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How cyborgs transcend Maturana's concept of languaging: A (bio)engineering perspective on information processing and embodied cognition

Rasmus Gahrn-Andersen
University of Southern Denmark, Department of Language and Communication
rga@sdu.dk

Robert Prinz
Rechenkraft.net e.V., Marburg, Germany
robert-prinz@web.de

Abstract With the purpose of establishing life-mind-language continuity, the paper thematizes an important phenomenon missing from Maturana's (1988) theory of *languaging*: the generative basis of second order consensual coordination. While Maturana suggests that coordination involving biological information is qualitatively different from coordination involving concepts, we make the case that the two should be seen as continuous. We critically expand on Clark's (2003) point that language and technical artefacts extend human cognitive capacities while challenging Clark's Shannon-based view on information. Rather than focusing on language as a representational medium we turn to how languaging is enabled by multiple, qualitatively different organizational levels in organism-environment systems. On our view, language is irreducible to the exchange of predetermined, conceptual meanings. Rather, we hold, human linguistic abilities are based in embodied hierarchies of molecular coding in the sense that some of these hierarchies rise to neuronal (electromagnetic) and cognitive patterns that enable meaning-making activities (including languaging) connected with a particular praxis. Our account is based on the case of synthetic evolution and engineering (Evoneering) of humans with intelligent (bio)nanomaterials and (bio)chips implanted into their body for medical purposes.

Keywords: Languaging, Shannon-information, Biosemiotics, Evoneering, Radical linguistics

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0. Introduction

Proponents of radical linguistics explore life-mind-language continuity by either pushing approaches faithful to Humberto Maturana's work on *languaging* (see, Kravchenko 2007; 2020, Raimondi 2014; 2019) or stressing the analogous connections between human language-use and biological functions (see, Cowley and Markos 2019). While both strategies have obvious advantages, we find that they overlook how, in generative terms, biological mechanisms interplay with enlanguaged cognition. Considered in relation to

Maturana's (1988, 2002) account on languaging we thus find it necessary to thematize what can be described as a gap between, on the one hand, first order activity (or strictly biological ways for organisms to coordinate consensually) and, on the other, the phenomenon of languaging which emerges as coordination of coordination that draws on a consensual domain. For by merely stressing the logical coherence between first order consensual coordination and languaging, Maturana abstains from clarifying the ontogenetic basis upon which the biological information of the former gives rise to the conceptual information exploited by the latter.[1] In what follows, we thus present a preliminary attempt at uncovering the generative basis of languaging.

The paper is structured as follows: We start out in Section 1 by setting up a negative target: Andy Clark's (2003) conception of language and cognition as involving informational content. We trace Clark's view on information back to its roots in Claude Shannon's influential account on general communication systems and argue that Clark's view of language is at odds with that of radical linguistics in that it builds on the assumption that enlanguaged cognition has a representational basis in the brain. Then, in Section 2, we consider the case of synthetic evolution and engineering (*Evoneering*) and, more specifically, humans with intelligent biomimetic nanomaterials and (bio)chips implanted into their bodies. We use evoneering to showcase that human linguistic abilities link with embodied hierarchies of molecular coding in the sense that these hierarchies give rise to electromagnetic and cognitive patterns that enable, at least in part, languaging activities in a given praxis. We hypothetize that languaging emerges through a molecular medium, and that it must be considered as a bearer of the imprints of the lower levels that enable its production. Section 3 relates the principles of evoneering to biosemiotics and shows how the extension of flesh and blood to carbon and metal, to bits and bytes, is not only informational relations without a vehicle, but also links with human languaging and embodiment. We argue that the interdependency of different relations through hierarchies is key to next-level, man-made biochips, medical or multimedia devices built to bridge molecular, cognitive and linguistic domains. Finally, Section 4 ties everything together by considering evoneering as opening up a meaning potential that is irreducible to either the strictly localised code-based coordination between the molecular biology of the agent or that of the algorithmic control device. Information is distributed locally across the levels, and connected systemically by meta-codes between hierarchies that generate meaning.

1. Information beyond Clark (and Shannon)

Andy Clark (2003) stresses an important point concerning the possibility of life-mind-language continuity when pointing to the fact that human cognition unfolds in extended cognitive systems. Such unfolding, he submits, arises from how we humans complement our 'basic biological modes' of processing information with the use of language and material artefacts. Such extended cognitive systems are special since they allow for «computational and problem-solving profiles [which] are quite different from those of the naked brain» (Clark 2003: 78). Yet, in accordance with representationalist

[1] More technically, Maturana stresses that language happens «in the flow of consensual co-ordinations of consensual co-ordinations of actions between organisms that live together in a co-ontogenic structural drift» (Maturana 1988: 47). By placing emphasis on language as a phenomenon that is relationally constituted between co-ordinating individual organisms, Maturana leaves unaccounted for the intra-individual basis that enables such co-ordination to take place. This basis requires clarification; also considering that Maturana rightly recognises that linguistic activity need not only unfold in embodied, social encounters but also in instances of solitude as in the case of basic object perception (cf. Gahrn-Andersen 2019b).

cognitive science and information-theory research, Clark (2003) effectively takes the brain to be an information-processor (cf. Hutto and Myin 2013). In so doing, he ascribes to a view on information that is often being referred to as *semantic information* or, named after its inventor, *Shannon-information*. We find the following two aspects from Claude Shannon's theory to be relevant in the present context:

First, Shannon evokes a vehicle-content distinction when describing how information is processed. The *content* is the information – or what he also terms the message – that is communicated across entities (=the vehicles) that constitute the technical side of a given communication system. He submits that the communication process involves four stages: 1) an information source encodes the information that 2) is then transmitted in a medium. Subsequently, that 3) a receiver is decoding «the message from the signal» thus allowing it to 4) reach the intended recipient. The core of Shannon's account is that content and vehicle exist in separation in the sense that they do not affect one another. Because of this, the information remains intact – or self-same – throughout the communication process (i.e., stages 1-4) despite being subject to encoding, transmission and decoding throughout the process.[2]

Second, Shannon submits that information is semantic when it involves 'meanings.' Meaningful messages, he rather vaguely argues, «refer to or are correlated according to some system with certain physical or conceptual entities» (Shannon 2001: 3). By arguing that information frequently entails meanings, Shannon acknowledges that information can be either a) meaningful and, thus, semantic, or, alternatively, b) non-semantic and, thus, devoid of meaning. Yet, b) is underdeveloped in Shannon's account given his preoccupation with man-made communications systems (e.g., telegraphs, TVs) that serve to facilitate communication between people and, thus, language-users that compose messages by means of concepts: «In telegraphy, for example, the messages to be transmitted consist of sequences of letters. These sequences, however, are not completely random. In general, they form sentences and have the statistical structure of, say, English» (*ivi*: 6). Simply put, Shannon's focus falls on a) thus entailing that he takes information to be synonymous with meaningful information.

