

Article

Roads to Consciousness: Crucial Steps in Mental Development (Part I)

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Abstract

This contribution explains several “roads to self-awareness”, all of them based on the natural sciences. The first one follows our bio-psychological evolution. The second road starts with the engineer’s point of view and mainly builds on information science and technology, in particular robotics. The third road taken is the most abstract - It exploits complex dynamic systems and their emergent properties. Despite their different origins and methods, these lines of investigation converge. That is, the findings of various fields can be combined into a unified theory of mind and self-awareness, which is the main purpose of this paper. This overall synthesis suggests that the mind results from a multi-hierarchical organizational structure, and self-reflexive flows of information in embodied systems. In addition to this, stable self-awareness appears spontaneously in sufficiently complex robots, when the system’s capability of describing itself crosses the level of conceptually clear information processing (thinking). As an application, one obtains a number of construction principles for mentally developing systems that are explained towards the end of this contribution.

Part I of this four-part Article includes: 1. A Psychobiological Theory of Self-awareness.

Keywords: Self-consciousness, self-awareness, free will, dynamic systems, hierarchical systems, language.

1. A Psychobiological Theory of Self-awareness

It’s the brain in a body in a world that matters (Smith 2009)

In a sense, much of the reasoning of the first section is well-known. However, it is one thing to be aware of some relevant components and steps to be taken. It is quite another to assemble these pieces into a logically-sound blueprint of an extremely complex machine.

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Step 1: Information processing. The most important property of (animal) nervous systems is that they process information. The incoming information, the input of the system, stems from the outside world. This input may be stored and internally processed in many ways. Often, the stimuli have to be transformed into behavioural responses that are adequate with respect to the momentary situation.

In a nutshell, stimuli are processed somehow in order to reach some behavioural response. This Stimulus-Organism-Response paradigm is a classic, introduced by behaviouristic psychology about one hundred years ago (Watson 1913). Since a classic computational device reads input, processes it, and produces an output, “S-O-R” (“Input-Process-Output”) is also the most fundamental model of information processing in the computer sciences.

Step 2: Representation. In order to produce reasonable motor actions, the brain needs to represent relevant parts of the external world. These representations are based on the input provided by the sense organs, and every sense organ is associated with typical units or items: touches, smells, tastes, sounds, and, of course, images. The items may be stored and retrieved from an internal memory or be evoked by some external stimulus. But these are details. The point is that, altogether, they constitute a (possibly very crude) model of the world which, despite all the interrelations amongst the items, must be based heavily on sensory input if it is to be of any value to the individual. For human beings, images are by far the most important representations.

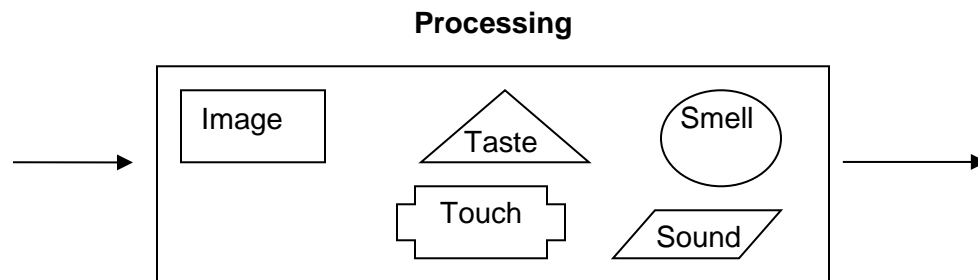


Illustration II (Various internal representations, e.g., of a single external object)

Contemporary scientists face a similar problem: If a robot is to accomplish some task, it first of all needs to be informed about (relevant aspects) of its environment. Thus a crucial question becomes how to represent or “model” the external world in the robot.

Step 3: Integration. Given some external object, this object is perceived by various sense organs: An observer sees a cup of coffee, smells its odour, recognises its temperature, and tastes the characteristic flavour. All these bits of information, transmitted by various channels – to use modern jargon – need to be integrated into a comprehensive and single impression: a fine cup of coffee, or, more precisely, the cup of coffee as you perceive it. Gestalt psychology stressed the necessity of integration with respect to visual perception; but also many contemporary authors emphasize that diverse sensory impressions need to be combined. Damasio (2010) calls the integrated chunks of information a “map”. In a chapter entitled “Putting it together”, he highlights the role of the brain stem in this endeavour.

