

## **Tracking the Origin of Signs in Mathematical Activity: A Material Phenomenological Approach**

Wolff-Michael Roth  
*University of Victoria*

### **Introduction**

The semiotics literature tends to take signs as given. Even in constructivist and embodiment accounts of cognition, a signifier, such as a gesture that exhibits some linear relation or trend, is merely the enactment of a pre-existing schema the enactment of which results in the external production of a sign. Yet empirical evidence shows that the human sign form, as thing that stands for another thing, does not constitute the beginning—children do not make a distinction between the thing and its name. To understand signs, we therefore need to take a genetic perspective. In this paper, I present a material phenomenological account of how signs and thoughts emerge in ongoing activity. I provide a detailed description of a lecture excerpt essential features of which cannot be explained by presupposing signs, thoughts, or mental schema. The approach I offer provides explanations for some of the difficult problems in education, psychology, and cognitive science.

Many years ago, I participated in an event that catalyzed my interest in the emergence of signs that had not existed as such before. It still took many years thereafter to make the phenomenon a priority of my research agenda. In 1994, I a colleague invited me to participate in the analyses of physics lectures. He and I were watching videotaped science lectures and, at one instant, observed the physics professor produce hand-arm movement that those already “in the know” could see as an iconic gestural signifier the signified of which was a curve that he had drawn on the chalkboard during the previous lecture: the trajectory of an object with a velocity so large that it escaped the earth’s gravitational field. This episode became a focus of our analysis because it had been evident from subsequent tests in our hands that the students did not understand what the professor was talking about (Roth et al. 1997). While engaged in the discussion of our analyses, all members of our research team began to refer to the episode no longer in terms of a description but by producing a hand-arm movement that bore an iconic relation to the professor’s gesture. That is, the production of the gesture became among us something like the name for the situation we analyzed. Even later during our collaboration, the signified of the hand-arm movement was shifting. It no longer denoted the episode itself but, in our use, signified instances in science lectures that leave the

student audience clueless. One has to ask, “What allows us to become aware of the experience of the movement *as* hand movement?” and “What is it that allows the hand-arm movement to become a signifier for something else?”

In this situation, a new sign initially emerged. A particular hand-arm movement initially reproduced the signifier in the sense that the professor had used it. The signified was the gesture, itself a signifier for a graph that the professor had previously drawn. In our use, the signified then changed: (a) it initially denoted the situation itself and (b) then shifted to become a signifier for situations in which the audience does not understand (“clue into”) the lecture talk of science professors (the focus of our larger study). Whereas those interested in semiotics discuss the sign as such, the interest in studying semiotics from a genetic perspective is much less common. Yet there are scholars who suggest that we cannot understand any aspect of cognition, including sign use, unless we take genetic perspectives, both at individual (ontogenetic) and cultural-historical (phylogenetic) levels (Vygotsky 1989). A few years after my first noticing of the phenomenon, I observed and described the emergence of gestures from simple hand movements with which students had set up and completed some science experiments (Roth and Lawless 2002). In this situation, a piece of equipment initially was inserted in an explanation of the associated scientific phenomenon but subsequently replaced by an arbitrary object of the same shape (steel rod → pencil). During the explanation, the students moved a hand back and forth over the equipment in the same way that they had seen an object move next to it and that they used to move this object to and away from. This hand-arm movement subsequently became a gesture denoting the movement of the object and still later for signifying both the movement of microscopic particles in the rod.

In these instances, we observe the emergence of signs (signifier-signified pairs) that have not existed as such before. The purpose of this paper is to describe and theorize the emergence of signs and the becoming aware of the signifier *as* signifier on the part of the agent. As the empirical touchstone for my discussion, I draw on one particular episode derived from a third-year university course on thermodynamics. The fragments from the transcript used here derive from the explanation of the magnetocaloric effect. How do the particular signifiers emerge that come to litter the chalkboard following the lecture fragment? What other signifiers are produced in the process? What is the genetic origin of these signifiers? Ultimately I am interested in understanding the origin of signifiers in the lecture and their genetic origin in the development of the person. What enables the emergence and use of signs? My approach is transdisciplinary, bringing together phenomenological, psychological, and scientific modeling in the manner that these areas are brought together in *On Becoming Aware* (Depraz et al. 2003).

### **Conditions of Communication: Cognition, Embodiment, Incarnation**

“Spatiality may be the projection of the extension of the psychic apparatus. No other derivation possible. Instead of Kant’s a priori conditions of our psychic apparatus. Psyche is spread out, does not know thereof” (Freud 1999: 152).

In the past, some scholarly orientations have theorized human communication in terms of information transmission, much in the way this would occur via a telephone apparatus. The disciplines of education and psychology tend to focus on communication in terms of signs that can be recorded, such as words and, to a lesser extent, diagrams. Human communication, however, involves more than words and diagrams. Gestures, body movements, body positions, and prosody constitute other possible communicative modalities (Roth and Pozzer-Ardenghi 2006). How are these different modalities related and interconnected? For example, “What is the relation between speech and gesture?” or “What is the relation between words and prosody?”

### **Theories of the Relation of Communicative Modalities**

How we think about communication—and, therefore, about the nature and origin of the sign—depends on how we think about cognition. There is an ongoing debate about the relationship between different communicative modalities. On the one hand, there are those who attribute both speech and gesture to the same conception or idea, that is, the same psychological structure (e.g., McNeill 1992). On the other hand, there are those who suggest that an existence of multiple psychological structures underlying communication—based on the observation that during their development children may express concepts of different developmental levels, generally the more advanced appearing in gesture and the less advanced appearing in speech (e.g., Alibali and Goldin-Meadow 1993). Others again propose gesture and speech to constitute separate, ancillary channels of communication and subordinate functions of gestures to aid word retrieval (e.g., Beattie and Coughlan 1998; Hadar and Butterworth, 1997). Theories of communication tend to be informed or subtended by the way in which the psychic apparatus as a whole is conceived. At the end of his life, Freud had the intuition that the psyche is not somewhere in the mind but that it is extended and that spatiality—which in Kant is an a priori and in development psychology an early achievement of the mind that leads to an independently functioning mental conception, that is, representation of space (e.g., Piaget and Inhelder 1972)—is in fact the result of a physically extended psyche. The role of the entire body in cognition, and therefore the role of the body in communication, is the focus of an area of studies loosely referred to as “embodied cognition” (e.g., Johnson 1987).

### **Embodiment Theories**

Embodiment theorists suggest that cognition and therefore communication evolves as “embodied (image) schemata” are metaphorized and thereby constitute new or expand existing areas of application. The embodied image schemata, though non-propositional, already need to have some structure if they are to be transformed by means of metaphorization—and they do so: “image-schematic models characterize structure”

(Lakoff 1987: 155). One key author attributes his use of the concept to Immanuel Kant, who is said to have “understood schemata as nonpropositional structures of imagination” (Johnson 1987: 19). For Kant, in fact, the concept or schema always precedes experience:

Pure a priori conceptions, in addition to the function of the understanding in the category, must contain a priori formal conditions of sensibility (namely of the inner sense), which again contain the general conditions under which alone the category can be applied to any object. We shall call this formal and pure condition of sensibility, to which the conception of the understanding is restricted in its use, the *schema* [*Schema*] of the understanding concept; and we shall call the procedure of the understanding with these schemata [*Schematen*] the *schematism* [*Schematismus*] of pure understanding. The schema is, in itself, always only a product of imagination (Kant 1956: 188–189, my translation).

This means, that the sign always must have its schema. What this literature does not explain is how these structured image-schematic models—if they exist as such—emerge in the first place.

The embodiment theorists, as phenomenological philosophers point out, do not get us out of the Cartesian predicament that Kant created for us (Sheets-Johnstone 2009), and which was subsequently taken over by psychologists such as Jean Piaget and (radical) constructivists such as Ernst von Glasersfeld. Precisely because schemata are thought as structures of imagination (Kant: *Einbildungskraft*) they cannot explain how any form of thought has emerged during the phylogenesis of *Homo sapiens*. The semantic field of Kant’s *Einbildung* is different or richer than that of the English *imagination*, for *Bildung* refers to, in one of its senses, to the formation (-ung) of an image (*Bild*). The prefix *Ein-* would be translated as “in,” “within,” or “into.” That is, with the term *Einbildung*, we hear the bringing of an image *into* the mind. Today, *Einbildung* has strong negative sense because the word is used to denote “phantasies.” Thus, “image schemata need to be specifically packaged corporeally—to be embodied—in order not to remain embedded in a purely mental sphere” (Sheets-Johnstone 2009: 220). Some theorists take recourse to the unconscious, arguing that it “consists of all those mental operations that structure and make possible all conscious experience, including the understanding and use of language” (Lakoff and Johnson 1999: 103). But an unconscious, when structured like the conscious, does not get us out of the predicament that schemata precede action.

Consider the following analysis of a lecture as a concrete example of how the concept of schema enters current conceptualizations of embodied cognition and therefore communication. The example is relevant to the episode I present below, because it, too, involves a professor producing and gesturing in front of lines on a chalkboard. The analysis draws on the source-path-goal schema, which is defined as a “fundamental cognitive schema concerned with simple motion along trajectories” (Núñez 2009: 314). This schema is the source of the actions that a mathematics professor produces while

lecturing about a mathematical problem as part of which he draws a line representing the function  $y = x$ .

As he says “increasing,” he gestures with his right hand (palm down), with a wavy upward and diagonal movement (slightly along the line  $y = x$ ). This gesture is co-produced with the enactment of a source-path-goal schematic notion, where the source corresponds to a generic location  $(x, f(x))$  with low but positive values of  $x$  and  $f(x)$ , the goal of the instantiated schema corresponds to a generic location  $(x, f(x))$  with greater values for both  $x$  and  $f(x)$ , the trajectory is indexed by the external edge of the right hand, and the trajectory (path) is the trace left by the motion of the hand that is indexing the increasing values of the function as  $x$  gets increasingly greater values (Núñez 2009: 320).

In this analysis, the schema is said to precede the act and, in this approach, is the condition and source for the action to be produced. But there is a problem with such a formulation, because it constitutes movements as the result and outcome of the application of something that is itself the result of a cognitive act. Thus, to

say that the power of the ego over its organic body is exercised through the intermediary of a corporal schema conceived as an image or as some mediation between originally subjective movement and the terminus of this movement is to fall back into the intellectualist thesis according to which a representation of movement or of its instruments always precedes the real accomplishment thereof (Henry 1965: 125).

Schema theory, as used in the embodiment literature, does not assist us in escaping the metaphysical aporia of how we come to know the world. If we take a sense impression, for example, some photon or light wave causes some sensation in the organism. “What the physical thing would be outside of this inevitable reference, the ‘thing in itself,’ that which Kant called the ‘noumenon,’ remains the unknown and unknowable” (Henry 2000: 10). It is therefore not surprising to read a philosopher of dance state that embodiment literature raises the specter of Cartesianism (Sheets-Johnstone 2009). A schema-based theory “does not take us back to ordinary corporeal-kinetic experiences and to rigorous and detailed analyses of those experiences. In effect, it does not take us back to nonlinguistic corporeal origins” (Sheets-Johnstone 2009: 222). Instead, the author states emphatically, “Archetypal corporeal-kinetic forms and relations do” (Sheets-Johnstone 2009: 222).