Clark (2003) embraces both of these aspects. He evokes reference to a vehicle-content distinction by presupposing a duality between, on the one hand, the brain that processes incoming information (= the vehicle) and, on the other, the information that is processed (= the content). But he also acknowledges that there are instances where information is not transmitted for immediate retrieval and usage. In such cases, information is stored in different media and awaits later retrieval. In referring to the example of encyclopedias, Clark argues that «often, the biological brain is insufficiently aware of exactly what information is stored outside to make maximum use of it» (Clark 2003: 69). For Clark, this not only holds for conventional information (e.g., messages with meaning) but also strictly biological information. Thus, he argues that when considering information, «what matters is how information is poised for retrieval and for immediate use as and when required» (*ibidem*). In this connection, man-made artefacts come to function as cognitive tools because they offer ways of «encoding, storing, manipulating, and transforming data that the biological brain would find hard, time consuming, or even impossible» (*Ivi*: 78).

In the case of language, Clark states that linguistic capacities have changed our brains from being solely biological to becoming 'word brains' in that we from early infancy are embedded in an enlanguaged environment. On his view, this change has taken place in

[2] Shannon acknowledges that this is not always the case given that in certain circumstances a noise source may interfere with the signal that is being transmitted in a given medium. Consequently, «this means that the received signal is not necessarily the same as that sent out by the transmitter» (Shannon 2001: 20).

functionalist rather than essentialist terms meaning that the plasticity of our brains due to being enlanguaged is evident from the different means by which we can engage with our surroundings. Still, however, the brain is a processor that comes to represent the world by means of concepts. For instance, Clark argues, when doing math humans exploit

> the kind of mathematical reasoning unique to our species appears to depend, in part, upon neural representations of number-words. It depends, therefore, upon a learning cycle that essentially involves experience with one of the most basic and ubiquitous species of cognitive technology: the spoken words of our public language (*ivi*: 73).

According to Clark, written language allows for an *exchange of ideas* (*ivi*: 109) in that it makes it possible for us to *freeze* the representational content of our cognitive states: «When we freeze a thought or idea in words, we create a new object upon which to direct our critical attention» (*ivi*: 79).

Although we agree with Clark that language and material artefacts extend human cognitive powers, we disagree with his attempt at explaining such extension by means of reference to Shannon-style information. By contrast, in accordance with radical linguistics, we push a non-representational approach to language and cognition that renders content-vehicle distinctions obsolete (cf. Chemero 2009, Hutto and Myin 2013).[3] We do so with the purpose of providing some preliminary insights into the generative basis of languaging. Crucially, in the sections that follow, we engage with research on evoneered medical devices with the purpose of uncovering the substrate that allows for linguistic information to be constructed through dynamical agent-environment relations. In this connection, we show that the non-representational construction of linguistic information is deeply grounded in the embodiment of individual organism (whether biological or partly artificial) and, thus, biological hardware that, underlying different organizational levels, comprises an agent's capability to engage in activity involving linguistic information – or, as we prefer calling it, conceptual meanings.

Before setting out on this course, we first provide preliminary definitions of key concepts that we introduce in the sections to follow:

Information: In the context of the current paper, we take information to be deeply grounded in the relation between the molecular constituents of codes (following how Barbieri (2008) introduces the latter). A singular code consisting of two different types of molecules connected by an independent adaptor molecule comprises a minimal, irreducible building block of biological information. This building block might therefore be considered as a *biological information quantum* (*BIQ*). Codes are biological information quanta. In being relational, however, there cannot be anything like the mere (isolated) presence of a code, including *code-makers*. As such, both necessitate active code praxis i.e., the execution and perpetuation of the molecular or biophysical code infrastructure. Therefore, we define information as the presence of code activity in a code praxis. Code

[3] One way of conceptualizing the genealogy of radical cognitive science is to follow Chemero (2009) who takes it to be a direct descendent of so-called "American naturalism" (as advocated by John Dewey, William James and James Gibson). Especially the eliminativism central to this strand of naturalism is crucial since its proponents assume that «cognition cannot be understood as a mirror of the world, and cannot be understood apart from the activities, indeed the whole life, of the animal» (Chemero 2009: 21). In other words, they depart from brain-centrism by anticipating a focus on the cognizer as someone who is embodied, situated and, thus, embedded in dealings with worldly offerings thus rendering computationalism ill-suited for explaining cognition.

praxis and code habituation are processes that in themselves generate historicity and enable simple forms of embodied, or imprinted memory. Whereas Shannon-based information, Turing machines, and modern computers operate with *strings* of bits and bytes, i.e., series of 0 and 1, biosystems work with *networks* of BIQs that in an analogous sense are the *bio bits* of living information systems. Instead of two states, i.e., 0 and 1, there are literally unlimited combinations of three types of molecules forming a code. The very nature of those BIQs is that, in line with Barbieri's argument, they can only be named and not further be compressed as can be strings of 0s and 1s. Considering code relationality, there is no content to be separated from the vehicle at the BIQ level. We will use the term information throughout the text in the above sense or in a colloquial manner when this is clearly indicated by the context.

Meaning: Meaning amounts to contextual code-directionality and *meaning potential* pertaining to the theoretically possible directions which a set of connected codes relationally can establish. *Directionality* is the order of codes in regard to the actuation of the first code being related to the actuation of one of several possible subsequent codes in a row of codes triggering an identical or similar action.

