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EMBODIED COGNITION: LOOKING INWARD

*Being embodied is being able to take risk,
that is, being open and exposed to the
unknown.*

(Depraz 2005, p.173)

Introduction

Lawrence Shapiro, in his book *Embodied Cognition* (2010), distinguishes three types of relations between standard research on cognition and the embodied cognitive science: conceptualization, constitution, and replacement. In the first case, our conceptualization of the world is body-based. In the second case, the body and even some artifacts constitute cognition. In the third case, cognition should be explained in terms of embodied, ecological dynamical systems. As Shapiro (2010) and other commentators point out (e.g. Wilson, Golonka, 2013), only the last one is incompatible with research in standard cognitive science, and at the same time, it is the only really interesting option. Seven years after the publication of this book, it is quite clear that the replacement hypothesis is far from being successful (see: Goldinger et al., 2016). And, as noticed, even if it succeeds, it often fails to explain phenomena that are traditionally called cognitive (Aizawa, 2014; 2015a; 2015b).

This paper unfolds the view which integrates a computational and embodied approach to cognition (see also: Rupert 2016; Miłkowski 2016). However, I assume it here without argument. I argued for an integration of embodied and computational view on cognition somewhere else (Nowakowski, 2017). Still, many authors point out the role of action or interaction, body experience, or artifacts in cognition,

but more detailed works on internal processing are still rare (however, see: Allen, Friston, 2016; Clark, 2013; 2015; Miłkowski, 2016; Rupert, 2016; de Bruin, Michael, 2017). Therefore, I propose some introductory, empirical considerations on internal, cognitive processing in bodily cognitive systems.

In this paper, I start with remarks on internal, cognitive processing. After that, I refer to Alvin Goldman's moderate approach of embodied cognition (highly incompatible with replacement hypothesis). Goldman (2012; 2014) considers the crucial role of body representations (B-codes) in cognition. So, we can propose some remarks not only on internal processing but perhaps also on the role of body representations in this processing.

After the remarks on Goldman's approach, I will sketch my own approach (E-codes approach), based on some conceptual twists. Crucial for embodiment of cognition will be not the role of the body for cognition, but—as I will argue—the role of cognition for the body. This is nothing new, but sadly it is a still too-often neglected view on this matter (but, see: Haselager et al, 2008; Keijzer, 2015). This twist may lead to integration between work on embodied cognition and evolution of the nervous system. After all, embodied cognitive systems are mainly bodily machines, living organisms coping with problems they face in their own surroundings. In the view proposed here, E-codes should be efficient, robust, and body-specific.¹

Relating E-codes to Goldman's approach, we can say that the central nervous system is undoubtedly an essential part of the system responsible for cognitive processing. However, there is a reason to believe that such a system can extend beyond the boundaries of the brain (see: Nowakowski, 2017; Wilson, 2010). Therefore, we can differentiate:

B-codes: Body related processing;

E-codes: Efficient, robust, and body-specific processing.

Therefore, we can ask:

- a. Is it possible that B-codes are E-codes?
- b. What conditions must be met for B-codes to be a kind of E-codes?

¹ This issue will be elaborated in more detail later in the text.

I am strongly convinced and I argue that we should bind E-codes (not pure B-codes) with embodied cognition. Therefore, as was mentioned earlier, we should not ask what the body does for cognition, but what cognition does for the body. Hence, I start with some evolutionary considerations on cognition, and then relate this to considerations on the role of the body in shaping cognition.

1. The complexity thesis and the internal processing in the embodied cognition

I begin my remarks with cognition, and the body in which cognition is embodied, then I move to complexity theses and the work of Keijzer with Arnellos (2017, and Keijzer, 2015) on the evolution of cognition (Godfrey-Smith, 1996) with more recent works on the evolution of the nervous system, and I propose a more internalist view on the evolution of cognition. They argue for the important role of both environmental and bodily complexity. After that, I turn to initial remarks about internal processing in embodied cognition.

1.1 Cognition that is embodied

For our purposes, we can reuse a part of the title of Aizawa's paper (2015b): "What is this cognition that is supposed to be embodied?" There is an ongoing debate both outside and inside the research on embodied cognition about what cognition could be. Currently, there is strong criticism that in research on embodiment we deal not with cognition but behavior misdescribed as cognition (Aizawa, 2014; 2015a; 2015b). So what is cognition?

Here I refer to interesting remarks from Buckner's (2015) paper. He writes:

"[...] cognitive scientists should collect the behaviors that they are interested in explaining as the result of cognition. They should then theorize about a minimal set of capacities that would allow systems to display these behaviors, and see whether agents possessing capacities that allow them to pass one set of behavioral tests also tend to possess the others. If it is plausible that they do, then scientists should attempt to develop a model of the underlying mechanisms that could produce those capacities and explain why they

would tend to cluster together” (Buckner, 2015, pp.310-311).

Therefore, basic cognition (in our terminology: cognitive processing) is realized by a cognitive mechanism. This mechanism gives the system a set of capacities for the realization of some cognitive behaviors. Behaviors are the effect of employing a cognitive mechanism. In the same paper, Buckner (2015) describes cognition as an ecumenical, homeostatic cluster of properties such as context sensitivity, fast adaptation, grouping/categorization, abstract learning, multi-modality, inhibition, and monotonic integration. As far as this is the cluster, cognition doesn't need to exhibit all mentioned properties in order to be cognition. Certainly, in cases of minimal cognitive processing, it can contain only some of these properties.

