Habit, Self-Organization, and Abduction

Ramon S. Capelle de Andrade, Mariana Claudia Broens, Itala M. Loffredo D'Ottaviano, and Maria Eunice Quilici Gonzalez

Abstract In this paper we discuss the hypothesis of Dascal (Artificial intelligence as epistemology? In: Villa Nueva E (ed) Information, semantics and epistemology. Blackwell, Oxford, pp 224–241, 1990) according to which the main characteristic of intelligence is the ability to adapt pragmatically to changes in the context in which one is immersed. Our investigation is an inquiry into the role played by habits, in order to establish criteria according to which agents act in the world in reasonable and relevant ways. To begin with, we investigate the logical form of habits, focusing on the distinction between "rational habits" and "crystallized habits" ("degenerated habits"), and their function in the structuring of actions. We argue that habits manifest themselves in terms of a hypothetical prescription: If A (a circumstance), then B (a behavior). Our hypothesis is that habits can be transformed into abilities by means of processes of secondary self-organization that involve the dynamics of rupture, acquisition, and improvement of previous habits. More specifically, we suggest that abilities, characterized as habits that have been refined or perfected, involve a process of secondary self-organization which can be triggered by (a) the perception of (an agent's own) habitual behavior and the recognition (by the agent) of the necessity of altering part of this behavior and (b) experience of

R.S. Capelle de Andrade (✉)
International University for the Integration of Afro-Brazilian Lusophony, Institute of Humanities and Language – IHL, Avenida da Abolição, 03, CEP 62-790-000 Campinas, Redenção – CE, Brazil
e-mail: ramon.capelle@unilab.edu.br

M.C. Broens • M.E.Q. Gonzalez
Philosophy Department and Graduate Program in Philosophy, State University of Sao Paulo – UNESP, Avenida Hygino Muzzi Filho, 737, CEP 17525-900 Marilia, SP, Brazil
e-mail: mbroens@marilia.unesp.br; gonzalez@marilia.unesp.br

I.M.L. D'Ottaviano
Centre for Logic, Epistemology and the History of Science – CLE, State University of Campinas – UNICAMP, Rua Sergio Buarque de Holanda, 251, CEP 13083-859 Campinas, SP, Brazil
e-mail: itala@cle.unicamp.br

D. Riesenfeld and G. Scarafile (eds.), *Perspectives on Theory of Controversies and the Ethics of Communication*, Logic, Argumentation & Reasoning 2,
DOI 10.1007/978-94-007-7131-4_17,

a doubt that may initiate rational abduction. Furthermore, we adapt the notion of abductive reasoning, as defined by Peirce (In: Hartshorne C, Weiss P, Burks AW (eds) Collected papers of Charles Sanders Peirce, vols 1–8. Harvard University Press, Cambridge, MA, 1958), to deal with the creation of hypotheses of conduct and, in particular, the transition from the experience of a doubt to the acquisition of a habit (understood as a readiness to perform an action).

Keywords Habits • Self-organization • Abductive reasoning

1 Introduction

The concept of *habit* has aroused the interest of contemporary philosophy, especially within the areas of ecological philosophy, philosophy of mind, and cognitive science. Such interest is due especially to the fact that the processes of generation, improvement, and substitution of habits and abilities play a cognitive role of the highest relevance in the evolution of intelligent action. Thus, for example, Dascal (1990) points out that one of the main characteristics of intelligence is the ability to adapt pragmatically to changes in the context in which one is immersed. Referring to the field of artificial intelligence (AI), he argues that:

> ... The crucial question (for AI) is not that of 'representation of knowledge', nor that of 'providing (more) knowledge' to a system. Rather it is the question of designing systems that are not enslaved by something labelled 'knowledge', i.e., systems which are able to reject justifications that do not seem reasonable to them, and to select pragmatically even the criteria themselves of what is to be considered, in each context, as reasonable and 'relevant' .... (Dascal 1990: 236)

Anticipating in 1990 what today constitutes one of the central hypothesis of the theory of embedded embodied cognition, Dascal stresses the importance of *pragmatic aspects of knowledge* in the study of intelligence:

> Researchers in AI should direct their attention to the question of whether it is possible to develop systems which are not subordinated to the knowledge and to the rules and criteria which are supplied to them *ex machina*, and if so, how. And they should not forget that this pragmatic aspect of knowledge derives from the public/social character of justification. (Ibid.)