Interpretation (of meaning): This is a process of recursive, cybernetic referencing within a network of codes – that an observer may deem to be either extrinsic or intrinsic to a cell or organism – which contributes to the persistence of the cell or organism in question.

Metacode: Electromagnetic frequencies that interact within the brain deviate from Barbieri's definition of code, and therefore we use the term *meta-code*, which might also be considered as *epi-code*. It denotes the fact that there are not two different worlds anymore, as Barbieri calls it, connected by an adaptor, but rather electromagnetic states (frequencies). These can be considered as ontologically identical objects related arbitrarily to one another in a similar, if not seemingly identical topological manner as molecular codes.

Conceptual information (or concepts): Informational relations that exist dependently of a linguistic praxis and, hence, human socio-material entanglements, and which roughly correspond to linguistic signs in the sense of traditional linguistics - although it should be clear by now that we do not buy into such an (i.e., Saussurean) ontology. Consequently, two points of clarification are required: First, in focusing on the conceptual dimension of linguistic informational relations, we do not exclude the presence of other kinds of signification i.e., what Félix Guattari (1992: 24-25) terms "non-linguistic substances". Second, instead of assuming that concepts exist inside the heads of language-user, we take "concepts" to be synonymous with conceptual knowhow that is skilfully enacted by a language-user in a specific context (see also, Gahrn-Andersen, in press). Conceptual information is therefore relationally constituted by a language-user who engages with relevant aspects of the environment in concept-specific ways.

2. No content transmission: Evoneered medical devices and the bio-tech interface

In this section we introduce the case of evoneering with the purpose of showing that there is no need to evoke content-vehicle distinctions when it comes to explaining the transfer of non-linguistic information. This endeavour provides a first step towards ensuring life-mind-language continuity since it testifies to the fact that artificial devices are not mere extensions of the human organism, but rather can be designed so that they functionally substitute our biological embodiment while being integral to the human organism.

The emerging field of *evoneering* is dedicated to the development of smart micro- and nano-interfaces fused with actuated, bionic devices to enable lost or new capacities for the device-carrier. Implants with direct, permanent tissue contact as well as wearable (i.e., removable) devices are currently being developed. The engineering of such devices is partly based on synthetic evolution. Real-world cyborgs are no longer science fiction. They exist amongst us as augmented humans with enhanced, evoneered capabilities (Barfield and Williams 2017). Although usually originating from medical needs, we also witness a growing trend in the general public to acquire smart tech-tattoos as well as a growing biohacker community (Yetisen 2018) that treats devices as part of their everyday life-style (Ramoğlu 2019) thus culminating in artistic forms of expression and a sub-culture called *cyborgism*.

Progress in bio-engineering and the development of sophisticated implantable biomaterials such as carbon or silicon-based wires and meshes allow for real-time monitoring of biochemical and physiological states in blood, tissues and body compartments for both diagnostic and interventional purposes (Duan *et al.* 2013, Ruckh and Clark 2014, Gray *et al.* 2018, Osumi *et al.* 2019). Bio-engineering fuses human tissue directly with inorganic material that serves as either a measuring sensor or electrode (Feiner and Dvir 2020). This allows for a wire or cable connection to an external device that can read substrate-induced changes in, for instance, the electrical potential of an electrode. In brain research, elaborate methods and smart devices have evolved to map cognitive profiles (EEG signals) in real-time to software algorithms (Lee and Kuhl 2016, Shen *et al.* 2019a, Shen *et al.* 2019b, Siegmund *et al.* 2020) and thereby enable the device-wearer to control prosthesis movements, or to connect to computer interfaces non-verbally for controlling defined processes (Edelman *et al.* 2019, Mastinu *et al.* 2020, Ortiz-Catalan *et al.* 2020). Importantly, the principle of such approaches is not to exploit mental images but simply to read electromagnetic brain signals, and to use them to control the movements of a non-permanent prosthesis. In this setting, e.g., a patient sees an object to be grabbed, and intends to move the prosthetic arm towards that object. The electromagnetic signals emitted by the brain during this process are read by an EEG device (qua measuring sensor) and subsequently assigned to a desired actuation of the prosthesis by a computer program. The software then sends the corresponding commands to the device. Another scenario is a device being non-permanently attached to an amputees' stump so closely to allow its integrated sensors to directly measure electromagnetic signals emitted from nerve ends in the stump. Again, the device's control software is programmed (after training) to make sense out of the arriving signals and to execute movements as desired by the patient. This is possible thanks to patients' ability to voluntarily control the electromagnetic signals, or nerve firing so to speak, of the neurons ending under the skin of an amputation stump. Equipped with highly sensitive electrodes, the device also contains a signal processor and control software, and can thus process and execute information quite autonomously from its human bearer. In such cases, only orthopaedic intervention and no surgery is needed, which is safe and comfortable to the patient, compared to implants. This not only helps patients to compensate for missing limbs, to overcome paraplegia, or to replace deficient organ function, it also opens up a new perspective on language, embodiment, and the role of representations. Such devices allow patients to participate in communication (or what Maturana terms "first order consensual coordination") by means of passive or inert bodily extensions while, at the same time, enabling top-down control in the sense that the (implanted) body parts come to contribute to the substrate of dynamic communication between the agent and others through the evocation of conceptual meanings (i.e., *languaging* in Maturana's sense).

State-of-the-art human to machine connections, implemented via different types of interfaces work without content being transferred to or translated into the trans-human side of the interface, e.g., in an electronic control unit, microprocessor, or software environment. The control software of the prosthesis bridges from *bio* to *tech* as a microprocessor transforms incoming signals into information based on programmed algorithms. In the context of prosthesis usage information becomes meaningful for the device-wearer through purposeful, pre-reflective (bio)mechanical execution of the device. The device-wearer develops both tacit and overt controlling capabilities within the context of being merged with the device: The often, cognitively overt (and hence, reflective) learning process of trial and error is accompanied by tacit neuronal tinkering, i.e., subconscious adaptation and fine tuning of neuronal circuits and feedback loops that allow the subject to properly handle – and thus integrate – the device into their physical, physiological, and psychological state of being. Feedback in many cases will not return via the interface itself, but rather from indeterminate cross modal integration of visual, tactile, and acoustic signals produced during actual performance.

