a screen; rather, in the image the ground is rising to us. It is not merely, as enactivist theorists would say, that the organism is bringing forth a world – the world gives itself to the organism, which learns how to make any figure reappear. That is, the movements of the eyes are not random, not constructed, but they are entrained by the structures of the material world in which the organism is embedded. ‘It is in reference to my flesh that I apprehend the objects in the world’, as we have seen in the preceding section, so that ‘in my desiring perception I discover something like a *flesh* of objects’ (Sartre 1956: 392). It is in reference to my flesh that I apprehend the objects of the world, which means ‘that I make myself passive in relation to them and that they are revealed to me from the point of view of this passivity, in it and through it’ (ibid: 392). There is therefore a fundamentally passive component to perception that tends to be obliterated in the (social, radical) constructivist literature but that is essential to understand the dual, subjective | objective nature of mathematics or science that has become the point of unresolved contention between formal and constructivist accounts of these fields.

We can extend this experiment by changing the figure, turning it into one that follows the laws of perspective drawing. The investigation then constitutes another *variation of experience* – everything else being the same – teaching us about the underlying processes of perception. I begin by making a duplicate of the Adobe Illustrator™ file that I had used to make the first cube (Fig. 2.4). I draw four lines from the ‘front rectangle’ so that they intersect somewhere in the background to the right and back of the cube. I then use the individual point selection tool of the

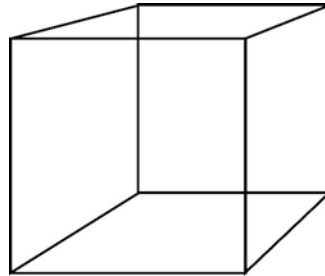


Fig. 2.5 A cube drawn according to the laws of perspective, which means, the four parallel line from ‘front’ to ‘back’ have to intersect even further back.

software to move the corners of the back square onto the corresponding line so that the four edges that lead from front to back all fall on a line. This gives me a new drawing (Fig. 2.5), which I can use for the same kind of investigation as before. (The steps in the construction are shown in appendix A3, p. 250.)

Readers may stop here and do this experiment on their own. You may notice that the cube seen from the top – oriented from the front left to the back and right – is more prominent than before, and certainly more prominent than another three-dimensional figure that we can see. If you do not yet see it, try what we have done before. Move to the lower of the two corners within the outline and move your eyes along the edge toward the left and back. What do you see? It is no longer a cube but a truncated pyramid – the front square appears smaller than the back square. That is, when we do the switching part of the experiment, we also move from a cube to a truncated pyramid.

An extension of these experiments came for me from another one related to the perception of lines. While on some long flight home from a conference, what is known as the Müller-Lyer illusion (Fig. 2.6) came to my mind (notice the passive construction of the sentence) while thinking about the perception of lines in geometry. I first took a pen and drew some lines into my notebook but then realized that the hand drawings and perhaps the background of the notebook itself – drawn lines to be written on – interfered with the effect I remembered to be associated with the phenomenon. An idea came to me: Use the drawing software on my laptop, draw the figure, and then begin investigating it.

As I began, I knew that the two lines were of the same lengths but could not get rid of the appearance of lines of different length. As much as I tried ‘constructing’ them the same in my mind, they *appeared (looked) different*. I was wondering whether I could make the illusion disappear by squinting or by turning the laptop in different directions. But nothing helped. I then had another idea: remove parts of the arrows on one or both of the figures to see how this would affect my perception. I then systematically removed lines only on the left or right or only on top or the bottom of the arrows. *This, thereby, constituted a systematic variation of the conditions of my experience*. I was attentive to what my eyes were doing, thereby coming to realize that they were following the arrowhead lines to make something like a perceptual completion. Readers who want to find out for themselves should stop here before reading on.

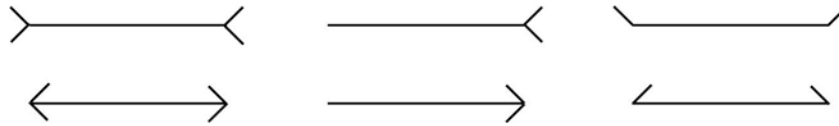


Fig. 2.6 The original version of the Müller-Lyer ‘illusion’ and two among many systematic variations produced with a drawing program. How do the changes in the drawing change what we see?