For many decades, the pragmatic aspect of intelligence was not given priority in AI research projects, but at present its importance is almost unanimously recognized. It is our understanding that the way to investigate the pragmatic dimension of intelligence is by means of the study of the processes that form habits and abilities.

With the purpose of clarifying the concept of *habit*, in the first section of this article we investigate the logical form of habit. We first define habit as a relation between antecedents and consequents which constitute ordered pairs of conditional prescriptions, understood as dispositions that generate patterns of action. We suggest that habit constitutes a readiness to act in a certain way (the consequent) under certain circumstances (the antecedent).

In the second section, we analyze the process of secondary self-organization (Debrun 2009), with the objective of clarifying the process of generation, improvement, and substitution of habits and abilities. Given a system, a self-organized process is characterized as the result of the interactions between the elements of which it is comprised, without following the dictates of central controllers or supervisors (Bresciani and D'Ottaviano 2000). Secondary self-organization occurs when the system acquires stability and is directly related to a system's capacity for learning and to the potential that a system develops for dealing with new events (Debrun 2009). We argue that in the case of abilities that result from the refining of habits, a process of secondary self-organization is present, making possible the emergence of *criteria of relevance* that direct the development of such abilities (Gonzalez 2005). A question that presents itself is this: How can the reasoning that is possibly implicit in this process of emergence be explained? A working hypothesis is that *abductive reasoning* is a good candidate for use in resolving this question.

Finally, in the third section, we adopt the notion of abductive reasoning, as defined by Peirce (1958), in order to deal with the process of the creation of hypotheses of conduct. We argue that habit and doubt bring about consequences that are contradictory, while at the same time also complementary, to our experience of the world. Habit, on the one hand, offers support for conduct. Doubt, on the other hand, can be a paralyzing "sentiment," but it can also stimulate the formation of new habits. We argue that the passage from paralyzing *doubt* (which offers no support to conduct) to *habit* (conceived as a readiness to conduct action in a certain way) unites characteristics of a process of secondary self-organization that incorporates features of abductive reasoning, thus aiding the emergence of action-directing relevance criteria.

2 The Logical Form of Habit

The objective of this section is to describe the logical form of habit. We may define habit as a hypothetical conditional sentence: *If A, then B: if circumstance A occurs, then the behavior B will probably be adopted by agent S*. This characterization was given by the philosopher Charles S. Peirce (cf. Peirce 1958). More specifically, Peirce considered that X is a habit if X is a readiness to act in a certain way under the influence of certain circumstances. Based on this definition, we specify the following condition for the constitution of habits*:* X is a habit if X is a relation R between circumstantial antecedents and behavioral consequents which constitute ordered pairs of conditional hypothetical prescriptions. R may be established by satisfying the following sentence: A happening $\underline{a}$ is in relation R with a behavior $\underline{b}$ if the occurrence of $\underline{a}$ is (in most cases) followed by the adoption of behavior $\underline{b}$.

Although we are suggesting that habit can be *represented* by a binary relation, we are not, however, arguing for the hypothesis that habit has a binary *nature*. As a relation, habit in fact possesses a *triadic nature*, given that it involves an antecedent, a consequent, and a connection (represented by the relation itself)

between antecedent and consequent. Freely using Peirce's terminology, we may say that habit is thirdness (the category of regularity) and not secondness (the category of otherness). In this sense, when we analyze a habit X, we have the following:

1. A set C_i of circumstances in which X may be applied with success
2. A set C_q of consequences that will probably follow if X is applied to the elements of C_i
3. A "readiness" to adopt the behavior prescribed by X if any of the circumstances of C_i occur

The "readiness" to adopt the prescribed behavior reflects the weak degree of determination present in the connection between antecedent and consequent in a habit. That is to say, much more than a *mere occasion* for the application of a *rule of action "if A, then B,"* the occurrence of circumstance A tends to weakly determine the actualization of the behavioral consequent B prescribed by habit X. The degree of determination is weak because (1) we may impede the actualization of behavior B, e.g., by rational reflection, and (2) we can alter habit X by means of the dynamics of action.