### **Incarnation: An Emergentist Account**

A central problem that neither constructivism nor embodiment theory resolve is this: the origin of intentionality. Thus, in my introductory example, the new sign emerged rather than being intentionally produced. Intentionality is central in all models of cognition that I am familiar with, making possible the sensible bodies in particular and the sensible universe as a whole. But intentionality is incapable of assuring its own manifestation, that is, to reveal itself to itself (Henry 2000). This also is the case for the senses: vision reveals the seen only on the condition that it reveals itself as that which allows to see, hearing reveals the heard only on the condition that it reveals itself as that which allows to hear, and so on. That is, we could not intentionally engage in communication unless the very capability of the communicative modalities were established and known to these senses. I cannot produce sound-words, prosody, gestures, or body positions unless I already know, *in an immanent way*, how to move my body. That is, “the transcendental body that opens us to the felt body, whether it is our own body or that of the things, rests upon a corporeity much more originary, transcendental in a final sense, non-intentional, non-visible, of which the essence is life” (Henry 2000: 168–169).

Incarnated does not mean to have a body, to constitute oneself as a corporeal being. Incarnation consists in the fact *of being flesh* (French *chair*, German *Leib*). The adjective “incarnate” points us to pathos as the constitutive moment of human life: “Incarnate beings are suffering beings, traversed by desire and apprehension, which feel the entire series of impressions related to the flesh because they are constitutive of its substance” (Henry 2000: 9). Although a title of a most recent installment of embodiment theory contains the term “flesh” (Lakoff and Johnson 1999), it does not in fact theorize the flesh or make reference to the way in which it allows us to understand fundamental experiences and the relationship between affect and cognition. Henry points us to the origin of an incarnate conception of human knowledge that not only predates the modern conception of embodiment but, in essential ways, constitutes an advance over them: the work of the little known French philosopher Pierre Maine de Biran. This work already has overcome some of the problems of the embodiment theories that Sheets-Johnstone (2009) has brought to our attention based on her own phenomenological analysis of movement in dance.

Maine de Biran focuses on the formation of habits in a manner that his conception joins up with the concept of *habitus* that has been articulated over a century later. Bourdieu uses and develops it across his work in its entirety. A non-determinist account of the concept may be found in *Méditations pascaliennes* (Bourdieu 1997). Maine de Biran’s concept of space, for example, is “directly opposite to a fundamental principle [space] of Kant’s doctrine” (Maine de Biran 1859a: 240). In fact, this conception comes close to that subsequently intuited by Sigmund Freud in the opening quote of this section. Thus, Maine de Biran postulated an internal space arising from a power to act that habits provide and “the form of this interior space, though vague and unlimited, really is the necessary form of all sensation and perceived and localized impression” (Maine de Biran 1859a: 240). Independent of any external, sign-mediated knowledge of my body or of any of its parts, “there is an internal apperception of the presence or the coexistence of

this body proper, everything relative to a special muscular sense that cannot act and know itself *but from within*, without being capable to represent itself *from without*” (Maine de Biran 1859a: 245). This means that there is a knowing in the living body that is not mediated from without, such as, for example, mental schemata. From this perspective, the knowledge of the body is immanent in its movement. In approaching corporeal knowing in/as movement, it is possible then to attribute (arbitrary) signs to originary movements of the living body and its organs rather than to the schemata of the mind. Thus, with respect to the origin of the arbitrary sign, he notes: “When the movements serve to remember or to manifest the impressions to which they have essentially taken recourse, we may properly call them *natural* or *first signs*” (Maine de Biran 1841: 56). But through some event, there is then a doubling that allows a person to take note of the first function. This taking note allows the person to extend the functions by means of a “reflected act, which is based in the great law of the linkage of ideas, to several other ways of being that have only more or less indirect relations with these movements, frequently even of pure convention” (Maine de Biran 1841: 56). Here, the sign is brought back to its origins in the fundamental movements of the living body prior to any representational structures and reflections. From the perspective of evolutionary theory, it cannot be otherwise, for the emergence of mind and signs have to be explained in a forward manner, from the absence of mind and signs, rather than in a teleological manner, as the necessary step to present-day cognition and semiotics.

### **The Real-Time Production of Signs and Thought during a Lecture**

How we theorize the world is a function of the data we consider. In linguistics, the tradition was to consider idealized cases of language for theorizing the sign from a synchronic perspective—a system of stable structures—rather than from a diachronic perspective that underlies the pragmatics of speech. This has serious consequences for thinking about cognition as it pertains to the phenomenon of communication (Bakhtine [Volochinov] 1977). The further our transcriptions of communicative events are removed from the real-time production of talk, the less our cognitive models are suitable to describe thinking and speaking as they actually unfold when a person is engaged in communication. In this section, I present about 31 seconds from a lecture in a third-year university course on thermodynamics. This is the second time that the professor is giving a try at the explanation of a phenomenon, having done it during the preceding lecture. Then, arriving at the end of the lesson, he told students that there is something wrong with the picture he has just provided them with. Why would a professor start what will turn out to be an extended explanation only to conclude that there is something wrong with what he has said? How can we model such an event where an expert concludes *after* having said something intentionally for the benefit of his students that it is incorrect? The declared intent of this part of the lecture I analyze here was to give students a better understanding of a process of the magnetocaloric effect, which is used to lower the temperature of substances to temperatures near absolute zero (0 K). This description

shows that despite having prepared for the lecture, its production in real time is not a mere outflow of cognitive structure into language (and gesture). There are hesitations, speeding up and slowing down, and hand-arm movements that have no apparent reason within an idealist (constructivist) model of cognition. That is, my presentation shows, the development and articulation of an idea is not as simple and straightforward as it appears in the account of the above-provided example of a mathematician using gestures during a lecture (Núñez 2009).

### **The Set Up**

The professor is in the process of explaining the magnetocaloric effect. In this effect, the temperature of a sample is lowered by means of a two-step process. In the first step, the sample is magnetized while holding its temperature constant. The application of the magnetic field ( $B \neq 0$ ) aligns the microscopic magnets. This alignment is equivalent to an increase in order and therefore a decrease in entropy ( $S$ ). The sample then is demagnetized—a movement from  $B \neq 0 \rightarrow B = 0$ —while holding its overall entropy constant. In this process, the microscopic magnets get out of alignment because of the removal of the magnetic field, which leads to a decrease in the temperature of the sample (a change of thermal entropy into magnetic entropy).

The professor opens this part of the lecture reminding the students that during the previous lesson, they started to look at a different way of understanding the process of adiabatic demagnetization. He had ended that lecture by saying that there was something wrong with what he had produced on the chalkboard. On this day, he begins the explanation again by drawing a set of coordinate axes, which he labels with the letters  $S$  (for entropy) and  $T$  (for temperature). He walks to the far right end (from perspective of the audience) of the chalkboard, then returns. His speech is interrupted by short and long pauses. He says that insights could be gained by looking at the “de-processes” in an “entropy-temperature diagram.” He draws two curves, labels one with the signifier “ $B = 0$ ” and the other with the signifier “ $B \neq 0$ ,” and then steps back pondering the graph for a long time. After about 6 seconds, he says “when you (0.30) put the material in a magnetic field at a constant temperature (0.47) it’s just like that” while, with the very last part of the utterance, drawing a vertical line. He steps back again (line 01 a) and it is at this point that I take up a close look at the real-time production of a piece of lecture. This description subsequently serves me as the material for the analysis of signifying processes and their necessary antecedents.

### **Producing and Describing the First Adiabatic Temperature Change**

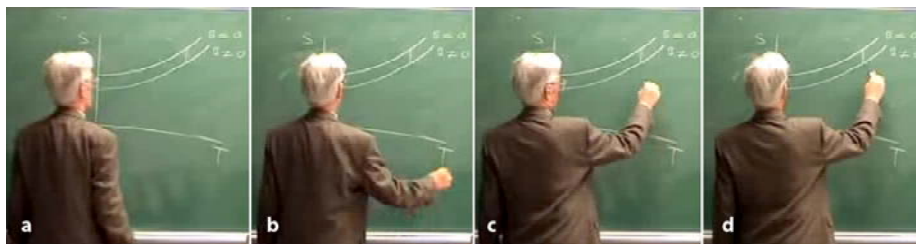
At a cursory level, we may gloss the events of the first fragment in this way: With pauses, repetitions, drawn-out syllables, and filler sounds, the professor then announces the second part of the phenomenon: an adiabatic demagnetization (lines 01–03) followed by



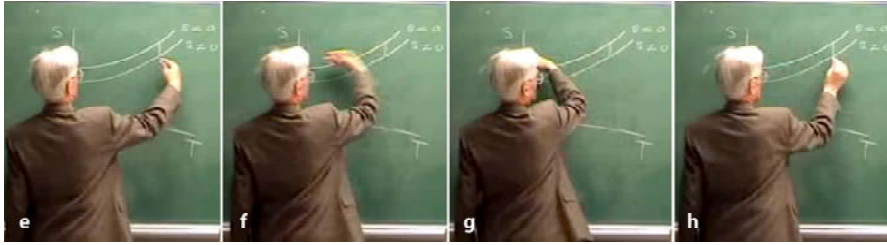
a repetition of an earlier utterance “it’s that” during which he draws a horizontal line from the intersection of the vertical with the  $B \neq 0$  curve toward the left (line 04). He then provides a verbal description of what happens during this stage: “its temperature is lowered (line 05). The time measurements for the sound track have been made using PRAAT, a freely downloadable software package common among linguists ([www.praat.org](http://www.praat.org)). The measurements are accurate to  $\pm 10$  milliseconds. The video was recorded at a picture rate of 33 ms/image. The coordination between the sound track and video therefore is accurate to 33 ms. The transcript contains the following elements:

```
01 0.....1.....2. ← Time in seconds
    |a |b |c          ← Image in Figures 1–3
    [-----] [      ← Extent of movement
    a:nd WHEN you; (0.95) ← Sound track transcribed
    [hand moves up [   ← Transcriber’s description of movements
```

```
01 0.....1.....2.....3
    |a          |b          |c d          |
    [-----] [-----]
    a:nd WHEN you; (0.95) uh::: that when
    [hand moves up          [hand hovers
```



```
02 .....4.....5.....
          |          e| f g          h
          [-----] [-----] [-----]
    you when you THEN uh A::di:a::BATICly:: (0.53)
    in about same spot          [gesture right to left
                                [retraction
```

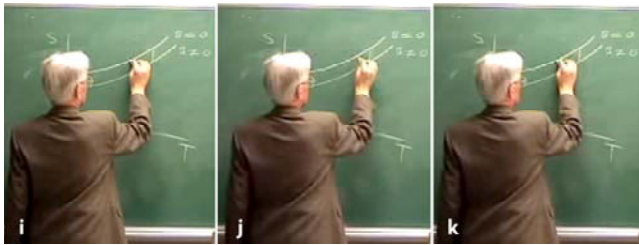


03 ·6······7······8·····

h | i | i j | k  
 [-----] [-----]

dEmagnetizeIT, (0.44) it uh:::

[rH moves left] [rH moves away and returns to board]



04 ·····9······

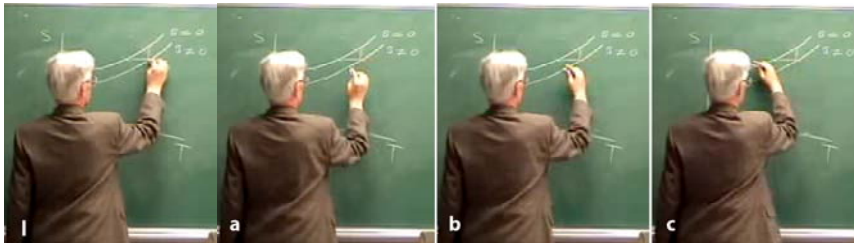
k | l a b c  
 [-----] [-----][-----]

