

University of Groningen

## Evolution in Action in Perception

Keijzer, Franciscus

*Published in:*  
Philosophical Psychology

*DOI:*  
[10.1080/09515080701447287](https://doi.org/10.1080/09515080701447287)

**IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.**

*Document Version*  
Publisher's PDF, also known as Version of record

*Publication date:*  
2007

[Link to publication in University of Groningen/UMCG research database](#)

*Citation for published version (APA):*

Keijzer, F. A. (2007). Evolution in Action in Perception. *Philosophical Psychology*, 20(4), 519 - 529. DOI: 10.1080/09515080701447287

### Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

### Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

*Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.*

(To appear in *Philosophical Psychology*)

**Evolution in action in perception**  
**A review of Alva Noë's *Action in perception***  
**(MIT Press, 2004)**

Fred Keijzer

*Faculty of Philosophy*  
*University of Groningen*  
*The Netherlands*  
(f.a.keijzer@rug.nl)

When I started on Alva Noë's *Action in perception*, I expected to be pleased with the book and to cheer him along. The reason for this expectation came primarily from his paper with Kevin O'Regan: "A sensorimotor account of vision and visual consciousness", and also from his paper with Susan Hurley: "Neural plasticity and consciousness". Both papers, in my view at least, made wonderful contributions to articulating the importance of sensorimotor relations for understanding cognition and consciousness. *Action in perception*, I thought, would be a more in-depth and general treatment of the issues in those (and some other) papers. Somehow, it only partially worked out that way.

In *Action in perception*, Noë provides a so-called enactive approach to visual perception, which he differentiates from Varela, Thompson and Rosch's original use of this term, and uses as another name for what he and O'Regan called a sensorimotor contingency account (p.233). The key idea of the book is that perceiving is a way of acting. He starts out with the image of a blind person tapping his cane in a cluttered space, "perceiving that space by touch, not all at once, but through time, by skillful probing and movement." (p.1). Noë argues in this book that all perception, specifically vision, is touch-like in this way: What we perceive is determined (a) by what we do, and also (b) by what we are ready to do. The first point is important in opposition to the idea that perceiving is like having an inner snapshot of what is outside. The second point refers to Noë's notion of *sensorimotor knowledge*: the implicit practical knowledge of the ways movement gives rise to changes in stimulation. We may not move all the time, but all the time we have the knowledge that we are capable of probing the world with our eyes and other senses at will. Noë claims that such sensorimotor skills are constitutive of experience.

As an example, Noë considers the case of a tomato in front of us, where we experience the whole tomato, not just a facing side: "You visually experience parts of the tomato that, strictly speaking, you do not see, because you understand, implicitly that your sensory relation to those parts is mediated by familiar patterns of sensorimotor dependence." (p.77). More crudely, you experience this tomato as a whole three-dimensional object because you know that at any moment only a little craning of the neck allows you to bring more of the tomato into view.

In the book, this basic idea that perception involves action is elaborated and eloquently defended against all kinds of problems. For example, Noë discusses the differences between his enactive approach and the idea that visual experience is like having an internal picture. He discusses further the sensorimotor profiles of colors and how visual experience acquires spatial content. He develops the claim that perceptual content is two-dimensional, involving both a factual and a perspectival dimension corresponding to how things are, and how things

look. For example, when I look at a plate from an angle, I see the plate as round, but if I take the effort I see it is also elliptical (p.172). He argues further that experience is conceptual, a claim that he uses to stress the fact that we *understand* what we see, which is more than just having sensory stimulation. In the last chapter before his conclusion, he provides a plea for externalism concerning experience. Experience is not restricted to the head but involves the whole animal within its environment. All this is way too much to deal with in a short review, but merely mentioning the diverse topics should give an inkling of both the richness and the controversial nature of the book.<sup>1</sup>

As said at the beginning, I consider myself an enthusiast of O'Regan and Noë's sensorimotor contingency account. However, I have my doubts about this book. For my taste, the book did not focus sufficiently on the sensorimotor contingencies—the specific ways in which action changes sensory stimulation—of the earlier papers, and too much on topics like sensorimotor *knowledge* and the claim that this knowledge is *conceptual*. For me, these contingencies are the key to progress in the study of consciousness and cognition, while Noë seems to cast them in a supporting role for his account of conscious experience.

