Self-Steered Self-Organization

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Abstract
Self-organization has become a well-established phenomenon in physics. It is now also propagated as an important phenomenon in psychology. What is the difference between these two forms of self-organization? One important way in which these two forms are distinguished is by the additional presence of some internal guiding force in the psychological case. Kelso in particular defends such a two-component view on self-organization. I will refer to this addition to mere physical self-organization as *self-steering*. This chapter attempts to conceptualize the idea of self-steering. Kelso's interpretation of self-steering as intentional and informational forcing will be criticized. This interpretation amounts to the invocation of an unexplained intentional force that falls victim to many of the problems related to regular representation-based cognitive science. Instead, I argue that the notion of self-steering is wider and needs to be developed in its own right rather than being forced into existing intentional or representational molds.

Introduction
Self-organization has become a well-established phenomenon in physics. It is now also propagated as an important phenomenon in psychology (Haken, 1995; Kelso, 1995, This volume). What is the difference between these two forms of self-organization? One important way in which these two forms are distinguished is by the additional presence of some internal guiding force in the psychological case. Kelso in particular defends such a two-component view on self-organization (1995, This volume). I will refer to this addition to mere physical self-organization as *self-steering*. This chapter attempts to conceptualize the idea of self-steering. Kelso's interpretation of self-steering as intentional and informational forcing will be criticized. This interpretation amounts to the invocation of an unexplained intentional force that falls victim to many of the problems related to regular representation-based cognitive science (Clark, 1997; Haselager, Bongers & Van Rooij, This volume; Keijzer, 2001).

Self-steering can be seen as the introduction of a representational domain in theories of self-organization. However, I will argue that self-organization requires steering factors that remain tied to a particular organization in which they perform a modulatory function. As a consequence the steering factors may be like representations, but they have no meaning or

existence apart from the self-organizing processes that they help to regulate. In this respect there remains a major difference with traditional representational theories.

The chapter consists of the following sections. The next section will first develop the two-component view of self-organization in its most basic, that is biological context. The following section discusses Kelso's application of the two-component view to psychology. This section criticizes his intentional interpretation of the steering factor and is also critical of Jordan's (This volume) wide interpretation of intentionality. The next section applies a more basic interpretation of self-steering to the psychological domain. I will argue that this interpretation maintains a distance from the invocation of regular representations. Also, the need to understand self-steering in a more concrete empirical sense leads in a natural way to an appreciation of non-human basic behavior as an important topic for developing a self-organizing view on psychology.

Self-organization and 'representational steering': the two-component view

The notion of self-organization is a familiar one nowadays. For many years, after the second law of thermodynamics was formulated, it was common sense that the universe was inextricably moving toward a state of increasing disorder. Then, beginning in the nineteen-fifties, it became slowly evident that in systems far from thermal equilibrium—that is in systems pumped with energy—spontaneous order could arise. Even when the universe as a whole becomes increasingly disordered, there are parts of this same universe that become increasingly ordered. This insight became widely known after Ilya Prigogine and Isabelle Stengers published their book "Order out of chaos" in 1984, which provided a generally accessible introduction to this phenomenon. Since then it has become common place that certain kinds of physical, chemical and biological systems have this self-ordering capacity in which a collection of initially disordered components become mutually coordinated and come to show patterns as a collective.

It should be stressed at this point that the pattern-formation exhibited by self-organizing systems is a perfectly general, physical phenomenon. Haken (1987), for example, originally formulated his account of self-organization in the context of laser-light, while the development of convection rolls in a fluid heated from below provides one of the standard cases to introduce the idea of self-organization (Haken, 1995; Kelso, 1995). Self-organization then is a general phenomenon that is not necessarily related to biological or psychological phenomena. The patterns generated simply follow general mathematical rules (Stewart, 1998).

The question that immediately follows from this observation is, of course, in what way does self-organization then bear on psychology? If the psychological domain is to be thought of in terms of self-organization, how is it then separated from physical phenomena in general? Intuitively there seems to be a big difference between laser-light and convection rolls on the one hand, and thought and action on the other. Actually, this question already applies to biology where the pattern-formation occurring in living systems is often much more complex than what happens in non-living systems. What then makes the difference between general, physical forms of self-organization and what occurs in biological and psychological systems?

The general solution to the problem is to add an extra ingredient to the self-organizing process. This ingredient consists of a factor that 'steers' the pattern forming processes into specific directions. In biology, DNA plausibly performs this role, while in psychology notions like mental representations and intentions come to mind. Kelso calls this addition that makes biological and psychological self-organization different from self-organization in general "the second cornerstone of biological self-organization" (1995, p.137-138), self-organization itself being the first one. This second cornerstone is most easily introduced for the biological case, which will be done in the remainder of this section. In the following sections, I will turn to the

issue how this steering has to be interpreted in psychological systems.