(0.30) y its tHAT and so its

[draws line]

[turning hand, arrow config]

[horizontal gesture left]



05 ··10······11

| d e |

temperature is lowered. (0.32)

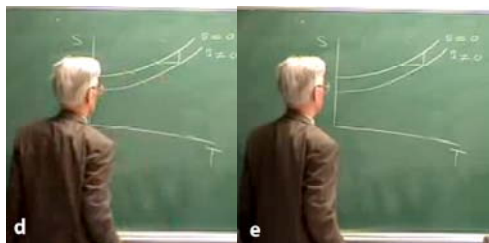


Figure 1. *Video stills and transcript from a lecture segment—part 1*

Observed at a micro-level, the event is much more complex. We see, for example, in the course of line 01, the professor's head and gaze move twice across the existing display (line 01 a→c, line 01–02 1c→e). During this time, the right hand moves, from hanging down upward toward the display near the vertical line between the two graphs (line 01, d). Even this movement is not homogeneous, but begins slowly to about the height of the horizontal line on the chalkboard (line 01 b) and then accelerates to its highest position (line 01 d). The hand then rests in approximately the same position while the verbal action unfolds. The head and gaze turn toward the place in the figure where the “S” is marked before the hand turns, takes on an “arrow configuration,” and moves across the figure from right to left—all the while the gaze remains oriented toward the right part of the display (line 02 g) in the direction of the point where the hand, upon returning, moves closer to the chalkboard.

The right hand then moves left, places the chalk at the board, there is a pause but then, as if hesitating, moves away as if looking whether it will end up in the right place and returns to the position (line 03 i→k) while he produces an interjection in the verbal modality (line 03). There is another pause before the professor actually draws a line from left to right such that it intersects the  $B \neq 0$  curve at the point where the vertical line also intersects with it (line 03 k).

In this instance, the gesture precedes the drawing of the line, but itself follows the onset of the adjective “adiabatically” that denotes the process to be explained. The adiabatic process in the representation, however, is from right to left, whereas the drawing of the line  $\{S, B \neq 0, T_1\} \rightarrow \{S, B = 0, T_2\}$  where  $T_2 < T_1$ . Here, the gesture and the line drawing are not iconic, and the movements are in fact reverse versions of each other. In the second case (the drawing of the line), the movement corresponds to the retraction phase of the earlier movement that prefigured the coming of the line. The line is the signifier of the process as a thing, whereas the hand gesture is an iconic signifier, also representing the direction in which the process unfolds as the sample under consideration is demagnetized while holding the entropy  $S$  constant. However, in the second hand gesture, which occurs against the chalk line as a background, a second signifier is layered upon the first. This gesture actually reproduces the earlier gesture with smaller amplitude. But when the line is drawn from left to right, a contradiction emerges

with respect to the movement of the gesture. The second gesture therefore can be seen as an “instruction” for reading the line, which itself does not have a direction. The movement immediately doubles up, becomes not only a first movement but also enables and projects the line to come:  $\{S, B \neq 0, T_1\} \rightarrow \{S, B = 0, T_2\}$ .

Why is there so much hesitation, including pauses, drawn-out sounds, interjections, and hand-arm movements? Why does the professor not simply enact some existing “sensori-motor schema” and put the lines on the board? Why does he not, if there is cognitive structure in his mind, convert it into an action that produces the line on the board?

Here, then, prior to actually drawing the line, we can observe the professor shifting his gaze across the graphic as a whole; his hand rests on the chalkboard; and he moves away and then engages in a hand movement, prior to the actual drawing of the line with the chalk. First the head movements anticipate the hand movement, which in turn anticipates the line drawn with the chalk into the existing figure. If anything, the head and hand movements constitute the developing idea in progress, and once it is realized, it is then transcribed into the line. (There is other evidence that the idea emerges together with such gestures rather than preceding them.) The gaze and hand movements are actually forms of epistemic action, thinking that is occurring in and as of the hand movement, rather than as happening in the form of a schema or other *re*-presentation, though some brain activity is indeed involved in making the hand move. In other words, these are actions that influence thought (Goldin-Meadow and Beilock 2010). But the possibility of the epistemic action itself exists at the same time that it is realized concretely, for otherwise it could not be recognized as such.

In this situation, we see that the line as it comes to be configured on the chalkboard is not just the result of some prior thought or schema. The slow delivery suggests that a different kind of process than the reading out of memory and mental structure into material form is occurring. It therefore is not an enactment of a source-path-goal schema in the way that Núñez (2009) describes in the case of his mathematics professor. Rather, there is a lot of hesitation, changing the gaze back and forth, and hand movements across the display as well as away from the board. There is no reason for a cognitive system to engage in all of this extraneous movement if all that the agent intends to be done is drawing a line. There may be a sense that something like a horizontal line is the next part of the graph to be produced, but this production is not straightforward. If there is some personal sense on the part of the professor, it might be better to characterize it as the “dawning of an idea [sign]” (Roth 2008) and that it concretizes itself only in and as of the head/gaze and hand movements across the board.

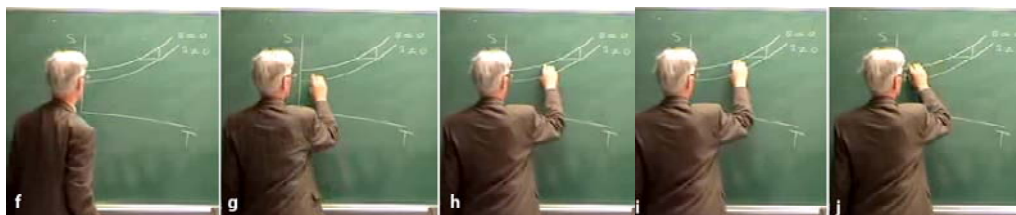
In one sense, these movements provide opportunities to anticipate or model the line that will ultimately be recorded on the chalkboard. But by the same token, these movements, because some audience sees them and can take it as signifying something else, also constitute a form of gesture and, therefore, a sign form. The interesting aspect of thinking in/as movement rather than gesture is that it allows us to consider a trajectory of development where initial random movements become movements that get something done to eventually become hand gestures (Roth and Lawless 2002). It is not that the mind metaphorizes an existing schema into something else. It is the same movement, the same

kinetic melody that emerges, then does work (ergotic and epistemic function), and then takes on signifying (symbolic) function. But it is the same movement; what has changed is the function of the movement. Hand movements may also be configuring and structuring space and emerge as specific kinetic melodies. That is, the specific hand-arm movement may be possible from a motor perspective, but no habit has formed for a specific trajectory.

### Producing and Describing the Isothermal Magnetization

Following the statement that the temperature is lowered, the professor steps back, and gazes at the graph (line 06 f). A pause unfolds. He turns slightly, brings up his right arm and hand toward the left part of the graph (line 06 g) and begins uttering slowly a drawn out “and,” while his hand moves to the right and toward a point on the  $B = 0$  line (line 06 h). The hand rests there for a brief while he utters the interjection “uh,” and then another pause develops. Until now, his hand has rested in approximately the same position. There is a 2.25-s pause during which he first moves his right hand slightly to the right, then, while producing some rasping sound “khm,” the hand moves near the left end of the  $B = 0$  line (line 06 j), moves back to the right some 10 cm to the left of the intersection between this and the horizontal line he had previously drawn (line 07 k). The hand moves rapidly to the left (line 07 l) and then, as he pushes the chalk against the chalkboard, the professor produces a thin line parallel to the preceding one he has drawn and beginning at the point where the  $B = 0$  line intersects with the ordinate axes ( $S$ ) (line 07 a).

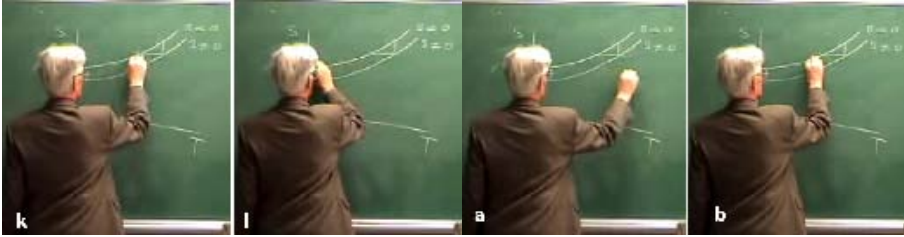
06 .....12.....13.....14  
 f | g h | h i | j |  
 (1.00) (0.32) a:nd uh:: (0.44) kh:m (0.25)  
 [-----][-----][-----][ ][-----][--  
 [forward [l>R [hold [reposition  
 [R>l [l>R



07 .....15.....16.....17  
 k l | a | b |  
 (1.00) (1.00) and then i i said it by  
 -----][-----][-----][-----][-----]

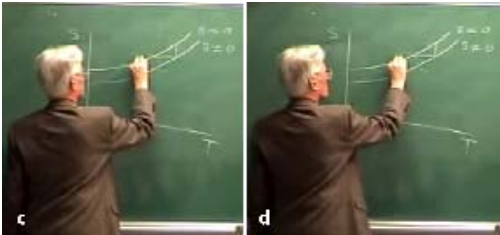
l>R [R>l

[draws line l>R [hand moves to B = 0  
 [elbow hand, as if  
 beginning to draw



08 .....18.....19

c | d |  
 the tIME you get to HE:a (0.65)  
 -----][-----][--  
 [steps left and back



09 .....20.....21

| |  
 (1.00) (0.48) when you put  
 -----

10 .....22.....

e f | g  
 it ina magnetic fIE:ld and that we=r kinda putn  
 -----][-----][-----  
 [lift off [holding





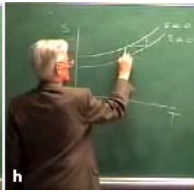
12 .....25.....26.....27

g | h | i |

the magnetic field it goes to the axis (0.88)

-----]-----]-----]

[drawing down [retract [holding pattern



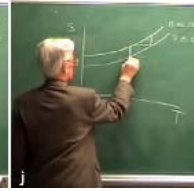
13 .....28.....29..

| i | j |

(0.80) and then when you demagnetize it

-----]-----]-----]

holding [movement to graph [draws line



14 .....30.....31

k | | l

(0.55) it goes all the way there.

-----]-----]

draws [retracts, walks away





Figure 3. *Video stills and transcript from a lecture segment—part 3*

In this instance, it has taken nearly 15 seconds to produce the vertical line that corresponds to the isothermal magnetization of the sample with an associated drop in its entropy. There are hand movements back and forth across the display, as if the professor were searching or trying out something. He then produces a fine chalk line the intersection of which with the  $B \neq 0$  curve becomes the endpoint of the vertical line. In this part of the episode, there are considerable changes in the rate of delivery. Initially there are long pauses (lines 06–07), a rapid utterance (lines 07–08), more pauses (lines 08–09), and then another rapid delivery (lines 09–12). Interestingly, the beginning of the vertically drawn line does not fall together with the endpoint of the preceding step introducing some form of inconsistency. Either there is a process moving the system along the  $B = 0$  curve or there are other events moving the system to the new spot, but which have not been described verbally. The professor also tells his audience that he has already talked about this (“and then I, I said,” line 07). This, in fact, was the case at the very end of the preceding lecture.