At the very core of the interfaces, the bio faces the tech. But how is this possible in a non-disruptive, meaningful way? In the next section, we present examples from the literature on how this can be achieved. Specifically, we stress the role that biosemiotics might play in the future development and evolution of cyborg interfaces. Furthermore, we presume, the underlying code-based (biosemiotic) principles of human physiology will stipulate the rules any advanced cyborg device must follow in order to achieve *total integration* in the sense of the unrestricted accessibility of the full potential of a device, in both directions, i.e., from bio to tech and vice versa. The presences of coded interactions that relate two independent classes of molecules with each other by means of an adaptor that is another type of molecule, is in line with Barbieri's definition of code. At the same time, however, it also resembles triadic structures described by Peirce, and constitute the biosemiotic aspect of the interactions we describe later for specific interfaces. The mind controls (non-living) matter when a patient moves an artificial hand to engage in, for example, sign languaging, which we would consider here as the top-down complement to the bottom-up emergence of languaging assumed by Maturana, where language(ing) is tied to individual organisms in the absence of mental or linguistic representations. This being said, the biosemiotic nature, so to speak, of any advanced, evoneered biotechnological device will be the key to seamlessly enable device integration and, possibly, extension of human languaging capacities. On our view, the functionality of such devices illustrates the possibility of bottom-up emergence.

3. Biosemiotic interventions: cases and considerations

3. 1. The Case of Nano-wired Interfaces

The group of Charles Lieber has developed methods for creating biocompatible nanofibres from which wires and meshes can be built and implanted into animal brains to record, for example, neuronal action potentials in vivo (Hong *et al.* 2018). Such structures comprise the actual interfaces that have direct contact over tissue and single cells. More importantly, they can even address multiple regions of a single neuron in a non-disruptive, reversible manner, as opposed to established procedures like the patch-clamp technique used for such measurements in vitro. The authors call this *minimally invasive intracellular recording* (*Ibidem*). The overall idea behind such nanowires and meshes is to mimic natural tissues in terms of size, softness, and three-dimensional organisation for seamless integration into host tissue. Ultimately, this development has culminated in the realisation of artificial synapses that form when neurons are cultivated on arrays of so-called *nanowire field-effect transistors*. These subcellular-sized sensors can be integrated into axons and dendrites of live mammalian neurons thus allowing action potentials to be recorded or manipulated (Patolsky *et al.* 2006). While enabling live recording of action potentials or measuring biochemical parameters, such as pH, devices described by the Lieber group also showcase the tech to bio transformation as electrical stimulation produces purposeful information that bridges the gap from non-living (tech) to living (bio) thus generating physiological meaning (*Ibidem*).

The underlying technical, chemical, and computational details are out of scope of this article, but we would like to make a point concerning a possible biosemiotic interpretation of aspects of this biotechnology. From a technical and engineering perspective, one is used to speak of compatibility and reference is especially made to the technical term, *adaptor*. We are all familiar with power adaptors or USB adaptors, but in more complex machines, where different tasks are executed at the same time, a variety of sub-systems have to be compatible with each other to merit synergism and functionality in the context of a composite device which often depends on forms of translation by hardware and/or software adaptors as seen in complex machines, such as automated agricultural tractors, harvesters or robots. In medicine, robot-assisted surgery systems are complex machines with both human-machine, and machine-human interfaces, intricate control software, and sensory-mechanical adaptors mediating haptic feedback. The same requirements apply to nanofibers and meshes fabricated from inorganic materials or building blocks that are inert and mostly incompatible with biological tissue, thus demanding further modifications to increase biocompatibility. The Lieber group has successfully modified nanofibres by attaching so-called cell-penetrating peptides in order to facilitate internalisation of the fibres through mechanisms comparable to endocytosis (Lee *et al.* 2016). Technically speaking, the peptides are adaptors that connect the fibre to the cellular internalisation apparatus. Such peptides consist of five to forty amino acids and are derived from naturally occurring sequences, e.g., the HIV-1 tat peptide, that have recently been investigated as a drug delivery vehicle (Rizzuti *et al.* 2015) and which allow for cell-type specific drug targeting (Zahid and Robbins 2015). Interestingly, most of the sequences themselves do not serve membrane crossing naturally, but have other functions within protein domains, or as single peptides. New information with a meaning potential is thus artificially engineered in the context of cargo delivery, or more specifically in cell penetration.

Another interesting point here is that the cell acts as a molecular agent akin to a human languaging agent. It does so by engaging in de novo meaning-making through internalisation of the peptide that is interpreted as a sign, triggering the process of membrane folding and object internalisation. Importantly, this flexibility is a specific aspect of biosemiotic organization, and in our example, the used cell-penetrating peptide is a totally new occurrence of such a molecule in this context for a neuron. It is exactly the endocytosis-like internalisation by means of existing mechanisms that allows a neuron to properly handle the modified nanofibres and enable their non-disruptive internalisation. The memorisation of this process by cellular mechanisms, like *sensitization* or *habituation*, can permanently establish the human-machine connection by use of coded interactions. So, we see here the molecular complement to languaging, creating communicative flexibility in the context of cyborg devices. At the human side, i.e., cell side of the interface, information is generated locally and perpetuates through succeeding levels of hierarchy by molecular embodiment. In the next paragraphs we will see how this molecular information perpetuation translates into electrophysiological and finally electromagnetic embodiment.

3. 2. The Case of Wireless Interfaces

Deep physiologic integration of prosthesis and devices is complex and poses several health risks for its carrier, ranging from immune responses, infections, and risks generally associated with the invasiveness and the surgery itself that is necessary for device implantation. Wireless, contactless control of wearable prosthesis, i.e., non-permanently attached devices, using eye movement or "mind" control is another area of cyborg research where thoughts control prosthesis movements. The basic idea behind this approach is to read neuronal activity of the patient and translate measurable electromagnetic signals into algorithmic commands via software tools that operate prosthesis or device movement. There are also approaches that combine implanted devices with wireless prosthesis control, i.e., there is a physical gap between implanted sensor, external computational signal processing, and prosthesis actuator.

