Constraint satisfaction, agency and meaning generation as an evolutionary framework for a constructive biosemiotics

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Abstract
Biosemiotics deal with the study of signs and meanings in living entities. Constructivism considers human knowledge as internally constructed by sense making rather than passively reflecting a pre-existing reality. Consequently, a constructivist perspective on biosemiotics leads to look at an internal active construction of meaning in living entities from basic life to humans.
That subject is addressed with an existing tool: the Meaning Generator System (MGS) which is a system submitted to an internal constraint related to the nature of the agent containing it (biological or artificial). Simple organisms generate meanings to satisfy a "stay alive" constraint. More complex living entities manage meaningful representations with more elaborated constraints. The generated meanings are used by the agents to implement actions aimed at satisfying the constraints. The actions can be physical, biological or mental and take place in the agent or in its environment.
The case of human agency is introduced with meaningful representations that may have allowed our ancestors to become self-conscious by representing themselves as existing entities. This paper proposes to use the MGS as a thread to address the above items linking biosemiotics to constructivism with relations to normativity, agency and autonomy. Possible continuations are introduced.

Keywords
meaning, constraint, representation, Meaning Generator System, biosemiotics, constructivism, agent, evolution, normativity, autonomy, self-consciousness, anxiety.

1. Introduction

The purpose of this paper is to present a constructivist perspective of biosemiotics by focusing on meaning generation where "meanings" are generated by and for living entities in order to satisfy internal constraints. Organisms are then agents that internally construct their relations with the world, thus they can be studied following a constructivist approach.
We begin by recalling how meaning generation is related to both biosemiotics and constructivism.
A simple example of meaning generation for a "stay alive" constraint satisfaction leads to an elementary model of meaning generation and brings to position constraint, meaning and action relatively to each other. The meaning Generator System (MGS) already introduced in previous papers[1]is presented as part of an agent in an evolutionary perspective. The MGS offers a link between biosemiotics and constructivism and has also a potential link with the Peircean triadic approach to semiotics.
In this paper I discuss the relations of the MGS with normativity, autonomy, agency and action. Then I present the evolutionary factors that have possibly resulted in the development of self-consciousness in humans. This evolutionary scenario accounts for the MGS and introduces human specific constraints related to anxiety management.
At the end conclusions and perspectives for future studies are provided.

2. "Meaning" as a key notion for biosemiotics and for constructivism

The term "meaning" has its most widespread use in ordinary language, in philosophy of language and in linguistics. We use it here in an evolutionary background where language comes in at the human level of evolution and is not a prerequisit.
Biosemiotics and constructivism both focus on meaning generation in agents.
Constructivism emphasizes active role of humans in the learning process, where the learner "constructs" meanings through his/her learning experience [Ballard 2003]. Constructivism considers humans as builders of their knowledge rather than just receivers of pre-existing information on the status of the world. Knowledge is constructed by agents who are also sense makers or meaning generators.
Biosemiotics is the study of meaning-making and its consequences in living systems [Kull, Favareau 2017]. In his 1940 book Jacob Von Uexküll presents the concept of Umwelt as a subjective universe where "The question of meaning is, therefore, the crucial one to all living beings" [Von Uexküll 1940, 1982].
The Umwelt is the meaningful world for an organism, i.e. the perceptual world in which the organism exists and acts as a subject. In biological organisms control processes originate within organisms. Uexküll considered

[1] *Publications on the MGS [Menant, 2003, 2011]. Presentations of the MGS at Biosemiotics Gatherings [Menant 2002, 2015].*