The hand movements—line 06  $f \rightarrow g$ ,  $g \rightarrow h$ ,  $h \rightarrow i$ ,  $i \rightarrow j$ ; lines 06–07  $j \rightarrow k$ ; line 07,  $k \rightarrow l$ —give structure to the perceptual field, which is then recorded in the final movement (line 07  $l \rightarrow a$ ) when the chalk is placed at and drawn across from the intersection of the ordinate with the  $B = 0$  line horizontally to the right. This line is the result of preceding events: it has emerged from the movements that have been produced before. If it had already existed as the intended movement, then there would not have been a need to do all this moving around and about. We see that the endpoint is a vertical line of the structure  $\{S_1, B = 0, T\} \rightarrow \{S_1, B \neq 0, T\}$ . The hand, however, moves to different places on the  $B = 0$  line, from a lower to a higher temperature. It thereby enacts a search that is about the precise placement, that is, at which temperature  $T$  this process is to occur. The first possible starting point is marked while uttering “and then I, I said by the time you get to here” (lines 07–08). The professor then moves backward, as if he wanted to get a better look. He then articulates the experimental process of putting the sample in the magnetic field, at which point the hand lifts off the chalkboard (lines 05–06  $e \rightarrow f$ ), moves to a new place (line 06  $f \rightarrow g$ ), and then draws the line. Verbally, he repeats the description once the hand is at the new place and the vertical movement then coincides with the verbal articulation of “magnetic field.” This is precisely the process iconically signified by the hand movement and denoted by the line drawn. Although the two signifiers have the same structure, they do refer to two different physical realities: two different states of the system under question. Most importantly, from an experimental point of view, how does the system get from the endpoint of the preceding process  $\{S_1, B = 0, T_1\}$  to the

beginning point of the subsequent process  $\{S_2, B = 0, T_2\}$  with  $S_2 < S_1$  and  $T_2 < T_1$ ? The answer to this question is crucial, as the lowering of the temperature is precisely at the heart of the entire phenomenon under discussion: cooling by means of adiabatic demagnetization. In the diagram, the non-intersection of the two processes means that another process would have had to occur. But this process does not appear in the verbal modality.

Why did the professor place the chalk to the left of where he ultimately drew the line? Why did he draw the thin horizontal line when he did not subsequently use its endpoint in the way he would subsequently? Why, if it did not matter where the line meets up with the  $B = 0$  line, did he not move upward from the intersection of thin line with  $B \neq 0$ ?

When he finally does produce the canonical representation of the process—some 20 minutes later and after abandoning the present attempt—he actually moves in step-like fashion from top right to bottom left between the now-corrected curves that intersected at the origin.

### **Producing and Describing the Second Adiabatic Temperature Change**

Following the production of the vertical line and the step-back, there is a 1.68-second pause during which the professor merely gazes at the display: as if he were waiting. He then begins again: “and then when you demagnetize it” (line 13) while moving forward (line 13  $i \rightarrow j$ ). He places the chalk at the intersection of the preceding (vertical) line with the  $B \neq 0$  graph and draws a horizontal line that intersects with the ordinate at the point of the intersection with the  $B = 0$  graph (line 13–14  $j \rightarrow k$ ). There is a pause in his delivery; and the professor then notes, “it goes all the way there” (line 14).

He steps back, turns, and while walking to the desk where his lecture notes are placed, he tells students “well I think I said there was something wrong with that picture.” There are more pauses, interjections (0.87-s pause, “and,” “uh,” 0.79-s pause) and expressions of hesitation (“well, uh, we’ll maybe see a little later on what, what if anything is wrong with it”).

In this fragment, the final signifier, a horizontal line, is drawn in the manner one might have expected it earlier on, beginning at the intersection of the previous vertical line with the  $B \neq 0$  curve on top of the thin line to the origin. This movement unfolds from right to left. It is iconic to the process denoted: a cooling through adiabatic demagnetization at constant entropy. In contrast to the preceding horizontal line, there is no gesturing before or after. However, the very movement that produces the line is itself iconic to the process, which in the earlier instant was produced by the gesture. Thus, in this final stage—as in the two vertical signifiers—the hand-arm movement that produces the chalk line (signifier) also may have symbolic function, as the iconicity between signifier and process signified requires the movement or some indication of direction.

This signifier is already prefigured in the earlier hand movement with the chalk that has left a trace on the chalkboard. It therefore emerged from the hand movements that structured the perceptual field in a horizontal manner. From a set of possible movements, one comes to be singled out to stand as a signifier for a process. This is so for the vertical as for the horizontal lines. That is, the intention for any *this* line also is the result of a “searching” process, which is a process for thought to develop itself in interaction with the expressive forms that the body produces.

## Prosody

Before turning to further analyses of this example, I note that there are other forms of signs produced as part of communication that question—perhaps even more so than the precise analysis of gestures—current embodiment accounts of communicative signing specifically and cognition more generally. One of the sign forms produced in communication requires a form of consciousness very different from linguistic consciousness (representation): prosody. It is produced without our conscious attention. It has no iconic relation to the ultimate diagram produced. Yet prosody contributes in fundamental ways to how we understand speech specifically and communication more generally; and it thereby contributes to the constitution of the content and the sense of the said. We hear very different things in the utterance “when you adiabatically demagnetize it” when the pitch rises strongly, moderately strongly, falls slightly, or falls strongly marked in transcriptions by means of question mark, comma, semicolon, or period: as question, premise, one item in a series, or incomplete statement.

In the present episode, we observe that almost all indexical terms that function as demonstrative adverbs are emphasized in speech by means of increased pitch or speech intensity: “here” (line 08, 11), “there” (line 12), and “that” (line 04). We also note that each items of the pair “when”/“then” (lines 01, 02) are emphasized. These forms of emphasis are very different from the linguistic emphases by means of inflection or the addition of adverbs (of degree).

The final indexical “there” is actually not emphasized prosodically and it is immediately followed by the articulation of doubt. It subsequently turns out that precisely the ending location is the problematic issue: in the canonical view, both of the  $B = 0$  and  $B \neq 0$  curves intersect; and they do so, by convention, at the origin of the Cartesian grid where  $T = 0$  and  $S = 0$ . The process, therefore, never achieves, in finite time, the point of absolute zero (0 K).

Prosody, because it is based on a different form of consciousness, therefore requires a different form of modeling than the one that embodiment theorists generally use. (Lakoff [1987] does write about prosody but not about the fact that it is very different from the kind of conscious phenomena that categorization is about.) Especially, what we need is a theory that explains the coincidence of two or more different forms of consciousness (or the coincidence of something produced consciously with something produced unconsciously).

## Toward a General Model of the Birth of Signs

In the preceding section, we see that the lecture segment, although it had been prepared and although it had been given, exhibits a lot of disfluency, pauses, gestures, and sounds that apparently have no signifying function. Some of the hand-arm movements initially do not have symbolic function, though some eventually are executed with such function. Thought itself appears to *emerge from* rather than to pre-exist expression; and, therefore, signs come into being rather than being ready-made and a priori. How might we think of the birth of new signs?

### The Original Movement and Its Self Relation: A Phenomenological Formulation

At the beginning, before there can be any signifying function of a movement (gestural, vocal), the intentional movement that produces the sign has to exist as a possibility. Any movement, such as a gesture, has to be *possible* before it can do material or signifying work. There is therefore a period during which a habit of movement is formed from what are initially random movements. Vygotsky (1989) refers to a description whereby a child's random hand/arm movements come to be reinforced as intentional gestures in and through the interaction with parents. Intentional pointing thereby can be shown to have a *social* origin. This initial formation leads to what has been referred to as *kinetic melody* (Luria 1973) or *archetypal corporeal kinetic form* (Sheets-Johnstone 2009). It arises from an auto-affection of the flesh, in which the particular trajectory of the movement comes to be established. I represent this first part of the process as the establishment of an auto-reference, which allows a particular muscle movement to become a habit that can be reproduced over and over again (Figure 4). This description is consistent with the phenomenological one describing the emergence of the power of the subject: “the ‘hand’ is nothing other than the subjective power of touching and taking, this power given to itself and put into possession of itself in the pathetic auto-donation of life—in the flesh of our originary corporeity” (Henry 2000: 205). What might be the originary relation of all relations, the one that is the base of all other relations? It is a “relation that institutes itself at the interior of subjectivity itself and in virtue of which the latter reveals itself immediately to itself in the phenomenon of the internal transcendental experience” (Henry 1965: 176). This relationship is actually its own negation, because it is not mediated by another term. We experience this self-relation in the form of pathos. This pathos is the original language of life and constitutes the foundation of all language (Henry 2004).

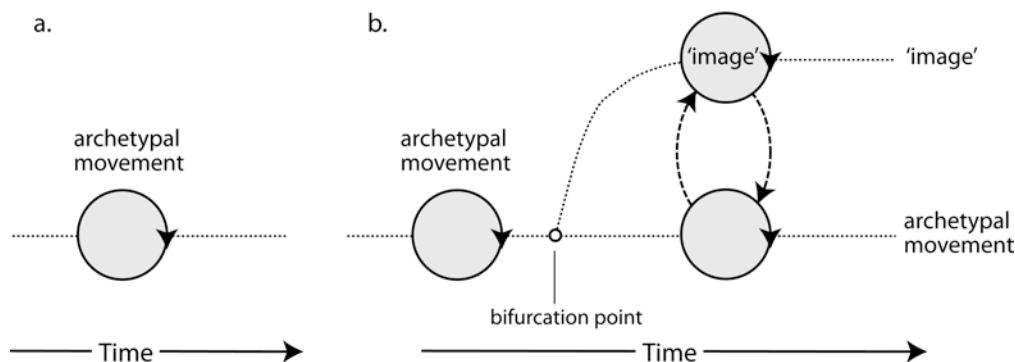


Figure 4. *Auto-affection generates “immemorial” memory, which becomes explicit memory in a process of doubling*

A general pattern in the organization of an organism constitutes an archetype (Thom 1981). We can then imagine that some system develops as it bifurcates. This point corresponds to the horizontal bar in Lacan’s (1966) sublation of the Saussurian relation between signifier and signified in the “algorithm”

$$\frac{S}{s}$$

This algorithm is to be read as S (signifier) over *s* (signified), where the bar, which separates the two stages, is the “primordial (and foundational) fact” (Nancy and Lacoue-Labarthe 1992: 36). Moreover, “it is the signifier of the very *lack* of such a symbol (and of God?), on the basis of which the chain of signifiers can be articulated. This is the signifier ‘without which all the others would represent nothing’” (Nancy and Lacoue-Labarthe 1992: 48). Maine de Biran (e.g., 1988) suggests that a hand movement, for example, following the outline of some figurine, could be produced again, because the movement “remembers itself.” At this level, no cognitive system that *re*-presents and occasions the movement is required. From the perspective of a phenomenology of memory, this process of self-reference is described in the following terms: There is an interior law of constitution, for example, for the “sonorous impression which allows me to repeat this impression, to reproduce it again as many times as I care to, and to recognize it constantly in the course of this reproduction” (Henry 1965: 111). This is achieved because the knowledge underlying the constituting power “is immanent to its exercise and therefore one with it” (Henry 1965: 111). This description is quite different from the way in which embodiment theories explain, for example, the gestural movement of a hand, where it is “co-produced with enactment of the source-path-goal schema” (Núñez 2009: 220). It is not only that there is a self-relation that allows the reproduction, but also it is through approximate reproduction that the capacity asymptotically is achieved. It is not by an act of representing that we get to the gesture as sign, but rather, the movement that ultimately does the representing by means of the gestural sign is based on the capacity of moving. Once this capacity exists, the intention to execute the movement can emerge.