At first sight, invoking DNA as a steering factor in biological systems seems to contradict the importance of self-organization there. In the general media in particular, DNA is often staged as a complete set of master instructions that specify the organization of a living system. The latter is then seen as a direct derivative of the instructions present in the DNA. In this image, DNA acts as a controlling agent that actively forces an essentially passive and compliant medium (consisting of intra and extra-cellular processes) into specific patterns. However, this general view of DNA as the sole origin of biological order is more and more disbanded in favor of a view that stresses the additional importance of self-organizing processes in biological systems (Kauffman, 1993; Goodwin, 1994; Maynard Smith & Szathmáry, 1999; Stewart, 1998). Stewart puts it as follows:

> The complexity of an adult organism, such as a tiger, exceeds that of its DNA by virtually any sensible measure. The wiring diagram for a tiger's nervous system alone is more complex, by several orders of magnitude, than the tiger's entire DNA sequence. That sequence, complex as it is, versatile as the contingency plans may be does not contain enough information to specify how to build a tiger's brain, let alone an entire tiger. … The missing information is supplied by the mathematical rules (the laws of physics) that govern the behavior of matter. (1998, p. 13)

Although there is definitely no agreement about the relative importance of the two components—self-organization and genetic instructions—it is now increasingly clear that both are essential. Most important for present purposes is the shift in interpretation this brings about when it comes to the functioning of DNA in biological systems.

The notion of steering takes on a different meaning when it involves a self-organizing process. Steering is not a matter of forcefully imposing order onto a system where there is no order to begin with. The system that is being steered is not passive matter waiting to be molded into shape. On the contrary, the steered medium provides itself the pattern forming process. Steering is much less direct and rather takes the form of modulating a set of ongoing processes. When a system is in the position to develop into two different directions at a certain moment, steering takes the form of giving it a little push into one direction rather than another.

There are two concepts that are important to make this idea of steering a self-organizing process more concrete: the order parameter and the control parameter. The order parameter represents the large-scale (macroscopic) order brought about by the interactions between a number of parts at a smaller (microscopic) scale (Haken, 1987). In turn, the macroscopic order parameter constrains or "enslaves" the behavior of the microscopic parts. Whether an order parameter arises or what form it takes depends on the state of the system as described by a set of parameters. Some of these parameters act as control parameters. That is, by varying these parameters, the system as a whole can be shifted from a disordered state into an ordered state, or from one such a macroscopic pattern into another. Going back to the example of convection rolls above, changing the temperature difference between the bottom and top of the fluid layer is a way to shift the system from a disordered macroscopic state into one which exhibits large-scale convection rolls (and back again). This makes the temperature difference a control parameter for this particular form of self-organization. Manipulating the control parameter offers a way to manipulate the order parameter.

In the general physical occurrence of self-organization, such as in the example of the fluid rolls, the presence and the value of the order parameter is a matter of chance as far as the order producing system is concerned. Whether or not someone puts on the fire beneath a pan filled with oil is not for the oil to decide. However, the situation is different in biological forms of self-organization where the genetic factor comes into play. Using the language of order and control parameters, one can hold that a biological system is capable of manipulating its own

control parameters, turning them on and off in order to achieve specific macroscopic states that can be described by low-dimensional order parameters. As Kelso puts it, in biological self-organization there are "specific parametric influences" at work (Kelso, 1995, p.138).

Genes can then be interpreted as a set of control parameters that are stored inside the biological system on a long-term basis. Genes provide the specific parametric influences that are required to modulate self-organizing processes in such a way that they develop into the many different structures and shapes of living systems. Following Meijer and Bongaardt (1996, see also Keijzer, 1998, 2001), I will call this form of control parameter *internal control parameter*, or ICP for short. The difference between general, physical forms of self-organization and biological self-organization can then be summarized by saying that biological systems are capable of manipulating their own control parameters, and in this way the order parameters that make up the large-scale structure of biological systems.

The link between genes and ICPs brings to the fore another aspect of ICPs before they can act as the steering factor of biological self-organization. These ICPs must themselves be steered by other factors. In simple cases, an inactive ICP can be activated by some other external and essentially arbitrary parameter. For example, Meijer and Bongaardt (1996) use the effect of cornstarch on the viscosity of soup as an example of an internal control parameter. In this example the temperature of the soup triggers the internal parametric influence of the cornstarch. When the soup starts to boil, it becomes viscous. The drawback of this setup for biological self-organization is that this process is still dependent on an unregulated external force; someone who wants to make soup and puts in the cornstarch, assuming there is already a fire on beneath the pan. In biological systems the triggering of genes that could act as ICPs is itself under the control of the living system. There is a complicated loop-like system of regulatory genes that turn on and off other regulatory genes as well as structural genes that actually code for proteins. In addition there is a widespread feedback of metabolic processes or substances that when present or absent in turn influence the transcription of particular genes and so on. The whole takes the form of a so-called genetic regulatory network (Kauffman, 1993) consisting of widely dispersed and reciprocal influences between genes, proteins and metabolic processes. As Kauffman argues, such networks are themselves to be interpreted as a self-organizing process that are very robust to change and very flexible in overcoming disturbances. I will refer to the invocation of such a loop-like regulatory network for turning on and off ICPs as self-steering.