Step 4: Representation of own body. There are not just sensory impressions of the external objects. The mental realm also contains representation(s) of the animal's physical body or body parts. These special items are rather easy to obtain, since all input information is associated with sense organs that are embedded in the physical body.

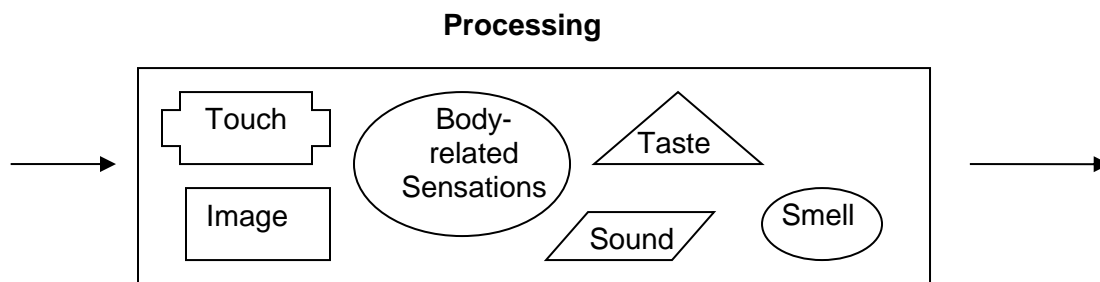


Illustration I2 (Internal representation of body parts or body-related phenomena)

Given this, there is (at least, at first) not much special about one's own body. Various sensory impressions are combined into one mental entity, typically called a body image (cf. Gallagher 2006, De Preester and Knockaert 2005). In other words, any animal or robot, possessing a body and equipped with sensory organs is able to perceive its own body and may thus form a comprehensive body image. But although, in a sense, it is a map like any other map, there is something peculiar about it. You perceive your own body from a unique perspective. Owing to your viewpoint, you see at least parts of it, e.g., your arms, chest, belly, legs and feet. Recognizing your own voice may even be easier than listening to others. Moreover, this – your - (integrated) body map takes centre stage.

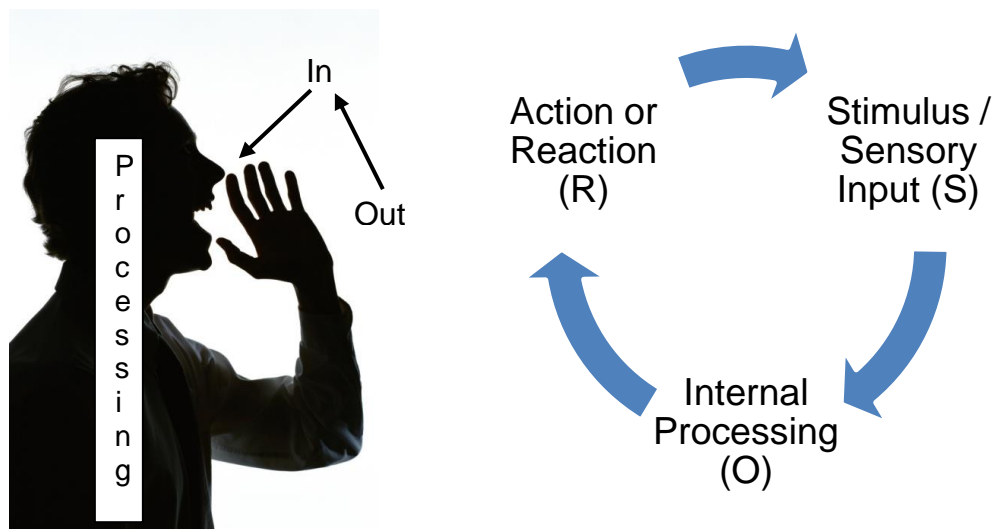


Illustration I3 (Circular Information Processing: – the sensorimotor loop)

Step 5: Circularity. On the one hand, it is the body which is receiving external information. On the other hand, the body is acting in the outside world. Therefore, things start to become circular here: The individual takes action in the real world, causing some change there, which subsequently - within hours, minutes, or seconds - may have some noticeable consequence. In other words, for every animal but also every human being and every robot, anything takes place around a centre which is the personal body (being agent as well as observer).

