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Semiosis is cognitive niche construction

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Abstract: Here we describe Peircean post-1903 semiosis as a processualist conception of meaning, and relate it to contemporary active externalism in Philosophy of Cognitive Science, especially through the notion of cognitive niche construction. In particular, we shall consider the possibility of integrating (a) the understanding of "semiosis as process" within Peirce's mature semiotics with (b) an elaboration of the concept of cognitive niche from the point of view of niche construction theory and process biology research.

Keywords: semiosis, cognitive niche construction, process philosophy, C. S. Peirce

1 Introduction – semiosis is cognitive niche construction

Here we describe Peircean post-1903 semiosis as a processualist conception of meaning, and relate it to contemporary active externalism in Philosophy of Cognitive Science, especially through the notion of cognitive niche construction. We shall consider the possibility of integrating (a) the understanding of "semiosis as process" within Peirce's mature semiotics with (b) an elaboration of the concept of cognitive niche from the point of view of niche construction theory and process biology research (see Nicholson and Dupré 2018, for an introduction to this field).

Situated cognition, distributed cognition, and the "4E" paradigm (Hutchins 1995; Clark 2008; Clark and Chalmers 1998; Wheeler 2005; Kirsh 2009; Menary 2010) are positions that attack cognitive internalism by claiming that cognitive processes as they happen "in the wild" are not brain-bound information processing, but also integrate perceptual and motor systems, non-biological material inside and outside of the body, and are decisively integrated in social, multi-agent contexts. In another paper, we have argued that Peirce can be seen as a precursor of anti-internalism and distributed cognition thesis (see Atã and Queiroz 2014).

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The notion of cognitive niche construction, formulated in the context of anti-internalist Philosophy of Cognitive Science, can serve as a *locus* of observation for Peirce's processualist semiosis.

2 Semioses as processes

Peirce's late (post-1903) doctrine of signs is processualist. Processualism refers to the application of a philosophy (ontology and epistemology) of processes, as opposed to a philosophy of substances. Processes are coordinated occurrences of changes in reality (Rescher 1996). A process ontology stresses relational and emergent properties, and stresses change as more fundamental than stability. The contrasting notion is of substance ontology. Substances are stable and internally undifferentiated building blocks of reality. Substance ontology stresses properties as intrinsically possessed by substances, and stresses stability as more fundamental than change (Bickhard 2011; Seibt 2012).

Process ontology stresses the centrality of time and ubiquity change, so that the question "why change happens?" becomes less relevant than the question "why stability happens" or "why is there some regularity or stability in change?." In Peircean semiotics, one central concept that captures this processualist concern is the notion of habit (Atã and Queiroz 2016; Määttänen 2010). A habit is a "pattern of constraints," a "conditional proposition" stating that certain things would happen under specific circumstances (EP 2: 388), a "rule of action" (CP 5.397, 2.643), a disposition to act in certain ways under certain circumstances, especially when the carrier of the habit is stimulated, animated, or guided by certain motives (CP 5.480), or, simply, a "permanence of some relation" (CP 1.415). A habit is a regularity and implies some degree of stability. In Peircean philosophy, acquisition of stable regularities is described as a process of "taking habits," which is probabilistic and cumulative:

> ... all things have a tendency to take habits. For atoms and their parts, molecules and groups of molecules, and in short every conceivable real object, there is a greater probability of acting as on a former like occasion than otherwise. This tendency itself constitutes a regularity, and is continually on the increase. In looking back into the past we are looking toward periods when it was a less and less decided tendency. But its own essential nature is to grow. It is a generalizing tendency; it causes actions in the future to follow some generalization of past actions; and this tendency is itself something capable of similar generalizations; and thus, it is self generative. (CP 1.409, circa 1890, from "A guess at the riddle," reprinted in EP 1: 277)

This view of change and stability through accumulation of self-generated probabilistic regularities is at the core of the process of semiosis, since "what a thing means is simply what habits it involves" (CP 5.400). This corresponds to a process-ontological basis for semiosis. One consequence is that Peirce's late semiotics does not focus on the "sign" as a substantial unit, but on "semiosis," the process or action of signs (Fisch 1986: 330). Accordingly, "meaning" in semiosis is not a property of some sign, and it is not to be found in a medium of transmission, nor in a referent, nor in the head of an utterer or of an interpreter (as an intracraneal or neuronally-based system of signs, for example).