There are two aspects to this way of interpreting biological cases of self-organization that are particularly important when this interpretation is also applied to psychological systems. First, it must be stressed that ICPs are a part of the microscopy. Self-organization implies a distinction between a microscopy and a macroscopy as two different levels of aggregation and description. The microscopy self-organizes into a macroscopic pattern as described by an order parameter. ICPs are factors that happen to initiate and maintain particular macroscopic patterns and in this sense are closely linked to the macroscopy. However, to act as control parameters ICPs must have an existence prior to and independent from the macroscopic patterns they help to bring about. Without such independence, new instances of a particular biological form could never be generated in this way. Normal control parameters remain outside the range of the microscopy-macroscopy system and are thus by default independent from the macroscopic order. ICPs however, must be part of this two-level system, and the only place where they can function as a parameter independent from the macroscopy is within the microscopy.

In addition, these internal control parameters must also maintain a certain independence from the microscopic processes to which they belong. When ICPs are to act as a switching device, initiating and stopping specific biological self-organizing processes, they cannot continuously take part in the ongoing interactions between the microscopic elements. Their continuous physical presence within the microscopy must not lead to a continuous specific

parametric influence. This influence has to be a variable, sometimes present sometimes not. An ICP must in this sense be buffered from the microscopy at large, while its parametric influence has to be triggered by some other influence.

All of this corresponds in a general way with current knowledge about the operation of genes in metabolic processes and morphogenesis. DNA, the material embodiment of genes, situates the genetic factor firmly within the biomolecular operation of living systems. At the same time DNA remains relatively sheltered from the immediate ongoing biomolecular processes and influences these processes indirectly by coding for particular proteins that do the actual work. Also, the specific codings present within the DNA are derived from long-term evolutionary selection and in this sense are independent from the short-term ongoing, biomolecular processes.

To summarize, bringing self-organization to bear on biological systems thus involves thinking in terms of and teasing out complex regulatory networks with their self-organizing properties. There is 'plain' physical self-organization such as in convection rolls. There is the steering of this self-organization by specific parametric influences in the form of ICPs. Finally, there is self-steering by a mesh-like system of multiple, parallel and reciprocal influences, involving regulatory genes, structural genes, gene products, and factors deriving from the large-scale build up produced by all this activity. So far, it seems that proper conceptual tools that would allow us to deal efficiently with this complex, mesh-like organization have not yet been developed (Bell, 1999). Deciphering how such networks succeed in producing and maintaining large and structurally differentiated biological systems thus looks like a key issue in understanding biological systems in general and self-steering self-organization in particular.

I want to end this section by turning to a conceptual issue that, I think, tends to obscure the problems and possible solutions that are at stake when it comes to these genetic regulatory circuits. This factor consists of the regular use of notions like symbols, representations, and encodings to describe the functioning of genes. Of course, there is nothing wrong with these words themselves, but they are often indicators of a particular interpretation of genetic functioning. In this particular interpretation, genes are seen as symbolical description of the organism they are helping to bring about. The metaphor here is still that of the genome as a blueprint for the construction of an organism (Savageau, 1998). Seen through this metaphor, the genome is interpreted as a symbol system, containing the *description* of complete organisms and as a symbol system equivalent to other coding systems like natural languages, logic, formal mathematics, and programming languages (Pattee, 1995). However, this interpretation brings us back to the old conceptualization of an intelligent force set apart from the universe at large that infuses a mere material system with its order. The idea of an immaterial vitalistic life force may have been abandoned within biology, but many of its characteristics have been attributed to DNA, acting as its material replacement. The idea of genes as symbols is a very influential metaphor. However, the presence of this metaphor does not help to think about genetic regulatory circuits in terms of genetic regulatory circuits but rather imposes a traditional frame of mind onto this kind of organization. As Savageau says: "The common metaphor of the genome as a blueprint for construction of the organism masks the difficult task of relating structure and function of the intact organism to its underlying genetic determinants." (1998, p.55).

The story that I have sketched in terms of ICPs is in opposition to a symbolical or representational interpretation. Internal control parameters do not provide descriptions of what is to take place, they act only as triggers for specific self-organizing processes in a specific context. In turn, such ICPs are part of complex network of regulatory factors, involving initiation, modulation and feedback loops at and between different levels of organization. The challenge is to decipher the operation of such regulatory networks. Apart from the sheer complexity involved

there is also the counterproductive interpretation of symbolical descriptions involved which obscures the kind of interaction involved in relating a genome to a whole organism. It is unhelpful to see the genome as just one more instance of a symbol system as we already know them.

This is not to deny that there may be close links between genetic regulatory networks and the processes at work behind the human mind and behavior. However, instead of using psychological symbol users as a conceptual framework for interpreting genetic functioning, it is better to work the other way round. By starting with a genetic regulatory framework in mind, it becomes possible to outmaneuver the symbol-metaphor, not only in the biological case, but, as I will argue in the next section, also within psychology.

Kelso's intentional interpretation of the two-component view
How does the two-component view impact on psychology? A good way to introduce the topic is by looking at Kelso's way of dealing with the issue. Given his well-known workhorse task of bimanual finger-movements, self-organization comes into play as the spontaneous transition from antiphase movement to in-phase movement when the movement's frequency is increased. To be more concrete, the simplest version of the phenomenon is when you move your two index fingers up and down in an antiphase fashion—that is one up, the other down. Speeding up the movement will result in a switch to an in-phase movement—both fingers being up or down at the same time—without any intention to produce this synchronization. The body does that for you 'on its own'.