For this situation, computer scientists coined the term “embodied cognition”, and placed it in stark contrast to traditional artificial intelligence (AI): “Instead of emphasizing formal operations on abstract symbols, the new approach...foregrounds the fact that cognition is a highly *embodied* or *situated activity*..., and suggests that thinking beings ought therefore be considered first and foremost as acting beings” (Anderson 2003, p. 91, italics in the original). “Grounded cognition” is also a prominent new concept in psychology: “[It] rejects traditional views that cognition is computation on amodal symbols in a modular system, independent of the brain’s modal system for perception, action, and introspection” (Barsalou 2008).

With the “sensorimotor loop” (Der & Martius 2012) or “perception-action” loop (Shapiro 2010) in place, perceptions are always related to the body, which subsequently may take suitable, i.e., input-dependent actions (S-O-R). Starting with motor actions, they and their consequences can be perceived and may have some impact on the body (R-S-O). Finally, it is only the body that can take action and perceive what has happened (O-R-S).

Various iterations of the loop (S-O-R-S-O-R-...) reveal that there is something special about the body (O): It does not just take centre stage with respect to perceiving (it has a unique

perspective), it also takes centre stage with respect to acting – its “effectors”, i.e., its hands, feet etc., change the environment. Using this loop effectively means learning what consequences an action has, i.e., an inept beginner may evolve into an adept master. Subsequently the processing within the body may choose a certain action in order to provoke a certain effect on the body.

Accordingly, science nowadays distinguishes between the (integrated) body image which is mainly sensory, the (complete) body schema which is both sensory and motoric, and agency which is mainly motoric (De Preester and Knockaert 2005). But, of course, all these entities are intensely linked. In humans, precise hand-eye coordination is nothing but a tight feedback loop of the above kind: We embark on a certain action, observe intermediate results, may thus alter our (re)actions, until, finally, we obtain a desired result involving some external object or one’s own body. Obviously, there are many feedback loops around, involving other effectors and sense modalities. Moreover, internal feedback loops within the brain seem very likely. We may thus simulate a certain action and anticipate its results without actually performing it in the real world.

Step 6: Self-perception. The crux of the Chinese room argument (Searle 1980) is that the room (or anybody in it) does not know what is really going on: Received input is merely transformed into output in a perfect way. The machinery has no concept, no map or token for itself. With the flow of information changing drastically, and the body becoming a major player, the situation is completely different, and qualitatively new “emergent” phenomena become likely.

If action and perception are closely related, e.g., if the animal's (own) body is acting and - almost at the same time - the animal perceives that the body (located in the centre of activity, and being of paramount importance) is in motion, it is a small step to assume that the animal “notices” itself. That is, it observes that there is something special about this body; that a distinction should be made between oneself and the rest of the world. As human beings rely mostly on the visual sense, the perceived image of the own body is by far the most important representation of oneself.

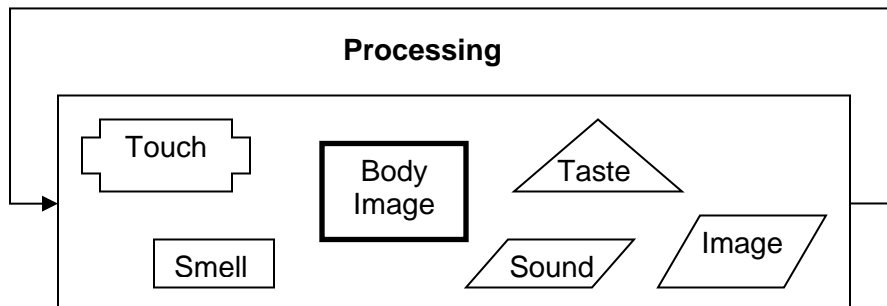


Illustration I4 (An accentuated image/representation of the body emerges)

Due to the circular situation, the body plays a double role. It is a (rather) passive object being perceived and (its map) being processed. At the same time, it is the active subject, acting in the external world. On the one hand, just like any other object, the body is perceived by the sensory organs, and represented by a cognitive, i.e., internal map. On the other hand, the body's nervous system, in particular its brain, is doing all this processing. That's a very peculiar and unique property, distinguishing the body and its (mental) activity from all the other objects around.