I assume that cognition is based on the information processing process of problem-solving. This process should be context sensitive, rapidly adapting to new problems, and related to categorization and inhibition, but it not need be abstract or multimodal. We can also mention that it may not need to be representational. Here I follow some works of Keijzer and his colleagues (Keijzer 2003; van Duijn et al, 2006), assuming that cognitive processing is problem-solving, embedded in sensorimotor coordination and interaction with the environment (Keijzer, 2003). I don't reduce the whole cognition to sensorimotor coordination, but try to show that cognition is something primary related and submerged in this coordination. Some of this coordination requires solving some environmental and body complexity problems. Therefore, minimal cognition is a problem-solving process embedded in sensorimotor coordination. Of course, as cognition becomes more sophisticated, more elements from Buckner's (2015) cluster should be included.

1.2 Embodiment of the cognition

It seems that what we, as theoreticians of the embodiment, should be particularly interested in is the extent to which the body, excluding the central nervous system, is part of the cognitive system (see the definition of embodied cognition in Wilson and Foglia [2011]). This is undoubtedly an important and by no means trivial question. However, in this paper, I focus on internal processing. As argued earlier in embodied

cognition cognitive processing, the base should extend beyond the central nervous system (Nowakowski, 2015). However, the body never independently performs cognitive processes but co-realizes cognition together with the central system (Nowakowski, 2017). Therefore, we deal here with a system characterized by a trade-off between what the peripheral nervous system and non-neuronal body parts do, and what the central system does. I defended the view that in many simpler systems peripheral systems play a greater role in base realizing cognition, whereas in the case of more complex systems (e.g. mammals) the central nervous system plays a greater role in cognition. Some authors (Fuchs 2011; Jacob, 2012; Gallagher et al. 2013), driven by the need of simplicity in cognitive processes, believed that one should conceptualize cognition as depending as much as possible on the peripheral system, whereas periphery should make cognitive processing simpler. Naturally, this will simplify the complexity of central processing. However, sometimes the simplest solution, in general, is to increase dependence on the central processing. There are possible types of embodiment where cognition relies mostly on central processing.

Here, I believe that we can connect this approach with Wilson and Golonka's (2013) idea that "to explain cognition we should focus on a specific task and their sources used during the task." Undoubtedly, among the resources an essential element is the central system; in the case of many animals, it's the central nervous system and we should be able to show what this system really does. Therefore, in this context we can ask: How important is the brain as a resource for the bodily cognitive system or as a central processing machine? Even if an exhaustive answer is not available, we should be able to say what condition central processing should meet to be a part of the bodily cognitive system. I will return to this issue when discussing Goldman's approach and my own proposal.

1.3 Environment and Body Complexity Thesis

In the literature we can find ideas very similar to the proposal in this paper. In his seminal work on the evolution of cognition, Godfrey-Smith (1996) defended the environmental complexity thesis:

"Environmental complexity thesis (ECT): The function of cognition (and of a range of protocognitive capacities) is to

enable an agent to deal with environmental complexity.”
(Godfrey-Smith, 2002, p.135).

We can add that *function* is understood here as “the effect or capacity [...] responsible for [...] success under a regime of natural selection” (Godfrey-Smith, 2002, p.135). And *cognition* is “a collection of capacities which, in combination, allow organisms to archive various kinds of adaptive coordination between their actions and the world”. (Godfrey-Smith, 2002, p.135). Additionally, the environment is not only natural but also social. Therefore, such a cognitive system must also deal with the complex behavior of other living creatures.

Keijzer and Arnellos (2017) describe this view on the evolution of cognition as externalist, where it is shaped by environmental factors to which it is adapted. In response to Godfrey-Smith, they propose a more internalist approach, where not only environmental but also body complexity is important, especially when it comes to multicellular organisms with complex active bodies (see: Trestman, 2013). In these organisms, they see the importance of not only input-output interaction between an organism and its environment but also the internal coordination of internal activity in complex multicellular systems (Keijzer, Arnellos, 2017). For this purpose, the authors propose the concept of the animal sensorimotor organization [ASMO]. They accentuate the “importance of the (internal) multicellular organization as a precondition for the macroscopic environment by animals to become accessible for these animals” (Keijzer, Arnellos, 2017). And it is important that ASMO “fulfils criteria for a minimal cognition” (Keijzer, Arnellos, 2017), and is compatible with our considerations from part (1.1). For them ASMO includes:

1. a multicellular body, constituting an ‘inner space’ or domain, which is differentiated from the body’s ‘outer space’ or environment.
 2. the presence of contractile epithelia.
 3. complex, standardized body architectures.
 4. sensitivity to tension and stress at the level of (intra) cellular processes.
 5. reversible, contraction-based changes in body-shape.
- (Keijzer, Arnellos, p.2017).