"meaning" as interconnection between meaning-carrier, meaning-utilizer and meaning-receiver. It appears clear that the Uexküll's theory of meaning is on the constructivist side. Meanings take place in the organism and are not simply acquired from a pre-given external world. As noted by Andreas Weber "Uexküll thus creates a biological constructivism avant la lettre" [Weber 2004].
Uexküll's work has been continued by biosemiotics, an "interdisciplinary science that studies communication and signification in living systems", as a specialized branch of semiotics focusing on communications in living systems [Sharov 1998]. Meaning is a key notion in biosemiotics where the main challenge is to naturalize biological meaning [Sharov et al. 2015].
Several biosemioticians have chosen to use the Peircean semiotics triad (object, sign, interpretant) as a framework for biosemiotics, and considered that "meaning is nothing more and nothing less than the formation of interpretants in the Peircean sense" [Hoffmeyer 2010].
Other authors follow a different approach and consider that meaning making involves polysemy and may include incompatibility. Meaning generation is then poorly predictable and physical modeling becomes mostly inadequate [Kull 2012].
Another option is to apply the Peircean model of semiosis to animals and consider at the level of cells an alternative model of semiosis based on coding rather than on interpretation [Barbieri 2009].
What is proposed in this paper is to use an existing model of meaning generation in a way that combines the Peircean approach with an evolutionary viewpoint. We show that this approach links biosemiotics to constructivism and can be used to address the notions of normativity, autonomy, and agency.
Before presenting the Meaning Generator System it is worth recalling that meanings do not exist by themselves but exist by and for agents. We consider here that meanings are meaningful information generated by agents that have internal constraints to satisfy. When a mouse, submitted to a "stay alive" constraint, sees a cat, the sensed information is connected with the constraint and produces meaningful information: "danger". And this meaning leads to action like hiding or running away in order to satisfy the "stay alive" constraint.

3. "Meaning" and internal constraint satisfaction. The Meaning Generator System (MGS)

3.1. Meaning generation in unicellular organisms and in evolution. The MGS

As said, we use here an evolutionary perspective where meaning generation can exist in any type of agent (animals, humans and artificial agents). The proposed modeling of meaning generation follows a system approach in order to identify what could be the key components of the generation process in an agent.
Biosemiotics encompasses all living systems from the single-cell organisms to humans [Brier 2005]. Following an evolutionary lineage backwards brings us to meaning generation in simple unicellular organisms like paramecia. Paramecium life is bound by the "stay alive" constraint which is the major foundational constraint of all living entities[2].
It has been shown that a drop of acid in the water at the vicinity of a paramecium will make her move away toward a less hostile location [Dryl 1961]. That simple reaction can be used to formalize the notion of meaning for an organism relative to its internal constraints. (This is close to Varela and Hoffmeyer examples of bacteria swimming up a nutrient gradient [Varela 1997, Hoffmeyer 1997]. What a meaning generation process brings in addition is a modeling of the significance of the chemical gradient for the organism). The acidity of the environment as sensed by a paramecium is an incident information that participates in the generation of some meaning within the cell. Figuratively speaking, the meaning is what a paramecium "wants to say": "the environment is becoming too hostile for the satisfaction of the vital constraint". And this meaning then produces an action by the paramecium aimed at putting her away from the acid environment. It is clear that a paramecium does not possess an information processing system to use such an inner language. But she has sensors that participate to the identification of the danger in the environment. The information generated by the sensors evokes processes that propel the paramecium in a direction of less acid water.
We can say that the paramecium has created a meaning related to the hostility of her environment in connection with the satisfaction of a vital constraint. This example highlights several issues related to the notion of meaning generation that we need to explicit for the MGS.
1) A meaning (the environment is becoming hostile versus the satisfaction of a vital constraint) is associated with information (level of acidity in water) which is directed to an entity capable of processing information (the paramecium).
2) Meaning is generated because the entity receiving the information possesses a constraint linked to its nature (vital constraint that is to be satisfied in order to maintain a living nature).
3) Meaning is generated because the incoming information has a connection with the constraint of the entity (too much acid in the water impacts the satisfaction of the vital constraint of the paramecium).

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[2] *We position the internal* constraint *of an agent as characterizing its nature and governing its behavior (see section 3.2.1). Defining life as "the sum of the functions by which death is resisted" [Bichat 1805] brings to consider living organisms as submitted to a "stay alive"* constraint *(individual and species).*

4) “Meaning” is meaningful information relatively to the constraint of the entity (information meaning that the environment becomes hostile versus the satisfaction of the vital constraint).
5) The meaningful information is used to initiate an action (movement towards a less acid location) in order to satisfy the constraint.
These five characteristics introduce a definition of meaning generation in the framework of a relation between an information processing entity submitted to an internal constraint and information received by that entity:
Meaning is meaningful information that is created by an entity submitted to an internal constraint *when it receives information that has a connection with the* constraint. *The meaning is the connection existing between the received information and the* constraint. *The function of the meaningful information is to participate to the determination of an action that will be implemented in order to satisfy the* constraint[3].
In the above example the paramecium receives information, generates meaning and acts.
We want to use that simple example to build a model of meaning generation based on a system approach where a system is a set of components linked by a set of relations, whatever the components and the relations.
For that we need to isolate in our example what is not strictly part of meaning generation, like components associated with sensing and action.
Such system approach leads to the Meaning Generator System (MGS) represented on Fig.1 with the paramecium example.