To find out what happens, look at the right-most variation of the Müller-Lyer lines (Fig. 2.6). As the eyes follow the remaining lines from the arrowheads, you notice how they follow these so that the horizontal line appears to be in the back; the eyes follow the arrowhead lines from the horizontal line toward the back in the lower instances. I only realized this after some reflection (second phase of epoché) and after leaving the experiment for a while (third phase of epoché): The two instances are like fragments of railroad tracks, where the tie is further back than the ‘free’ part of the arrowhead in the upper case, but where the tie is further in front than the arrowhead in the lower case. I realized that my eyes were doing what they have learned from parallel lines that recede into the back and toward the horizon (e.g., while standing on a railroad track following them into the distance. Even though the ties of a railroad are of constant length, those further away and in the back look smaller. If I were to see two ties of the same length but one further away from me than the other, the former would appear larger, because a tie of the same length that is closer to me would appear smaller.

We can now take these results and reflect upon them in the context of the second cube investigated earlier. In the perspective drawing (Fig. 2.5), the eye sees the smaller square as lying behind the bigger square but consider them to be the same size, as it would be for any railroad tie a little further away that appears smaller but that the eye recognizes to be the same size. On the other hand, in the second perspective, the actually smaller square comes to lie in front of the bigger square. Now the effect is even further emphasized. The drawing appears like a truncated pyramid with the base further in the distance than the smaller square. The effect with the Necker cube is enabled by the identical sizes of the two squares, which allows one or the other cube to be seen alternatively, each equally possible because the relations between the front and the back square – and therefore the corresponding horizontal lines that constitute them – are the same.

An Experiment in Original, Everyday Perception

During a stay in the ‘Neurosciences and Cognitive Sciences’ section of the *Hanse Institute for Advanced Studies* (Delmenhorst, Germany) I took this problematic head on: How does something that we have not known appear to us in our perception? While analyzing the videotapes collected during a 20-lesson tenth-grade high school physics course on static electricity, I also conducted an inquiry into the experience of learning and into the process of *coming to know*. I had been inspired by

a series of publications concerning first- and third-person methods (e.g., Varela 1996; Varela and Shear 1999) and therefore kept daily notes not only about my learning while analyzing the videotapes – my third-person perspective on learning – but also about things I noticed while riding my bicycle through the countryside for pleasure or while riding to the university. Most importantly for my research, I designed an experiment for the purpose of tracking knowing, learning, memory, noticing something for a first time, and so on. In this experiment, I would take the same tour for 20 days in a row. Each time preceding the trip, I would write down everything I anticipated seeing – an empty set {} on the first day, because I had never been where the trip would take me. Upon returning, I would write either in my notebook or in my dated electronic files what I remembered having seen. The trip turned out to be about 25 km in length, taking me from the *Institute* outside the city, through valleys, fields, and an extended forest and back.

Central to the experiment were the planned trips themselves. Each day I would go out – rain or shine – and, upon returning, write my entries including the following:⁷

Day 1. As I was riding along, I was aware of my surroundings (trees, flowers, and so forth) without really focusing on anything in particular. Although I was aware at the moment outside of what I was looking at, here at home, I remember few things in particular, few stretches of the trip. But those things I do remember are associated with a particular type of experience. There were things, like a particular house or a road sign ('Landwehr') that was pulling my gaze to take a closer look. As I focus, sometimes with considerable delay, a memory surfaces – the house looks like the one I had lived in 40 years earlier, 'Landwehr' was the name of a professor and of a street in the city where I went to university. [E01p7–8]

Today (my fifth) trip, I notice for the first time the little plates, inscribed with numbers that increase by 0.1 about every 100 meters. I infer that these are distance indicators with reference to some starting point. [E01p31] (I subsequently found the starting point during an explicitly planned trip.)

Today (my seventh) trip, I notice for the first time the upper parts of two gigantic towers that are visible above the treetops. [NBp13] (From then on, I not only saw the towers each time I came by this place, but I was expecting them to show up even before I got to the place.)

Later on, sometimes on the same day, sometimes following a particular observation during the data analyses that I conducted at the time, I returned to notes and drew on one or the other to illustrate some idea I was having or to make a comparison between what I had experienced and what I observed on the videotapes. For example, my analyses – stage 2 of the epoché – included the following commentaries:

The movement of the body with respect to the surroundings and of the eyes with respect to the body is so central to the experience that it is easily over-

⁷ I use a bar on the left of those texts that have been excerpted from my database. Codes in square brackets – e.g., '[E01p7–8]' – refer to the original data source ('E01'), specific electronic files and the page numbers within the files ('p7–8').

looked. These data show that I am *perceptually tuned* to my surroundings, which enables me to move about, my perception is indeterminate: initially, few features come to stand as figures against the ground, to be remembered subsequently. Before my awareness grasps detailed features, the physical world appears to exist, indistinct, and as invitation to be articulated. I remembered few concrete things after the first and even subsequent trips along the same route. However, in the course of the repeated experience, new features emerge into consciousness: I see the road sign with the ‘Landwehr’ inscription, the distance signs, and the towers for the first time.