Edelman *et al.* show how such non-invasive brain-computer interfaces can be used to control the movement of an robotic arm (Edelman *et al.* 2019). They focus on developing and improving training methods for subjects to use and interact with software by controlling a virtual cursor or external robotic arm. Participants were wearing a EEG headcap detecting neuronal activity that was mapped to execution algorithms that finally translated into cursor movements on a screen or real actuation of an robotic arm. Their study shows the practical deveolpment of noninvasive, mind-controlled technology to be used by patients.

Li and Zhang report a combined approach where human test subjects could remotely control the movement of a cyborg cockroach (Li and Zhang 2016). The test persons were watching a cockroach remotely on a computer monitor and were able to control the cockroach's track by moving their own eyes along track borders projected into a live video feed. A wearable EEG device measured the persons´ brain signals during this process and transmitted the signals via bluetooth to the implanted chip on the cockroach. The cockroach walked on its track in a box and the test persons were able to direct them left or right without any direct contact. In this example we find on the cockroach side the type of invasive technology outlined above, and the aspect of wireless control via wearable, i.e., detachable devices. Both have biosemiotic implications; the former were already presented earlier in Section 3.1, while the latter will be discussed in Section 3.3.

Even-Chen *et al.* report a trial with a brain-implanted sensor that sends its measurements wirelessly to a processing computer which forwards its processed information and commands to the prosthetic controller which actuates an artificial arm (Even-Chen *et al.* 2020).

3.3. Considerations: Crossroads of Codification

Our direct contact with the world and our immediate surroundings, or *Umwelt*, is through our senses. We experience the material world through sensory organs, and integrate information gathered through vision, hearing, or tactile exploration, amongst other senses, depending on context. Mechanisms of sensation and perception are cross-modal, meaning that information in many situations is derived from a combination of several sensory inputs. This cross-modality would deserve extra attention in the cyborg context, but the focus in this section should remain on biosemiotics.

One hallmark of the nervous system and its building blocks, neuronal cells, is the ability to transfer signals electrically by their so-called *excitable membrane*, allowing very fast information processing and signal transmission. Neurons are charged negatively inside,

and positively outside, generating an electrical potential at the cell membrane based on active and passive ion transport systems across the membrane. Any change in membrane potential may add up and lead to membrane depolarization across the length of the axon. Depending on the identity of the neuron, it will "fire" an *action potential* at a certain threshold of membrane depolarization and propagate a depolarization "wave" that will once arrive at the distal end of the axon.
Using *Peirce*-inspired terminology, we could say that for the touch sense, a cup of coffee we grab is the *object*, the mechanical force immediately exerted on the neuron is the *sign*, and the mechanically gated ion channel is the *interpreter*. In *Barbieri*'s terminology, the involved ion channel would be an *adaptor* that relates two independent worlds, namely the world outside the body to the world inside the nervous system. Upon touching the cup of coffee, pressure builds up leading to forces that mechanically open ion channels in the sensory neurons embedded in the skin, causing an inflow of positively charged ions into the neuron. This leads to a feedforward inflow of further positively charged ions and additional opening of electrically gated ion channels. Again, the electrically gated ion channels can be considered interpreters or adaptors, just "deeper" within the neuron. At a certain threshold, this depolarization phase in the cell body will translate to the firing of the neuron, starting from the so-called axon hillock and then propagating through the axon. At the axon terminals, the depolarization of the membrane will lead the release of neurotransmitter molecules (signs) that can be interpreted by receptors (interpreters) in the membrane of the subsequent neuron, and so forth. During all those processes, thousands of neurons simultaneously fire and distinct patterns "emerge", that can be considered as (composite) signs in themselves. The next level of coding takes place within the nervous system by integrating and canalising the firing patterns of those thousands of neurons towards the brain via nerve bundles and fibres along the spinal cord. Again, a firing neuron, or a group of firing neurons will be the sign for the following (group of) neurons which are interpretants using *Peirce*–inspired terminology, while the object remains the cup of coffee if you will, but a step farther remote, so to speak.
We arrive here at a very interesting point, or more accurately, at the crossroads of codification. Gennaro Auletta gives plausible arguments that the brain does not code information itself, but rather controls codified information from the sensory inputs (Auletta 2011). He distinguishes between *local* information *coding* and *global* nonlinear excitation *patterns* which can be summarised as a description of a functional mapping of peripheral signals to central excitation patterns (Auletta 2011). Alessandro Villa discusses neuronal coding in the context of spatio-temporal firing and spiking patterns and comes to the conclusion that future research in this field should not be restricted by the boundaries of coding concepts (Villa 2008). Adding our view, we reach also the limits of Barbieri's adaptor-concept at higher hierarchies of the nervous system: Strictly interpreted, there are no different worlds anymore within and between higher instances of the central nervous system, especially the brain, which could be connected by independent adaptors. Cognition and the underlying communication processes between different areas of the brain use the same "language" without translation, so to speak, meaning there are no different worlds to be related by adaptors anymore in this context. So where are the codes gone if they depend on adaptors? There is no doubt, at the molecular and cellular level of each and every single neuron in the brain they are still present and "work" perfectly fine. For the cognitive functions performed by the brain, we may identify meta-codes that could be composite, distributed oscillators synchronized and orchestrated through distinct brain frequencies. That such patterns of frequencies play an important role in cognition is long known and discussed by György Buszáki in the context of neuronal syntax (Buzsaki 2006, 2019). Single agents to be