For Rosenthal (1994: 27), meanings should be understood as relational structures that *emerge* from patterns of behavior. The term "emergence" is frequently employed in an intuitive and ordinary way, referring to the idea of a "creation of new properties." In a technical sense, "emergent" properties can be understood as a class of higher-level properties related in a certain way to the microstructure of a system. A number of investigators maintain that meaning must be considered in terms of complex emergent properties, in self-organizing adaptive systems (see Loula et al. 2010; Port 2009; Bickhard 2007; Steels 2000, Steels 2003; Wagner et al. 2003; Christiansen and Kirby 2003; Cangelosi and Turner 2002; MacLennan 2001; Vogt 2002; Briscoe 1998; Merrell 1997; Hutchins and Hazlehurst 1995). As Kelso (1995: 1) argues, "symbols, like the whirlpools in a river, may evince relatively stable patterns or structures that persist for a certain lapse of time, but actually they are neither static nor atemporal."

Semiosis is emergent (Queiroz and El-Hani 2006a, Queiroz and El-Hani 2006b; Gomes et al. 2007; Loula and Queiroz 2011). It corresponds to a consistent relationship between S, O and I which is not reducible to properties of these three terms. Sign, object and interpretant are functional roles of this triadic irreducible relationship. In a pragmatic level, we can characterize these functional roles according to a communicational framework. The internal relationships in the S-O-I triad are "the same theoretical relationships" (MS 318; see Ransdell 1977) as between an utterer, a sign, and an interpreter in a communication act – "[i]t is convenient to speak as if the sign originated with an utterer and determined its interpretant in the mind of an interpreter" (MS 318: 11; see Bergman 2009). Under this communicational description, the sign is seen as a "medium of communication":

> ... a Sign may be defined as a Medium for the communication of a Form ... As a medium, the Sign is essentially in a triadic relation, to its Object which determines it, and to its Interpretant which it determines ... That which is communicated from the Object through the Sign to the Interpretant is a Form; that is to say, it is nothing like an existent, but is a power, is the fact that something would happen under certain conditions. (MS 793: 1–3. See EP 2: 544, n.22, for a slightly different version)

According to this description, semiosis is a consistent relationship between variations in the form[1] of an object (O) and the corresponding effects on an interpreter (interpretants – I), with this O-I relationship being determined by the mediation of a sign (S). This corresponds to a communicational process of self-organization or self-correction between S-O-I: the behavior of an interpreter is constrained by the sign to be in some coordination with the form ("rule of action") of an object (Queiroz et al. 2008).

Semiosis in a processual ontology also involves an embodied-situated view. As a process, the action of signs needs to be spatiotemporally instantiated and realized. Thus, if a sign is to have any active mode of being, it must be materially embodied (or, at least, it results from a previous operation with material signs; Emmeche 2003: 317). Peirce can be considered a precursor of embodied-situated cognition. For Peirce, mind is semiosis in a materially embodied form, and cognition is the development of available semiotic artifacts in which it is embodied as a power to produce interpretants. It takes the form of development of semiotic artifacts, such as writing tools, instruments of observation, notational systems, languages, and so forth, as stressed by Skagestad (1999, 2004) and Ransdell (2003) with respect to the concept of "intelligence augmentation." As Kirsh (2009: 297) stresses, "Peirce first mentioned this idea – that people use external objects to think with – in the late nineteenth century, when he said that chemist think as much with their test tubes as with pen and paper."

Semiosis doesn't include only concepts, but also events and qualities. Just as it is impossible to think without signs, so also thought itself is impossible without the material incorporation of some active component of the world. Semiosis exhibits a rich variety of morphological patterns. The morphological space of semiotic processes in which cognitive systems are embedded includes proto-symbols (quasi-symbolic structures) and variations of indexical signs, besides iconic processes (images, diagrams, metaphors). The icon is an important component in Peirce's semiotic view of mind, because it embeds a kind of signification especially dependent on the material of which the sign is made (Atã and Queiroz 2013).