Of course, complaining that the author of a book does not precisely discuss those topics that a reviewer finds interesting is bad practice. And since Noë specifically claims to focus on visual *experience*, rather than sensorimotor relations, one should not criticize him on this point. Nevertheless, going through the book these misgivings remained. In particular, I thought that Noë, because of his focus on experience, could, and did, step aside from some very important factual criticisms (e.g. Block, 2005, Clark & Toribio, 2001), which I will discuss later on, while at the same time he had to confront a number of different problems. In order to resolve these, Noë develops his views in ways that I find in places questionable and even detracting from his focus on a sensorimotor or enactive approach. All in all, it seemed to me that what Noë aimed to do—provide a sensorimotor based or enactive account of visual experience—was like trying to solve a jigsaw puzzle with too many pieces missing. The two components just did not seem to fit without extensive reworking and ignoring some glaring misfits. At the same time, in both previous work and this book very strong reasons are given for thinking that both ought to be connected somehow.

These general misgivings became greatly clarified, and enhanced, when I arrived at the final four-page epilogue of the book. Things happen very quickly here. First, Noë acknowledges that the enactive approach as elaborated in the book "takes consciousness for granted" (p.228). Consequently, this approach must be considered circular as it presupposes consciousness rather than explains it. Noë subsequently writes: "It was precisely to avoid this kind of circularity that O'Regan and I (O'Regan & Noë, 2001a, 2001b) insisted on characterizing laws of sensorimotor contingency in terms of patterns of change in sensory *stimulation* rather than in terms of changes in sensation or appearance." (p.228) And later on the same page: "The main problem with this strategy, I now believe, is that we purchased noncircularity and explanatory power at the expense of giving up phenomenological aptness." (p.228) To which a note is added that says: "There is a second problem as well. It may be that we underestimated the difficulty of giving an account of cognition." (p.248)

Thus Noë did really choose a rather different tack in this book compared to earlier work. However, in my view, his motivation led him to some questionable results. It may be that his current theory is more phenomenologically apt, but this is bought at the cost of circularity, and, more importantly, a continuing disregard for the second problem: the very difficulty of giving an account of cognition. In the epilogue, Noë further suggests that a solution for the circularity problem may be found by "placing the theory in an evolutionary setting." (p.229) To which he adds:

"We can make sense of the idea that simple organisms have, if not fully fledged experience, then something like simple modes of consciousness. I don't know how to

prove this, but what makes it plausible is the fact that we ourselves, in all our cognitive and phenomenological complexity, are descended from such simple organisms. It seems reasonable to hold that the conscious mind did not simply appear on the evolutionary scene, full-blown, but that it emerged gradually." (p.229)

Noë subsequently raises the suggestion that consciousness and cognition are themselves aspects of the development of life and even that the presence of consciousness could be explained by claiming that it comes together with life itself: "To take *life* for granted in an account of the emergence of consciousness may be, then, to take a *little* bit of consciousness for granted." (p.230) In this way, by making a fairly 'small' assumption, he says, we can get started with an enactive explanation of consciousness in the natural world.

To conclude, in this epilogue Noë acknowledges a circularity in his enactive account and as a remedy he places it in a biological and evolutionary context where he hopes to find what he considers to be the missing ingredient, consciousness.

### **Biological aptness**

In the following discussion, I will focus on the connection between Noë's striving for the "phenomenological aptness" of his enactive approach on the one hand and his evolutionary commitment on the other. I will argue that the two do not link up well. In his urgency to remain phenomenologically apt, Noë casts the general phenomenon of sensorimotor contingencies into a form which remains close to the human intentional idiom, for example by stressing that what is at stake is a form of sensorimotor knowledge (throughout), and by arguing for a conceptual interpretation of sensorimotor skills (Chapter 6). From an evolutionary perspective, this tactic creates the problem that it draws up the very bridge that could plausibly connect the human case with the biological domain more generally.

Noë raises the option of an intrinsic connection between life and cognition and consciousness.<sup>2</sup> I find this an important idea, but also an issue that is too large to discuss here. However, even if Noë's 'small' assumption is accepted, severe problems remain. The most urgent problem for an enactive approach would be that it seems to disconnect the intrinsic link between sensorimotor contingencies and experience, as it places the origins of consciousness at the deeper level of life itself rather than with sensorimotor contingencies more specifically. A second problem would be to articulate how evolutionary changes have come about. Starting with early creatures, less minimal forms of consciousness have arisen over evolutionary time with the development of modern animals, including humans. Thus, if Noë is to fall back on evolution and biology as the ultimate foundation for his enactive approach, it seems that much more should be said on these counts.