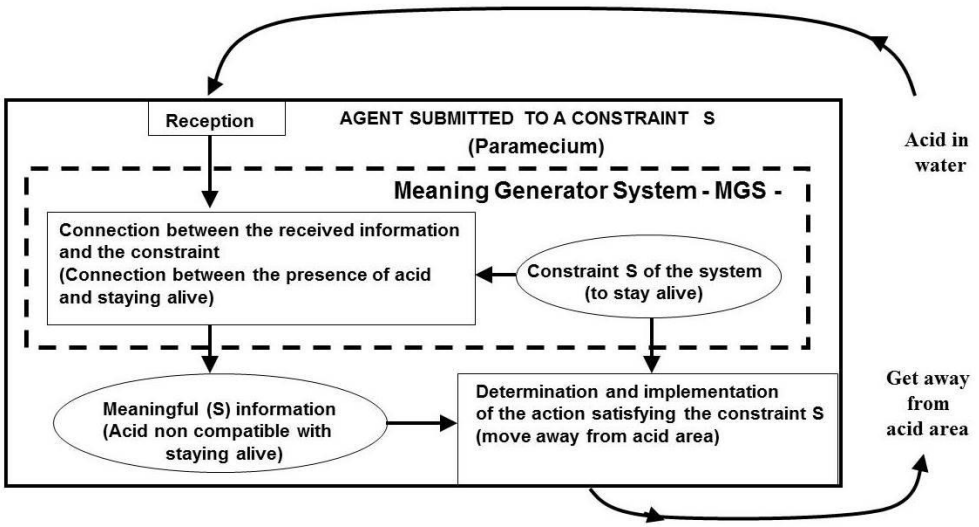

Fig. 1. Meaning Generation in Paramecium

The proposed definition of meaning as generated by a system part of an agent is general and does not depend upon the type of agent (biological, human or artificial). It is a system approach where the agent is an entity submitted to an internal constraint.
The above presentation brings to consider the MGS as a part of biosemiotics as it addresses, in the words of Uexküll, the “question of meaning” which is “the crucial one to all living beings".
The MGS is also close to constructivism as meaning generation is internally done by agents and does not reflect a pre-existing external reality[4] .Thus the MGS highlights the constructivist aspects of biosemiotics.

3.2. Characteristics of the MGS

The MGS as a model for meaning generation has been introduced with a simple example of a unicellular organism submitted to a “stay alive” constraint. Looking at the MGS as part of an agent brings in characteristics that complement the above introduction.

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[3] *Such definition of meaning linking the agent to its environment can be compared to the one presented by [Zlatev 2000] where meaning is defined as “the relationship between an organism and its environment, determined by [...] value”. What comes in addition with the MGS is a formal modeling of meaning generation by a system approach applicable to any type of agent submitted to internal* constraints *[Menant 2003].*
[4] *Meaning generation and action determination in agents can use memorized meaningful information about the environment coming from past experiences.*

3.2.1. The MGS is driven by internal constraint satisfaction

The constraint of the MGS is a constraint of the agent that contains it[5]. Constraints are here internal factors that apply to agents in addition to the physico-chemical laws which apply globally [Pattee, Kull 2009].

The concept of constraint is rich and complex. It is used in different disciplines (physics, chemistry, biology, ...) where it can be summarised by: "constraints refer to certain conditions or rules additional to the laws of dynamics (that are taken as basic), that rule/govern the behaviour of the elements and that arise from the aggregation of those" [Umerez, Mossio 2013]. For the MGS we use "constraints" in a sense close to this last one as: "conditions or rules that characterize the agent and govern its behaviour in addition to basic physico-chemical laws".

The MGS and the agent are local entities. The constraint applies to the agent and does not apply to its environment (in the paramecium example the "stay alive" constraint is applied to the paramecium, not to the water surrounding it).

The MGS allows looking at the agent as building up relations between internal constraint, meaning and action. The constraint produces the meaning that determines the action which will be implemented by the agent to satisfy the constraint. The constraint and the meaning exist before the action which can be internal or external to the agent, and can be physical, biological or mental depending on the nature of the agent. Meanings and actions do not exist by themselves but are part of constraint satisfaction processes in agents.

The internal constraint brings normativity to the agent because the constraint can be satisfied or not depending on whether the nature of the agent is maintained[6].