### A Materialist Dialectical Formulation

The move to begin with a self-relation as the starting point in the genesis of signs and their subsequent historical proliferation by means of unlimited semiosis is structurally identical to the approach taken in material dialectics. Here, the history of some phenomenon has its origin in an inner contradiction that is at the source of the external manifestations of difference. The external contradiction of two things is taken as the necessary expression of the internal contradiction of an entity that is not identical with itself. This inner contradiction leads to an external contradiction, which “emerges as an inner identity of mutually exclusive moments mediated through a relation to something else and reflected through something else, as an internally contradictory relation of a thing to itself” (Il’enkov 1982: 266). The inner contradiction is *immanent* to the phenomenon, whereas the expressions are *transcendent* with respect to the phenomenon.

The present proposal is consistent with the materialist dialectical approach; it is also consistent with the materialist phenomenological approach arising from the work of Maine de Biran (1859a, 1859b) and Henry (1965, 2000). For Marx, value is the “*relation of a commodity to itself*, rather than to another commodity” (Il’enkov 1982: 266). And it is precisely because of this self-relation that “it emerges as a living, unsolved and insoluble inner contradiction” (ibid: 266). In the same way, Maine de Biran and Henry are concerned with understanding the living cognition enabled through the self-relation of life to itself, which eventually leads to anthropogenesis and the emergence of philosophy and the sciences. It is the dynamic of life rather than the structures of formalisms that is at the heart of this materialist description.

We may think of the development of thoughts (ideas) in the same way. Thinking begins “from the first dim stirring of a thought” (Vygotsky 1986: 217) and then develops until its full formulation. The dim stirring, the seed, is a *growth point* (McNeill 2002) and, for it to describe the movement of its development, it has to embody an inner contradiction. This auto-reference is a characteristic of a sign that frequently is not being discussed and yet that is central to dialectical materialist forms of thought: “The value concept expresses the *inner* relation of the commodity form rather than the external relation of one commodity to another” (Il’enkov 1982: 258–259, emphasis added). As a consequence, “a commodity is considered *not in relation to another commodity but in relation to itself reflected through the relation to another commodity*” (ibid: 259, original emphasis). This is so because without this self-relation, there cannot be different ways in which a phenomenon externalizes, phenomenalizes, and manifests itself—such as in the different ways that value manifests itself in *Das Kapital*, as use-value and exchange-value (Marx and Engels 1962). It has been shown that there is a fundamental equivalence between the commodity, as understood by Marx, and the sign, as understood in recent philosophy (Roth 2006). Thus, it is because of the inner difference with itself that the sign manifests itself differently: as signifier and signified.

## Doubling Movements: The Emergence of the Sign Proper

In the preceding subsection, we see how a movement emerges and becomes a sign for itself, which expresses itself as habit. But in this form, the originary sign is also the antithesis (absolute negation, other) of the sign because signifier and signified are one and the same. To obtain the sign as we know it, the original self-relation has to unfold to become the external relation between a signifier and a signified. This is achieved by means of a doubling. Such a doubling not only can be accounted for in material phenomenological terms but also by means of a catastrophe theoretic description.

In the lecture, we see movements that have no apparent signifying function—other than signifying themselves. Thus, all the movements depicted in line 06  $f \rightarrow g$ ,  $g \rightarrow h$ ,  $h \rightarrow i$ ,  $i \rightarrow j$ , lines 06–07  $j \rightarrow k$ , and line 07  $k \rightarrow l$  are “gratuitous.” If anything, the movements appear as if they were seeking something. I suggest above that they precede thought—constituting a form of epistemic action. As a result, they structure dynamic and perceptual aspects of space, a description consistent with current views on the relation of actions, gestures, and thought (Goldin-Meadow and Beilock 2010). But then the movement that produces a thin chalk line (line 07  $l \rightarrow a$ ) with  $S = \text{constant}$  anticipates the movement that produces the thick, permanent line (line 13  $j \rightarrow k$ ) with  $S = \text{constant}$ , and it also serves to delimit the drawing of the vertical line where  $T = \text{constant}$  (line 12  $g \rightarrow h$ ). Similarly, the gestural hand-arm movement in line 2 ( $e \rightarrow g$ ) anticipates and denotes the line drawn in line 04 ( $k \rightarrow l$ ); and both are the signifieds of another hand-arm movement in line 04 ( $b \rightarrow c$ ). But even before the first hand movement emerges in the second instance, the movement capacity has to exist. Moreover, this first movement may not be representational at all, but may be a form of expression that *leads to* the emergence of a horizontal line with representational function. Because recognition (self-reference) is immanent in the cognition by means of movement, it can become at any moment the explicit theme of thought (Henry 1965). From this arises a new form of intentionality, this time directed to the transcendent object, which, in the present case, is the form of the movement that produces the gesture and chalk line. This object can be recognized as something that I have seen before. This leads Henry to conclude that “habit is the foundation of memory” (ibid: 137). Concerning his own theory of *habitus* Bourdieu (1997) notes—consistent with Henry—that the past is present in the form of the dispositions that it has produced.

## The Dual Nature of the Sign

A sign is the relation of one segment of the material continuum to another segment of the material continuum (Eco 1984). The relation between a signifier and the signified therefore is external, arbitrary rather than an internal and necessary. The inner relation of the signifier to itself, however, is by nature inaccessible. It expresses itself in and manifests and reveals itself transcendently in and through the relation to another segment of the material continuum. As an outside reflection, the nature of the signifier manifests itself in the external relation between signifier and signified, in the referential

relation that is actually reversible (a signifier also may be the signified of another signifier). For Vygotsky (1986), the relation of thought and language, thinking and speaking, are of the same nature: external expressions of a higher-order unit that for him is “word-meaning.”

Each segment of the material continuum that participates in a signifier–signified relation also bears a relation to itself. Thus, the sound transcribed as /dɔg/ not only denotes the thing DOG, but also relates to itself, indicates its own presence, though it tends to become invisible as soon as the sound is taken in a signifying function. That the sound denotes itself becomes apparent during the transcriptions of video or audio recordings, when the researcher hears that something is said without being able to understand *what* is being said. In this case, we hear in fact a *human voice* rather than just sound that we have to interpret. Thus, a recognizing hearing of the sound /dɔg/ constitutes a self-relation of the type presented in the preceding subsection. Similarly, the recognizing visual perception of a shape DOG constitutes a self-relation of the same type. When the two are recognized as related, when they constitute different manifestations of the same situation, then we have a relation of two self-relations. In the case of hand-arm movements, some originary movement—which may have arisen in doing work (ergotic function) or in structuring the perceptual field (epistemic function)—doubles as a transcendent parallel emerges, that is, an “image” of the originary movement (Figure 5). The image is not independent but inherently tied to the execution of the archetypal movement. In the neurosciences, this doubling has its equivalent in the mirror neurons (Rizzolatti et al. 2006). To recognize a movement, these neurons, which mirror movement capacities of the organism, have to be present and active. That is, an organism only recognizes a movement when it is already capable of this movement. Rizzolatti et al. make explicit reference to the field in which my own work is grounded by noting “that philosophers in the phenomenological tradition long ago posited that one had to experience something within oneself to truly comprehend it” (Rizzolatti et al. 2006: 56).

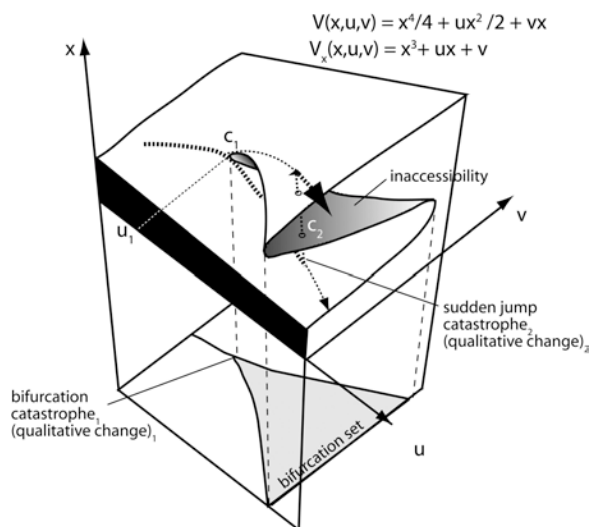


Figure 5 – Catastrophe theoretic model of the emergence of signs



As it presents itself, the structure of the diagram (Figure 4b) is close to the original definition of the sign and the relation between signifier and signified (de Saussure 1916/1995: 99). As the broken line in the relation between the “image” and the original self-affecting movement intimates, the relation is not that of a direct mutual determination. There is a gap such that even if the individual were to have an intention to move, based on the operation of the image, the movement would unfold on its own and the match between the intended movement and the actual movement would have to be ascertained after the fact. It is only in this way that we can understand the empirical data that even highly educated experts in their field may find sometimes after having done something—such as a fish eye dissection—that what they have actually done is not what they had intended to do (Roth 2009).

### **Doubling: A Catastrophe Theoretic Formulation**

We might ask the question, “How might such a doubling occur?” or rather, “How might we model such a doubling?” Figure 4b is suggestive: there is a bifurcation process. Such bifurcation processes can be described mathematically using catastrophe theory (Thom 1981). A process of morphogenesis is described based on a generative kernel, which, by means of consecutive bifurcations, produces increasing structure and organization. Thom calls the generative kernel an “archetype.” Most readers will be familiar with the popular presentations of chaos theory, where the number of stable solutions of the simple recursive system

$$x_{n+1} = \lambda x_n(1 - x_n) \quad (1)$$

with  $0 \leq x \leq 1$  depends on the value of  $\lambda$ . For  $\lambda < 2.7$ . As the parameter  $\lambda$  is increased, there is a point where a situation emerges characterized by two stable solutions. The system oscillates between the two values. In catastrophe theory, such doubling is discussed in terms of the transition of potential  $V \equiv x^4/4 + x^2/2$  to the potential  $V \equiv x^4/4 - x^2/2$  via the singularity  $V \equiv x^4/4$ . This constitutes a catastrophe. This situation is depicted in Figure 5. Whereas there is only one stable state for the system for  $u < u_1$ , there are two stable states for  $u > u_1$  within a certain range of the variable  $v$ . The projection of the three-dimensional case onto a plane (Figure 5) leads to an image that resembles the bifurcation that equation 1 leads to when the parameter  $\lambda$  reaches the critical value 2.7.

### **Doubling: Empirical / Phenomenological Dimensions**

The first moment of this doubling lies in the fact that our body is a power, which is a form of *immediate* and immanent knowledge that characterizes any form of praxis. As the

adjective “immediate” indicates, this form of knowledge is not of the *re*-representational type: it is unmediated, without intermediary. A professional soccer player does not require *re*-presentational forms of knowledge about the trajectory of a football to play it properly to another player; and the player does not have to know the physiology or mechanics of the human body to shoot a goal. But as soon as the player moves the leg or arm intentionally as a gesture, a doubling has occurred where the movement not only refers to itself in an immanent fashion but also makes thematic this movement in an externalized (ekstatic, transcendent) fashion.