How about the second, steering component in this context? Our fingers may have a tendency to synchronize when we let them. However, we can also disturb such tendencies by consciously trying to maintain the antiphase pattern, and getting better at it as time passes. We can also decide not to move our fingers in the first place, in which case the synchronization does not occur at all. There is definitely more going on in the case of finger movements than mere physical self-organization, and it is here that Kelso's already mentioned "specific parametric influences" come into play (1995, p.138, see also Kelso, This volume). There are some interesting differences between Kelso's view and the one presented above for biology. I will first sketch Kelso's position and then come to a comparison. Most important is that Kelso brings in the concept of intention at this point. He claims that intentions "do not lie outside self-organized coordination dynamics. They are an intrinsic, inseparable part of them. Intending and doing are but two aspects of a single behavioral act." (p.145) Given the distinction between the symbolic realm—of which information and intentions are a part—and the world of dynamics, Kelso solves the problem how the two are to be related by a move that is the opposite of the one made in the previous section. Instead of placing self-steering on the dynamical side of the divide, he solves the dilemma by claiming that "self-organized coordination dynamics are, at their very roots, *informational*." (Ibid.) In this way he "turns the mind-matter, information-dynamics interaction on its head. Instead of treating dynamics as ordinary physics and information as a symbolic code acting in the way that a program relates to a computer, dynamics is cast in terms that are semantically meaningful." (Ibid.) Kelso claims empirical evidence for this step but is very short in specifying what exactly makes self-organizing processes intrinsically informational. If I read Kelso correctly here, he says that order parameters are intrinsically meaningful to organisms, as the order parameters consist of, or provide the information that specifies the coordinative relations among an organism's parts or between it and the environment. And what could be more meaningful to an organism? In this way, Kelso reconciles intentions with self-organizing processes and casts the former in the role of the necessary steering factor in biological and psychological self-organization. Intentions provide the "specific

parametric influences" that enable us to force our fingers to move in ways that go against their intrinsic dynamics.

As far as I can tell, Kelso's interpretation of the steering factor in biological cases of self-organization in terms of intentions is not a good one. However, this is not the severe criticism it might have been because his account leaves ample room for a different interpretation that does not invoke intentions, meaning or information from the start. This interpretation is the one in terms of internal control parameters as described in the previous section. First, let us have a look at the problems that surround Kelso's intentional explanation of steered self-organized processes.

The first problem is that it is unclear whether non-biological cases of self-organization, such as convection rolls, are semantically meaningful or not. Both options make trouble for Kelso's intentional steering. The idea that all physical forms of self-organization have semantic meaning is unattractive. It smacks of panpsychism in which large parts of the universe are inherently mental, which is in direct contradiction with the received view that mind and meaning only come about in very particular configurations of matter (such as embodied nervous systems). On the other hand, when only biological forms of self-organization exhibit intrinsic meaning, the question arises how this difference comes about in a non-question begging way? Kelso says that order parameters are meaningful to organisms, but this would make the semantics derivative on there being organisms in the first place, which cannot be given the assumption that living organizations are dependent on these steered self-organizing processes. The last point also brings to the fore the difficulty that steered self-organization is supposed to be part and parcel of living organizations from the very (evolutionary) start. Any self-organizing processes within even the most primitive bacteria already involve all kinds of steering, supposedly done by factors that act as internal control parameters. Bringing in mind and semantics at these early stages of biological self-organization sure seems like explanatory overkill. And last but not least, notions like semantics, intentions and—in this particular context—information are part of what is to be explained. These concepts cannot be simply injected at this point without any independent specification. Considering these problems, the conclusion is warranted that the steering factor of self-organizing processes is not to be cast in terms of intentions.

In contrast to this conclusion, Jordan (This volume) defends a view in which intentionality is assumed to be present in all living systems—interpreted as autocatalytic processes—whether these are single cells or humans. Jordan acknowledges that it sounds bizarre to claim that a single cell "intends" to be what it is (that is to autocatalyze its own existence) but claims that this bizarreness merely reveals hidden assumptions concerning intentionality that deserve to be criticized. Without going into the details of his account, an important motivation for his view seems to be that it explains the occurrence as well as the specialness of intentionality (and consciousness) in a natural and ultimately physical world. By casting intentionality so wide, Jordan builds upon the generally acknowledged sharp transition between nonliving and living systems and makes intentionality as special as life itself. However, given the arguments stated above, such a view remains very problematical, while it also remains unclear what this wide reading of intentionality will add to our understanding of basic biological and psychological processes. The difference between the biology of single cells and the psychology of humans is huge. We need a suitably differentiated vocabulary to make sense of this wide range of phenomena. Finding a cutoff point that will allow us both to maintain that intentionality is special indeed *and* to stick to the notion of intentionality as intrinsically psychological ought not to be too difficult when we acquire a better understanding of this range of phenomena.

To return to the main argument, where does the rejection of intentional steering leave

Kelso's account? Well, in better shape than it was before, I should say. Shedding the problematic intentional interpretation of the steering factor leaves the more basic ideas intact and turns them into a coherent conceptual framework. This conceptual framework has already been outlined in the previous section. Instead of intentions there are internal control parameters—or whatever one wants to call them—that influence or force ongoing bodily coordinations in particular directions, partly overcoming the intrinsic tendencies of our bodily dynamics. Rather than shifting the dynamics into the symbolical realm, it is the steering factor that is shifted into the dynamical realm.