In sum, Peirce's processual philosophy conceives of semiosis as an emergent pattern of organization or coordination of habits. This process is embodied-situated, cumulative and self-organized, and communicational. That is, it needs

1 For Peirce, form is nothing like a "thing" (de Tienne 2003), but something that is embodied in the object (EP 2: 544, n. 22) as a "real potential" (EP 2: 388) or, simply, a "permanence of some relation" (CP 1.415). Form is also defined as having the "being of predicate" (EP 2: 544) and it is also pragmatically formulated as a "conditional proposition" stating that certain things would happen under specific circumstances (EP 2: 388).

to be spatiotemporally extended, it mediates probabilistically acquired reiterated regularities, and it is an irreducible emergent pattern between interpreters and utterers. In the remainder of this paper, we argue that this conception of semiosis can be associated to the contemporary notion of cognitive niche construction. This association aims to provide a locus of observation of the formal abstract notion semiosis as phenomena of distributed cognition.

3 Niche construction: From processualist biology to cognitive science

According to our view, semiosis as a process is equivalent to what philosophers of Cognitive Science call "cognitive niche construction." The central claim of Peirce's theory of mind – that mind is semiosis – when brought to this contemporary theoretical frame, can be reinterpreted as a claim that cognition is cognitive niche construction.

The word "niche" conjures the image of an architectural recess where a statue is displayed, a space that can be occupied, a "carved" space where an element fulfills its function. In ecology, the concept of ecological niche addresses the questions: "what combinations of environmental factors allow a species to exist in a given geographic region or in a given biotic community, and what effects does the species have on those environmental factors?" (Peterson 2011: 14). The concept is akin to the environmental and/or ecological context of an organism, everything that surrounds it and that makes its existence possible and likely. There is a close interdependence between organisms and environments (as well as ecosystems and niches):

> There is no organism without an environment, but there is no environment without an organism. There is a physical world outside of organisms and that world undergoes certain transformations that are autonomous. Volcanoes erupt, the earth precesses on its axis of rotation. But the physical world is not an environment, only the circumstances from which environments can be made. The reader might try describing the environment of an organism that he or she has never seen. There is a non- countable infinity of ways in which the bits and pieces of the world might conceivably put together to make environments, but only a small number of those actually have existed, one for each organism. (Lewontin and Levins 1997: 96)

Accordingly, for Lewontin and Levins (1997: 97), organisms "do not experience or fit into environment, they construct it." In the same sense, organisms not only fit into previously available niches in an ecosystem, but also construct their

niches. In this view, niches are not a set of environmental circumstances independent of an organism. The definition itself of the environmental circumstances already necessitates the active presence of an organism: niche necessitates niche construction. Furthermore, all animal behavior is environment-creating and potentially environment-transforming. This includes both environment transformation with large scale noticeable effects (e.g. beavers build their dams, changing whole landscapes and ecosystems), as well as perhaps more discrete cases of environmental transformation (e.g. every terrestrial organism constantly creates a thin layer of warm moist air around it, its own personal atmosphere which encapsulates it as its environment [Lewontin and Levins 1997: 97]). The environment accumulates the results of organisms' behavior and environmental transformations are bequeathed to future generations. This constitutes an inheritance system different from genetic inheritance. According to Niche Construction Theory (NCT), niche construction is an evolutionary process often overlooked or not given enough emphasis (see Scott-Phillips et al. 2013 for a discussion on the premises of NCT): organisms not only respond to selective pressures from the environment, but both organisms and environments co-evolve, and any behavior whatsoever of an organism, since it interacts with the environment, is constitutive of niche construction.

Niche is also a traveling concept that has been making its way from evolution and philosophy of biology to philosophy of cognitive science, through investigations of evolution of cognition (Tooby and DeVore 1987), evolution of culture (Laland et al. 2000), and evolution of language (Bickerton 2009). In Biosemiotics, a field directly interested in the intersection between biology, philosophy of cognition and semiotics, Hoffmeyer (2008) has proposed the notion of semiotic niche – "the world of cues around animal (or species) which the animal must necessarily interpret wisely in order to enjoy life" (Hoffmeyer 2008: 7) – to overcome the "de-semiotized understanding of the interplay between organisms in nature" (Hoffmeyer 2008: 13). Tooby and DeVore (1987) first proposed the term "cognitive niche": a specific ecological niche that human ancestors would have constructed at some point of our evolutionary history, and that would explain several of our species features (such as complex organized behavior, use of language, learning and cultural transmission, division of labor, among others) without having to resort to ad hoc explanations. Pinker (2010) has refined and extended the concept to treat "the co-evolution of cognition, language and sociality." However, to arrive at a usage of cognitive niche more in tune with the way we employ it here, the concept had to undergo another transformation in usage. While Pinker (2003) had called language an adaptation to *the* cognitive niche, Clark (2005) spoke of language as *a* cognitive niche:

> Language, I have tried to show, is usefully understood as an animal-built material structure (a cognitive niche) that systematically alters the computational burdens involved in learning, reasoning and self-control. In this respect language stands to thought as a self-constructed behavior-enhancing niche stands to its animal "occupant." (Clark 2005: 264–265)

In Clark's writings, cognitive niche is related to materiality of artifacts and structures. This material understanding of cognitive niche fits in the author's overall view about the material extension of cognition. For Clark, humans are cognitive cyborgs, symbionts "whose minds and selves are spread across biological brain and nonbiological circuitry" (Clark 2004: 3). Clark's view is only one strand of anti-internalist conceptions of cognition, that claim that cognition cannot be isolated or even understood separately from physical/task-based, environmental/ecological, social/interactional contexts (Seifert 1999; Menary 2010). Two examples of such approaches are Situated Cognition and Distributed Cognition. Their main theses are, respectively: *cognition is situated* – it is uniquely determined by its context, so that to study it in isolation is to lose sight of its defining properties (Seifert 1999) – and *cognition is distributed* – it emerges from the interactions between the elements of its context, so that the notion itself of context and focal process is questioned (Hutchins 2014; see also Davies and Michaelian's 2016 discussion on the problem of "cognitive bloat").

Clark defines cognitive niche construction as:

> ... the process by which animals build physical structures that transform problem spaces in ways that aid (or sometimes impede) thinking and reasoning about some target domain or domains. These physical structures combine with appropriate culturally transmitted practices to enhance problem solving and, in the most dramatic cases, to make possible whole new forms of thought and reason. (Clark 2008: 62)

A different description of "cognitive niche construction" is given by Lorenzo Magnani. For him, humans are "chance seekers" (Magnani 2007; Bardone 2011), "continuously engaged in a process of building up and then extracting latent possibilities to uncover new valuable information and knowledge" (Magnani 2007: 918). He emphasizes cognitive niche construction as a process through which we create "chances," a notion that he relates to affordances. Cognitive niches are viewed as sets of affordances, and describe "how humans exploit external resources and incorporate them into their cognitive systems" (Magnani 2009: 332).

Some examples of the use of cognitive niche include:

1) Clark (2005), quoted above, speaks of language as a cognitive niche (for alternative views of language as a niche, see Sinha 2009; Pinker 2003): language is result of a vast cumulation of cognitive behavior that feedbacks into further specialized cognitive behavior. The result is the emergence of new forms of cognition that weren't possible before.

2) Clark (2008: 62) refers to the differently shaped glassware and cocktail furniture as a pre-structured niche for bartenders. Expert bartenders spatially order the differently shaped glasses corresponding to the temporal order of the drinks to be prepared. This transforms the problem of remembering which drink to prepare next into a problem of perceiving different shapes and associating them with different drinks. This example is only one of a vast collection of cases of situated problem solving, when instead of creating some kind of abstract mental representation of a problem, agents use the actual world as a problem space (for many examples, see Kirsh 2009).
3) Clark (2008: 63–64) makes reference to Tribble's (2005) analysis of distributed cognition in the Globe Theater to state that the theater function as a "singular dramatic [cognitive] niche." Tribble describes the stage in Elizabethan theatre as the "work-space" of the company, embedding a system of conventions and constraints that allowed the prolific output characteristic of the period (a new play staged every fortnight). In such a distributed system, the position of stage-doors, the use of "plots" (large sheets of paper that could be hanged on the walls, displaying a two-dimensional overall map of the play in terms of entrances, cues, etc.), and the use of verse (more easily memorized than prose), all serve to create a cognitive niche that supports cueing and memorization and distributes the organization of the many different agents involved in performing a play without a central higher-level manager. In this case, the cognitive niche is not one particular structure, artifact, technique or practice, but a whole collection of them, organized in specific ways and collectively referred to through the architectural space that encloses and spatially organizes them: the Globe Theater itself.