An obvious candidate to provide such a link between life more generally and the human mind in particular comes in the form of sensorimotor coordinations (Van Duijn et al., in press). Sensorimotor coordinations seem to be a key phenomenon that could help to build up a gradualist approach concerning the mind, including both cognition and consciousness. Noë himself has made a strong case that there are strong connections between sensorimotor contingencies and consciousness. Sensorimotor contingencies seem to be more specifically connected to mental and cognitive phenomena than life more generally. At the same time, they are present from very early on in the evolution of life, arguably starting out with bacteria (ibid.), and they come in a bewildering variety of forms and, presumably, levels of complexity all across the animal kingdom, humans included. Also, while conscious experience remains a difficult subjective phenomenon, biological forms of sensorimotor coordinations are objective phenomena that can be studied like other natural phenomena, and so provide a suitable handhold for a systematic study of the origins of cognition and consciousness.

The focus on more basic sensorimotor relations does not imply a neglect of phenomenological issues. For example, consider this observation by Sheets-Johnstone, who

aims to develop an account of experience starting out from the biological capacities for movement:

The body is not merely a thing of which we make sense as a functioning unit. Our bodies, through movement, through what Landgrebe calls "kinesthetic motions," are the very source of our being in the world—"the center of a spontaneous ability to move"—and the very condition of our constituting the world—"the transcendental condition of the possibility of each higher level of consciousness and of its reflexive character." (Sheets-Johnstone, 1999, p.148-149).

Thus, a plea for a more strict focus on sensorimotor contingencies in their biological context need not involve a plea to abandon experience, but to investigate it at a wider scale than the strictly human.

Considerations such as these should already push the study of sensorimotor contingencies—and their use by animals—to the forefront of current developments in embodied, situated and otherwise enactive approaches. The urgency of such a project is amplified by general evolutionary considerations. While Noë presents the evolutionary setting as a mere option, it seems to me, and many others, that for a fully naturalistic approach, this setting ought to be a primary constraint: When it comes to the human mind, one should not only get the experience-side right—no one is questioning that!—but also mentality's evolutionary and biological context. We are all evolved, biological creatures, and it is counterproductive not to take this background into account.

Lyon (2006) makes a relevant distinction between anthropogenic and biogenic approaches of cognition based on usually implicit presuppositions. She describes the underlying assumptions of the anthropogenic approach as "assume human cognition as the paradigm and work 'down' to a more general explanatory concept. The biogenic approach, on the other hand, starts with the facts of biology as the basis of theorizing and works 'up' to the human case by asking psychological questions as if they were biological questions." (p.11). An anthropogenic approach is not necessarily anthropocentric, that is, focused primarily on humans, and it can be quite 'biological'. However, an anthropogenic approach does assume is that the human experience of cognition—which places emphasis on such things as language, conceptuality, beliefs and desires, and consciousness—is the best guide to cognition more generally considered. In my view, Noë's book is a clear case of an anthropogenic approach. His focus is on human experience, and even though animal examples appear in his text, as I will discuss below, the basic starting point and context remains the human condition. His plea for an evolutionary setting in his epilogue also fits this picture. It comes late, does not genuinely contribute to the main ideas, and is primarily used as an ad hoc quick fix for some remaining problems.

A biogenic approach, in contrast, takes biology as the primary source of constraints for theories on cognition and consciousness. The major advantage of a biogenic approach is that it provides strong constraints on cognition, connecting it with the theoretical structure of an overarching, empirically robust scientific domain in ways that anthropogenic approaches to cognition do not. Lyon names ten such constraints, suggesting that more can still be formulated. Of these ten, I will only mention *continuity*: "Complex cognitive capacities have evolved from simpler forms of cognition. There is a continuous line of meaningful descent." (p.15) Another constraint might be derived from a paper of Andy Clark (1987), and can be called *scruffiness*. Clark drew attention to the haphazard, 'kludge-like' character of biological systems. Evolution works by gradual improvements, changing existing systems with new additions, changing functions, improving them, changing functions again and so on. The result is a messy and undecipherable system, a kludge in computer programming terms, which as a whole does function satisfactory. Thus, from a biogenic perspective, one would expect cognition and consciousness to be an outwardly neat phenomenon which on closer

acquaintance is rather scruffy, a conjunction of many different but intermingled components which work sufficiently well as a whole, but also with all kinds of quirks and unpredictable strengths and weaknesses.