At this point it must again be stressed that ICPs are non-specific with respect to the self-organized order that they happen to control, or at least influence. What makes certain factors within a biological organization ICPs is the effect they happen to have on the pattern formation in a particular self-organizing process. There is no intrinsically meaningful connection between an ICP and the self-organized macroscopic order. Order does not flow from the ICP into the macroscopy. An ICP is nothing more than an unspecific parameter that has the property that it can act as a switch that turns on or off, or modify a particular self-organizing process. When there is talk about *specific* parametric influences, it relates to the *effect* an ICP has on self-organization. An ICP acts a switch and has in this sense a predictable and repeatable influence on particular occurrences of self-organized pattern formation. And, of course, a particular ICP is present in a living organization because it has this influence on the pattern-forming processes of that living organization (assuming this is its proper function in Millikan's sense (1989)). However, the ICP does not symbolize or represent the order it brings about in any way, it only triggers—one might say it catalyzes—pattern-forming propensities that are already present. It is important to keep these two readings of 'specific' separate, because the difference between approaches based on self-organization and more regular representational and computational based approaches, hinges on the distinction (Keijzer, 2001). The possibility for confusion here is a final reason for being very critical of Kelso's intentional interpretation of ICP-like factors. The concept of intention suggests a much more direct and intimate connection between the intention and the intended movement than what is provided for by ICPs. Kelso also occasionally seems to suggest that intentions have an intrinsic meaningful connection with order parameters: "Intentions ... are written in terms of the very order parameters that characterize the coordination activity of the nervous system." (1995, p. 146). The meaning present in intentions is the same as the order produced in the intended movements. This reading comes very close to the old cognitive science interpretation of a computational program that specifies what the motor system has to do in order to produce coordinated movement, the exact opposite of Kelso's own ideas! What goes wrong? I would say that Kelso tries to do two things at once here, both providing an account of self-steered self-organization, as well as providing an account of intentionality that fits into the first story. However, the second enterprise interferes easily with the first one, when the first has not been very clearly, explicitly and independently established. When it comes to applying the idea of self-steered self-organization to psychology it is very important to keep both enterprises conceptually distinct.

Applying the two-components view to psychology
Kelso's intentional account of self-steered self-organization made an easy connection with psychological matters. By bringing in intentions as a steering factor, his plea for a psychology that takes self-organization seriously moves in a fluent way beyond any retorts that all of this is no more than a movement science. Intentional self-steering is undoubtedly a central psychological topic.

The conclusion arrived at in the previous section was, however, that self-steering in self-organization must be stripped of its intentional robes, leaving the self-steering component quite

naked. What is left is a two-component view that applies to the most basic forms of biological self-steered self-organization, such as those occurring in bacteria. The obvious and important question here is: How does such a basic interpretation bear on psychology?

The first thing to consider is that the steering factors are very different in the two domains. Intentions are definitely not the same as some internal control parameter influencing a self-organizing process within a bacterium. The same goes for any process of self-organization itself that might be involved. The structures arising in bacteria are not the same as intentional movements. Kelso deals with these differences by stressing that self-steered self-organization is a general, abstract dynamical pattern that is to a large extend independent from—or multiply realizable by—different physical instantiations. This strategy has the great advantage that this conceptual framework can be applied to many structurally different phenomena, including psychological ones, in an intuitively plausible way. As argued above, however, this loose usage of the framework does not help to explain how intentional steering is any different from biological self-steering in general.

A more productive use of the self-steered self-organization framework would do the following: (a) Help explain the difference between more simple and more complex forms of biological and psychological self-steering. (b) Help explain how the steering factor itself seems to become increasingly symbol-like when we go from the most basic ICPs to unquestioned cases of intentional action. Whereas ordinary ICPs are easily seen as mere triggering factors, in the case of intentions there is a strong subjective experience that any self-organized effect or action is already symbolically present beforehand. How can ICPs be fitted into this intentional domain?

For the first problem the conceptual outlines of a solution have already been described. Self-steered self-organization is said to be controlled by genetic regulatory networks or, when it comes to psychology, their neural equivalent. In Kauffman's interpretation such regulatory networks are themselves to be interpreted in terms of self-organization. Consequently, a self-steered self-organizing organization can in turn be envisioned as being 'steered' by an overarching regulatory network. The original regulatory network then turns into a first-order system, which itself is steered by a second order system. In this way, it becomes thinkable that self-steered self-organization is an arbitrarily extendable organizational form that can, in principle, be build up until it includes genuine intentional forcing. This layered interpretation is reminiscent of Brooks' well-known subsumption architecture in robotics (Brooks, 1999). Brooks started out with a robot and a control structure that could only perform a very simple task, say standing up for a six-legged robot. Once the robot could do this, an extra layer was added to the existing control structure that enabled it to lift and move its legs in such a way that the robot moved forward, and so on. Although these robots are not cases of self-organization, they do give an impression how self-steering can be extended by adding regulatory feedback loops on top of an existing self-steering organization.