As the examples above illustrate, there are different things and processes that can be described as taking the role of cognitive niches. A cognitive niche can be understood as materially extended sets of problem spaces that demand or select a set of cognitive abilities. Whenever one says that 'X is a cognitive niche', one refers to a structured scope of possibilities and likelihoods for cognitive/semiotic interactions between X and a cognitive system, in which both X, the capacity of the cognitive system to use X as such, and the possibilities for interaction themselves are mutually-dependent, materially distributed, and have co-evolved through niche construction. This is a development and refinement of Clark's above quoted definition of cognitive niche construction in terms of problem spaces that aid or impede thinking. What can be X? Whenever one says that X is a cognitive niche, one is referring to a structured pattern of interaction between X and an agent. As long as X shapes cognitive activity in interaction with an

agent, providing a materially distributed structure for cognitive behavior, whatever X may be, it can be understood as a cognitive niche (if that is useful or helpful). There are no well-defined classes of things that can and cannot count as cognitive niches. A non-exhaustive list of things and processes can be understood as cognitive niches includes: (a) external artifacts, media products, technical media, as well as assemblages, sets or groups of these; (b) basic and qualified media types; (c) semiotic systems, conceptual spaces, thinking styles, representational techniques, mental models; (d) man-made material structures (buildings, rooms...); (e) embodied and behavioral practices, techniques, protocols, rules; (f) patterns of interaction between agents, information flows, communication networks.

4 Cognitive niche construction as a *locus* of observation of semiosis

Semiosis is cognitive niche construction. By using the notion of cognitive niche, we acknowledge that a semiotic process is constructed by environments of semiotic likelihoods, frequencies, or "chances," stabilized through habit-taking, and at the same time that semiosis is a constructor of such environments; that our cognition highly depends on these evolutionary histories of specialization of environments and structures; and that any semiosis is only one possible semiotic relation selected among many. Cognitive niche construction also stresses the environmental, ecological-like relations between a wide morphological variety of embodied-situated semiotic processes. By referring to an entity, system or process as a cognitive niche, we acknowledge it as an environment for cognition to develop, for meaning relations to be created, transformed or supported. This proposition addresses a persistent problem in Peircean semiotics: how to provide a locus of observation for a formal notion of semiosis. This problem can be traced back to Peirce's 1908 "sop to Cerberus":

> I define a Sign as anything which is so determined by something else, called its Object, and so determines an effect upon a person, which effect I call its Interpretant, that the latter is thereby mediately determined by the former. My insertion of "upon a person" is a sop to Cerberus, because I despair of making my own broader conception understood. (SS 80–81, 1908)

Peirce's "sop to cerberus" is to indicate the locus of an interpretant as "a person." This is a concession in an otherwise markedly processualist theory of semiosis which is concerned with functionally defined formal terms and not with psychological entities. However, Peirce also understands a person as different from the

notion of a psychological individual, stressing a dialogical nature and a social nature of personhood:

> Two things here are all-important to assure oneself of and to remember. The first is that a person is not absolutely an individual. His thoughts are what he is "saying to himself," that is, is saying to that other self that is just coming into life in the flow of time. When one reasons, it is that critical self that one is trying to persuade; and all thought whatsoever is a sign, and is mostly of the nature of language. The second thing to remember is that the man's circle of society (however widely or narrowly this phrase may be understood) is a sort of loosely compacted person, in some respects of higher rank than the person of an individual organism. (EP 2: 338)

It is important to notice that this definition of person is given in a context of discussion about the nature of reasoning and thought. It is a discussion that today takes the form of the debate in Philosophy of Cognitive Science about whether cognition should be seen as bound to individuals (see Clark and Chalmers 1998). In fact, Peirce can be considered as a precursor of contemporary anti-internalist views of cognition (see Skagestad 1999; Ransdell 2003; Atã and Queiroz 2014). In this sense, our proposition of cognitive niche construction as a locus of observation of semiosis can be understood as an update of Peirce's sop to Cerberus, but one that hopefully brings advantages in comparison with the original concession of a 'person' locus: first because the contemporary debate on cognitive anti-internalism is one oriented by a fortune of empirical evidence (e.g. Clark 2008) and by the development of experimental methods, such as in Cognitive Anthropology (e.g. Hutchins 1995), Experimental Psychology (e.g. Kirsh 2009), Biorobotics (e.g. Laschi and Mazolai 2016), Dynamical Systems modelling (e.g. Chemero 2009); second, because the notion of cognitive niche construction also recruits a fortune of philosophical and empirical evidence on the contemporary understanding of evolution, centered around niche construction and Cultural Evolution (e.g. Odling Smee et al. 2003; Laland 2017). On the other hand, the contribution of Peirce's semiosis to these contemporary discussions can be formulated as a "semiotization" of Distributed Cognition and Cultural Evolution. In Distributed Cognition, this contribution is related to how Peirce's processualist semiotics can reframe and reconceptualize the debate around the notion of "representation." In Cultural Evolution, this contribution is related to how Peirce's processualist semiotics can orient a theory of transmission, variation and selection of cultural information. In both cases, what matters is whether "semiosis" can serve as a "guide for discovery" that can motivate and orient further experimental investigations and development of experimental methods.