Despite the self-awareness that the experiment is about recalling the maximum number of features and despite an extended effort to recall as much as possible, I perceive one or more new features ‘for the first time’, each time I travel. Consequently, my world becomes more (perceptually) articulated, allowing me to articulate it (verbally) in my notes. At the same time, certain entities (e.g., the ‘Landwehr’ sign) have a certain ‘grabbiness’, which turns out to be related to (and is articulated in terms of) previous experience. Encountering these entities brings forth an experience of *déjà vu*, including specific details (features) that come to stand as figures against ground. The descriptive articulation follows the perceptual articulation.

It is with respect to this last episode that I articulate the first-person method further. What became important in this experiment was to notice those aspects of original perception that we do not normally attend to or take for granted. The following analysis of the events on Day 7 of the experiment actually shows an engagement with a form of experience that I first became first aware of in my teens. In those days, I was taking the bus from my village to the nearby city to attend an academically oriented high school (*Gymnasium*). Because my village was the second-to-last pick-up location, the bus was always full and I had to stand near the driver or even on the steps next to the door up front in the bus. One day, just as we drove down the valley toward the city, I noticed a cathedral that I had never seen before, even though I had stood in this place in the bus for the past seven years. At the time, I could not make sense of this experience and had long forgotten about it. Why would it be that we can look at some scene every day for more than seven years and then, all of a sudden, see something that I had never seen before and yet which predates my existence – the cathedral was hundreds of years old?

In the following, I provide an example of the way in which I ‘worked up’ the initial entry into my logbook that expands on the original experience and sets it into the perspective of the analytic questions that I have had with respect to learning and the problematic framing thereof by constructivist theory. The episode shows that the phenomenological epoché (a) does not take the world in the way it offers itself, where we do not pay attention to much of the surroundings but take them for granted (e.g., we seldom become conscious of the floor or street we are standing or walking on) and (b) notes the different levels of awareness related to (specific aspects of) the surroundings.

On the side of the road I saw a set of twin silos. They were so big that they can easily be found on aerial photographs, sitting about 40 meters apart at a distance of 200 meters from the road. An entire slew of questions began to

appear and unfold in my mind. How could I not have seen these twin silos on my first or at least second ride? I immediately realized that I could not have answered questions about the twin silos following my six earlier trips, and, during an examination, would have failed the test *even though the examiners could have thought that I had had already six times the experience*. I understood that I could not have aimed at seeing these twin silos precisely because I had no clue about their existence. I was in a situation not unlike that in which students find themselves when science teachers set up in 'inquiry learning'. How was I to know that these twin silos were relevant and not something else? There is nothing that 'construction' of my experience would have allowed me to arrive at the twin silos, because nothing that *was given to me in my perception* would have lend itself as material to 'construct' anything useful from it.

Another important question during my inquiry was, 'How did these shapes come to stand out against everything else as a ground?' 'Why these shapes and not some other shapes that could have become figure against ground in precisely the same setting?'

As the questions raced through my head, I experienced another shock: I realized that I had forgotten the world that existed for me before. Now I was thinking about a world populated with the twin towers, and I asked questions such as 'How could I not have seen the twin silos?' I realize that these questions presupposed the existence of the silos prior to my first actual experience of them. I immediately realize that if there had been a teacher with me, presupposing a world in which the silos existed, would anticipate me, the student, to see the twin silos, whereas I could not intentionally look for them. And this, I realize today, is precisely where Jean Piaget and his constructivism are wrong. He assumed that there are (mathematical) structures in the world, which children (he considered them to be little scientists) can discover. Thus, he assumed children to look and interact with a balance beam and then, depending on their developmental stage, *abstract* a more or less mathematical pattern. But to do so, one has to see the weight as weight and distance as distance, which is absolutely not the case even among older students who might see, for example, locations on the beam and number of objects suspended. Even mature scientists may see one aspect, such as the slope of the curve, when the relevant values required in solving a problem are the absolute values of the curve. There is nothing, I realized, that children can inherently abstract from the balance beam much in the same way that there was nothing for me to abstract the twin silos from the perceptual experience. *These things did not exist for me*. I lived in a world *without* twin silos.