To summarize, a biogenic approach comes with a host of preconditions and constraints that apply from the start on any attempt to make sense of experience. Simply adopting the biological context as a starting point has a strong influence on default assumptions and on the theoretical frame of reference that one brings to bear on the study of cognition and consciousness.

### **Topics to work on**

How does all of this bear on Noë's book? In the following, I will give a short sketch how such a biological orientation could impact on an enactive approach to perceptual experience by discussing—very quickly—four topics that arise in *Action and perception*. In each case, I claim, they consist of issues that can be approached more productively, or at least differently, by taking biology more seriously: 1) the issue of sensorimotor contingencies in robots; 2) the question how the enactive approach relates to the ventral-dorsal distinction of Milner and Goodale; 3) Noë's argument for the conceptual nature of experience; and 4) the plausibility of an externalism concerning the vehicles of experience.

The first issue concerns the question how to deal with robots and other mechanisms exhibiting sensorimotor contingencies. Clark and Toribio (2001), for example challenged O'Regan and Noë (2001a) to admit that a ping-pong playing robot, having the proper sensorimotor contingencies, should be deemed conscious in their view. As O'Regan and Noë used the example of a goal-seeking missile to elucidate the notion of sensorimotor contingencies, the charge seemed very much to the point. O'Regan and Noë (2001b) denied the ascription of consciousness to the ping-ponging robot by claiming that it was far too simple to be a plausible candidate for such an ascription. What remained unclear was what kind or kinds of complexity were necessary to make the difference, despite their introduction of some new constraints (*ibid.*). In *Action in perception*, Noë refers to the ping-ponging robot only in a note (p.248) and seems to sidestep the issue by taking visual experience as given, and only then considering the question how action plays a role. Clark and Toribio follow up their robot problem with another one, which they call 'sensorimotor chauvinism'. They argue that a sensorimotor account is too closely tied to particular fine-grained sensorimotor relations, while it is rather plausible that our conscious visual experience is more directly related to "memory, thought, reason and planning." (p.980) Noë returns to this issue in his book, and claims that a limited chauvinism is acceptable. He claims that the visual systems of the human, the crab, and the bumblebee are visual because "there is sufficient high-level, gross sensorimotor isomorphism between these different perceptual systems to count one and all as *visual systems*" (p.113). As there are also many lower-level sensorimotor differences between the human and the bumblebee, this will be sufficient to make their experiences different. According to Noë, this is exactly the result that one should want from a theory.

I agree with Noë very much that this is the kind of result that one should want. I just have doubts whether this result is something that one can have with the account as it stands. The talk about higher and lower level makes intuitive sense, but how would one differentiate the two? Do the sensory details matter very much? Do the particulars of the embodiment come strongly into play, and if so how? Wouldn't the ping-ponging robot exhibit exactly the higher-level isomorphism, necessary for counting the robot as having a *visual system*, while the lower-level details only make its experience *different*, rather than absent? Noë explicitly disagrees with the latter option, and again I would agree, but how could one argue this point in the context of crabs and bumblebees? Do they have different sensorimotor *knowledge*? And what does it mean to say that?

To my mind a biogenic approach, when combined with a study of sensorimotor contingencies, would make all the difference to this array of problems. It would provide *detail*, by studying and integrating different kinds of organisms at various levels of complexity. In this way, it would also provide a *comparative approach*, which searches for and explicates the differences that matter when it comes to the sensorimotor contingencies of various animals. This would also enable a more specific comparison between the capacities of animals and robots (Keijzer, 1998; Sharkey & Ziemke, 2001). Finally, and maybe most importantly, it would place notions like cognition and consciousness squarely in a *biological context, where they evolved*. This implies, for example, that replicating processes ordinarily part of an experiencing system artificially does not at all imply that one has *replicated* an experiencing system. For example, replicating in a laboratory a chemical reaction that is ordinarily part of a metabolic system does not mean that the same reaction in the laboratory would compose a metabolic system in its own right. This situation would also apply to the reliance on sensorimotor contingencies in animals. Having a robot that replicates a particular kind of sensorimotor contingencies, like the ping-ponging robot, would in no way be sufficient to count as a cognitive or conscious system. Even when disregarding the fact that a robot would not be alive, any animal—be it a worm, cephalopod, insect, or vertebrate—has such a vastly richer repertoire of sensorimotor contingencies that it would be absurd to put such a robot on the same level.