References

Atã, Pedro & João Queiroz. 2013. Icon and abduction: Situatedness in Peircean cognitive semiotics. In Lorenzo Magnani (ed.), *Model-based reasoning in science and technology*, 301–313. New York: Springer.

Atã, Pedro & João Queiroz. 2014. Iconicity in Peircean situated cognitive semiotics. In Torkild Thellefsen & Bent Sorensen (eds.), *Charles Sanders Peirce in his own words: 100 years of semiotics, communication and cognition*, 527–536. Berlin: Walter de Gruyter.

Atã, Pedro & João Queiroz. 2016. Habit in semiosis: Two different perspectives based on hierarchical multi-level system modeling and niche construction theory. In Donna West & Myrdene Anderson (eds.), *Consensus on Peirce's concept of habit: Before and beyond consciousness*, 109–119. New York: Springer.

Bardone, Emanuele. 2011. *Seeking chances: From biased rationality to distributed cognition*. New York: Springer.

Bergman, Mats. 2009. *Peirce's philosophy of communication*. London: Continuum.

Bickerton, Derek. 2009. *Adam's tongue*. New York: Hill and Wang.

Bickhard, Mark. 2007. Modern approaches to language. *New Ideas in Psychology* 25. 67–69.

Bickhard, Mark. 2011. Some consequences (and enablings) of process metaphysics. *Axiomathes* 21(1). 3–32.

Briscoe, Ted. 1998. Language as a complex adaptive system: Coevolution of language and of the language acquisition device. In Philip Cohen & Wolfgang Wahlster (eds.), *Proceedings of the eighth meeting of computational linguistics in the Netherlands conference*, 3–40. Nijmegan.

Cangelosi, Angelo & Huck Turner. 2002. L'emergere del linguaggio. In A. M. Borghi & T. Iachini (eds.), *Scienze della mente*, 227–244. Bologna: Il Mulino.

Chemero, Anthon. 2009. *Radical embodied cognitive science*. Cambridge, MA: MIT Press.

Christiansen, Morten & Simon Kirby. 2003. Language evolution: Consensus and controversies. *Trends in Cognitive Sciences* 7(7). 300–307.

Clark, Andy. 2004. *Natural-born cyborgs: Minds, technologies, and the future of human intelligence*. Oxford: Oxford University Press.

Clark, Andy. 2005. Word, niche and super-niche: How language makes minds matter more. *Theoria* 54. 255–268.

Clark, Andy. 2008. *Supersizing the mind: Embodiment, action, and cognitive extension*. Oxford: Oxford University Press.

Clark, Andy & David Chalmers. 1998. The extended mind. *Analysis* 58. 7–19.

Davies, Jim & Kourken Michaelian. 2016. Identifying and individuating cognitive systems: A task-based distributed cognition alternative to agent-based extended cognition. *Cognitive Processing* 17. 307–319.

de Tienne, Andre. 2003. Learning qua Semiosis. *S.E.E.D. Journal* 3. 37–53.

Emmeche, Claus. 2003. Causal processes, semiosis, and consciousness. In Johanna Seibt (ed.), *Process theories: Crossdisciplinary studies in dynamic categories*, 313–336. Dordrecht: Kluwer.

Fisch, Max H. 1986. *Peirce, semeiotic and pragmatism: Essays by Max H. Fisch*, Kenneth Laine Ketner & Christian Kloesel (eds.). Indianapolis: Indiana University Press.

Gomes, Antonio, Charbel El-Hani, Ricardo Gudwin & João Queiroz. 2007. Towards the emergence of meaning processes in computers from Peircean semiotics. *Mind & Society -- Cognitive Studies in Economics and Social Sciences* 6. 173–187.