These conditions are really similar to the role of the body that I describe as constraining conditions (1.2.1). The complex (multicellular) body system must learn its own properties to act and perceive. As we see, cognitive processing is here described in internalist terms (but not only internalist). To be able to cope with changing environmental problems, the system must first be able to coordinate its own stable and changing properties. So, the body is here not only something that enables an animal to perform particular actions—particular ways of dealing with environmental problems. The body, its complexity and coordination is also a problem which must be solved in order to cope with environmental problems. Therefore, even if there are differences between the external and internal (bodily) environments, the animal must coordinate both. Therefore, according to our initial considerations, we should notice that if we consider embodied cognition as the role of cognition for a particular body, we should think of not only the issue of environmental complexity but also of bodily complexity. This leads us to more detailed remarks on cognition and embodiment.

1.3 Toward internal processing in bodily cognitive systems

In the previous parts of this paper, I proposed that in embodied cognition cognition is construed by some kind of a minimal cluster, mainly embedded in sensorimotor coordination problem-solving processes. The body is here described as a whole organism, inducing an important tradeoff between the central and peripheral systems. Then I showed that the brain is not self-sufficient. I finished with remarks on one of the most interesting views on embodied cognition.

From this, we can see that any view of embodied cognition should include an account of internal, cognitive processing². Even if it extends to some body parts going beyond the central nervous system or even some morphological and dynamic properties of the physical body. This processing is, then, highly integrated with the functioning of the whole body and solves the problem raised by body features. It also

² It is important to show that the model of cognitive processing in question is appropriate for a system with specific bodily features, so that it is a model of embodied cognitive processing.

exploits some of them to solve some of the problems raised by the environment.

Now, we can look in more detail at the internal processing itself. Here I defend the embodied theory of cognition and show that it is necessary to propose a special approach to internal processing. I will start my consideration by discussing one of the most interesting approaches to this processing. After presenting some of the limitations of this proposal I will develop an alternative approach.

2. Goldman on B-codes and embodied cognition

It is not easy to say what a good theory of internal cognitive processing in embodied cognition should look like. Here I choose one—even if it is not the most widely accepted, it is undoubtedly one of the most interesting proposals: Alvin Goldman's moderate approach to embodied cognition and his idea of B-codes, which embody cognition.

2.1 Moderate approach to embodied cognition

Goldman in his papers (2012; 2014) makes a distinction between a question of the embodiment of cognition in general and the embodiment of a particular cognitive token or exemplar. This distinction seems to be innocent but it is not.³ I believe that most of the more philosophically oriented research is about a general type of embodiment of cognition (see: Shapiro, 2004; Wilson, Foglia, 2011), but most of psychological work is related to a token or exemplar type of embodiment of cognition. In this context, Goldman (2012; 2014) is an interesting exception because he is interested in embodied tokens or exemplars. This makes his approach more compatible with psychological than philosophical works on embodiment. As already mentioned, in the context of Shapiro's (2010) distinction regarding the relation between embodied and traditional views on cognition, Goldman proposes a moderate approach of embodiment, which is in line with traditional research, and refuses the need of any replacement.

³ I think it is right to point out similarities between the distinction, present in works about consciousness, between creature consciousness and state consciousness. In this case creature consciousness is analogous to embodied cognition in general, and state consciousness is analogous to embodied tokens or exemplars.

Surprisingly, Goldman also argues that if we describe embodied cognition as a role of the physical body in cognition, we will trivialize this idea. He agrees that when we close our eyes⁴ it has an impact on seeing, but says that this is trivial and we cannot base our research on such influence of the body on cognition. I believe and try to show in this paper that, on the one hand, it's impossible to reduce the role of the physical body in cognition to closing eyes or putting fingers in the ears, on the other, that there are non-trivial accounts of the role of the physical body in cognition.

2.2 On B-codes and their re-use

Goldman's approach is based on two ideas. The first one is the idea of the bodily codes or bodily formats. This idea comes from the paper co-authored with Frederique de Vignemont (Goldman, de Vignemont, 2009). The second one is the idea of "reuse", borrowed from the works of Michael Anderson.

The most recent form of Goldman's definition of embodied cognition is as follows:

Cognition (token) C is a specimen of embodied cognition if and only if C uses some (internal) bodily format⁵ to help execute a cognitive task (whenever the task may be) (Goldman, 2014, p.102).

To understand this definition, we need to understand the B-codes and how a system uses these formats to "execute cognitive tasks".

⁴ This example, taken from Goldman papers (2012; and with de Vignemont, 2009), only seems to be trivial but is really interesting. A system with eyes which can be closed could have eyes built of a more fragile and sensitive material, and they could also simply have bigger eyes. A system able to close eyes should have the ability to rapidly update information, taking into account the difference between signals before and after closing eyes. Such a system should integrate visual information with tactile or proprioceptive information for smooth movement coordination in short periods without visual information. Therefore, the fact that I close my eyes is not fundamental for embodied cognition. However, the fact that our eyes can close and open possibly has a big influence on the way we process visual information.

⁵ Although, Goldman uses the terms *B-codes* and *B-formats* interchangeably, I only use the term *B-code*.