There are two forms of memory, two forms of intentionality, implied in this model: memory related to the power of constitution (by means of repetition) and memory related to the sonorous impression (Husserl 1928/1980). The first form of memory takes place at the level of immanence, where it is the result of a production that does not require constitution but is merely the immanent reproduction of the movement. The mode of memory is the result of a constitution at the transcendent level, where the sonorous impression is constituted before the processes of recognition and repetition set in.

In an interesting anticipation of the capacities that we now attribute to the mirror neurons, Maine de Biran notes during the early part of the 19th century:

At the instant when the sonorous shaking is communicated to hearing, other than the simultaneous and unperceived motor reaction that completes the *sensation*, there is another determination of the same order that puts into play the vocal instrument; this one repeats the external sound and provides an *echo* to it, hearing is confronted with two impressions, one direct, the other reflected, internal; these are two imprints that add up, or rather, it is the same that doubles itself, it is as if the smell, having been initially impressed directly . . . had the faculty to reproduce precisely the same sensation, it would find itself truly doubled (Maine de Biran 1988: 172–173).

Michel Henry (1965: 111) comments on this passage: “The two sonorous impressions are both constituted, the power of constitution is the same in both cases, it is a reaction or a motor action, it is the originary of the subjective movement, it is the body.”

The reflexive doubling corresponds to the philosophical phenomenon of *ekstasis*, the fact that objects and the world come to stand out in consciousness. They are no longer perceived and acted upon/in in an immanent manner, but, in standing out, they become intentional objects. In Husserl’s work, doubling is discussed in terms of the emergence of *representations* that allow retention and protention. In Heidegger’s work, it corresponds to *ekstasis*, the articulation of Being (German *Sein*) by means of beings (German *Seinendes*). This standing out enables intention (see below). That is, phenomenal objects are not primarily *re*-presented (Heidegger’s *vorhanden*) but immediately lived through the powers by means of which we relate to them (Heidegger’s *zuhanden*). Heidegger (1977) frequently speaks of representations as derivative forms of knowing, e.g., talk. This doubling already has been recognized at the beginning of the 19th century: “When,

in new circumstances where we place the individual, the sensations vary and succeed each other, while the effort remains the same, there is a felt or perceived *plurality* in the *unity* because there is a fixed module, a common term that all instants take as referent” (Maine de Biran 1988: 166). In this way, we have an explication for why an individual recalls that s/he already has heard, felt, smelled, tasted, or seen something.

### **Doubling and the Emergence of Intentionality**

Fundamental to human cognition, and therefore to communication, is the intentional deployment of signs. The intentional movement toward something else requires the movement to exist in transcendental form. I cannot intend moving my hand to gesture without the capacity to anticipate the movement. That is, the doubling corresponds to the birth of a new form of intentionality directed toward the object. That is, “there is a new intentionality that is born, an intentionality in which the recognition of the solid is the theme for an explicit thought, the solid is recognized as that which it has already known, or rather, the movement of grasping the solid is explicitly posited as the movement that had already been produced” (Henry 1965: 137). In the body, different movement forms emerge, e.g., vocal cords, which become submerged as soon as we recognize recurrent sounds, which come to be submerged in turn as soon as we recognize words. In the development of the child, sound and thing initially are part of one and the same situation. The sound-word does not exist independent from the thing or, put differently, the child is familiar with and recognizes situations that contain both but not the word only. Object permanence is possible only when memory is possible, which requires the capacity to make the object present even in its absence: this requires *representation*. At that point, too, the object comes to exist independent of the word, and the word independent of the object.

At the first stage, when a movement becomes habit, we are no further than other organisms that do not have an ekstatic, transcendental intention, that is, the thought *about* an action that precedes the action proper. Intention requires, following Husserl (1928/1980), another form of presentation that is connected to the first. It denotes the first, allows the first to be present again to in other form and allows it to become a *representation* of the first. At this stage, we still have the original movement and another sign form, its “image” (Figure 4b). As can be seen, both original movement and its “image” bear self-relations. Moreover, each of these signs refers to the other in a form of circular relation. Thus, out of several hand-arm movements one comes to be “distilled” as, in its reproduction, it is used to produce a chalk trace. Subsequently, the movement is reproduced as the hand now moves again with the previously drawn line as the backdrop. That is, we have three forms of movement, the first being more or less arbitrary, the second being a reproduced earlier form used to produce the chalk line, and the third standing in for the second. This was also suggested by the analysis of the genesis of scientific explanations that students evolved in and through conducting hands-on

investigations (Roth and Lawless 2002). When the hand movement functions as a gesture, the signified has already taken over such that the signifier can and has become invisible. Sound becomes invisible as the word appears, words disappear as the signified appears. Previous studies among scientists already suggest such a relation: when research biologists investigating light absorption in fish retina they are confronted with the problem that the contents of the visual images from the microscopic slide and the contents of the graphical representation of the absorption spectrum are mutually constitutive (Roth 2009). To know what a graph displays, the scientists need to know the object on the microscopic slide; but to know the object on the microscopic slide, the scientists need to know what the graph displays.

### **Doubling and the Social**

In embodiment accounts of knowing, culture tends to be overlooked or merely acknowledged (e.g. Núñez 2005). What the literature does not show in a rigorous manner is how corporeal movements constitute a foundation of cultural-historical forms of knowing. Yet such a link between the subjective work and objective representations has been provided in an explanation of the historical development of geometry (Husserl 1939). That is, current embodiment accounts are useful only if they can show the *necessity* of corporeal forms in the objective, culturally shared nature of mathematics. The present approach to theorize knowing as grounded in the immanent self-reference of the living body does indeed provide such a linkage; and it is consistent with a neuroscientific account based in mirror neurons that underlie all forms of social cognition and intentional attunement (Gallese 2006).

An immanent relation inherently constitutes pure subjectivity. It alone cannot serve as a foundation of collective knowing and tradition. However, this approach allows us to connect the individual and the collective, of which the former is a constitute moment. That is, the phenomenological description at the level of the individual that Maine de Biran and Henry describe leads us directly into the (phenomenological) sociology of Bourdieu. Both systems of thought have a central place for habits (French *habitudes*). For Henry (1965: 134) “the being of my body is habit, that is, a general and indefinite possibility of knowledges. This possibility is the real being of the ego . . . it is the identity of the body” (Henry 1965: 134). For Bourdieu (1997), *habitus* are systems of structured structuring dispositions that are at the origin of our habitual ways of perceiving and doing (vision and *division*): “The ‘I’ that practically comprehends physical space and social space is a habitus, a system of dispositions” (Henry 1965: 157). The individual is a habitus with its history, a system of incorporated corporeal properties. Habitus allow agents to perform acts of practical knowledge, without thematization and rational calculation, based on identification and recognition of situations. Habitus, being the product of the incorporation of structures and tendencies of the social field, makes it possible to adapt endlessly to the changing situation because of a “quasi-corporeal *anticipation* of the immanent tendencies of the field and of the behaviors engendered by all isomorphic habitus” (ibid: 166). That is, the tendencies are not explicit but immanent

just as the corporeal knowledge is immanent before it is and can be transcendent. Bourdieu maintains that most foundational forms of social learning—e.g., gender and gender difference—occur via the body, which, in the process, “is treated as a *memory board*” (Henry 1965: 169).

Practical comprehension does not mean thematic consciousness but the “practical sense of a habitus inhabited by the world it inhabits, *pre-occupied* by the world in which it actively intervenes” (Bourdieu 1997: 170). Thus, “the body is a power it is habit, the totality of our habits. With regard to the world, it is the terminus of all our habits, and it is in this sense that we are truly its inhabitants” (Henry 1965: 134). As a result, there is an “almost perfect coincidence between habitus and habitat” (Bourdieu 1997: 176). This is so because the body constitutes the “possibility of knowledge in general, a *know-how of the world in its absence*, that it also is, and for that reason, *remembering of the world, memory of its forms, knowledge a priori of its being and its determinations*” (Henry 1965: 137).

### **Discussion: Expanding the Understanding of Existing Problems: Thinking and Speaking**

“[Psychological functions] must be explained not on the basis of internal organic relations (regulation), but in external terms, on the basis of the fact that man controls the activity of his brain from without through stimuli” (Vygotsky 1989: 59).

From the two perspectives articulated here, we can therefore understand the lecture as an unfolding event of communicating and thinking, which are not ready-made but develop in real time. Thus, any movement—be it visible as whole-body movement, hand-arm gesture, changing gaze, or prosody—provides material to the unfolding thought process. In the process, specific signs (e.g., a specific line or gesture) actually emerge from the possibilities produced in hand-arm movements that do not yet have a signifying function. The emergence of signs and the emergence of thought therefore are united in the same overarching process of which both are but manifestations.

Much of the literature concerned with the speaking act, including embodiment accounts, present it purely in intentional terms. Thus, a person has an idea in the head and uses speech, perhaps gesture, to present this idea to the outside. If this were the case, then we would not understand the real-time performance of the professor, which contains elements of disfluency, conversationally long pauses, additional nonrepresentational gestures, (rasping) sounds (e.g., “khm”) and interjections, gazes across the entire display drawn, and so on. This disfluency is especially astonishing given that (a) he has prepared lecture notes containing the material that he is presenting here, (b) he has already drawn the figure before and talked about it, and (c) he has concluded the preceding lecture saying that there is something, “if anything,” wrong with the graph and associated conclusions. Especially interesting are situations—such as the one in line 03 or lines 06–07—where there are hand movements that have no apparent representational functions because they are reversed and superseded by other hand-arm movements. These

movements, however, do not have to be seen as disfluency or as errors: the very fact that they are produced structures the perceptual field. In the very production, the speaker perceives that the movement is not the one that will allow the unfolding (thought) process to proceed. This is precisely what cognitive scientists proposed while analyzing players of the game Tetris, who were making movements faster than possible if they had processed the information on the computer monitor, interpreted it, and used the result of the interpretation to mobilize subsequent actions (Kirsh and Maglio 1994). The authors refer to these actions as *epistemic* and contrast them to *pragmatic* actions. That is, actions or, more generally, movements of the body and things in the world constitute a form of thinking even in the case when the person has no intention to move in a particular way, that is, does not yet know what the movement will yield. This, then, would be consistent with the introductory quote to this section, in which Vygotsky states that the external stimuli are tools humans use to control their brain activity. This is precisely what we can distill from the account that James Watson (1968) provides of the instant when he and Francis Crick discovered the DNA structure. They moved about paper representations of the structures of the four bases involved. Then, all of a sudden, they saw the structure of the rungs that make the DNA before thinking of it. That is, rather than thinking of the professor as engaging in a memory dump, we may see him as realizing and unfolding a rather indistinct and undeveloped thought. Both Vygotsky (1986) and Merleau-Ponty (1945) suggest just precisely that: communicating in real time and the thinking it articulates are two developing processes themselves related by a process that is in development. That is, new structures, signs, emerge from movements that cannot have specific goals because that which is learned in the process is unknown.