Hoffmeyer, Jesper. 2008. The semiotic niche. *Journal of Mediterranean Ecology* 9. 5–30.
Hutchins, Edwin. 1995. *Cognition in the wild*. Cambridge, MA: MIT Press.
Hutchins, Edwin. 2014. The cultural ecosystem of human cognition. *Philosophical Psychology* 27(1). 34–49.
Hutchins, Edwin & B. Hazlehurst. 1995. How to invent a lexicon: The development of shared symbols in interaction. In Nigel Gilbert & Rosaria Conte (eds.), *Artificial societies: The computer simulation of social life*, 132–159. London: UCL Press.
Kelso, Scott. 1995. *Dynamic patterns: The self-organization of brain and behavior*. Cambridge, MA: MIT Press.
Kirsh, David. 2009. Problem solving and situated cognition. In Phillip Robbins & Murat Aydede (eds.), *The Cambridge handbook of situated cognition*, 264–306. Cambridge: Cambridge University Press.
Laland, Kevin. 2017. *Darwin's unfinished symphony: How culture made the human mind*. Princeton: Princeton University Press.
Laland, K. N., J. Odling-Smee & M. W. Feldman. 2000. Niche construction, biological evolution, and cultural change. *Behavioral and Brain Sciences* 23(1). 131–175.
Laschi, Cecilia & Barbara Mazzolai. 2016. Lessons from animals and plants: The symbiosis of morphological computation and soft robotics. *IEEE Robotics & Automation Magazine* (September). 107–114.
Lewontin, Richard & Richard Levins. 1997. Organism and environment. *Capitalism Nature Socialism* 8(2). 95–98.
Loula, Angelo, Ricardo Gudwin, Charbel El-Hani & Joao Queiroz. 2010. The emergence of self-organized symbol based communication in artificial creatures. *Cognitive Systems Research* 11. 131–147.
Loula, Angelo & Joao Queiroz. 2011. Modeling the emergence and evolutionary history of semiotic systems and processes. *International Journal of Signs and Semiotic Systems* 1. i-iv.
Määttänen, Pentti. 2010. Habits as vehicles of cognition. In Mats Bergman, Sami Paavola, Ahti-Veikko Pietarinen & Henrik Rydenfelt (eds.), *Ideas in action: Proceedings of the applying Peirce conference*, 201–210. Helsinki: Nordic Pragmatism Network.
MacLennan, Bruce. 2001. The emergence of communication through synthetic evolution. In Mukesh Patel, Vasant Honavar & Karthik Balakrishnan (eds.), *Advances in the evolutionary synthesis of intelligent agents*, 65–90. Cambridge, MA: MIT Press.
Magnani, L. 2009. *Abductive cognition: The epistemological and eco-cognitive dimensions of hypothetical reasoning*. Berlin: Springer.
Magnani, Lorenzo. 2007. Creating chances through cognitive niche construction. In Bruno Apolloni (ed.), *Knowledge-based intelligent information and engineering systems*, 917–925. Berlin: Springer-Verlag.
Menary, Richard (ed.). 2010. *The extended mind*. Cambridge, MA: MIT Press.
Merrell, Floyd. 1997. *Peirce, signs, and meaning*. Toronto: University of Toronto Press.
Nicholson, Daniel & John Dupré. 2018. *Everything flows: Towards a processual philosophy of biology*. Oxford: Oxford University Press.
Odling-Smee, F. John, Kevin Laland & Marcus Feldman. 2003. *Niche construction: The neglected process in evolution*. Princeton: Princeton University Press.
Peirce, Charles S. 1931–1966. *The collected papers of Charles S. Peirce*, Vol. 8, C. Hartshorne, P. Weiss & A. W. Burks (eds.). Cambridge: Harvard University Press. [Reference to Peirce's papers will be designated *CP* followed by volume and paragraph number.].

Peirce, Charles S. 1967. Manuscripts in the Houghton Library of Harvard University, as identified by Richard Robin, *Annotated catalogue of the Papers of Charles S. Peirce*. Amherst: University of Massachusetts Press. [Reference to Peirce's manuscripts will be designated *MS* or L.].

Peirce, Charles S. 1982. *Writings of Charles S. Peirce*, Vol. 6, M. Fisch, E. Moore & C. Kloesel (eds.). Bloomington: Indiana University Press. [Reference to Peirce's writings will be designated W followed by volume and page number.].

Peirce, Charles S. 1992. *Essential Peirce: Selected philosophical writings*, Vol. 1, (1867–1893), N. Houser & C. Kloesel (eds.). Bloomington: Indiana University Press. [Reference to vol. 1 of *Essential Peirce* will be designated *EP* 1.].

Peirce, Charles S. 1998. *Essential Peirce: Selected philosophical writings*, Vol. 2, (1893–1913), Peirce Edition Project (eds.). Bloomington: Indiana University Press. [Reference to vol. 2 of Essential Peirce will be designated *EP* 2.].