For science teachers, *therein* lies the quandary. Having forgotten about the world without the twin silos, they can no longer *empathize* with the children and students, who inhabit a world that they have forgotten. They inhabit a world that they must forget unless they are to drown in the co-presence of all the worlds that they have lived in before. As I was able to experience, this world is in continuous flux because with every bicycle ride, there were so many new features that had come to stand out for me. Today, I know that

learning is associated with a form of amnesia, a forgetting of the world in the ways we know it. (Roth in press)

We see in this excerpt from my analytic writing how the method separates the specifics of the experience, here the first emergence of the twin silos into the consciousness, to unearth and excavate the invariants. To be sure that something is invariant across experiences, analogies and parallel examples are useful, because it is precisely in the comparison that the invariants become invariants: aspects that do not vary when we move from one to the other context. The account also shows that I did not just notice the twin silos to go on and no longer attend to them, taking their existence as a matter of course, as something that goes without saying. Rather, I paid particular attention to what was happening at the instant, the process by means of which thoughts and questions arose within me. In fact, the questions that arose were unintended. So we observe a double intention that is oriented, on the one hand, toward the experience of the twin silos emerging into my consciousness, to the process by means of which this occurred, and the events that immediately followed. For example, in the quoted text I attend to the fact that a particular question arises in and constitutive of the experience: ‘How could I not have seen these twin silos on my first or at least second ride?’ Moreover, I also note the next question or realization associated with this question: The twin silos are accepted as entities that existed prior to this experience, that is, during the first or at least second ride. The first question is in fact the same that had first occurred to me some 30 years earlier (around 1970). But it is a keen awareness directed toward the presuppositions and to the questionable nature of the presuppositions in this first question that was occasioned for me in the experience of the twin silos.

What is interesting about this experience is this: it exhibits an orientation toward the process of *phenomenalization* itself. It is not the thing, the twin silos, that is of interest but the very way in which these came into being and what happened to me in and after that split second when these first appeared to me in my consciousness. Here, they are given because visual perception is not aware of them. But it is equally evident based on physical principles that the light from the twin silos must have fallen onto my retinas before. Yet the twin silos did not stand out – they were not *ek-static*. In this experience, they literally came to be placed outside (me), an expression that returns us to the etymological roots of the term in the ancient Greek language, *éksta-*, stem of *éxístánai*, to put out of place, from *ek-*, out, and *ístánai*, to place. In phenomenology (e.g., Henry 1990), using the hyphenated spelling therefore is a means to take us back to the original emphasis on the two parts of the phenomenon, the *placing*, on the one hand, and the *outside*, on the other hand. In fact, when the Swiss psychologist Jean Piaget investigated object permanence, he pursued a related phenomenon but from a very different perspective and from a very different epistemology and ontology. He assumed the world to be constant and little children to be deficient thinkers. Through experience, they ‘construct’ object permanence as they become older and develop. For objects to be permanent, these do in fact have to stand out in the way the twin silos came to stand out for me, and in my adult perception: the changeover from perception to stable object occurred so fast that I almost lost my object, the *phenomenalization* of the twin silos as given to my perception and then their becoming the independent (Galilean) objects that they were afterwards.

Over time, I extended the reflections on this experience. Frequently a new realization struck me out of the blue and even though I had not explicitly thought about this episode; but at other times, I realized something new precisely while thinking about the episode in which the twin silos first appeared to me. I revisited this episode in various places to think about learning from the perspective of the learner – including presentations and a book on learning that makes use of the interplay between third-person and first-person perspectives (Roth 2006). That is, in extended reflection with frequent long pauses between the reflective episodes, ever-new realizations *were given to me* in what constitutes the third part of the phenomenological *epoché*. That is, the third phase of the *epoché*, in this situation, was not limited to a brief period following the original experience and the first reflections upon it while I was still in Delmenhorst and in the course of completing the experiment in everyday perception.