2.2.1 B-codes

In his earlier paper, Goldman (2012) writes that code is something which is “language-like, [...] has a distinctive vocabulary, syntax, and a set of computational procedures” (Goldman, 2012, p.73). In his proposal, every sense modality has its own code, and some even have many codes, as in the case of visual perception for action and recognition (Milner, Goodale, 1995). Bodily formats are here described as formats which “in the mind/brain represent states of the subject’s own body, indeed, represent them from an internal perspective” (Goldman, 2012, p.73). This is interpreted to mean that bodily formats represent the body through interception, proprioception, and by other somatosensory modalities. However, Goldman describes it neither in detail, nor in terms of syntax, nor computational procedures. We can only say that the syntax and procedures are somatosensory-specific. So we can assume that bodily formats are, to put it widely, somatosensory, internal body representations, primarily involved in body control and representations.

This idea needs more specification. Even if somatosensory, auditory, and visual areas differ from each other and have a distinctive organization (e.g. primary somatosensory cortex is organized somatotopically), at the bottom all neurons work in quite a similar way. For Goldman, codes are distinguished by their connections with separate areas of the brain. B-codes are performed by areas which process information about the body. Of course, there could be many B-codes – there are probably nociceptive, tactile discriminatory and affective codes, and also proprioceptive codes. But what is their nature? In visual perception, the vision-for-action (dorsal) and vision-for-recognition (ventral) streams have differing codes just because one is related to the ventral and the other to the dorsal stream. *Prima facie* it sounds convincing – action coordination and object identification should be executed by distinct computational procedures. However, this difference is one thing, the nature of these codes being the source of the difference is another.

It’s possible that this situation is caused by the fact that Goldman is mainly interested in using (actually: reusing) these codes in order to explain cognition, not the brain.

2.2.2 Reuse of B-codes

If Goldman remained interested only in theories of representing and processing information about own body, his approach would be extremely limited. However, he argues that “Embodied cognition is a significant and pervasive sector of human cognition” (Goldman, 2012, p.81). Therefore, he introduces an extension of this theory by adding that: “B-formats are massively redeployed or reused for many other cognitive tasks...” (Goldman, 2012, p. 81).

Based on the results of studies on the activity of the central nervous system, it is argued that a specific type of cognitive activity is embodied (Caramazza et al, 2014; Meteyard et al, 2012; Kubanek, Snyder, 2015). This research indicates that the same areas of the central nervous system are active in the exercise of control tasks as well as in the monitoring of the state of the body and in performing non-related-to-body cognitive tasks. It is not possible to discuss even a small portion of these studies, and, additionally, it doesn't seem to be necessary. We will only use two examples of such research to illustrate the general characteristics of this kind of approach. Goldman (2012; 2014) refers to Pulvermuller's (2005) papers on the connection between language and action, to Glenberg and Kaschak (2002) work on mirror neurons, and to Proffitt and colleagues (2008; 2012) on the role of action and body representations in spatial perception. Because of controversies⁶ in his later papers, Goldman (2016) admitted that Proffitt's research cannot be used in his research on B-codes so I will not refer to this research here.

Pulvermuller (2005) relates motor activation to language comprehension. He argues that the motor cortex has somatotopic organization. If language is embodied, then comprehension of action-related words or sentences should also have an effect on somatotopic activation. As Goldman writes (2014, p.96-97), we can observe such activation.

⁶ The key point of Proffitt's approach (that is the relationship between the physiological state of the organism and the perception of the steepness of the terrain) was called into question (Durgin et al, 2012; Shaffer et al, 2013). Additionally, Firestone and Scholl (2014) argued that Proffitt's whole concept was based on El Greco fallacy.

Hearing different sentences involving *lick*, *pick*, and *kick* activated motor areas that control the tongue, the fingers, and the leg, respectively (Goldman, 2014, p.97).

According to Goldman's approach, if B-codes are involved in motor control and the only criterion for the distinction is the brain area, then Pulvermuller's research is an example of the reuse of motoric B-codes for language comprehension.

Goldman's work complements Michael Anderson's (2007; 2010) research on massive redeployment. This approach is based on several theses: (a) in the evolution of the nervous system, old components, if only possible, are reused for new purposes; (b) the same circuits or areas in "different arrangements" i.e., in connection with separate areas are employed for separate tasks, (c) phylogenetically earlier areas are widely connected and more often used for separate task realization. Therefore, areas phylogenetically earlier are the best candidates for being related to B-codes reused later in other not-related-to-body cognitive tasks.

We can now wrap up. The central system uses various B-codes to represent the body, and it reuses these codes to solve problems not related to the body. It seems that the relation to the body is not really so important for Goldman. It is important insofar as we need to distinguish B-codes from other codes. So this is really a weak kind of embodiment, which tells us nothing about dealing with the body and environment complexity.

2.3 From criticism of B-codes to E-codes

Goldman's approach is as interesting as it is controversial. Gallagher points out that in this context there is no real important role for the body itself (Gallagher 2015a; 2015b). In the same vein, Kyselø and di Paolo (2015) write that Goldman's approach is too narrow, and does not include the body's real role in cognition. But the most interesting remarks are in Firestone's paper (2016), who shows that Goldman's use of Anderson's re-use conception is problematic in the case of vision. To be precise, vision can't be embodied in circuits responsible for grasping, because eyes evolved earlier than hands. Goldman (2016) accepted this critique and accepted that his theory doesn't explain the embodiment of vision. Therefore, in Goldman's approach, visual perception is not

embodied. It's a really surprising result, and it's worth remembering, that if vision is in fact embodied, then it is an argument against Goldman's approach.