Vygotsky (1986: 217) is concerned with understanding and theorizing “the process of verbal thinking from the first dim stirring of a thought to its formulation.” He proposes a framework subsequently confirmed in Soviet psychological studies. Thought and word are one-sided transcendental manifestations of a higher unit. Speaking and thinking are expressions of a unit and their relation is a process, a continual, to-and-fro movement from one manifestation to the other. This process itself undergoes change such that it “may be regarded as development in the functional sense. Thought is not merely expressed in words; it comes into existence through them” (Vygotsky 1986: 218). Vygotsky expands, “thought undergoes many changes as it turns into speech. It does not merely find expression in speech; it finds its reality and form” (Vygotsky 1986: 219). In the process, thought “moves, grows and develops, fulfills a function, solves a problem” (Vygotsky 1986: 218). Each of the two processes has its own law of development, the inner semantic aspects, on the one hand, and the outer, phonetic, on the other hand. Thus, “the structure of speech does not simply mirror the structure of thought; that is why words cannot be put on by thought like a ready-made garment” (Vygotsky 1986: 219).

Vygotsky focuses on speech. But human communication does not simply occur by means of speech. An initial expansion of the Vygotskian framework had been proposed in psycholinguistics, where hand gestures are integrated with speech into one psychological unit (McNeill 2002). In subsequent work, we have expanded this fundamental unit of communication to include any modality of expression, including body movements other than the hand, body position, prosody, and perceptual aspects of

the ground (Pozzer-Ardenghi and Roth 2008, 2009, Roth 2004, Roth and Pozzer-Ardenghi 2006). In a chapter entitled “The body as expression, and speech,” Merleau-Ponty suggests that it is through the whole body that I both express thought and comprehend the thought of others. “The sense of the gesture thus ‘understood’ is not behind it, it confounds itself with the structure of the world that the gesture designs and that I take up on my own account, it spreads itself over the gesture” (Merleau-Ponty 1945: 216–217). As Vygotsky, Merleau-Ponty speaks of an inner relation that relates thought and word, and he rejects as implausible the outer relation that would exist if speech were merely a signifier of thought. But the philosopher goes beyond the psychologist in taking the body in its entirety as constituting an expression rather than the sound-word alone. “If speech presupposed thought, if talking were first of all a matter of joining the object through a intention of knowledge or through a representation, we could not understand why thought tends towards expression as towards its completion” (Merleau-Ponty 1945: 206). More importantly, the author notes that even the “thinking subject himself is in a kind of ignorance of his thoughts so long as he has not formulated them for himself, or even spoken and written them” (Merleau-Ponty 1945: 206).

The thought concerning the different processes come into being through the expression, and, as such, become possible subjects of revision. It is through the expression that we make thought our own. In the case of our professor, we do not know whether some movement he produces is an intended gesture. The intention for a particular gesture itself emerges from the movements. Thus, a movement from right to left (line 06 i→j) or from left to right (lines 06–07 j→k) seems to be “searching” for placement of a line. I suggest that we may better gloss them as epistemic movements, movements to learn from. They are not yet signs: specific signifier or signified do not yet exist—even though there may be a vague notion that some yet-to-be-determined signifier may exist to stand for a process that is articulating itself. Some movements anticipate subsequent drawing movements (line 02 e→g), a movement in the same direction leaving a trace (line 04 k→l, in reverse), and other movements can be seen as iconic gestures over and against a line (line 04 a→c). Some of these are movements toward the emerging signifier, and some movements may become signifiers whereas others, such as the drawing of a line, become signifieds. A line is signifier and signified simultaneously, when a gesture seen over and about it provides an iconic image.

### **The Unity of Gestures, Speech, and Inscriptions: A Material Phenomenological Perspective**

In developmental psychology, the different modes of experience are in some disarray and their coherence requires, as it has done for Kant, extensive effort of cognitive construction (e.g., Piaget and Inhelder 1972). Traditional studies in linguistics consider speaking and gesturing as having very different origins (Beattie and Coughlan 1998). As a consequence, listeners are said to have to attend to very different sources of semantic

content (Beattie et al. 2010). Studies taking such an approach may therefore be concerned with looking for differences between what a person says publicly and what she really thinks for herself, which may be articulated in gestural form (Cohen et al. 2010). In the embodiment literature, the problem is also present because of the distinction between schema and the movement that researchers associate with it. Thus, if a source-path-goal schema is the source for a gesture, then we have to explain how the mental schema has any bearing on the corporeal action. If the hand-arm gesture is merely “co-produced with the enactment of the source-path-goal image schematic notion” (Núñez 2009: 220), then the origin of this co-production must be explained (e.g., to understand any necessity of the corporeal form to cognition).

A very different perspective on the relationship of gestures, speech, and other modalities in communication derives from a material phenomenological perspective. From this perspective, there is a fundamental unity underlying all forms of movement. Its decomposition into the acts of separate organs is something that arises only with reflection. Even the relationship between different sensations is not equivalent to the movement(s) that produce(s) the sensation(s): “*the relationship between our movements and our images is in no way reduced to the relationship between our kinesthetic sensations and our visual sensations*, because these two types of sensation, for example, are equally present in the sole exercise of vision” (Henry 1965: 126). Henry insists that there is no difference whether I trace out a curve, see it, or feel it if I were to do a gesture in cold air or draw on a chalkboard: it is all *the same curve*. The unity of my body is my feeling and experience of immanence in all modes of my concrete life and of my power to produce and repeat. The unity derives from the unity of a power that transcends itself. “It is because the unity of the transcendent body is the subjective unity of the originary body that these two bodies are but one and are traversed by one and the same life” (Henry 1965: 174). What I can see is also what I can hear, smell, taste, or feel. This “also” presupposes integration and a unity of the sensorial world. There is a unity, “*because the subjective movement is immanent to the exercise of each sense, because it is the being itself of the body*” (Henry 1965: 115). It is precisely this immanence that allows the living body (flesh, French *chair*, German *Leib*) to be the place common to all sense impressions. Because of the immanent form that the knowing takes, there is no difference between knowing and recognition of the movement. The world and all the objects it contains is nothing but the term of the immanent powers. There is therefore no difference between knowing the object and the immanent knowing to grasp, see, smell, feel, or taste it.

The reproduction of a movement, such as the hand/arm gesture anticipating or following the drawing of a line, requires the identification and unity of four forms of knowing (Henry 1965). In the present instance these involve the following: (a) the original, immanent knowing that the subjective body has of the movement itself; (b) the recognition that the movement has already been produced before; (c) knowledge of the transcendent term of the movement, that is, the chalkboard line or form described by the gesture; and (d) the recognition of the transcendent term as having previously been linked to the same movement—e.g., the gesture  $\{S, B \neq 0, T_1\} \rightarrow \{S, B = 0, T_2\}$  where  $T_2 < T_1$  (line 02 e→g, line 04 b→c). To say that knowledge is “embodied,” we have to be able to



state why there is this unity and how it comes about rather than simply asserting that there is a some iconic relation—which would be an external relation based on the history of thought rather than an internal relation that is able to give rise to the historical relation of the hand movement and the shape of the chalkboard line.

Although different in its ekstatic and immanent forms, the former kind of knowledge requires the latter kind. According to Maine de Biran (1859b), all movements that the hand/arm have executed, all positions they have taken, for example, by following the curves of an object, leave traces (Luria's [1973] *kinetic melodies*). These traces can be relived in an internal sense by the same movements that have followed the form even in the absence of the object. "These movements are the signs of the diverse elementary perceptions they can therefore serve to recall ideas, and this recall, executed by means of the available signs, constitutes memory properly speaking" (Maine de Biran (1859b: 147). He concludes that this would be the real memory of tangible forms. A particular object or trace therefore is given twice. First, it is given as something that I can achieve by means of a particular, concrete and specific movement; and, second, because the movement is a possibility, it is something that I can achieve *in principle*, that is, in general. This leads to the fact that the world is constituted by the totality of my experiences; it is the transcendent term of all the real and potential movements that I can produce.

### **From Embodiment to Incarnation**

Above I quoted from the description and explanation of a hand movement that appears in a lecture of a mathematician (Núñez 2009). In the explanation, the "source-path-goal image schematic notion" is evoked. I note in that context the material phenomenological objection that schemata, which constitute an ekstatic form of knowing that can be metaphorized by the reflective mind, cannot constitute the foundation. For the same reason, kinesthetic sensation, being an externality with respect to the movement itself, cannot be the foundation of the constitution of a visual image (Henry 1965), such as the one that goes with the gesturing, drawing, and perception of a horizontal line (line 02 e→g, line 04 k→l, l→a). Thus, Henry provides the following material phenomenological account of the act of tracing a curve in space:

In the original phenomenon of the act of tracing a curve in space with my index [finger], the movement of my gaze that constitutes the spatial figure of the curve is the same as the movement of my hand which traces the curve, and the unity of the two movements, which are but one, is an ontological unity, it is a unity in the absolute immanence of subjectivity. Here the theme of thought is the visual image of the curve, which is the transcendent object of my look, but also of the subjective movement of my hand that traces such a curve, which touches it so to speak, and which

creates it. The theme, or more simply the terminus of the movement of my hand, is therefore not at all a kinesthetic impression; the latter is absent from the central and original phenomenon constituted by the subjective movement and its transcendent correlate, and it is this absence that we wanted to mark by declaring that the impression was unconscious (Henry 1965: 124).

In this description, which is consistent with the data that I provided above, a radical difference is articulated between subjective movement and its transcendental correlate. The interiority of kinesthetic impressions is very different from the interiority of subjective movements that constitutes an absolute interiority. Impressions are transcendent and therefore only relatively interior, within the person. The curve of a gesture is transcendent, but in the world, that is, objectively.

At the origin of the mind-body problem in the cognitive sciences is the historical confusion of different conceptions of the body. In phenomenology, a distinction is made between three conceptions: (a) the original, subjective body, life force; (b) the organic body, transcendently experienced at the interior of the individual; and (c) the objective body, open to inspection and exterior perception, which is the object of the sciences (Henry 1965, Maine de Biran 1859a, 1859b). What many philosophers and scientists have overlooked—and most still do so—is the fact that the investigation of the objective body—e.g., the eye that sees, the hand that touches and feels—requires a more fundamental knowledge that precedes the scientific investigation. This competency is precisely that of the experience of the subjective body with its movements and its holistic experience in union with the organic body that allows making distinctions. The objective body is but a representation, a manifestation of the originally experienced subjective body.

This problem remains in embodiment approaches, which intended to overcome the body-mind split. Critics of the embodiment position on knowing in mathematics rightly point out that existing studies—though showing that there are bodily expressions consistent with mathematics—have not shown the *necessity* of the body in mathematical knowledge (e.g., Roth, 2011, Sheets-Johnstone 2009). In the embodiment literature, knowledge is thought to arise from a metaphorization of structures of basic experiences that are recorded in the body as “embodied image schema.” However, the data presented here show that there are hand/arm movements that do not exhibit the source-path-goal schematic structure described in the literature. These movements do not have the intentional structure at all and yet constitute a form of thinking.

In the literature, expressions (signs) of a phenomenon tend to be taken as the phenomenon itself. Thus, for example, if a person were to say “I see,” researchers might take this as identical with the process of seeing. However, “the expression ‘I see’ is not based on my internal transcendental experience of vision, but upon a reflection directed toward this experience” (Henry 1965: 152). This experience no longer is immanent but becomes the transcendental object of another experience, that of reflection. My primitive experience of vision thereby becomes a transcendental reality. It is therefore not on the real experience of “in” that a metaphorization can be based but on the representation of

the “in.” But the signification ultimately rests upon the immanent experience itself. “It is at the heart of this sensible and motor life that originally knows itself, and not in the representations of our organs and their properties, that the signs by means of which we express its diverse modalities find content and sense” (Henry 1965: 155). It is precisely on the ecstatic (transcendental) aspect of the schema, products of our imagination, that the embodiment construct is founded. But this is not a foundation in the corporeal aspects, but precisely in the transcendent aspect.