identified as *mental codemakers* (Barbieri 2008) remain elusive, but interestingly enough it appears that at least multiple, composite molecular codemakers generate electromagnetic frequencies – that are outside their own world so to speak, in our view. According to the *code theory of the mind* proposed by Marcello Barbieri, cognitive processes would rely on code-based, manufactured artefacts, and enable autonomy of the mind just because they are not spontaneous or emergent (by)products of the underlying physiological processes (Barbieri 2015). This very appealing idea nevertheless apparently requires a form of downward causative agency making choices, a requirement we do not infer from the cyborg experiments described in the previous sections of this article. The cyborgs are deeply embodied and so must be the mind – otherwise it would not work out to have plug and play cyborg devices. With this catchy claim we want to draw attention to the investigation of embodiment, languaging, and cognitive coding in the cyborg context and the potential merits of this idea.
The bidirectional use of EEG readers and other evoneered devices may serve as a relay between different brains taking advantage of signalling with yet undiscovered meta-codes to establish a true dialogue between tech and brain, as well as between brains. The science fiction of cyborgs became real, so might even the concept of telepathy because the bridge provided by technical devices will enable interlocking of neuronal codes bypassing sensory systems. In contrast to information *transfer*, this brain-to-brain talk involves code praxis and therefore is information itself as defined in Section 1. It might be compared to a game of dominoes: There is no content transported across the falling dominoes (vehicles), but the "information" or state of falling is there from domino to domino. It is the very nature of code praxis that this type of information propagates, or spreads around rather than being transferred like cargo, and it is the very nature of embodiment that the content cannot be separated from the vehicle. Cyborg devices will thus probably contribute to solving some of the most fundamental questions regarding language and embodiment.

3. 3. Conclusion

The "biologization" of materials and components allow for integration of artificial, evoneered devices to create real-world cyborgs, and thus allows for yet unachieved benefits for patients. Therefore, biomimetic materials used for implantable meshes are a first step towards total integration of biotechnological devices permanently implanted into living organisms. In many of the examples, one can find relations between the parts that can best be described in biosemiotic terms. Not only do biomimetic materials lead to less side-effects in terms of tissue integrity, overall tolerability, and specific immune reactions towards the inserted device, they also enable two-way communication based on molecular codes. The deeper the integration is, the higher the compatibility of the device must be with underlying rules, e.g., physiological and neuronal codes (Barbieri 2006, 2015, Bruni 2007). Only if the device becomes part of a triadic relation involving biomolecules from the host (device carrier), i.e., code-wise, will it be evolvable and fully accessible to the device-carrier including in means of acts of languaging (thus contrasting with inert mechanical appendages). So called *bionic manufacturing* (Srivastava and Yadav 2018) might further enhance the materials used for the cyborg interfaces and possibly increase the degrees of freedom, technically speaking and, biosemiotically speaking, its meaning potential. Ready-to-use cyborg-organoids may be available in the not so far future (Li *et al.* 2019) that are not only highly compatible regarding organic codes (amendable to *Peircean* description), but which might already be built in vitro from a patients´ own stem cells and allow thus total integration.

The *process* of action execution by the device, and feedback integration by its carrier, does not only resemble languaging, but is actually its molecular, and mechanically extended, complement. The efforts taken in this field can be considered successful partly because languaging does not require representation. More than obvious, the brain speaks electrically, and the presented cyborg examples show how astonishingly "simple" interfacing can be in a cyborg's world. In this extraordinary context, the brain itself, and particular in respect to cognition, appears to be devoid of adaptors and representations in a narrow sense.

4. Going full circle: The Languaging Cyborg

As stated in the introduction, the paper thematises the generative basis of languaging and, more specifically, how the biological information of first order consensual coordination can be seen as continuous with the conceptual information involved in languaging. In this connection, the case of evoneering turns out to be of considerable value given that it showcases how aspects of languaging are inseparable from first order activity. It now becomes possible to go full circle by not just acknowledging (as do Clark and Maturana) that languaging potentially allows for the design of smart devices but also that such devices can be integrated on the biochemical level in organisms and, consequently, form part of languaging's substrate. To put it simply, it is through languaging activities that humans come to observe the world thus allowing for us to tweak or re-design it (including our own organism) by developing implants, prostheses etcetera. At the same time, however, it is these very same redesigns that we come to integrate into the substrate of our languaging activities which thus also comes to shape the practices we partake in.

While Maturana uses the term *domain* to denote qualitatively different relations between organisms, we prefer his term *praxis* which is not theoretically laden to the same extent given that it functions as a basic descriptor of activity or, to paraphrase Maturana, «what one does» (Maturana 1988: 31). What we want to emphasise at this point is that doings associated with a praxis (such as that of second order consensual coordination, or languaging) are not restricted to a particular level of organization but rather characterise us as who we are, what we do etcetera. As such, it unfolds across the scales of living organisms while, at the same, extending beyond the individual language-user to members of the same species, members of the same practice, individuals with similar knowhow, ontogenesis etcetera, while overall being deeply embedded within the physiological reality of its user/doer. In the case of bio-tech interactions, we have aimed to show this in the different examples above. For whether considering the basic modification of nanofibers or a particular cyborg's emergent controlling capacities of an implant device, the case remains the same: although no meaning (in Shannon's sense of *content*) is conveyed, a meaning potential nevertheless emerges from the relations that unfold recursively in the bio-tech domain internal to a given organism precisely because it is connected with a praxis that is shared with a higher order of consensual coordination. On the local scale, transmitted electronic signals allow the agent to explore a movement potential related to, for instance, a prosthesis. Yet, it also comes with another, higher meaning potential in that such movements either are or may come to be imbued with practical significance. In the case of the first order coordination between the agent and a device, the potential first and foremost conflates with coordination between brain signals and the movements of a prosthesis. Yet, it is important to note that we're here only considering one out of many organizational layers that are mutually constitutive and enabling for the emergence of languaging activity. Indeed, the gradual mastery of basic movements actualises the meaning potential which eventually grants access to a meaning potential of a higher order: the mastery of expressive movements (e.g., gestures) or complete gestures with socio-practical significance (e.g., speaking, sign language, running, pointing, waving etcetera) having, at least in principle, a global outreach (i.e., in the sense that they can be repeated across contexts) and a conceptual dimension (i.e., they can be named as specific types of movements). Here, the praxis comes to influence what the biotechnologically enhanced agent is capable of doing thanks to a merged device which forms part of the substrate of the agent's wholly embodied languaging abilities.