There are different types of internal constraints which characterize the type of agent containing the MGS. Biological agents are bound by natural constraints like the foundational "stay alive" constraint which applies to individuals and to species. At individual level the constraint leads to actions like avoiding predators or regulating metabolism. At species level the constraint leads to actions like reproducing and saving offspring. Actions implemented to satisfy the constraint may exist only at a given time but the constraint is always active on interactive and survey modes. Also, constraints can be conflicting. For an ant colony to cross water, several ants may sacrifice themselves and get drowned to allow the build up of a bridge usable for the colony. The species constraints are there stronger than the individual ones.

"Live group life" is another constraint that takes into account the integrity of composite agents like multicellular organisms and animals in groups.

Human specific constraints include "limit anxiety" and "look for happiness". These constraints are more complex and linked to the nature of human mind (see section 4).

Artificial agents are submitted to derived constraints that come from the human designer. The distinction between natural and derived constraints makes possible the positioning of artificial intelligence relatively to living organisms and to human mind. Ethical problems associated to artificial agents can be introduced [Menant 2013].

3.2.2. The MGS links agents to their environments

The meaning generation process relates the agent to its environment. What comes from the environment is connected to the constraint of the agent for meaning generation and action determination with implementation on the agent or on the environment. The MGS links the agent to its environment and participates to the build up of its knowledge.

Actions on the environment will modify that environment and correspondingly change the received information and the generated meaning, leading to new actions using at best already memorized experiences. Meaning generation and constraint satisfaction build up a permanently active interacting processes that adapt the agent to its environment[7] and develop the knowledge of the environment. It is clear that such interacting process is agent specific and that the same information received by different agents can produce different meanings (a sound of thunder generates different meanings in people on the beach as compared to people in their houses). Also, information can be already meaningful before being received. For example, alert signals are meaningful for the tribe before being received by members of the tribe where they generate individual meanings. In both cases the generated meanings link the agents (tribe and individuals) to their environments.

The environment of an agent can contain other agents. This brings to look at the MGS as linking agents together. Communication between agents is about exchanges of meaningful information. Different agents will attribute the

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[5] *The* constraint *of the MGS is an internal constraint. It is worth noting that an external constraint refers to the internal constraint that led to the action of considering the external constraint as so. External constraints need internal constraints.*

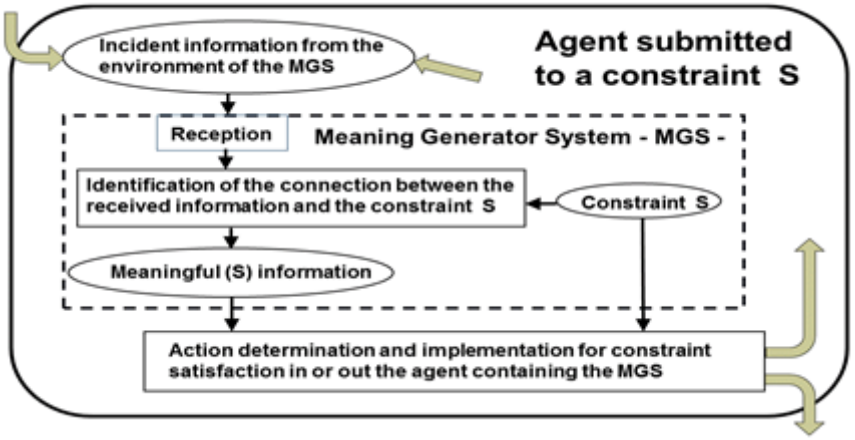
[6] *Another approach to define normativity is to consider the emergence of norms in agents [Barandiaran, Matthew 2014]. Such perspective is different from the one presented here where constraints exist with the agent and are linked to its nature.*

[7] *The adaptive characteristic of the MGS adds to positioning it close to constructivism for which cognition is an adaptive activity [Von Glasersfeld 1999].*

same meaning to a received information if they have similar MGSs and comparable past experiences.
The MGS links agents to other agents of their environments (meaning transmission has been introduced in Menant 2003).