While Noë tries to delimit the mental domain by relying on the notion of sensorimotor *knowledge*, to my mind this remains a too high-level and unconstrained approach. A biogenic sensorimotor approach gives more concrete handholds to make progress. Of course, it is not at all clear yet how to integrate explanations of cognition at the level of phenomenology and biology, but working on the former with a keen eye on the latter seems like a sensible way to proceed. The key tenets of Noë's enactivism can easily accommodate such an approach.

### **Widening up**

The second point concerns Milner and Goodale's two visual systems hypothesis and is also taken up by Block (2005). Milner and Goodale (1995) proposed a now widely accepted new interpretation of two cortical visual systems. The ventral system is a what-system for 'semantic seeing,' such as the conscious identification of objects. The dorsal system is for on-line visual guidance and is unconscious. The latter is awkward for Noë's enactive approach, as this is a clear case of the use of sensorimotor contingencies, but without the experience that ought to go with it. Noë discusses this work, though briefly, and says that the two visual systems hypothesis is "at best, orthogonal to the basic claims of the enactive approach" (p.19). As I read him, he argues that in the enactive approach action is for perception, while the dorsal system merely implies the mundane fact that perception is for action. Thus, the latter is not a problem, such as perception without action would be. Strictly speaking, Noë's point may stand, but it does remain awkward that such a primary example of ongoing sensorimotor contingencies does not square nicely with the enactive approach as Noë sets it out in this book.

Again, a biogenic sensorimotor approach could make a difference. Noë's enactive approach strives to give an account of perceptual experience in terms of a direct linkage with sensorimotor contingencies by means of sensorimotor knowledge, which is possessed by a whole animal or human. The difficulty with this approach is that it is at heart a single-fix theory that tries to solve the problem of perceptual experience with a single major idea. A biogenic approach would proceed more piecemeal, and take cognition and consciousness to be scruffy phenomena that involves many different component processes, which come in many forms and levels of complexity. This also relates well to a point raised by Noë, and mentioned above, concerning the possible underestimation of giving an account of cognition.

It seems unlikely that cognition and consciousness, like life itself, could ever be dealt with by a single-fix theory.

While taking in sensorimotor contingencies as a starting point, for a biogenic sensorimotor approach it goes without saying that across the range from bacteria to humans many new and additional features arise that play essential roles in all kinds of unforeseeable interactions. In such a view, sensorimotor contingencies could easily play a key role without being in opposition to the idea that additional off-line processing may be necessary for higher-level cognition and consciousness. There is no need to postulate or even expect a direct link between Milner and Goodale's dorsal stream and visual experience.

On the third and fourth points, I will be very brief, simply mentioning them to mark two final implications of a biogenic sensorimotor approach for Noë's position. The third point concerns Noë's argument for the conceptual nature of experience. In his own words: "I propose that we should think of sensorimotor skills as themselves conceptual, or "protoconceptual" skills" (p.183). It seems obvious that from a biogenic perspective the claim that experience is basically conceptual is highly implausible, even when cast in a weak form as Noë does. Sensorimotor skills are widely dispersed across the animal kingdom and why would, leave alone how could, one really interpret such skills in strongly anthropogenic terms? Or would we interpret the skills of the crab and the bumblebee in conceptual terms? To me Noë's claim is a way to make a bridge between uncontroversial cases of human cognition and consciousness and the sensorimotor skills on which he builds his own account. However, for a biogenic sensorimotor approach it is not necessary to stress links with the human case in order to gain credibility as an account of conscious *experience*. Being fully naturalistic, an independent account must be given anyway—as acknowledged by Noë in his final turn to biology. The only thing that a conceptual interpretation of sensorimotor skills could do is shy away from this problem, not solve it.

In contrast, a biogenic sensorimotor approach would be much more congenial for another controversial claim made by Noë: his externalism concerning the vehicles of experience. In this view, the physical processes that constitute phenomenological processes extend into the environment (Hurley, 1998). This claim is hotly debated and very controversial within philosophy of mind and cognition (e.g. Menary, forthcoming). A biogenic sensorimotor approach would tend to support Noë on this count as it places higher-level cognition within a larger living system, which is itself constructed around the ongoing use of sensorimotor contingencies. In this case, externalism could apply even when particular higher-level cognitive functions themselves turn out to be strictly restricted to processes occurring within the skin.