There is one more critic, important for this paper. At the end of his remarks about Goldman's (2012) approach, Shapiro (2014) directs attention to a very interesting issue. Why can we say that B-codes provide a good account of embodied cognition? More accurately, why are B-codes good in terms of being reused for cognition? Goldman describes B-codes as bodily because they primarily represent the body. But, as Shapiro notices, this is not enough as Goldman doesn't give any reason why they are good for reuse for cognitive purposes. This is, in my opinion, a crucial issue related to Goldman's approach to embodied cognition, and, as Shapiro writes, it "should not be overlooked and is one that places the burden on Goldman to justify his claim that any reuse of B-codes suffices to embody cognition" (Shapiro, 2014, p.87-88). If B-codes are individuated by their primary role of representing the body, and then they are reused because of other reasons, it seems doubtful that we should still maintain that this is embodiment in B-codes.

Further, in this paper I propose a solution which is not dependent on any appeal to the representation of the body.

3. E-codes: Internal processing beyond B-codes

Here I want to sketch some ideas about an alternative to Goldman's view on internal processing in embodied cognition. I call it *E-codes*, because it is coding and processing information embedded in the whole bodily system, and it should be able to give the system the ability to deal with the risk and uncertainty that it must deal with in everyday conditions (see: epigraph at the beginning of this paper). Therefore, contrary to Goldman, I'm interested mainly in an embodiment of cognition in general, not an embodiment of a particular cognitive token or exemplar.

3.1 E-codes: general outline

Embodied cognition need not be a kind of cognition primarily related to the body or about the body. It is essential to consider two types of properties of E-codes: body-specific and body-general. Body-specific properties of E-code are shaped by particular properties of the body. Even if in almost all living organisms their building blocks are quite similar, their structure and organization are quite different. Systems

different in size, morphology, sensors, and effectors solve problems of internal coordination and efficient action in the environment in individual ways. Therefore, cognitive processing differs among them. Body-general properties are also shaped by the body but are related to properties present in all living creatures (energy consumption, dealing with risk and uncertainty). I must point out that the research presented here wasn't developed as research on embodied cognitive processing. It was developed quite independently, but is essential for studies about embodied cognition.

As I argued earlier, cognitive processing is probably, at least partially, extended beyond the central cognitive nervous system (see: Nowakowski, 2015). However, no matter whether this processing extends beyond the central system or not, it should have some properties. In this part of my paper, I try to indicate the kind of properties they should be.

My solution is partially inspired by Keijzer's (2015) research on the evolution of the nervous system as a process of development – a sophistication of a specialized control system. This system is engaged not only in solving problems of interaction with the environment but also internal coordination of neural and muscular tissue activity (see part 1.3). So, we deal here with the problem of efficient action and internal coordination. I describe this as a process of the system “learning” of its properties, possibilities, and constraints. In the context of such processes cognitive systems emerge.

Even if there is not much research on this topic, I can show some body-specific and body-general properties of E-codes:

a. *The laziness of E-codes*: Haselager and colleagues (2008) argue for the lazy brain hypothesis, where the brain in dealing with problems is not searching for the best solution but trying to use the easiest, most accessible, most preferable solutions. Therefore, it's trying to choose the “cheapest”, often biased, way to solve the problem. In a similar vein, Clark argues for productive laziness, that cognitive processing should be based on “economic but effective strategies and heuristics” (Clark, 2015, p.244).

b. *Organization and robustness of E-codes*: Our considerations are related to the possible evolution of the whole bodily system. Even though I don't accept Goldman's approach in its entirety, I assume that Anderson's idea of reuse is compatible with E-codes. The evolved system

reuses in any way available subsystems developed earlier. This can be connected to the possible nested organization of a nervous, cognitive system (Bolt et al, 2017). To some degree, we can connect this proposal to a more general idea of degeneracy (more than one subsystem serves a particular function) and redundancy (one subsystem serves more than one function). Such an organization of a cognitive system can increase its robustness and effectiveness⁷.

c. *Cost effectiveness of E-codes*: Laughlin (2001) and Niven (2016) argue that energy consumption by the nervous system is a relevant constraint on information processing by the brain. Therefore, brain size, number of connections between neurons, and tradeoffs in processing between the central and peripheral systems are determined by energy consumption. E-codes should be organized in the most energetically economical available way for efficient, fast signaling and minimization of energy consumption at the same time. Wang and Clandinin argue that wiring economy is a significant determinant of nervous system layout (Wang, Clandinin, 2016, p.R1101)

d. *Prospectivness of E-codes*: We can also say, in the context of the motto of this paper, that such bodily systems are almost constantly exposed to the risk of being cheated, injured, or even dying. They must constantly anticipate possible changes in the environment and in their internal milieu. Of course, every system should be anticipatory to some degree. This property can be connected with contemporary works on integration between embodied cognition and predictive processing (see: de Bruin, Michael, 2017; Allen, Friston, 2016; Bruineberg, Kiverstein, Rietveld, 2016; Burr, Jones, 2016). However, there are still controversies about the nature of this integration.