3.2.3. The MGS as part of agents.

As already introduced, meaning generation does not exist by itself but is always related to an agent having a constraint to satisfy. The MGS is part of an agent and the information received by the MGS comes from the agent. But the source of that information can be the environment of the agent or the agent itself. And the action implemented to satisfy the constraint can be on the environment or on the agent itself to adapt internal states[8] (the sight of a predator in the environment will generate the meaning "danger" that can lead to external actions like hide or escape, or lead to an internal action like memorizing the presence of predators at a given location).
The MGS manages internal and external interactivities of the agent.
Figure 2 extends Figure 1 by positioning the MGS as part of an agent where the meaning is generated relatively to the constraint of the agent. The drawing also highlights that the received information can come from the agent or from its environment and that the action can be in or out the agent. The figure recalls the different types of agents with the different types of constraints.
The MGS proposes a modeling of what the meaning is and of what the meaning is for.



*** Animal** constraint**s:**
- *stay alive (individual & species)*
- *live group life.*

* **Human** constraint**s:**
- *Look for happiness*
- *Limit anxiety*
- *Valorize ego,*
- *…*

* **Artificial Agent** constraint**s:**
- *Derived* constraints *(as programmed)*

Fig. 2. Meaning Generator System in agent

The MGS within an agent is linked to other functions like memory, other MGSs, simulations of scenarios, selection of actions and their implementations.
In a given agent the generated meanings are networked into representations [Menant 2011]. Such meaningful representations contain past experiences (including emotions for organic agents). These meaningful representations are compatible with constructivisms and participate to the built up of the agent's cognitive content[9].
We have been so far using the word "agent" without defining it. Agency is a key notion in biosemiotics and its significance is increasing as some biosemioticians propose to shift the focus from living organisms to agents in general [Sharov 2010].
Agents can be items of different natures. The purpose of this section is to use the system approach of the MGS to see if agency can be defined relatively to internal constraint satisfaction and to cover both natural and artificial agents.
Two papers about agency can be outlined in relation to our approach. The first is "Defining Agency: Individuality, Normativity, Asymmetry, and Spatio-temporality in Action" [Barandiaran et al. 2009]. It is proposed in that paper that to be a genuine agent a system must meet three conditions:
a) A system must define its own individuality (...distinguishing itself from its surroundings; in doing so, it defines an environment in which it carries out its actions).
b) It must be the active source of activity in its environment (interactional asymmetry) and
c) It must regulate this activity in relation to certain norms.
These conditions integrate the environment, the action capability and the normativity of agents.

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[8] *Strictly speaking an external action always comes after an internal one. Catching a piece of food is an external action on the environment but it comes after the internal actions commanding the movement of the corresponding muscles.*

[9] *These meaningful representations built up by the agent with the MGS are different from the representations of traditional AI which are made of meaningless symbols [Menant 2011].*

The other paper summarized the results of a questionnaire on the understanding of agency by biosemioticians and concluded that "most respondent agree that core attributes of an agent include goal-directedness, self-governed activity, processing of semiosis and choice of action, with these features being vital for the functioning of the living system in question" [Tønnessen 2015]. These core attributes are close to covering the three conditions of the first paper: difference versus environment, action capability and normativity.
The consistency of the constraint satisfaction process of the MGS with the analysis of agency in the two papers brings us to define an agent as "an identifiable entity submitted to internal constraints and capable of actions for the satisfaction of the constraints". This definition does not depend upon the type of agent and applies to all types: organisms with natural (intrinsic) constraints and artificial agents with derived constraints. Such definition for agency based on internal constraint satisfaction brings to look at what could have been present at pre-biotic times in terms of local constraint, introducing a possible pre-biotic agency. Even if it is difficult to address the concept of agency when only inert matter is present it is possible to consider in that case a defined volume in a far from thermodynamic equilibrium. Such volumes exist but do not last (ex: tornadoes, fires). What looks worth being investigated is the concept of local constraint maintaining such local status (see continuations).
Among the features of agents, autonomy is one of the most important. Autonomy is a rich and complex notion which is discussed in various disciplines such as biology, philosophy, evolution and artificial intelligence. An autonomous agent can be defined as "a system able to act on its own behalf" (Kauffman, Clayton 2006). Such ability to act using its own tools and resources is implemented differently in plants, animals, humans and artificial agents. Plants and animals are autonomous agents as they can satisfy their vital constraints without external help. Humans possess a higher level of autonomy as they can, in addition, consciously choose their actions and decide freely to implement them. Artificial agents display autonomy by action management based on the programmed resources and tools they carry. Looking at autonomy with a focus on actions informs us about what the agent can do but it does not tell much about what the agent is, about its nature. This highlights the interest for using internal constraints in defining autonomy because the constraints are related to the nature of the agent and are part of the meaning generation leading to action determination.
This brings us to propose defining an autonomous agent as "a system able to act to satisfy its internal constraints by its own". Including the constraint in the definition tells about the agent and about the reason of being of the action.