All perceptual as well as motoric information is linked to the brain. More precisely: Within the flow of information coming from the senses and finally resulting in motor actions resides "central processing". The brain's mental transformations are an integral part of the complete situation, or – rather - a pivotal element of/in the sensorimotor loop. Now, if feedback is strong and rather instantaneous, i.e., if the various perception-action loops are tight and numerous, the body and its mental processes can hardly escape their own presence. Thus a straightforward question arises: How much do they "notice" their own activities? Or, to put the question slightly differently: How much does a body endowed with an information processing unit understand about its status, i.e., the role it plays in the above situation? In particular, is it able to distinguish between private and external, self vs. context?

Obviously, the answer to the latter question forms a **continuum**, the continuum of self-awareness. One extreme consists of beings (be they living or artificial) without the slightest idea about themselves. The other extreme shows up in healthy, grown-up humans who know exactly where they are and what they are doing. In between seem to be animals (and perhaps robots) that - more or less - understand their situatedness. Depending on their "equipment" (both mentally and physically) they approximate the "human end" of the continuum of self-awareness to varying degrees. However, since complex life forms originated more than half a billion years ago and humans are the only conscious species we know, it also seems to be very difficult to overcome obscurity, and to reach the "enlightened" endpoint. Thus a straightforward question is which powerful tool(s) enabled man to get there.

Step 7: Language. The crucial innovation of homo sapiens is an effective, omnipresent language. With the naming of objects, the verbal description of facts and the narrative planning of actions, a second, language-based internal representation (i.e., model) of the real world evolves. Although the verbal model is strongly connected with the first (mainly visual) representation of the world, the individual has **two** distinct ways to realize things. Typically, two representations of one and the same fact are available – an *image* and a *name*. A concept is just this: Some sensory impression plus a corresponding verbal description (de Saussure 1907).

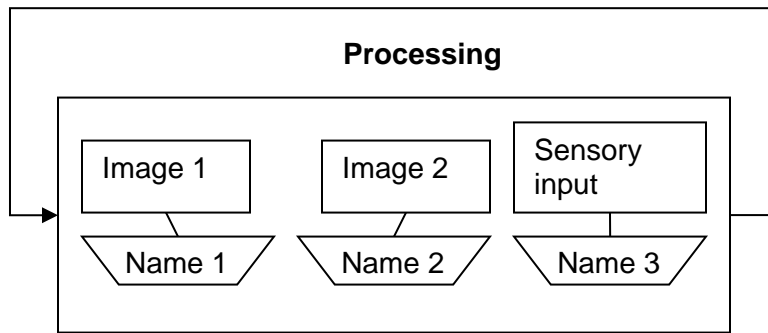


Illustration I5 (Concept formation. Concept = word plus meaning)

With language comes conceptual precision and clarity. One may systematically name objects and delineate a situation. Whereas maps are located on the perceptual “side” of the sensorimotor loop, speech production is an active feature, rather located on the motor “side”. Thus language immensely helps in describing, analysing, and moving in the world we inhabit. It makes way for a deeper understanding of our natural and social environment, our place in it, and our personal characteristics - be they external (such as the expression on my face) or internal (e.g., the mood I am in).

To cut a long story short, many scientists and philosophers think that our exclusive language skills make the difference (e.g. Deacon 1997, Arbib 2001 & 2014, Hauser et al. 2002): As an extremely versatile and powerful tool, language is the single most important disparity between man and animals (even the most developed ones). It seems to be no coincidence that those animals considered closest to us (in particular certain primates, whales and birds) have remarkable language competences. Moreover, it has been reported that people who learned language late in their lives refer to themselves as some “phantom” that existed before. See, for example, the “extraordinary mind of Helen Keller” in Donald (2002, Chapter 6), and Schaller (1991).

Step 8: A special image and a peculiar name. In particular, perception and language yield two distinct representations of the subject. There is a nonverbal and a verbal description of oneself available: the image of the body – which already has had an accentuated position - and its (specific) name. Body and name are not like all the other objects, there is something special about them, for word and image – both - represent the individual.