Many years after these events, I read a little book entitled *La croisée du visible* (Eng. *The Crossing of the Visible*) (Marion 1996); in it, the author takes the question of visibility by analyzing paintings and the work of the painter. Painting gives this philosopher a particular vantage point to provide us with a phenomenology of perceiving something for the first time. When I read the text in the following quotation, I immediately highlighted it because it reminded me of the twin silos. And it is precisely because of the experience related to the twin silos that I found the following quotation intelligible: It made sense because I already have had related sense experiences. ‘The unseen that the painter will look for remains therefore, up to the point of its ultimate appearance, unforeseen – unseen thus unforeseen. The unseen, or the unforeseen par excellence. Like death, which (in principle) is not here so long as I am here, and which appears only when I am no longer here, the unseen remains inapparent as long as it is, and disappears the moment that it appears as visible. The unseen appears only to disappear as such. Further, one is not able in any way to foresee the newly visible on the basis of its unseen, by definition invisible’ (ibid: 54). The philosopher does not stop there but shows that even the painter does not know what he is going to show in and through his painting (drawing). In fact, there are numerous painters who talked about painting as a way by means of which they themselves find out what there is to see. Painting is *not* expressing what already exists on the inside, in their minds, as if the painter squeezed his/her inner contents onto the canvas. This is precisely the same what others have recognized about everyday (improvised) speaking where speakers themselves find out from the utterance just what they have thought (Merleau-Ponty 1945; Vygotskij 2002).⁸ I continue to pursue this inquiry and the methods for such investigations in chapter 9.

Iterating First- and Third-Person Perspectives

An important aspect of my research concerns understanding a variety of phenomena related to the knowing and learning of mathematics and science. To me it is

⁸ I am not talking about the situation where a person reads from or regurgitates a memorized text.

always the phenomenon that determines what I want to use as method. I am not (and advise others not to be) a ‘mono-maniac of method’ (Bourdieu 1992) who knows but one method and who selects research problems as a function of it. But despite the popular saying that to the person who only has a hammer and only knows how to operate *it*, the whole world looks like a nail, many researchers use only the one method they have ever learned, often during their graduate work. I frequently hear graduate students and junior faculty say, ‘I want to do a qualitative study’, ‘I am going to use a questionnaire with Likert-type items’, or ‘I want to do a phenomenological study’. But, I ask, ‘What is your research question?’ ‘What do you want to find out about?’ ‘What are your interests?’ Surely it is not the method – unless you are a methodologist.⁹ I personally saw a good example of what might happen when a person knows only one method and has to abandon what she really wants to do. I had organized sessions where faculty could discuss and develop ideas for research that they sought funding for. A young colleague was interested in pregnant women who join online forums. Being pregnant herself, she intended to organize such a forum, which would grow as the study went along. The problem is that she only knew how to statistically analyze questionnaires. She wanted to do an experimental study with treatment and control groups. But in this situation, because the women would be joining the forum over time, she could not make the assumptions that are required for a psychological experiment. She abandoned what she was really interested in because it did not fit the method she knew. Rather than pursuing the question that really interested her and in which she had a lot of personal investment and experience, and rather than acquiring the practical understanding of method in the process or by taking some course where she could have been introduced to what she needed, she abandoned researching this line of interest.

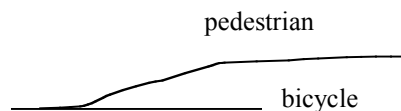
My personal advice always is to find a problem and then, if necessary, to learn and evolve the method(s) required for providing an answer. I begin in this way to show that I research some phenomenon irrespective of the method it requires. I do not do a phenomenological study of something, fitting the object of research to the chosen method. Because of this reason, I may actually take multiple methods that give or promise me a better understanding of the phenomenon. My research notes bear witness to the multiple methods, as I hold up the results of one method against what I am finding out using another method. Relevant to this book, I hold up the findings of some third-person method against the findings from a first-person method. This guards me against something that I also experienced in the context of my work at the *Hanse Institute*. While I was studying the videotapes from the tenth-grade physics class that a local researcher had made available to me, I often found myself in a situation where the colleagues laughed about the students because these were doing this or that. For example, my colleagues laughed about students who said that a plastic foil ‘was used up’ and no longer produced static electricity. However, one night while I frantically attempted to understand and

⁹ I insist on the difference of method and methodology. A *method* is the way in which we conduct a research study. *Methodology* is the science of research methods concerned with understanding these methods. Correspondingly, we have to use the adjectives methodical when the issue concerns method and methodologically when the issue concerns the science of methods.

model some phenomena, I found myself putting plastic foil aside to pick up another one to continue the research. It was in putting a foil aside that I realized I was in the process of doing the same as the tenth-grade students had done. I had observed and noticed in my own actions a behavioral invariant rather than something to be laughed about. Here, combining a first-person method with a third-person method promises new understandings and a critical questioning of our normal ways of seeing things.