3.2.4. Comparison of the MGS with other approaches.

The MGS is compatible with the animal part of evolutionary theory because the satisfaction of the constraints of living entities is part of natural selection (stay-alive constraints). Also, the constraints and the data processing functions can be considered as aspects of the evolution of the agents. Regarding human evolution, other constraints come in addition to the animal ones. Section 4 proposes an evolutionary scenario introducing specific human constraint.
The MGS has also some compatibility with the Peircean triadic approach where it can be related to a simplified version of the Interpreter leading to the Interpretant[10].
The MGS can be used for artificial intelligence where agents are submitted to derived constraints coming from the human designer. Such approach based on internal constraints brings to highlight ethical concerns [Menant 2013]. In all cases the generated meaning is constraint dependent. More generally, the MGS can be used for all agents submitted to internal constraints, assuming we have a clear enough understanding of these constraints.
Regarding enaction there are some questions when trying to position the MGS approach relatively to the enactive one. There is some concern about the reluctance of enaction to consider the concept of representation that is needed in the MGS approach. Also, it is difficult to link the MGS to the prominent position of lived experience attached to enaction. The MGS is usable for animals, humans and AAs. And the performances of today AAs are far from the ones of living entities. The gap comes from our lack of understanding about the nature of life which may request to look for "something unknown" in our models for understanding the nature of life. We might currently "be missing something fundamental and currently unimagined in our models of biology" [Brooks 2001]. These compatibility concerns have been presented with more details in [Menant, 2011].
The compatibility of the MGS with biosemiotics and with constructivism has been developed in the previous sections. In addition, it may be interesting to look at what an approach based on constraints (like the MGS) can bring to an action oriented one (like constructivism). A general perspective could be about the MGS bringing to constructivism relations between information, constraint, meaning, action, autonomy and agency. An application could be the possibility for an internal build up of knowledge based on relations between internal constraint, meaning and action (see continuations).

4. <u>Biosemiotics, meaning generation and self-consciousness. Anxiety management and constructivism</u>

Biosemiotics encompasses all living systems, including humans. Thus, positioning the MGS as part of

[10] *Peirce defined the Interpretant as "something created in the mind of the Interpreter", the Interpretant being Peirce's term for the meaning of a sign [Noth 1990].*

biosemiotics brings to look at how it can be used for humans, more precisely for human consciousness in an evolutionary perspective. Such approach to human mind using the MGS is naturally linked to constructivism by the links between human motivation and constraints. The science of consciousness is an active domain of research addressing different types of consciousness among which we favor here self-consciousness as it appears specific to humans. Evolutionary approaches currently occupy a modest place in the science of consciousness. This is partially due to the fact that at the end of the 20th century the philosophy of mind was focusing on phenomenological approaches, where evolutionary explanations of consciousness were viewed as a hard problem [Polger, Flanagan 1999].

In the same context it is also worth noticing that at the end of the 20th century the study of self-consciousness "has fallen on hard times. Though once regarded as the very essence of mind, most philosophers and psychologists today treat it as a marginal and derivative phenomenon" [van Gulick 1988]. But the beginning of the 21st century has opened new perspectives where self-consciousness is becoming a subject of interest in multiple disciplines [Crone et al. 2012]. Some authors discuss human self-representations [Vosgerau 2009]. Others take evolution into account [Carruthers et al. 2012, Menant 2014a]. We consider these developments as a comeback of self-consciousness in philosophy of mind and present here an evolutionary scenario based on meaningful representations and anxiety management[11].

The scenario starts at the level of our non self-conscious primate ancestors[12] and reaches an elementary version of self-consciousness by associating meaningful representations to the evolution of intersubjectivity[13].

The scenario is presented on Fig. 3 and can be summarized as follows (more detailed presentation at Menant 2014a, b):

Our non self-conscious pre-human ancestors had representations of their conspecifics as global entities existing in the environment. Our ancestors had partial representations of themselves (seen parts of the body, heard shouting, perceived actions, ...) that we call "auto-representation".