The second desideratum is much more difficult to deal with and its treatment here is much more hypothetical than the postulation of multiple layers of self-steering. How do higher-order ICPs finally turn into symbol-like entities that seem to incorporate—to describe Pattee would say—beforehand the very order they help bring about? A plausible place to look for transitional cases that become increasingly symbol-like steering factors is provided by the work of Milner and Goodale on visually guided action (Milner and Goodale, 1995; Goodale, 1998; Goodale and Humphrey, 1998). Milner and Goodale differentiate between a ventral and a dorsal stream in the brain's visual processing for action. Roughly, the dorsal stream consists of projections that run from the retina to the primary visual cortex and then end up in the posterior parietal cortex. The ventral stream consists of projections that after the primary visual cortex go on to the inferotemporal cortex. Earlier, Ungerleider and Mishkin had proposed that the ventral stream mediates object vision, providing a what-system, while the dorsal stream mediated

spatial vision, forming a where-system. In this view, both streams subserved different aspects of *perception*; the ventral stream identified an object, while the dorsal stream specified the object's location. Milner and Goodale (1995) on the other hand proposed that the dorsal stream was not strictly perceptual but a "complex network of visuomotor modules interconnected with other cortical and subcortical structures concerned with sensorimotor control", which is "in the business of transforming visual inputs into skilled motor acts." (Goodale, 1998, p.R489) Many neurons in the dorsal stream, for example, are activated both by visual stimulation and by concurrent behavior. The ventral stream on the other hand is seen as fundamentally perceptual, necessary for us to have phenomenal experience of the visual world, and only in a more indirect way connected to action by influencing the dorsal stream. The general upshot of this account would be that the ventral stream is a slower, relatively off-line system where longer-term decisions are made such as 'pick up that particular object,' while the faster dorsal stream under immediate visual control takes care that the hand moves to the proper place, that the hand is oriented suitably with respect to the object, that the finger-thumb separation is appropriate to grasp the object, and so on. So, Milner and Goodale's proposal differentiates between a direct, fast visuomotor system and a slower system for visual perception that acts by directing this fast visuomotor system.

How can this model be brought to bear on the problem at hand: coming up with symbol-like or even intention-like forms of ICPs? The first hurdle to take is linking up Milner and Goodale's account of the dorsal stream with an approach based on self-organization. Milner and Goodale themselves do not dabble (as far as I am aware) in theories of self-organization, but conceptually an interpretation in terms of self-organization seems at least a possible one. The dorsal stream in their work is specifically interpreted as a perception-action system, a loop-like structure that binds perception and action together. The dorsal stream does not come up with an internal, action independent reflection of the external environment. All this brings Milner and Goodale's view on the dorsal stream close to accounts of behavior in terms of organism-environment couplings and perception-action loops. Such accounts are exactly the ones in which self-organization features very prominently (Clark, 1997; Keijzer, 2001).

The second hurdle consists of the interpretation of the ventral stream. Does this stream contain symbol-like activity? Yes, the ventral stream performs a coding of object identities that are abstracted from any direct dorsal perception-action occurrences. The ventral stream does not deal with viewer-centered codings as does the dorsal stream, because "the perceptual constancies intrinsic to many operations within the ventral system would need to be protected from intrusions that could disrupt the continuity of object identities across changing viewpoints and illumination conditions." (Milner and Goodale, 1995, p.201) This is very symbol-like, and the only thing that could plausibly be held against this claim is that the codings in the ventral stream are not merely symbol-like but genuine symbols, entities that represent external reality independent of any action component. In this case the ventral stream could be seen as the beginning of an account of behavior in terms of specific instructions, just the kind of account that one based on self-organization is set up to avoid. I will not try to argue against this interpretation here. I will only argue that a symbol-like interpretation—that is one in terms of ICPs—is possible as well.

Clark (1999) provides a first link between Milner and Goodale's view on the ventral stream and an interpretation in terms of perception-action couplings. Clark argues that the perception-action loops of the dorsal stream can also be witnessed in the ventral stream. The difference is that the two streams involve different kinds of action. The dorsal stream is geared to action that involves movements that must deal with egocentric space and real locations. The encodings of the ventral stream "are geared to *action* in the sense in which actions reflect the specific needs, purposes and intentions of the agent." (p.11) In this sense the ventral stream is

also an action system, just like the dorsal one, only on a more abstract action-level. Clark provides here a nice general congeniality between perception-action accounts (where self-organization finds a psychological home) and the perceptual function of the dorsal stream. This suggests that the ventral stream does not provide strictly perceptual encodings but encodings that are dedicated to specific aspects of action generation. The important question then becomes how the ventral stream influences the dorsal stream. If the two streams are so different, how do they interact? Milner and Goodale (1995) recognize this as an essential question but their answer remains very general: The ventral stream 'flags' an object so that the dorsal stream can deal with it. Goodale and Humphrey (1998) use the metaphor of a human operator and a semi-autonomous robot for clarifying this 'flagging' (p.202). They state that the "operator uses a symbolic code to communicate with a robot that actually performs the required motor act on the marked goal object." (Ibid.) In this interpretation the ventral stream becomes very much like a homunculus using general—that is not action-related—symbolic encodings that manipulates the dorsal stream and other, lower levels of neural organization. This interpretation spells trouble for any invocation of high-level ICPs here. However, the interpretation is itself unattractive for the homuncularization of the ventral stream. Given the neuroscientific background of the ventral-dorsal interaction problem, an account in terms of possible neuro-computational mechanisms involved in the interaction between the two streams is much more plausible (Van der Velde and De Kamps, 2001). When the ventral-dorsal interaction is cast in terms that incorporate the neuro-computational mechanisms, involving the interactions between different cortical areas, modulation of neural activity, gating circuits and so on, little is left of the ventral stream as a domain of general symbolic encodings. In a very general sense, thinking in terms of ICPs comes easily here. ICPs are no more than triggering factors that are tied to a particular regulatory setup, and such factors seem to come naturally under the circumstances that are present in the ventral stream.