In the following example, I exhibit the manner in which my research may unfold. There are keen observations of something in the everyday world (first phase of epoché), which are then closely analyzed to exhibit possible invariants (second phase of epoché). I then explicitly attempt to reflect about the implications for the phenomenon in my research, which, in this example, pertains to learning physics. The difference between the method described here and the one used for investigating spatial perception using the Necker cube or the Müller-Lyer phenomenon lies in the fact that any experience in my everyday world may serve as the phenomenon to be investigated. The question of (perceptual) invariants is posed when I query a different context to see whether there are *analogies* between the situations. The presence of an analogy – as per the etymology of the Greek word, derived from *áná-*, back, again, new + *logós*, reason, ratio, proportion – means the presence of one or more invariants. In the following excerpt from my research notes, I dissect the original narrative of an experience (first phase of epoché), typed in italics, and begin to intersperse analytical text (second phase), typed in normal font. As a more advanced part of this second phase of the *epoché*, I also ask myself what this account of the perceptual experience during a bicycle trip from the *Institute* to the physics department at the university can teach me about the learning of physics.

May 11, 1999



I am cycling along a trail that was signed as a joint cycling-pedestrian trail. Then, all of a sudden, I see cyclists to my left on another trail that is part of the roadways. I had not seen where the two trails had branched off into separate trails.

In my objective experience there had not been a branch. I rode in a world where there was but one trail. In order to understand my actions, we need to understand what I perceived and thus, my world. For, if we began with some outside world, we need to assume that I was somehow defective in the moment where there was a branch. This would be difficult to argue. Thus, what is most crucial for understanding the actions of the learning and knowing person (organism) is the world from her perspective. We need to know what her world is, lest we want to operate with models in which human experience is always in some deficit mode.

I vaguely remember having been on this bicycle trail one time before. At that time then, my world had included either the bicycle trail only, or in fact a branching point which I had taken in favor of the bicycle trail.

In this case, I had a vague memory. I did not re-member exactly what had been the case before, just an impression that the first time I had come by this point, I had been driving differently. But, while realizing during the second time that there were two trails, I began to objectify this experience. The existence of two trails forced itself onto me. The next time (third) I came by this part of the road, I was consciously aware of the branching point. I perceived the branching point. This part of the road had become differentiated: there existed a fine structure to what and how I experienced it.

We see in the analytical text that *this* reflection occurs after repeated experiences of having come by this particular point en route to the university. The trip itself was not planned as part of an experiment in perception. Rather, anything and any experience could potentially become the starting point of an inquiry. It is evident that we cannot use ‘everything’, because this would mean that we never get out of experiencing the world to reflect upon these experiences. Perhaps because I was setting myself up in this manner, there were more than the normal amounts of puzzling events that happened to me and that entered my research notebooks or computer files in narrative form frequently accompanied by drawings. The analytic text exhibits my concern for developing an argument for studying learning from a first-person perspective. Whereas this might appear the self-evident thing to do for a researcher with phenomenological inclinations and preference to first-person methods, it was not and still is not the norm in the learning sciences generally and in science or mathematics education more specifically. Here presuppositions reign about what the learner *ought to do* and generally does not do.

The research note then continues with a highlighted question: ‘What can we learn from this?’ and, more specifically, ‘What can we learn from *this* especially about learning physics?’ That is, how can the experience of ‘missing the branch in the cycling path’ teach us something about learning physics?

What can we learn from this? (And what can we learn from this especially about learning (physics)?) Here, the first and second time, I experienced in the world. There was no fine structure, but I found myself on one then on the other trail. What I had perceived was not the world I perceived afterwards, which included a branching point. Rather, in my world there had been no branching point. But at the moment when I saw cyclists left to me on another trail, I was startled. In this instant of being startled, I began to objectify my experience, my presence on the pedestrian trail. Being startled here is similar to [students noticing] ‘This doesn’t work’. But whereas I was already objectifying my experience in terms of a branching point that I had not experienced, the [tenth-grade physics] students did not and perhaps could not yet know (not enough experience, and many more possibilities for doing things that make them arrive at where they are) why what they expected to achieve had not yet been achieved.