We consider that the intersubjectivity among our ancestors has evolved into an identification with conspecifics that has led them to tune some aspects of their auto-representations to resemble the representations of conspecifics[14]. More precisely the auto-representation progressively accessed the characteristic of an entity "existing in the environment" which led our ancestors to represent themselves as global entities existing in the environment. We consider that our ancestors becoming progressively aware of themselves as entities existing in the environment have acquired an elementary and primitive version of self-consciousness that we name "ancestral self-consciousness".

The identification with conspecifics has also produced a huge anxiety increase coming from the identifications with suffering or endangered conspecifics[15]. The resulting psychological suffering brought anxiety limitation to become a key constraint for our pre-human ancestors. To limit that anxiety increase our ancestors have developed efforts to support conspecifics and have enriched the efficiency of tools like imitation, communication, and cooperation[16].

This has been a significant behavioral change for our pre-human ancestors when compared to today great apes whose social life is structured more by competition than by cooperation [Tomasello et al. 2005, Tomasello 2016].

The evolutionary benefits produced by the anxiety limitation tools and by the positive feedback on intersubjectivity have progressively built up an evolutionary engine that has powered the evolution from ancestral-self-consciousness to our contemporary human self-consciousness[17].

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[11] This scenario has been partly published [Menant 2011].

[12] Taking primates as a starting point leads to a grounding self-consciousness in life. An understanding of the nature of life is needed to consider the possibility for a grounding of self-consciousness in matter.

[13] It is accepted by the scientific community that our pre-human ancestor were quite similar to today great apes [Bednarik 2003]. They were capable of some level of intersubjectivity as are today great apes.

[14] The expression "'identification with others" comes from psychiatry where it is about modifying the self to resemble the other [Olds 2006]. It has been used with different meanings by primatologists [Tomasello 2000, DeWaal 2008] and by linguists [Zlatev et al. 2005]. We use that term here for our pre-human ancestors with a meaning close to its original one by using 'auto-representation' in place of 'self''.

[15] That anxiety came in addition to normal anxiety which is a positive emotion that has been shaped by natural selection to allow early alerts against threats [Marks & Nesse 1994].

[16] The scenario also proposes that the sufferings coming from the huge anxiety increase has been unbearable to some primates that have consequently rejected the development of identification with others. These primates went through a very limited evolution to become our today chimpanzee and bonobos [Menant 2011]. Fig. 3.

[17] Such perspective positions the first evolutionary benefits related to self-consciousness as coming from its evolutionary history rather than from performances produced by self-consciousness.