This is why corporeal knowledge is not a provisional knowledge, a primitive knowledge, perhaps, but one rapidly surpassed by the intelligent human, it is rather a primordial and irreducible ontological knowledge, the foundation and ground of all our knowledge and, in particular, of our intellectual and theoretical knowledge (Henry 1965: 131)

We do not therefore *have* embodied knowledge, but rather it is a power (ability) of knowledge, a knowledge-ability (knowledgeability). “The knowledge of the world by the body and the original knowledge of the body by itself, however, are not two different knowledges because the second is rather the very substance of the first” (Henry 1965: 130). That is, the embodied knowledge of the world—the body in the knowledge of the world—is a *secondary* phenomenon based on the original and originating—immanent and therefore immediate—knowledge of the body by itself.

## Coda

The purpose of this paper is to contribute to the articulation of a theory of communication and cognition that does not presuppose transcendent forms of knowing. Rather than presupposing the existence of signs, any theory of cognition that is to be consistent with an evolutionary account needs to explain the emergence of signs. Such accounts are also required at other temporal scales, such as cultural history (e.g., the emergence of a science from non-scientific), ontogeny (emergence of signs for the child), and even, as my example from the physics lecture shows, in the moment-to-moment unfolding of speech and thought. Returning to the introductory example about my colleague and me analyzing a physics lecture in which we see the professor trace out a particular shape: it bears an iconic relation with a curve that the physics professor we are analyzing had drawn during a previous lesson on the chalkboard. Our seeing of the shape and our recognition that it is similar to the shape that had previously been on the chalkboard *both* presuppose our capacity to make the movement required in the production of the shape, if only in the form of eye movements required for perceiving *this* shape. (This is an unassailable fact that the research on mirror neurons also has shown.) That is, at the moment the shape stands out, my colleague and I are already in Figure 4b, where the phenomenality of the shape and its production rides upon the prior capacity of producing

the shape. Our mimetic production of the shape as part of our conversation about the lecture constitutes a description based on the shape as a transcendent phenomenon. As such, it is something that can be talked about. But then something else did happen. The shape, as entity, was adsorbed into the communicative region, becoming a sign for some other phenomenon. But it can do so only because it already bore this relation to itself, which allowed it to become a signifier of something else.

### Acknowledgments

Parts of this text were presented at the Workshop on Semiotics, Cognitive Science and Mathematics organized by the Fields Institute, Toronto, March 14–18, 2011 and, under the title “Dawning of Signs, Emergence of (Symbolic) Gestures: Contributions from Non-Intentional Phenomenology,” at the annual meeting of the American Educational Research Association, April 8–12, 2011, New Orleans, LA. The study was made possible by several grants from the Social Sciences and Humanities Research Council of Canada.

### References

- Alibali, Martha W. and Goldin-Meadow, Susan (1993). Gesture-Speech Mismatch and Mechanisms of Learning: What the Hands Reveal about a Child’s State of Mind. *Cognitive Psychology* 25: 468–523.
- Bakhtine, M. [Volochnov, V. N.] (1977). *Le marxisme et la philosophie du langage: essai d’application de la méthode sociologique en linguistique*. Paris: Les Éditions de Minuit.
- Beattie, Geoffrey and Coughlan, Jane (1998). Do Iconic Gestures Have a Functional Role in Lexical Access? An Experimental Study of the Effects of Repeating a Verbal Message on Gesture Production. *Semiotica* 179: 221–249.
- Beattie, Geoffrey, Webster, Kate, and Ross, Jamie (2010). The Fixation and Processing of the Iconic Gestures that Accompany Talk. *Journal of Language and Social Psychology* 29: 194–213.
- Cohen, Doron, Beattie, Geoffrey, and Shovelton, Heather (2010). Nonverbal Indicators of Deception: How Iconic Gestures Reveal Thoughts that Cannot be Suppressed. *Semiotica* 182: 133–174.
- Depraz, Natalie, Varela, Francisco J., and Vermersch, Pierre (2003). *On Becoming Aware: A Pragmatics of Experience*. Amsterdam: John Benjamins.
- Freud, Sigmund (1999). *Gesammelte Werke Band XVII*. Frankfurt: Fischer-Verlag.

- Gallese, Vittorio (2006). Intentional Attunement: A Neurophysiological Perspective on Social Cognition and Its Disruption in Autism. *Brain Research* 1079: 15–24.
- Goldin-Meadow, Susan and Beilock, Sian L. (2010). Action's Influence on Thought: The Case of Gesture. *Perspectives on Psychological Science* 5: 664–674.
- Hadar, Uri and Butterworth, Brian (1997). Iconic Gestures, Imagery, and Word Retrieval in Speech. *Semiotica* 115: 147–172.
- Heidegger, Martin (1977). *Sein und Zeit*. Tübingen: Max Niemeyer.
- Henry, Michel (1965). *Philosophie et phénoménologie du corps*. Paris: Presses Universitaires de France.
- Henry, Michel (2004). Phénoménologie matérielle et langage (ou pathos et langage). In *Phénoménologie de la vie III. De l'art et du politique*, 325–348. Paris: Presses Universitaires de France.
- Henry, Michel (2000). *Incarnation: une philosophie de la chair*. Paris: Seuil.
- Husserl, Edmund (1939). Die Frage nach dem Ursprung der Geometrie als intentional-historisches Problem. *Revue internationale de philosophie* 1: 203–225.
- Husserl, Edmund (1980). *Vorlesungen zur Phänomenologie des inneren Zeitbewußtseins*. Tübingen: Max Niemeyer.
- Johnson, Mark (1987). *The Body in the Mind: The Bodily Basis of Imagination, Reason, and Meaning*. Chicago: Chicago University Press.
- Kant, Immanuel (1956). *Werke Band II. Kritik der reinen Vernunft*. Wiesbaden: Insel Verlag.
- Kirsh, David and Maglio, Paul (1994). On Distinguishing Epistemic from Pragmatic Action. *Cognitive Science* 18: 513–549.
- Lacan, Jacques (1966). *Ecrits*. Paris: Seuil.
- Lakoff, George (1987). *Women, Fire, and Dangerous Things: What Categories Reveal about the Mind*. Chicago: University of Chicago Press.
- Luria, Aleksandre R. (1973). *The Working Brain: An Introduction to Neuropsychology*. New York: Basic Books.
- Maine de Biran (1841). *Œuvres philosophiques. Tome I. Influence de l'habitude sur la faculté de penser*. Paris: Librairie de Ladrangé.
- Maine de Biran (1859a). *Œuvres inédites. Tome I. Essai sur les fondements de la psychologie première partie*. Paris: Dezobry, Magdeleine et Cie.
- Maine de Biran (1859b). *Œuvres inédites. Tome II. Essai sur les fondements de la psychologie deuxième partie*. Paris: Dezobry, Magdeleine et Cie.
- Maine de Biran (1988). *Oeuvres Tome III. Mémoire sur la décomposition de la pensée*. Paris: J. Vrin.

- McNeill, David (1992). *Hand and Mind: What Gestures Reveal about Thought*. Chicago: University of Chicago Press.
- McNeill, David (2002). Gesture and Language Dialectic. *Acta Linguistica Hafniensia* 34: 7–37.
- Nancy, Jean-Luc and Lacoue-Labarthe, Philippe (1992). *The Title of the Letter: A Reading of Lacan*. Albany: State University of New York Press.
- Núñez, Rafael E. (2005). Creating Mathematical Infinities: Metaphor, Blending, and the Beauty of Transfinite Cardinals. *Journal of Pragmatics* 37: 1717–1741.
- Núñez, Rafael E. (2009). Gesture, Inscriptions, and Abstraction: The Embodied Nature of Mathematics or Why Mathematics Education Shouldn't Leave the Math Untouched. In: Wolff-Michael Roth, ed., *Mathematical Representation at the Interface of Body and Culture*, 309–328. Charlotte: Information Age Publishing.
- Ochs, Elinor, Gonzales, Patrick, and Jacoby, Sally (1996). When I Come Down I'm in the Domain State: Grammar and Graphic Representation in the Interpretive Activity of Physicists. In: Elinor Ochs, Emanuel Schegloff and S. Thompson, eds., *Interaction and Grammar*, 328–369. Cambridge: Cambridge University Press.
- Piaget, Jean and Inhelder, Bärbel (1972). *La représentation de l'espace chez l'enfant*. Paris: Presses Universitaires de France.
- Pozzer-Ardenghi, Lilian and Roth, Wolff-Michael (2008). Catchment, Growth Points, and the Iterability of Signs in Classroom Communication. *Semiotica* 172: 321–341.
- Pozzer-Ardenghi, Lilian and Roth, Wolff-Michael (2009). How Do We Know He Is Not Talking about Himself? Demonstrations in Science Classrooms. *Journal of Pragmatics* 41: 684–698.
- Rizzolatti, Giacomo, Fogassi, Leonardo, and Gallese, Vittorio (2006). Mirrors in the Mind. *Scientific American* 295(5): 54–61.
- Roth, Wolff-Michael (2004). Perceptual Gestalts in Workplace Communication. *Journal of Pragmatics* 36: 1037–1069.
- Roth, Wolff-Michael (2006). A Dialectical Materialist Reading of the Sign. *Semiotica* 160: 141–171.
- Roth, Wolff-Michael (2008). The Dawning of Signs in Graph Interpretation. In: Luis Radford, Gert Schubring, and Falk Seeger, eds., *Semiotics in Mathematics Education*, 83–102. Rotterdam: Sense Publishers.
- Roth, Wolff-Michael (2009). Radical Uncertainty in Scientific Discovery Work. *Science, Technology & Human Values* 34: 313–336.
- Roth, Wolff-Michael (2011). *Geometry as Objective Science in Elementary School Classrooms: Mathematics in the Flesh*. New York: Routledge.
- Roth, Wolff-Michael and Lawless, Daniel (2002). Signs, Deixis, and the Emergence of Scientific Explanations. *Semiotica* 138: 95–130.

- Roth, Wolff-Michael and Pozzer-Ardenghi, Lilian (2006). Tracking Situated, Distributed, and Embodied Communication in Real Time. In: Michael A. Vanchevsky, ed., *Focus on Cognitive Psychology Research*, 237–261. Hauppauge: Nova Science.
- Roth, Wolff-Michael, Tobin, Ken, and Shaw, Ken (1997). Cascades of Inscriptions and the Re-presentation of Nature: How Numbers, Tables, Graphs, and Money Come to Re-present a Rolling Ball. *International Journal of Science Education* 19: 1075–1091.
- Saussure, Ferdinand de (1995). *Cours de linguistique générale*. Paris: Éditions Payot & Rivages.
- Sheets-Johnstone, Maxine (2009). *The Corporeal Turn: An Interdisciplinary Reader*. Exeter: Imprint Academic.
- Thom, René (1981). Worüber soll man sich wundern. In Krzysztof Maurin, Krzysztof Michalski und Enno Rudolph (Hg.), *Offene Systeme II: Logik und Zeit*, 41–107. Stuttgart: Klett-Cotta.
- Vygotsky, Lev S. (1989). Concrete Human Psychology. *Soviet Psychology* 27: 53–77.
- Watson, James D. (1968). *Double Helix*. New York: Atheneum.