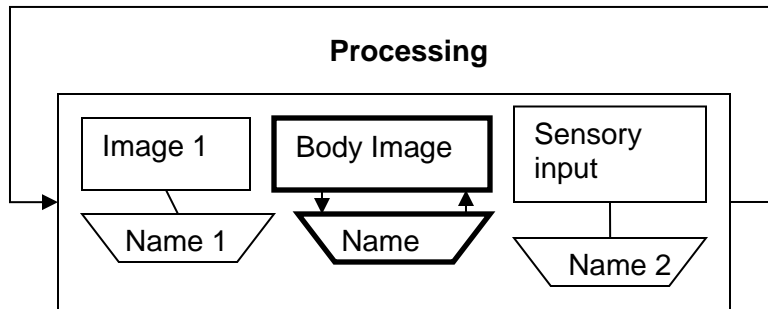


Illustration I6 (The Self-Concept = Body Image & corresponding name)

Since the purpose of our most important sense organs is to collect information about the outside world, these organs are directed away from us. However, when we look into a mirror the view is thrown back. I see my own body and my face, a peculiar part of my body, distinguishing myself from everybody else in the world. It is surely no coincidence that, with the help of this strong and immediate visual feedback, at least some animals of a few species are able to recognize themselves (Gallup 1970). They notice that the body and face they encounter are something special, that this impression differs from all other objects. (For an up-to-date overview of the species passing the “mirror test” cf. the entry bearing the same name in the English wikipedia.)

In other words, with the help of the mirror’s immediate feedback, there is an additional loop, and the mental processes in an animal’s body are able to distinguish between own and alien. That is, in front of a mirror, the animal - or rather its information processing - is able to draw a (cognitive) line between its individual existence and the rest of the world. In this sense, the mirror acts as a catalyst towards self-awareness. However, if these animals look in a different direction, the loop is gone and they seem to lose their fundamental insight almost immediately.

With our sense organs intact, humans - but also our cousins in the animal kingdom - perceive a rich model of the real world. That is, without any effort, we all observe what is going on around us. Homo sapiens, however, is the only species that is able to describe the situation in a second, completely different way. The crucial point seems to be that humans with a versatile, powerful language system possess a second (verbal) tier and thus a fully functional “internal mirror”.

Step 9: Self-Awareness. Already within the perceptual model alone, there is a special entity: the body. Since it is the central unit, all action taking place around it, and observation being directed towards it, it plays the primary-role.

In the world of language all kinds of objects and phenomena are given names. Here, too, evolves a concept with a special meaning. It is the concept that names the individual’s body and anything

directly related to it, such as the visual appearance, the sound of the voice, actions initiated by the body, and internal states.

From the very beginning of verbal utterances, the body map and the word used for myself are close. For what is the meaning of the latter concept? Its semantics are always very much related to the body's perspective, its parts, its actions, and, last but not least, the mental operations going on within the very head of this body. When processing words and sensations, the body image is reflected in its corresponding name and the name has a counterpart in the corresponding body image.

Something extraordinary happens when these parts, two different representations for the same "thing", melt into a single unit. Image and name combined constitute a concept of oneself (or one's self, respectively). This concept ("I" / "me") is very different from all other concepts: It describes the centre of existence, the source of actions and the spot where all perceptual input converges. In the verbal realm, everything that is going on "revolves" around this crucial token.

The entity that emerges is a self-concept of the individual, and the individual becomes self-conscious, i.e., fully aware of its position in the world. Identifying the body's name with the body's image is the crucial step that yields the self: an entity in the middle of everything, right at the centre of action and sensation, yet distinctively different from anything else in the world, and of paramount importance.

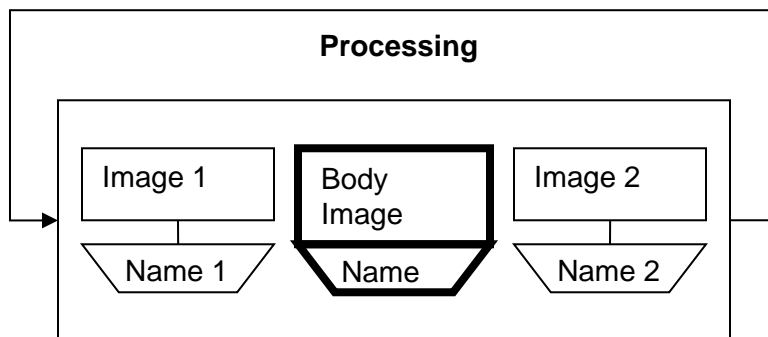


Illustration I7 (In the mental realm, clear self-awareness is the result of a crisp, stable distinction between the body concept and anything else)

Since step #9 is crucial, let us describe it once again from a more abstract point of view: Animals of all species possess at most one elaborated perceptual model. Some, like dolphins, use complex communication systems in addition. However, homo sapiens seem to be the only species with two very rich systems of description. Although they are closely related, they exist in their own right, and there is a pronounced difference between the world as we perceive it and the world we are talking about. An image and a concept are completely different chunks of information.