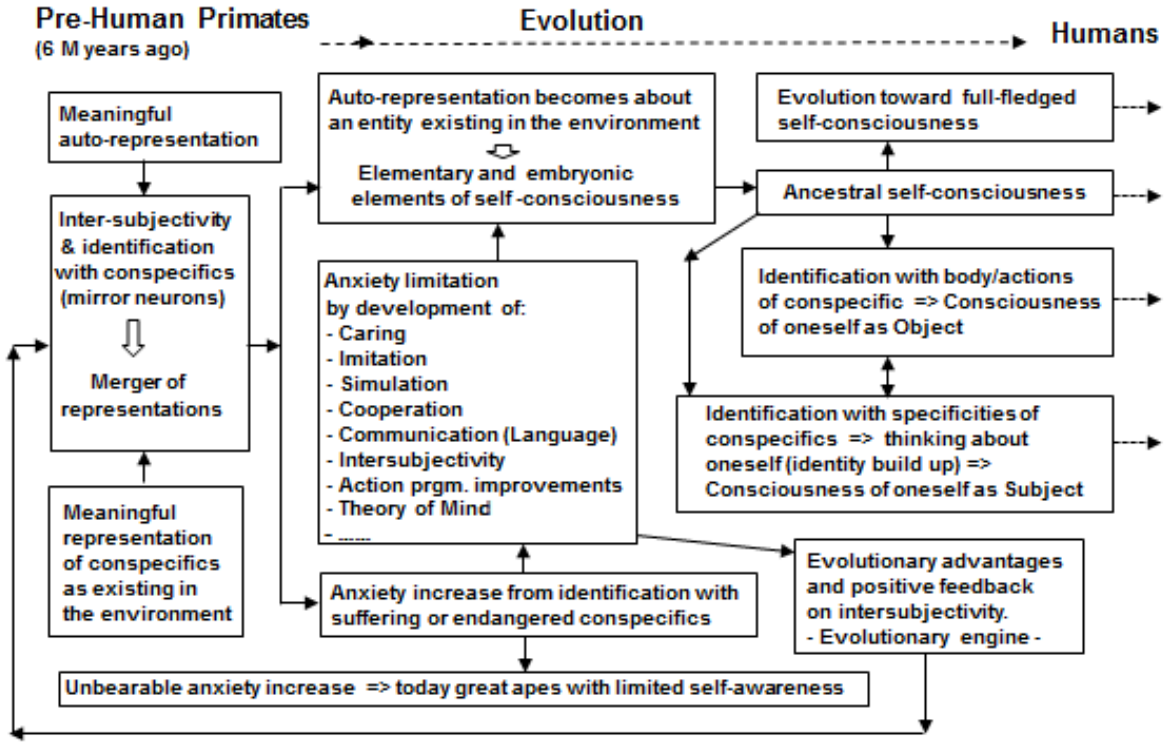

Fig. 3. Evolutionary scenario for self-consciousness

The evolutionary scenario positions ancestral self-consciousness and the constraint of anxiety limitation as both resulting from the development of identification with conspecifics. As our ancestors have limited that anxiety increase by tools offering evolutionary benefits we can say that the evolutionary nature of self-consciousness is interwoven with anxiety limitation processes. In other words, anxiety limitation and self-consciousness share the same human evolutionary history, and to some extend share a common nature. This status is proper to the human phylum. It is new to philosophy of mind and to anthropology and needs more developments (see continuations).
An important point is that anxiety limitation has been acting mostly as a generic constraint during the evolution of human mind. Modes of anxiety limitation implemented by our ancestors have created other anxieties requesting new limitation processes (ex: development of social life). Evolution has transformed anxiety limitations into more elaborated anxiety management processes that are still active in our today human lives, mostly at unconscious level. Some of these processes are not today explicitly related to anxiety management (valorize ego, look for happiness, ..). Identifying these processes with their mechanisms should bring new insights about the nature of human mind and lead to a better understanding of human behaviors [Menant 2018]. These topics are work in process [Menant 2014a, b].
The proposed evolutionary nature of self-consciousness is about one aspect of human mind. Phenomenal consciousness has not been explicitly considered here. More is to come on possible evolutionary relations between self-consciousness and phenomenal consciousness [Menant 2014a]. Work is needed on these subjects as human mind carries enormous challenges for science and philosophy.
Relatively to biosemiotics and constructivism, the evolutionary scenario introduces human constraints and provides connections with the science of consciousness. Also, anxiety limitation as a generic human constraint could introduce a thread for an analysis of motivation by constructivism.

5 Conclusion and continuations

5.1. Conclusion

In the paper we have presented the constructivist aspects of biosemiotics by using a model of meaning generation based on internal constraint satisfaction (the Meaning Generator System).
Meaning generation is viewed as the core of biosemiotics and the MGS is compatible with constructivism because the meaning generation is an internal construction that does not need a pre-existing external meaningful reality. It has been shown that the MGS structure has links with normativity and can help defining agency and autonomy.

The MGS also makes available to biosemiotics and to constructivism relations between information, constraint, meaning, agency, action and autonomy. The system structure of the MGS makes possible to address the evolution of agents relatively to meaning generation. Distinguishing derived constraints from intrinsic ones allows to differentiate and characterize meaning generation in artificial agents and in organisms.
To complete the biosemiotic spectrum of meaning generation up to humans we have presented an evolutionary scenario for a possible nature of self-consciousness. The scenario highlights anxiety limitation as a generic human constraint and positions anxiety management and self-consciousness as sharing the same evolutionary history. That perspective is new. More work is needed on that subject. Some consequences on our understanding of human mind have been introduced.
The scenario also makes available possible connections of biosemiotics and constructivism with the science of consciousness.

5.2. Continuations

Several points in the paper require more work. Some related to an evolutionary approach to self- consciousness have been presented elsewhere [Menant 2014a, b]. Others subjects to look at can be listed as follows:
- Meaning generation in a constructivist perspective for an internal build-up of knowledge based on relations between internal constraints, meaning and action. Links between anxiety limitation and motivations.
- Ancestral self-consciousness as relating biosemiotics to phenomenal consciousness.
- Specificities of human constraints and relations with the ones that can be looked at as extensions of animal ones.
- Future evolutions of human mind based on a better understanding and control of anxiety management (phylogenic and ontogenic aspects).
- Local constraint satisfaction as an evolutionary thread introducing the possibility for a pre-biotic agency (Menant 2017).
- Progresses on researches about the nature of life for a grounding of autonomy and self-consciousness.

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