Peterson, A. Townsend. 2011. *Ecological niches and geographic distributions*. Princeton: Princeton University Press.

Pinker, Steven. 2003. Language as an adaptation to the cognitive niche. In Morten Christiansen & Simon Kirby (eds.), *Language evolution*, 16–35. Oxford: Oxford University Press.

Pinker, Steven. 2010. The cognitive niche: Coevolution of intelligence, sociality, and language. *Proceedings of the National Academy of Sciences of the United States of America* 107. 8993–8999.

Port, Robert. 2009. The dynamics of language. In Robert Meyers (ed.), *Encyclopedia of complexity and system science*, 2310–2323. Heidelberg: Springer-Verlag.

Queiroz, João & Charbel El-Hani. 2006a. Semiosis as an emergent process. *Transactions of the Charles S. Peirce Society* 42(1). 78–116.

Queiroz, João & Charbel El-Hani. 2006b. Towards a multi-level approach to the emergence of meaning in living systems. *Acta Biotheoretica* 54. 179–206.

Queiroz, Joao, Claus Emmeche & Charbel El-Hani. 2008. A Peircean approach to information and its relationship with Bateson's and Jablonka ideas. *American Journal of Semiotics* 24(1–3). 75–94.

Ransdell, Joseph. 1977. Some leading ideas of Peirce's semiotic. *Semiotica* 19(3–4). 157–178.

Ransdell, Joseph. 2003. The relevance of Peircean semiotic to computational intelligence augmentation. *S.E.E.D. Journal* 3(3). 5–36.

Rescher, Nicholas. 1996. *Process metaphysics: An introduction to process philosophy*. New York: SUNY Press.

Rosenthal, Sandra. 1994. *Charles Peirce's pragmatic pluralism*. Albany, NY: State University of New York Press.

Scott-Phillips, Thomas, Kevin Laland, David Shuker, Thomas Dickins & Stuart West. 2013. The niche construction perspective: A critical appraisal. *Evolution* 68(5). 1231–1243.

Seibt, Johanna. 2012. Process philosophy. In Edward N. Zalta (ed.), *The Stanford encyclopedia of philosophy*. https://plato.stanford.edu/archives/spr2018/entries/process-philosophy/ accessed 25 January 2019).

Seifert, Colleen. 1999. Situated cognition and learning. In R. A. Wilson & F. C. Keil (eds.), *MIT Encyclopedia of the cognitive sciences*, 767–769. Cambridge, MA: MIT Press.

Sinha, Chris. 2009. Language as a biocultural niche and social institution. In Vyvyan Evans & Stéphanie Pourcel (eds.), *New directions in cognitive linguistics*, 239–310. Amsterdam: John Benjamins.

Skagestad, Peter. 1999. Peirce's inkstand as an external embodiment of mind. *Transactions of the Charles S. Peirce Society* 35(3). 551–561.

Skagestad, Peter. 2004. Peirce's semeiotic model of the mind. In Cheryl Misak (ed.), *The Cambridge companion to Peirce*, 241–256. Cambridge: Cambridge University Press.

Steels, Luc. 2000. Language as a complex adaptive system. In M. Schoenauer, K. Deb, G. Rudolph, X. Yao, E. Lutton, J. J. Merelo & H.-P. Schwefel (eds.), *Proceedings of the sixth international conference on parallel problem solving from nature*, 17–26. Dordrecht: Springer.

Steels, Luc. 2003. Evolving grounded communication for robots. *Trends in Cognitive Sciences* 7(7). 308–312.

Tooby, John & Irven DeVore. 1987. The reconstruction of hominid evolution through strategic modeling. In Warren Kinzey (ed.), *The evolution of human behavior: Primate models*, 183–237. Albany: SUNY Press.

Tribble, Evelyn. 2005. Distributing cognition in the globe. *Shakespeare Quarterly* 56(2). 135–155.

Vogt, Paul. 2002. The physical symbol grounding problem. *Cognitive Systems Research* 3(3). 429–457.

Wagner, Kyle, James A. Reggia, Juan Uriagereka & Gerald S. Wilkinson. 2003. Progress in the simulation of emergent communication and language. *Adaptive Behavior* 11(1). 37–69.

Wheeler, Michael. 2005. *Reconstructing the cognitive world – The next step*. Cambridge: MIT Press.