Given the mix of first order (in- and externally to the agent's evoneered embodiment) and second order consensual coordination (or languaging) which, as Maturana argues may even comprise basic concept-based perception in the absence of an interlocutor (cf. Gahrn-Andersen 2019b), the case of the evoneered organism comes to exemplify the deep continuity between life, mind and language (and human technology). Crucially, biotechnologically aided activity not only resembles languaging but, once mastered to meet socio-practical expectations, they can also be considered as extending the agent's languaging abilities.

Drawing on insights from Bruno Latour, Gahrn-Andersen (*Ibidem*) identifies the denotative dimension of language-use as being of vital importance to not just linguistic meaning-making but also for our basic capacity to engage in human-style socio-material practices. The possibility of engaging in languaging is foundational to the kinds of societies that we humans have come to build and habituate as well as the technologies we engineer. In this connection, we fundamentally agree with Clark's observation that

> the deepest contribution of speech and language to human thought, however, may be something so large and fundamental that it is sometimes hard to see it at all! For it is our linguistic capacities, I have long suspected, that allow us to think and reason about our own thinking and reasoning. And it is this capacity, in turn, that may have been the crucial foot-in-the-door for the culturally transmitted process of designer-environment construction: the process of deliberately building better worlds to think in. (Clark 2003: 78).

Clark's point is supported by Maturana (1988) who evokes reference to "languaging" as a means for describing a distinctive kind of human-specific activity that unfolds as second-order consensual coordination. Languaging, he informs us, gives rise to not just our capacity for observing (which is needed in order to plan projects, design technologies etc.) but also to engage in qualitatively different kinds of recursivity and consensuality compared to those of other species and pre-linguistic humans. On the view of Latour and Gahrn-Andersen, this exemplifies the fundamentally global outreach of human practices. Gahrn-Andersen writes:

> human sociality should be seen as different from the flat ontology of primate societies in that it is irreducible to the localised. Socio-material reality encompasses global structures that are spread in time and revolve around material objects and technologies. Thus, human sociality and language are fundamentally multi-scalar. (Gahrn-Andersen 2019a: 181).

"Global" should here be understood in the sense of our socio-material engagements being irreducible to localised interactions bound to a particular territory or spatio-temporal realm. On the contrary, thanks to the denotative dimension of enlanguaged cognition, we can make sense of artefacts, objects etcetera across situation (i.e., on a global scale) as we draw diachronically on our conceptual knowhow.

Interestingly, it appears that content-vehicle distinctions are useless in this context, in particular on the device side, and at the direct human-device interface. Such devices allow for a meta-mimetic dimension that is saturated by the praxis in which the activity unfolds. For instance, moving a prosthesis at random has an unfulfilled meaning potential on the global level of human praxis which can be actualised through recursive coordination in accordance with societal and/or practice-specific norms thus effectively actualizing a new meaning potential – a process which can roughly be cashed out as follows: random movements → fully controlled movements (e.g., speaking, sign languaging, running, pointing, waving) → realizing socio-practical meaning potential (e.g., uttering a friend's name, expressing a friend's name through sign language, running towards the door, pointing at a cup of coffee, waving at someone).
In conclusion, the field of cyborg research itself could benefit from biosemiotics and the languaging perspective outlined in this paper. In a philosophical treatment of robots and cyborgs, Emma Palese asks, whether we have a body or whether we are a body (Palese 2012). From the point we present here, the answer is clearly, we are the body we have, which will include any cyborg device the deeper the biosemiotics integration is.

References

Auletta, Gennaro (2011), *Cognitive Biology: Dealing with Information from Bacteria to Minds*, Oxford University Press, Oxford.

Barbieri, Marcello (2006), «Life and semiosis: The real nature of information and meaning», in *Semiotica*, vol. 158, pp. 233-254.

Barbieri, Marcello (2008), «The Code Model of Semiosis: The First Steps Toward a Scientific Biosemiotics», in *The American Journal of Semiotics,* vol. 24, 1–3, pp. 23-37.

Barbieri, Marcello (2015), *Code Biology. A New Science of Life*, Springer, London.

Barfield, Woodrow, Williams, Alexander (2017), «Cyborgs and Enhancement Technology», in *Philosophies*, vol. 2, n. 1. DOI: https://doi.org/10.3390/philosophies2010004

Bruni, Luis E. (2007), *Cellular Semiotics and Signal Transduction*, in Barbieri, Marcello, ed. by, *Introduction to Biosemiotics. The New Biological Synthesis*, Springer, London.

Buzsáki, György (2006), *Rhythms of the Brain*, Oxford University Press, Oxford.

Buzsáki, György (2019), *The Brain from Inside Out*, Oxford University Press, Oxford.

Clark, Andy (2003), *Natural-Born Cyborgs: Minds, Technologies, and the Future of Human Intelligence*, Oxford University Press, Oxford.

Cowley, Stephen J., Markos, Anton (2019), «Evolution, lineages and human language», in *Language Sciences*, vol. 71, pp. 8-18.

Duan, Xiaojie, *et al.* (2013), «Nanoelectronics-biology frontier: From nanoscopic probes for action potential recording in live cells to three-dimensional cyborg tissues», in *Nano Today*, vol. 8, n. 4, pp. 351-373.

Edelman, Bradley J., *et al.* (2019). «Noninvasive neuroimaging enhances continuous neural tracking for robotic device control», in *Science Robotics*, vol. 4, issue 31, DOI: 10.1126/scirobotics.aaw6844.

Even-Chen, Nir, *et al.* (2020), «Power-saving design opportunities for wireless intracortical brain–computer interfaces», in *Nature Biomedical Engineering*, vol. 4, pp. 984-996.

Feiner, Ron, Dvir, Tal (2020), «Engineering Smart Hybrid Tissues with Built-In Electronics», in *iScience*, vol. 23, n. 2, https://www.sciencedirect.com/science/article/pii/S258900422030016X.

Gahrn-Andersen, Rasmus (in press), «Concrete Concepts in Basic Perception», in *Philosophia*.

Gahrn-Andersen, Rasmus (2019a), «But language too is material!», in *Phenomenology and the Cognitive Sciences*, vol. 18, n. 1, pp. 169-183.