But students knew enough to know that what was supposed to happen did not happen. What they could not know is that the reality has to be ‘prepared’

in a quite particular way in order to make physics happen in the way physicists make it happen. Thus, phenomena do not just lie around, they do not just exist, but we must go through a particular preparation to make physics happen to be able to see physics. Physics is therefore not just something that can simply be observed, but is associated with a set of preparations to make it happen before it can be observed.

Readers may notice that the questions are similar to the one concerning the twin silos. But there are other elements in this text that point us to invariants. The text says, 'I was startled'. It was the starting point of a reflection, an objectification of experience and of a phenomenon. Similarly, I had observed the students producing new observation sentences precisely after having produced expressions of being startled. For example, Birgit was startled just prior to producing the statement about a gap she was seeing between the two electrodes of a glow lamp. Being startled and observing something unexpected for the first time are like two sides of the same coin. They are not two phenomena but one that expresses (manifests) itself in two ways. As my research note continues, we observe a second move. Not only did I relate the experience to the physics students I observed in *this* situation, that is, in my ongoing research project on knowing and learning in physics, but I compared, in the subsequent paragraph, what I observed in the present project with what I had observed in a physics class in Australia some four years earlier. I note the difference in the conditions that produces a difference in the observation, because the present student could anticipate what they should observe whereas the Australian students were not in such a position.

These students are already at a different point than those that we had observed in Australia. There, students were asked to look for patterns when objects were rolled down an inclined plane. There were no other indications what to do so that student did not necessarily begin by letting two different objects roll down the plane at the same time. When they did do this, it emerged from the contingencies of the setting. Furthermore, these students did not have the same checkpoint. Thus, they were in a double bind. In order to know whether what they had seen was what they were supposed to see they needed to know that what they had done was what they were supposed to do. Second, in order to know that what they had done what they were supposed to do, students needed to know that what they had seen was what they were supposed to see (Roth et al. 1997). Here, students already knew what it meant to work but they could not know what it was that made the outcome of their investigations different from what they expected. For example, there could have been something with the materials used, or with their preparation. But at this point, students' worlds were not differentiated. Few objects and operations populated their worlds. And from what they knew about these objects, it should have worked that is, they should have seen the bulb light up, and they should have seen the water stream bent under the influence of the sheet which they had rubbed before.

The notes then continue by returning to looking at the students through the lens of what I had experienced. Thus, those students with few prior experiences cannot

know what to expect and therefore ‘are at a similar point as I was on the pedestrian path’. This ‘similar point’ would then orient us to the invariant. However, the note also is cautionary by suggesting that a student investigation in the physics laboratory may be more like an entire bicycle trip. The paragraph that follows expands on the metaphor of the trip, introducing the possibilities of traveling with a map. This is a quite reasonable move in the reflections, as students in a classroom never ‘travel’ on their own but do so precisely in the presence of the teacher, other students, and their textbooks. These provide something like markers that the individual ‘traveler’ may use for navigating an unfamiliar world. Readers may also notice how, without having been explicitly configured or planned as such, doing the investigations involving trips lends itself to specific metaphors, some clearly allowing connections with existing discourses about ‘being-in-the-world’ or ‘finding-oneself-in-a-world’. This is both an affordance, an opportunity, and a constraint: Being in language, we cannot ask questions that fall outside of it, so that our questioning itself is a questioning in language. Once we accept as correct the characterization of language as the verbal expression of inner emotions, human activity, or imagistic-conceptual representation, then all questions with respect to language move within this field (Heidegger 1985). The metaphor is used here as a means to think about how students might move along trajectories in their investigations that contain branching points – from the perspective of the teacher, or, with their own subsequent hindsight – that they do not see.

The students with little experience are at a similar point as I was on the pedestrian path (though I knew that I must have ‘missed’ a branch), they found themselves in a situation where they did not expect to find themselves and did not know where they branched off in the trajectory of the investigation. In fact, in such experiments are much more complex and more comparable to an entire bicycle trip where there are many different possibilities for getting off the ‘right’ trail.

Students travel without a map. This is what they are to learn, the map. I already have some familiarity with maps, so that I can project what I might have to do, and what the experience might be like from looking at the map. For example, when there is a green spot next to the road that I need to pass, I know that I am likely to find a park in my experience. The map lets me expect a green space, park, trees, or something of that nature. Furthermore, there might be a ‘T’ in the road such that this becomes a checkpoint for my travel. If this checkpoint does not come up in some reasonable time, I will become alerted and know that I am ‘off track’.