Of course, the arguments for the ideas presented are of necessity merely suggestive, but I hope to have given an indication where the cards would end up when developing a biogenic sensorimotor account, and how such an approach would tend to differ from Noë's enactive approach.

### **Concluding**

In this review, I stressed some biological shortcomings of Noë's *Action in perception*, and proposed a turn toward a biogenic sensorimotor approach where biology and evolution would be much stronger guiding factors than currently is the habit in the study of cognition and consciousness. Having said this, I want to end by placing this criticism in its proper perspective: Noë presents a number of extremely important issues for thinking about cognition and consciousness, and his book ought to be read widely for that reason.



## Acknowledgements

I thank Daan Franken, Pamela Lyon and Marc van Duijn for their helpful comments. Work on this paper was supported by NWO research grant 016.038.301.

## References

- Block, N. (2005). Review of Alva Noë, *Action in perception*.#
- Clark, A. (1987). The kludge in the machine. *Mind & Language*, 2(4), 277-300.
- Clark, A. & Toribio, J. (2001). Sensorimotor chauvinism? *Behavioral and Brain Sciences* 24(5), 979-980.
- Edelman, S. (In press). Mostly harmless: A review of *Action in perception* (A. Noë, MIT Press, 2004). *Artificial Life*.
- Gallagher, S. (2005). Review of Alva Noë's *Action in perception*. *Times Literary Supplement*.#
- Gregory, R.L. (2005). A philosopher's vision: Action in perception by Alva Noë. *Nature*, 437, 817.
- Hurley, S.L. (1998). *Consciousness in action*, Harvard: Harvard University Press.,
- Hurley, S.L. & Noe, A. (2003). Neural plasticity and consciousness. *Biology & Philosophy*, 18, 131-168.
- Keijzer, F.A. (1998). Some armchair worries about wheeled behavior. In R. Pfeifer, B. Blumberg, J-A. Meyer & S.W. Wilson (Eds.) *From animals to animats 5* (pp. 13-21). Cambridge, MA: MIT Press.
- Lyon, P. (2006). The biogenic approach to cognition. *Cognitive Processing*, 7, 11-29.
- Maturana, H.R. & Varela, F.J. (1980). *Autopoiesis and cognition: The realization of the living*. Dordrecht: Reidel.
- Menary, R. (Ed.), (forthcoming). *The Extended Mind*. Ashgate.
- Milner, A.D. & Goodale, M.A. (1995). *The visual brain in action*. Oxford: Oxford University Press.
- Moreno, A., Umerez, J., & Ibañez, J. (1997). Cognition and life. The autonomy of cognition. *Brain & Cognition*, 34, 107-129.
- O'Regan, J.K. & Noë, A. (2001a). A sensorimotor account of vision and visual consciousness, *Behavioral and Brain Sciences* 24(5), 939-973.
- O'Regan, J.K. & Noë, A. (2001b). Author's response: Acting out our sensory experience. *Behavioral and Brain Sciences* 24(5), 1011-1031.
- Pace, M. (2006). Review of Alva Noë, *Action in perception*. *Notre Dame Philosophical Reviews*.
- Sharkey, N. & Ziemke, T. (2001). Mechanistic versus phenomenological embodiment: Can robot embodiment lead to strong AI? *Journal of cognitive Systems research*, 2, 251-262.
- Sheets-Johnstone, M. (1999). *The primacy of movement*. Amsterdam/Philadelphia: John Benjamins.
- Stewart, J. (1996). Cognition = Life: Implications for higher-level cognition. *Behavioural Processes*, 35, 311-326.
- Van Duijn, M., Keijzer, F.A. & Franken, D. (In press). Principles of minimal cognition: Casting cognition as sensorimotor coordination. *Adaptive Behavior*.

---

<sup>1</sup> For other reviews see e.g. Block (2005), Edelman (in press), Gallagher (2005), Gregory (2005) and Pace (2005).

<sup>2</sup> But see for example: Maturana & Varela (1980), Moreno, Umerez & Ibañez (1997), Stewart (1996), Van Duijn, Keijzer and Franken (In press).