And we can describe some body-specific properties of E-codes:

e. *E-codes and body size and shape*: Organisms of varying sizes and motor flexibility need individual control systems and individual computational procedures (see: Hooper, 2012), various systems to differing degrees offload control on dynamical and mechanical properties of the controlled system.

7 These properties can be increased by balanced (excitation/inhibitory) activation of network and top-down feedback (see: Denève et al, 2017)

f. *E-codes and sensorimotor specificity*: Organisms with individual sensors need individual solutions for effective processing of available sensory information (see: MacIver, 2009). Each individual visual system will need separate kinds of internal processing. An octopus with human eyes will be blind, but for humans seeing with a mantis shrimp eye will be computationally intractable (see: Nowakowski, 2017)

g. *E-codes and various solutions for general problems*: In reference to point 3, we can say that in individual organisms (e.g. with individual body size/brain size ratio), individual solutions for frugal processing are needed.

As we can see, we don't refer to representing or experiencing the body. We don't say what bodies mostly do, only what cognition does for the body, and how it is shaped by the body. But I believe this is the most convincing view on embodied cognition. In our proposal, we describe the embodiment of cognition as an element of the emergence of cognition in the process of effectively coping with the body and with environment complexity.

We can also answer the questions posed in the introduction. It's highly unlikely that B-codes, as described by Goldman, are examples of E-codes. However, if they have to be useful, they should have the properties of E-codes.

Conclusion

Embodied cognition is currently facing problems (Goldinger et al, 2016), so we should search for conceptualizations that are more consistent with the embodiment thesis but that are also consistent with the empirical data. I hope the E-coding approach presented here gives such an opportunity. However, I believe it needs more comparative meta-analysis and computational modeling than psychological experiments, because if cognition is embodied in the way described in this paper, we should observe the correlation between various body morphologies and the various kinds of cognitive processing employed in problem-solving.

If the solution proposed here is correct, it gives the opportunity to develop an account of the "embodied cognitive architectures". We should not forget that embodied cognition is a theory of cognition, not of the body. Cognition in beings *able to take risk, [...] and [beings] exposed to the unknown.*

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REFERENCES

- Aizawa, K. (2015a). Cognition and behavior. *Synthese*, 1-20. doi:10.1007/s11229-014-0645-5
- Aizawa, K. (2015b). What is this cognition that is supposed to be embodied?. *Philosophical Psychology*, 28(6), 755-775.
- Aizawa, K. (2014). The enactivist revolution. *AVANT. Pismo Awangardy Filozoficzno-Naukowej*, (2), 19-42.
- Allen, M., Friston, K. J. (2016). From cognitivism to autopoiesis: towards a computational framework for the embodied mind. *Synthese*, 1-24.
- Anderson, M. L. (2010). Neural reuse: A fundamental organizational principle of the brain. *Behavioral and brain sciences*, 33(4), 245-266.
- Anderson, M. L. (2007). Massive redeployment, exaptation, and the functional integration of cognitive operations. *Synthese*, 159(3), 329-345.
- Bolt, T., Nomi, J. S., Yeo, B. T., Uddin, L. Q. (2017). Data-Driven Extraction of a Nested Model of Human Brain Function. *Journal of Neuroscience*, 37(30), 7263-7277.
- Bruineberg, J., Kiverstein, J., & Rietveld, E. (2016). The anticipating brain is not a scientist: The free-energy principle from an ecological-enactive perspective. *Synthese*, 1-28. <https://doi.org/10.1007/s11229-016-1239-1>
- Buckner, C. (2015). A property cluster theory of cognition. *Philosophical Psychology*, 28(3), 307-336.
- Burr, C., Jones, M. (2016). The body as laboratory: Prediction-error minimization, embodiment, and representation. *Philosophical Psychology*, 29(4), 586-600.
- Caramazza, A., Anzellotti, S., Strnad, L., Lingnau, A. (2014). Embodied cognition and mirror neurons: a critical assessment. *Annu. Rev. Neurosci.* 37,1-15. doi:10.1146/annurev-neuro-071013-013950
- Clark, A. (2015). *Surfing uncertainty: Prediction, action, and the embodied mind*. Oxford University Press.
- Clark, A. (2013). Whatever next? Predictive brains, situated agents, and the future of cognitive science *Behavioral and Brain Sciences*, 36(3), 181-204.