Our discoveries with respect to a particular episode do not end with the analysis. This is only the second phase of epoché. We may actually return to an event repeatedly to reanalyze it. Or we might, in a new context, become aware of the relation that a previously analyzed event has with the current context. In the following excerpt from the research note, the parentheses indicate that at that point in my writing, I was pursuing an idea different from what I was writing immediately before and immediately thereafter. It is literally a parenthetical comment at the instant of writing. But in the course of writing, I remembered the event again and wrote a form of analysis. In part, such writing and re-writing of analysis allows me

(us) to evolve a suitable language for articulating what we can learn from the event. At the outset, we cannot know what this language will be, and therefore, we cannot select it based on some criteria. It is only afterwards, from the perspective of the suitable language that we have actually evolved, that we can say why it is superior to other languages and descriptions these afford. As the date on the note shows, it was recorded two days following the earlier note.

May 13, 1999

(When I was riding my bike down the bike trail one day, and on the next day found myself on the pedestrian path, my world in each case had only one option. I had done what the world afforded me to do. But when I marked that other cyclist where to the left of me, in fact on a trail that was not apparent from my position, I was puzzled, there was a difference between where I was and where other cyclists were. I drove across the grass onto the other trail, which I recognized as such immediately. When I came this way the next time, I re-recognized the situation and perceived the branching point that I had not seen as such on previous occasions. The branching point was at hand, present, cognized and from now on, I could re-present it even when I was not at that place. I could make it present again, make it present strongly even though I was not in the situation. I could carry the image of the branching point, could re-live my passing the branching point as well as the moment of my astonishment when I realized that I was on the pedestrian trail.)

Readers may instantly notice the insistence on *presence*, on what is present, and on representation and what it affords to being able to *recognize* or *re-live* something. That is, this investigation develops a language about memory and thinking, which are topics I take up and develop in chapters 5, 6, and 9. These connections between fundamental processes of perception, sense experiences, and higher-order experiences, sense making and learning, already should alert us to the role that these ‘primitive experiences’ have in complex understanding – even if the connections are not always immediately evident. The struggle of embodiment theories in the current context dominated by psychological theories of information processing and mental representations shows that this connection is not generally recognized even though these may be deemed to be inevitable and necessary by other theorists of cognition.

Conclusion

In this chapter, I present at least two important strategies for the researcher employing first-person methods: consistent variation within a context and consistent observation across (between) different contexts. We observe consistent variation in the experiments involving the Maltese cross, the Necker cube, the Müller-Lyer effect, and even the repeated traveling of the same route. In these instances I hold constant the context and investigate the variations that arise within it, by looking differently, by observing what is new each time that I engage in a particular set of actions, or by systematically varying an aspect of a given display. The second

strategy, consistent observation, was making observations about noticing things even though I might not have taken a route before or while taking a route in reverse. The point was not to do the trip over and over again but to take note of events that fall into a particular category. For example, in chapter 6 I describe the first-person method at work relating to memory, and memory became an important phenomenon that I investigated during that time at the *Institute* across a variety of very different contexts. In fact, in the preceding section of this chapter, there are traces of this inquiry relating to memory, as I describe the sense I had about having been on a particular bicycle trail before but remembering this only vaguely. I did not remember, however, that there was a fork in the trail heretofore shared by pedestrians and cyclists, which I had not been aware of the first time and only found out about during the second trip.

This chapter begins with the epigraph ‘Seeing is believing’. There are others – a simple Google search of the expression testifies to this – who turn this saying around to state ‘Believing is seeing’. In this second version, we can recognize a form of thought expressed in the Sapir-Whorf hypothesis that the language available to a person or people *determines* what they see. Apart from the fact that a lot of research provides little support for this hypothesis (e.g. Lakoff 1987), it also does not make sense on evolutionary grounds. The precursors of humans did not speak a language yet were perfectly adapted to their environments in perceptual terms. In this chapter, I describe methods for investigating a variety of perceptual phenomena. These methods do not take as their data the *description* of phenomena obtained from research participants, which would inherently mean that we limit our work to what language can express. Rather, our methods pursue the path of the pathic, investigating processes and movements that we are not normally conscious of and therefore subject and subjected to. Yet the investigation shows that there is a lot we may reveal about perception (a) under experimental conditions and (b) when observed in naturalistic contexts.

A corollary of this chapter is this: *Even though I, the investigator, produce the data, the purpose of the first-person method is not to find out something about me, something utterly singular that describes only this one and no other person. The converse is true. In and through such forms of investigations, invariants are sought that describe (visual) perception as such.*