Animals need the help of an external mirror to encounter themselves. With a rich perceptual as well as a sophisticated verbal model, that's different: Each of these models can serve as an "internal mirror" to the other. Moreover, both include a marked representation of oneself: the body map on the one hand, and a peculiar word for the individual on the other. In other words, the reflection of the concept "I" is the body map; and the body image is represented by the term "I" in the realm of language.

This internal feedback loop is immediate, tight and strong. In order to reach a clear understanding of oneself, all that is still needed is the identification of word and map, of a peculiar name and its visual image. When these two objects fuse, a comprehensive concept emerges, encompassing all properties belonging to the extraordinary entity right at the centre of everything that is going on. On the one hand, the chunk of information standing for oneself is body-related (all we sense, feel, think and do at a certain moment in time); on the other hand, it is a clear-cut, precise concept. On the one hand, it is passive/receptive (e.g., the image we see in a mirror upon opening our eyes), on the other it is active/motorial (e.g., planning, volition, and taking action). Thus a personal self is born, one's very identity established.

One could also say that the personal self comes into existence due to a permanent, stable distinction between oneself (or: one's self) and anything else. Learning the distinction between own and alien is considered crucial in developmental psychology. Rochat (2003) writes [italics in the original]: "Until the middle of the second year when linguistic and symbolic competencies start to play a major role in the psychic life of children, self-awareness remains *implicit*. It is expressed in perception and action, not yet expressed via symbolic means such as words. Prior to approximately 14–18 months there is yet no clear evidence that the children perceive traces of themselves, as *standing for* themselves, only themselves, and no one else, such as the little footprints they might leave in the mud or the image they see in the mirror." He calls the crucial step "identification": "At this level, the individual manifests recognition, the fact that what is in the mirror is 'Me,' not another individual staring and shadowing the self."

In other words (Saint-Mont 2001): Self-awareness emerges when we learn to draw a clear-cut cognitive line between us and the rest of the (perceived) world. It is this *permanent, stable distinction* which constitutes personal awareness (see the last and the next illustrations). We are self-conscious beings, aware of our individuality, because of a stable contrast between a world "out there" and ourselves (or "our selves", respectively)

Yet another way to express the step to self-awareness is to say that we are no longer strangers to ourselves. Instead of looking at ourselves from the outside, always with a certain distance, we understand that we are both the one perceiving and the one being perceived, that we are acting and, at the same time, observing what we are doing. Listening while we are speaking triggers the

insights that (1) speaker and listener are the same person, and (2) that we are trying to understand our own words, not somebody else's. In a nutshell, we come into our own, distinguish our identity from all others, and recognize our self (or: ourself) in a clear, conceptual way.



Illustration I8 (Given a person and their environment, conceptually clear self-awareness distinguishes oneself - one's self - from anything else)

This step is crucial, since we thereby reach the “enlightened” end of the mental continuum. The centre of all perception and activity leaves vagueness behind, the human agent reaches a completely new level of insight – the cognitive level. (“Cognitive” meant in a narrow verbal-conceptual sense; as opposed to imprecise emotions, multifaceted perceptions, not integrated lines of information processing, and a fuzzy perforated boundary between “inside” and “outside”, oneself and others.) That is, man finally understands the basic setup of the game and his distinguished role in it. Upon integrating all individual-related information into one conceptual entity, he forms an identity. Equivalently, one could say that upon establishing a stable frontier between own and alien the personal identity is assembled. The boundary is mainly conceptual and it is fundamental to all cognitive processes, since it creates a precisely defined “me”. So, equivocally speaking, “self comes to mind” (Damasio 2012), whereas, before, there was just “the feeling of what happens” (Damasio 1999).

Step 10: Major consequences

The steps taken seem to be straightforward. In particular, I described the last, crucial step as if it appeared all of a sudden, in a certain moment of “enlightenment”. Of course, in a certain sense, establishing a self is like picking a ripe fruit from the tree of knowledge. However, in the physical world, developments take time. First, it is well-known that new-borns need many months to develop the mental capacities necessary, in particular language skills, for them to finally reach their selves. Second, the crucial insight may appear all of sudden, but it may also be

forgotten in a minute. Therefore, third, it takes months until the “Me-But-Not-Me dilemma” (Rochat 2003) is finally dissolved, i.e., a stable individual identity endowed with clear self-awareness is established.