- de Bruin, L., Michael, J. (2017). Prediction error minimization: Implications for embodied cognition and the extended mind hypothesis. *Brain and cognition*, 112, 58-63.
- Denève, S., Alemi, A., Bourdoukan, R. (2017). The brain as an efficient and robust adaptive learner. *Neuron*, 94(5), 969-977.
- Depraz N. (2005). Radical embodiment, in. H. de Preester, V. Knockaert (ed.), *Body image and body schema: interdisciplinary perspectives on the body* (173 – 186), Amsterdam, Philadelphia: John Benjamins Publishing Company.
- Durgin, F. H., Klein, B., Spiegel, A., Strawser, C. J., Williams, M. (2012). The social psychology of perception experiments: Hills, backpacks, glucose, and the problem of generalizability. *Journal of Experimental Psychology: Human Perception and Performance*, 38(6), 1582.
- Firestone, C. (2016) Embodiment in Perception. in. B. P. McLaughlin and H. Kornblith (eds.) *Goldman and His Critics* (318-334), John Wiley & Sons, Inc.
- Firestone, C., & Scholl, B. J. (2014). “Top-down” effects where none should be found: The El Greco fallacy in perception research. *Psychological science*, 25(1), 38-46.
- Fuchs, T. (2011). The Brain – A Mediating Organ. *Journal of Consciousness Studies*, 18(7-8), 196-221.
- Gallagher, S. (2015a). How embodied cognition is being disembodied. *The Philosophers' Magazine*, (68), 96-102.
- Gallagher, S. (2015b). Reuse and body-formatted representations in simulation theory. *Cognitive Systems Research*, 34, 35-43.
- Gallagher, S., Hutto, D. D., Slaby, J., Cole, J. (2013). The brain as part of an enactive system. *Behavioral and Brain Sciences*, 36(4), 421-422.
- Glenberg, A.M., M.F. Kaschak. (2002). Grounding language in action. *Psychonomic Bulletin and Review* 9, 558–565.
- Godfrey-Smith, P. (2002). Environmental complexity, signal detection, and the evolution of cognition, in. M. Bekoff, C. Allen, G.M. Burghardt (eds.) *The Cognitive Animal: Empirical and Theoretical Perspectives on Animal Cognition*, (135-142) Cambridge: The MIT Press.
- Godfrey-Smith, P. (1996). *Complexity and the Function of Mind in Nature*. Cambridge: University Press.

- Goldinger, S. D., Papesh, M. H., Barnhart, A. S., Hansen, W. A., Hout, M. C. (2016). The poverty of embodied cognition. *Psychonomic bulletin & review*, 23(4), 959-978.
- Goldman, A. I. (2016). Response to Firestone. in. B. P. McLaughlin and H. Kornblith (eds.) *Goldman and His Critics* (335-336), John Wiley & Sons, Inc.
- Goldman, A. I. (2014). The bodily formats approach to embodied cognition, in. U. Kriegel (ed.) *Current Controversies in Philosophy of Mind*, (91-108), Routledge.
- Goldman, A. I. (2012). A moderate approach to embodied cognitive science. *Review of Philosophy and Psychology*, 3(1), 71-88.
- Goldman, A., de Vignemont, F. (2009). Is social cognition embodied?. *Trends in cognitive sciences*, 13(4), 154-159.
- Haselager, P., van Dijk, J., & van Rooij, I. (2008). A lazy brain? Embodied embedded cognition and cognitive neuroscience. in. P. Calvo, T. Gomila (eds.) *Handbook of cognitive science: An embodied approach*, ed. (273-287), Elsevier Science.
- Hooper S.L. (2012). Body size and the neural control of movement, *Current Biology*, 22(9), R318-R322.
- Jacob, P. (2012). Embodying the mind by extending it. *Review of Philosophy and Psychology*, 3(1), 33-51.
- Jékely, G., Keijzer, F., Godfrey-Smith, P. (2015). An option space for early neural evolution. *Phil. Trans. R. Soc. B*, 370(1684), 20150181.
- Keijzer, F. (2015). Moving and sensing without input and output: early nervous systems and the origins of the animal sensorimotor organization. *Biology & Philosophy*, 30(3), 311-331.
- Keijzer, F. (2003). Making decisions does not suffice for minimal cognition. *Adaptive Behavior*, 11(4), 266-269.
- Keijzer, F., Arnellos, A. (2017). The animal sensorimotor organization: a challenge for the environmental complexity thesis. *Biology & Philosophy*, 1-21. <https://doi.org/10.1007/s10539-017-9565-3>
- Kubanek, J., Snyder, L.H. (2015). Reward-based decision signals in parietal cortex are partially embodied. *J.Neurosci.* 35,4869-4881.doi: 10.1523/JNEUROSCI.4618-14.2015
- Kyselo, M., Di Paolo, E. (2015). Locked-in syndrome: a challenge for embodied cognitive science. *Phenomenology and the cognitive sciences*, 14(3), 517-542.