To conclude, the ventral stream is a place where ICPs could play a role, given that the dorsal processing and other neural centers are thought of as a many-layered setup of self-steered self-organizing processes, which the ventral stream modulates at yet again a new level of perception-action coupling. The question how such intentional ICPs become so much like regular symbols is easily answered now. By adding layer upon layer of self-steering the perception-action loops that become possible are increasingly involved in long-term goal achievement and dissociated from the physical here and now in which an agent is situated. Any ICP that would act within a regulatory network at such a level of perception-action coupling must be dissociated from specific motor actions. For any high-level goal, there are many possible motor actions that will lead to achieving the goal and this would bring in too many executive details that interfere with the coordination of the long-term goal. This is the same point that Milner and Goodale used in the first place for arguing that ventral processing must be isolated from dorsal processing. ICPs that are thus isolated from specific physical perception-action couplings are easily seen as fully independent from any perception-action coupling and thus as perfectly general symbolic codes. This interpretation becomes even more natural because there is a strong tendency to conceptually collapse all the many layers of a self-steering organization into a singular operational system that is effectively a black box. The close connections between intentional ICPs and the behavioral organization of which they are a part are easily forgotten then. The situation is similar to the old and pervasive image of genes as the fundamental factor for our phenotypic traits, while the context on which genetic functioning depends remains out of focus. The case is similar for intentional ICPs, which are easily mistaken for context independent symbols.

All this positive talk about the possibility and even the plausibility of the self-steering self-organizing conceptual framework in a psychological context should not be mistaken for

genuine evidence for this framework. I hope this has been clear all the time. Self-steered self-organization is an idea that needs to be cashed out with empirical findings and theory in order to make it more than a mere, although nice, idea. The discussion of ICPs in the context of the ventral and dorsal visuomotor stream is not more than an appetizer for what might be: an extensive empirical and conceptual psychological framework, based on self-steering, that reaches all the way up to a clearly cognitive and human context. This appetizer is no replacement for a main course and that dish still has to be prepared and cooked. The key issue is how to proceed from here on? How can self-steered self-organization be made a testable and more concretely elaborated theory about the generation of the human mind and behavior?

One important message, I think, is that self-organization in biological and psychological systems must become more closely tied with the structural—biochemical, morphological and neural—characteristics of those systems. A loose, butterfly approach that touches upon all kinds of different cases of self-organization and shows these to be instantiations of a general, multiply realizable phenomenon is good to establish that self-organization is genuine. However, *that* message should be digested by now. The problem at hand is to uncover how biological and psychological systems make specific use of the general principle of self-organization. This requires explicit attention for the details of biological structures, such as nervous systems.

An obvious way to go from here is to turn to cognitive neuroscience. The technological developments of the last few decades have made it possible to investigate monkey and human brains in unprecedented ways. However, even though I think that cognitive neuroscience is extremely important, for the purposes of uncovering the neural and behavioral organization behind self-steering, it seems not the best and should certainly not be the sole approach. The human brain and human action is just too complex for this purpose. The work of Milner and Goodale exemplifies how much comes to depend on positive interpretations when self-steered self-organization is to be developed in this highly complex context.

At stake here is not developing an account of the particular workings of the human brain and its role in human action. The problem is to uncover general principles of self-steering and self-organization that are supposed to be also at work in the human condition. What is missing in psychology is an understanding of the cyclic or loop-like organization present in perception-action couplings and in nervous systems themselves (Bell, 1999). Apart from a formal mathematical approach of such problems, the best place to study this kind of organization empirically is by turning to the simplest psychological systems. To define a psychological domain in this context, some cutoff point with biology in general will be necessary. The presence of mind cannot fulfil this role here. A mind is a very complex organization, and any really simple psychological organization would be a doubtful example of the presence of mind. A more plausible demarcation for psychology is provided by the presence of (animal) behavior that involves the activity of a nervous system (see also Keijzer, 2001). This demarcation (a) separates the kinds of system that ought to be addressed by psychology from biology in general, (b) includes the human condition but (c) also much more simple psychological systems, that is any organism in possession of a nervous system. The latter cases should help to unravel the basic cyclic operation of nervous systems and the problem how increasingly complex perception-action couplings are generated by increasingly complex neural organizations. Orlovsky, Deliagina and Grillner (1999) provide an example of this turn toward more simple behavioral systems. The three authors of this book all studied locomotion in cats until the beginning of the 1980s. Subsequently they all turned to much simpler organisms (lampreys and mollusks) because of "an increasing feeling of dissatisfaction caused by the fact that a number of principal questions concerning the locomotor system could not be answered in the cat model. … This difficulty was caused by the extreme complexity of the networks." (p.262) To conclude, the study of basic behavioral capacities in simple (when compared to humans) animals seems a

good place to study the basic principles involved in psychological instances of self-steered self-organization.