Fascinating as these developmental details may be, even more important is the reorganization of the psychological arena that occurs subsequently. With a perceiving and acting agent in the middle, perfectly aware of its position in the world, the information flow is altered dramatically. The self “coming to mind” triggers a *fundamental reorganization of the mental landscape* and completely new effects emerge:

1. Thinking becomes conceptually clear
2. Planning is thus rendered deeper and more complex
3. Subsequent actions taken are better-aimed
4. Attention steers the sensors towards the most interesting phenomena
5. Externally, individuals can quite systematically explore their whereabouts
6. Internally, they may explore their mental lives (feelings, preferences, traits, etc.)
7. Thus they gain a much deeper understanding of their status and development
8. Memory can become more selective, saving important information first
9. An extended self-view with an extensive autobiographical memory occurs
10. A sense of property emerges (all things that belong to me, but not to others)

Altogether, step by step, these abilities potentiate the individual’s reach, and, make no mistake, it is the developing agent that is actively extending its force. There is an owner who learns to handle the mental and physical tools available, and, in the end, can apply them as he / she pleases. Fortunately for us, it turns out that human brains are embedded into a versatile body with an appropriate size, and well-functioning in almost any natural environment, on land as well as in water. Even more important is the fact that we are able to design, to change our environment with the help of very sophisticated effectors: our hands (Wilson 1998). That’s a lucky coincidence, since self-awareness could also be “locked” in a body tailored to a narrow ecological niche; just suppose you were a raven, a dolphin or an elephant...

On their own, individuals can survive: they can assemble tools and equipment, hunt, produce clothing, and may even build a hut. However, many hands and brains, working together, are needed to piece together megalithic sites, pyramids, or walls stretching thousands of miles. With the help of language, writing and many more cultural techniques, man has been able to organize larger, work-sharing, stable groups that turned out to be the nucleus of complex societies. Nowadays, this historic quest seems to be cumulating in one truly global culture.

Impressive as all these steps are, we have omitted the single most important one, occurring quite early and adding a completely new dimension to our cognitive lives. This single most important

personal insight is the detection of time. Unlike all animal species, we do not just live in three-dimensional space: Looking back, we see that we were younger, with people telling stories about our birth, when our subjective life started. Looking ahead, however, each and every one of us has to concede that we are growing older, until finally, our lives are over. Understanding the past, and foreseeing at least a part of the future is an invaluable gift, it deepens and widens our consciousness immensely. However, this gift inevitably comes with knowledge about our inevitable fate. Each and every one of us must foresee and thus face the fact of death, i.e., a limited existence in time.

Consciousness has been a great invention, perhaps it has been the most powerful innovation ever since the Cambrian explosion (Cowen 2013), reaching a completely new level of insight and complexity, shaping much of us (our culture, and history), and altering the face of the planet. Nevertheless, self-awareness - in essence a mental borderline - comes with restrictions and limits: Opening one's eyes in the middle of the night won't make the sun shine, since the sensory system and the view of the world it provides are not affected by cognitions.

In more general terms, consciousness is a higher-level mental process with a certain influence. However, this process neither understands nor controls our psycho-physiological machinery completely. Freud and many others have pointed out that major mental tokens, like motivation, emotions, drive, pleasure or pain are beyond its reach. There is both voluntary and involuntary motor function. Moreover, everybody is born with a certain set of physical and mental properties. These properties constitute basic conditions under which our lives evolve. (It really makes a difference if one is blind or keen-eyed, emotionally stable or fragile, can move their limbs or not.) Although we are able to talk about almost anything, we are clearly aware of much and we are able to change some conditions, there are always many boundary conditions that we may neither oversee, nor understand, nor are able to alter.

So, finally, there we are: A well-defined identity with a distinct personality, precisely knowing where it is located in time and "space" (the latter being physical and social). In all the fields described, our boundaries have widened. However, inevitably, our psychological life is tied to a particular body. Instead of being like a "spirit hovering above the waters", we are "embedded intelligence", inseparably linked to some physical entity, to the extent of being this body's agent.

(Continued on Part II)