Gahrn-Andersen, Rasmus (2019b), «Interactivity and Languaging: How humans use existential meaning», in *Chinese Semiotic Studies*, vol. 15, n. 4, pp. 653-674.

Gray, Mark, *et al.* (2018), «Implantable biosensors and their contribution to the future of precision medicine», in *The Veterinary Journal*, vol. 239, pp. 21-29.

Guattari, Félix (1992), *Chaosmosis an ethico-aesthetic paradigm*, Indiana University Press, Bloomington-Indianapolis.

Hong, Guosong, *et al.* (2018), «Mesh electronics: a new paradigm for tissue-like brain probes», in *Curr Opin Neurobiol*, vol. 50, pp. 33-41.

Kravchenko, Alexander V. (2007), «Essential properties of language, or, why language is not a code», in *Language Sciences*, vol. 29, pp. 650-671.

Kravchenko, Alexander V. (2020), «A critique of barbieri's code biology», in *Constructivist Foundations*, vol. 15, nr. 2, pp. 122-134.

Latour, Bruno (1996), «On Interobjectivity», in *Mind, Culture, and Activity*, vol. 3, n. 4, pp. 228-245.

Lee, Hongmi, Kuhl, Brice A. (2016), «Reconstructing Perceived and Retrieved Faces from Activity Patterns in Lateral Parietal Cortex», in *J Neurosci*, vol. 36, n. 22, pp. 6069-6082.

Lee, Jae-Hyun, *et al.* (2016), «Spontaneous Internalization of Cell Penetrating Peptide-Modified Nanowires into Primary Neurons», in *Nano Letters*, vol. 16, n. 2, pp. 1509-1513.

Li, Guangye, Zhang, Dingguo (2016), «Brain-Computer Interface Controlled Cyborg: Establishing a Functional Information Transfer Pathway from Human Brain to Cockroach Brain», in *PLoS One*, vol. 11, n. 3, https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0150667.

Li, Qiang, *et al.* (2019), «Cyborg Organoids: Implantation of Nanoelectronics via Organogenesis for Tissue-Wide Electrophysiology», in *Nano Letters*, vol. 19, n. 8, pp. 5781-5789.

Mastinu, Enzo, *et al.* (2020), «Neural feedback strategies to improve grasping coordination in neuromusculoskeletal prostheses», in *Scientific Reports*, vol. 10, n. 1, https://www.nature.com/articles/s41598-020-67985-5.

Maturana, Humberto R. (1988), «Reality: The search for objectivity or the quest for a compelling argument», in *The Irish Journal of Psychology*, vol. 9, n. 1, pp. 25-82.

Ortiz-Catalan, Max, *et al.* (2020), «Self-Contained Neuromusculoskeletal Arm Prostheses», in *New England Journal of Medicine*, vol. 382, n. 18, pp. 1732-1738.

Osumi, Michihiro, *et al.* (2019), «Characteristics of Phantom Limb Pain Alleviated with Virtual Reality Rehabilitation», in *Pain Med*, vol. 20, n. 5, pp. 1038-1046.

Palese, Emma (2012), «Robots and cyborgs: to be or to have a body?», in *Poiesis & praxis: international journal of ethics of science and technology assessment*, vol. 8, n. 4, pp. 191-196.

Patolsky, Fernando, *et al.* (2006), «Detection, Stimulation, and Inhibition of Neuronal Signals with High-Density Nanowire Transistor Arrays», in *Science* vol. 313, n. 5790, pp. 1100-1104.

Raimondi, Vincenzo (2019), «The bio-logic of languaging and its epistemological background», in *Language Sciences*, vol. 71, pp. 19-26, DOI: 10.1016/j.langsci.2018.03.003

Raimondi, Vincenzo (2014), «Social interaction, languaging and the operational conditions for the emergence of observing», in *Frontiers in Psychology*, n. 5, https://www.frontiersin.org/articles/10.3389/fpsyg.2014.00899/full

Ramoğlu, Muhammet (2019), «Cyborg-Computer Interaction: Designing New Senses», in *The Design Journal*, vol. 22(sup1), pp. 1215-1225.

Rizzuti, Mafalda, *et al.* (2015), «Therapeutic applications of the cell-penetrating HIV-1 Tat peptide», in *Drug Discov Today*, vol. 20, n. 1, pp. 76-85.

Ruckh, Timothy T., Clark, Heather A. (2014), «Implantable nanosensors: toward continuous physiologic monitoring», in *Analytical chemistry*, vol. 86, n. 3, pp. 1314-1323.

Shannon, Claude A. (2001), «Mathematical Theory of Communication», in *Mobile Computing and Communications Review*, vol. 5, n. 1, pp. 3-55.

Shen, Guohan, *et al.* (2019a), «End-to-End Deep Image Reconstruction From Human Brain Activity», in *Frontiers in Computational Neuroscience*, vol. 13, n. 21, DOI: 10.3389 /fncom.2019.00021

Shen, Guohua, *et al.* (2019b), «Deep image reconstruction from human brain activity», in *PLOS Computational Biology*, vol. 15, n. 1, DOI: https://doi.org/10.1371/journal.pcbi.1006633

Siegmund, Janet, *et al.* (2020), «Studying programming in the neuroage», in *Communications of the ACM* vol. 63, n. 6, pp. 30-34.

Srivastava, Sarvesh K., Yadav, Vikramaditya G. (2018), «Bionic Manufacturing: Towards Cyborg Cells and Sentient Microbots», in *Trends Biotechnol*, vol. 36, n. 5, pp. 483-487.

Villa, Alessandro (2008), «Neural Coding in the Neuroheuristic Perspective. The Codes of Life - The Rules of Macroevolution», in *Biosemiotics*, vol. 1, pp. 357-377.

Yetisen, Ali K. (2018), «Biohacking», in *Trends Biotechnol*, vol. 36, n. 8, pp. 744-747.

Zahid, Maliha, Robbins, Paul D. (2015), «Cell-type specific penetrating peptides: therapeutic promises and challenges», in *Molecules*, vol. 20, n. 7, pp. 13055-13070.