Conclusion
Self-steered self-organization in psychology is still a hazy concept. What seems clear however is that it ought not to be interpreted in terms that particularly apply to an intentional, human-level psychological context. Self-steering does not involve intentional forcing or ordinary representations dissociated from their context of use. Compared to intentionality, self-steering is a more basic and general concept that applies also to lower levels of organization. Making sense of self-steering in psychology requires a fundamental understanding of perception-action couplings and the neural modulation of such couplings. Whether this understanding comes from studying humans or other animals is irrelevant, and as some invertebrate species provide much more accessible model systems for uncovering such principles, the implication is that the basic behavior of insect-like creatures becomes an important topic for a self-steering self-organized approach in psychology.

Having said this, it should also be stressed that this is not a plea to neglect genuinely human psychological phenomena. The picture sketched here is one of many layers of self-steered self-organization ranging from basic forms of biological organization to the classic cognitive capacity of playing chess. This is a very wide range of phenomena and it ought to be clear that over this range qualitatively new forms of biological and psychological organization have arisen (Maynard Smith & Szatmáry, 1999). For example, the difference between prokaryotic and eukaryotic cells is huge, and so is the difference between the psychological characteristics of lampreys, cats and humans. Lampreys may provide good model systems to study some basic principles. Still, the ways in which such basic principles are expanded on in cats and humans provide important psychological topics on their own account. In contrast to Jordan (This volume), it seems plausible that, somewhere along this range, but not from the start, classic mental concepts like intentionality and representation become appropriate. But even here one should be wary whether these concepts are helpful to cast light on human psychological functioning, or whether it is the other way round and these concepts will themselves be filled in and clarified by a better understanding of the many layers of human psychological functioning.

References
Bell, A.J. (1999). Levels and loops: the future of artificial intelligence and neuroscience. *Philosophical Transaction of the Royal Society in London B, 354*, 2013-2020
Brooks, R.A. (1999). *Cambrian intelligence*. Cambridge, MA: MIT Press.
Clark, A, (1997). *Being there*. Cambridge, MA: MIT Press.
Clark, A. (1999). Visual awareness and visuomotor action. *Journal of Consciousness Studies, 6*, 1-18.
Goodale, M.A. (1998). Visuomotor control: where does vision end and action begin? *Current Biology, 8*, R489-R491.
Goodale, M.A. & Humphrey, G.K. (1998). The objects of action and perception. *Cognition, 67*, 181-207.
Goodwin, B. (1994). *How the leopard changed its spots*. New York: Scribner's Sons.
Haken, H. (1987). Synergetics: an approach to self-organization. In F. Yates (Ed.), *Self-organizing systems: the emergence of order* (pp. 417-437). New York: Plenum Press.
Haken, H. (1995). Some basic concepts of synergetics with respect to multistability in perception, phase transitions and formation of meaning. In M. Stadler & P. Kruse (Eds.), *Ambiguity in mind and nature* (pp. 23-44). Berlin: Springer.

Haselager, W.F.G., Bongers, R.M. & Van Rooij, I. (This volume). Cognitive science, representations and dynamical systems theory.

Jordan, J.S. (This volume). The embodiment of intentionality.

Kauffman, S.A. (1993). *The origins of order*. New York: Oxford University Press.

Keijzer, F.A. (1998). Doing without representations which specify what to do. *Philosophical Psychology, 11*, 269-302.

Keijzer, F.A. (2001). *Representation and behavior*. Cambridge, MA: MIT Press.

Kelso, J.A.S. (1995). *Dynamic patterns*. Cambridge, MA: MIT Press.

Kelso, J.A.S. (This volume). Cognitive coordination dynamics.

Maynard Smith, J. & Szatmáry, E. (1999). *The origins of life*. Oxford: Oxford University Press.

Meijer, O.G. & Bongaardt, R. (1996). The maizena argument: a reaction. *Journal for Ecological psychology, 7*, 285-290.

Millikan, R.G. (1989). Biosemantics. *Journal of Philosophy, 86*, 281-297.

Milner, A.D. & Goodale M.A. (1995). *The visual brain in action*. Oxford: Oxford University Press.

Orlovsky, G.N., Deliagina, T.G. & Grillner, S. (1999). *Neuronal control of locomotion: from mollusc to man*. Oxford: Oxford University press.

Pattee, H. H. (1995) Evolving self-reference: matter, symbols, and semantic closure. *Communication and Cognition - Artificial Intelligence, 12 (1-2),* 9-28.

Prigogine, I. & Stengers, I. (1984). *Order out of chaos*. London: Fontana Paperbacks.

Savageau, M.A. (1998). Rules for the evolution of gene circuitry. *Pacific Symposium on Biocomputing, 3*, 54-65.

Stewart, I. (1998). *Life's other secret*. Harmondsworth: Penguin Press.

Van der Velde, F. & De Kamps, M. (2001). From knowing what to knowing where: modeling object-based attention with feedback disinhibition of activation. *Journal of Cognitive Neuroscience, 13 (4)*, 479-491.