- Laughlin, S. B. (2001). Energy as a constraint on the coding and processing of sensory information. *Current opinion in neurobiology*, 11(4), 475-480.
- Maclver, M. A. (2009). Neuroethology: From Morphological Computation to Planning. in. P. Robbins, M. Aydede (ed.) *The Cambridge Handbook of Situated Cognition* (480-504), Cambridge: Cambridge University Press.
- Meteyard, L., Cuadrado, S.R., Bahrami, B., Vigliocco, G. (2012). Coming of age: are view of embodiment and the neuroscience of semantics. *Cortex* 48, 788–804. doi:10.1016/j.cortex.2010.11.002
- Milner, A. D., Goodale, M. A. (1995). *The visual brain in action*, Oxford: Oxford University Press.
- Miłkowski, M. (2016). Models of Environment. In Frantz, R., Marsh, L. (eds.) *Minds, Models and Milieux* (227-238). Palgrave Macmillan UK.
- Niven, J. E. (2016). Neuronal energy consumption: biophysics, efficiency and evolution. *Current opinion in neurobiology*, 41, 129-135.
- Nowakowski P.R. (2015). Commentary: The Embodied Brain: Towards a Radical Embodied Cognitive Neuroscience. *Front. Hum. Neurosci.* 9:623. doi: 10.3389/fnhum.2015.00623
- Nowakowski P.R. (2017). Bodily processing: the role of morphological computation, *Entropy*, 19(7), 295; doi:10.3390/e19070295
- Proffitt, D.R. (2008). An action-specific approach to spatial perception. in. R.L. Katzky, B. MacWhinney, M. Behrmann (eds.) *Embodiment, ego-space, and action*, (177-200), Psychology Press
- Proffitt, D.R., Linkenauger, S.A. (2012). Perception viewed as a phenotypic expression. in.W. Prinz, M. Beisert, A. Herwig. (eds.) *Action Science. Foundations of an Emerging Discipline*. (171-198) Cambridge: MIT press.
- Pulvermuller, F. (2005). Brain mechanisms linking language and action. *Nature Reviews Neuroscience* 6, 576–582.
- Rupert, R. D. (2016). Embodied Functionalism and Inner Complexity: Simon's Twenty-first Century Mind. In Frantz, R., Marsh, L. (eds.) *Minds, Models and Milieux* (7-33). Palgrave Macmillan UK.

- Shapiro, L. A. (2014). When is Cognition Embodied, in. Uriah Kriegel (ed.) *Current Controversies in Philosophy of Mind* (73-90) Routledge,
- Shapiro, L. A. (2010). *Embodied cognition*, Routledge.
- Shapiro, L. A. (2004). *The mind incarnate*. Cambridge: MIT press.
- Shaffer, D. M., McManama, E., Swank, C., Durgin, F. H. (2013). Sugar and space? Not the case: Effects of low blood glucose on slant estimation are mediated by beliefs. *I-Perception*, 4(3), 147-155.
- Trestman, M. (2013). The Cambrian explosion and the origins of embodied cognition. *Biological Theory*, 8(1), 80-92.
- Van Duijn, M., Keijzer, F., Franken, D. (2006). Principles of minimal cognition: Casting cognition as sensorimotor coordination. *Adaptive Behavior*, 14(2), 157-170.
- Wang, I. E., Clandinin, T. R. (2016). The influence of wiring economy on nervous system evolution. *Current Biology*, 26(20), R1101-R1108.
- Wilson, R. A. (2010). Extended vision, in. Gangopadhyay, N., Madary, M., Spicer, F.(ed.) *Perception, action and consciousness*, (277-290). Oxford, New York: Oxford University Press.
- Wilson, R. A. (1994). Wide computationalism. *Mind*, 103(411), 351-372.
- Wilson, R.A., Foglia, L. (2011/2017). Embodied Cognition, in Edward N. Zalta (ed.), *The Stanford Encyclopedia of Philosophy*, URL = <<https://plato.stanford.edu/archives/spr2017/entries/embodied-cognition/>>.
- Wilson A.D., Golonka, S. (2013). Embodied cognition is not what you think it is. *Front. Psychology* 4:58. doi: 10.3389/fpsyg.2013.00058

ABSTRACT

EMBODIED COGNITION: LOOKING INWARD

The body is a highly complex, coordinated system engaged in coping with many environmental problems. It can be considered as some sort of opportunity or obstacle, with which internal processing must deal. Internal processing must take into account the possibilities and limitations of the particular body. In other words, even if the body is not involved in the realization of some cognitive explicit task, it is not a neutral factor of our understanding of why a system solves a task in one way or another. Therefore, when conducting research on embodiment and the body's cognitive system we should not neglect internal, cognitive processing.

I appeal to Goldman's research on embodied cognition to sketch the broader framework for internal processing in embodied cognition. I believe that even if we don't accept Goldman's approach as the viable proposal for embodied cognition in general, it's a quite natural starting point for our analysis. Goldman (2012; 2014, and with de Vignemont 2009) argue for the essential role of the bodily formats or bodily codes (respectively: B-formats and B-codes) in embodied cognition. B-codes are here described as the processing of regions or sub-regions of the central nervous system. They are primarily employed for body control or monitoring, and reused for cognitive tasks. Beyond doubt, this conception provides an excellent starting point for analyzing the internal (mostly neural) processing in cases of embodied cognition.

At the end of this paper, I will argue that the embodiment of cognition needs a conceptual twist. Following Keijzer's (2015) interest in the evolution of the nervous system, and the minimal forms of cognition, I argue that in investigating embodied cognition, we should investigate the role played by cognitive processing for specific kinds of organisms, meaning organisms with a body of a particular morphology (size, shape, kinds, and distribution of sensors and effectors). Doing that, I refer to some conceptual and empirical considerations. I will also try to show that research on embodied cognition is still not sufficiently anchored in evolutionary and comparative studies on cognition, nor on the nervous system and body morphology. Bigger reliance on these kinds of studies,

will make it make possible to gain a deeper understanding of internal processing in embodied cognition.

KEYWORDS: embodied cognition; bodily cognitive system; internal and cognitive processing; B-codes; E-codes