We would like here to concentrate on the "readiness to act in a certain way" furnished by habit. The first question to be responded to is the following: What is the function of habit? Among the various conceivable functions of habit, the most important would be that of *avoiding surprises*. If a behavior has led to positive consequences when applied in a certain circumstance, then, when the circumstance occurs, we may behave in the usual manner, unsurprised, because the usual manner will probably lead us to the desired positive consequences. On the other hand, an alternative behavior could bring about undesired consequences, and therefore we would simply prefer not to adopt it.

When successful, a habit can make possible the establishment of a skilled behavior. Under normal conditions, we have no need to imagine possible behaviors before acting effectively – a behavior spontaneously presents itself as "the option to be adopted." However, special circumstances, such as climbing a mountain on a rainy day, realizing a complex artistic performance, or executing a precise movement in a soccer game, for example, require the refining or perfecting of common habits that can result in the production of abilities which involve criteria of relevance.

If we find ourselves in a context in which we do not have at our disposition successful behaviors as responses to the circumstances, we may (a) imagine lines of behavior before acting in an adequate fashion or (b) permit new spontaneous forms of organization to manifest themselves pragmatically in the process of the restructuring and refinement of habits. In the first case, reason plays an important role, that of conceiving the possible results of different behavioral lines to be adopted. We would have, in this case, the perception and conception of a behavioral line and its presumed results.

In the second case, in which spontaneous forms of organization are manifested in the process of the restructuring and refinement of habits, we do not necessarily

depend on reason to foster an adequate line of behavior, as such a line of behavior is already pragmatically ingrained in the dispositions of the totality of the system of habits in question. It is as if certain habits were directly connected to sensory perception, memory, and behavior, occasioning the unfolding of successful forms of behavior. In this case, we behave in a way that is at the same time skilled and spontaneous (without the constant control and vigilance of conscious experience), on the basis of both old habits and self-organizing processes. Without being able to count on this pragmatic process of the ingraining of habits, we would have to conceive hypotheses of action and test new lines of behavior by means of prescriptive rules, as in AI modeling. In the next section we propose a characterization of this process and argue that in its formation a habit constitutes an important organizational component for the understanding of the emergence of pragmatically constituted criteria of relevance.

3 Ability and Self-Organization in the Emergence of Criteria of Relevance

In an inspiring passage in the article "The Idea of Self-Organization," Debrun presents an example of an attempt at self-structuring that is decidedly not a process of secondary self-organization: an unsatisfied "subject" decrees that "[. . .] from now on, I will redo my life on a completely new basis" (Debrun 2009: 45). The "subject" dreams of obtaining the illusory result that he or she can exist independently of the pragmatic process which characterizes the constitutive system of his or her identity, and intends to prescribe a magic formula that transforms, by decree, his or her unsatisfactory system of habits, ignoring the surrounding conditions. Here, in contrast to examples of self-organization, the "subject" wishes (or intends) to exercise the role of absolute central controller over his or her existence. Debrun argues that, first, if it were possible to "redo my life on a completely new basis," we would be dealing with a hetero-organization imposed on the subject by him or herself. Second, he argues that it is quite improbable (if not impossible) that a "subject" *S* would be really capable of completely self-structuring him or herself.

In contrast with hetero-organization, self-organization is a phenomenon of the creation and/or restructuring of an organization. Debrun (2009) characterizes the spontaneous "creation of an organization" as *primary self-organization*, in which there occurs a transition from independent elements to interdependent ones, without the domination of an absolute central controller. Once an organization is created, self-organization as the "restructuring of an organization" is characterized as *secondary self-organization*.

Secondary self-organization is developed within an already constituted system, which can be defined as a structure with functionality. The structure consists of a (nonempty) set of elements and relations. The organization of a system, which

is essentially the same as the system itself, constitutes a nonrandom arrangement of elements (particles, fields) and relations, and the system may be considered a structure in activity (Bresciani and D'Ottaviano 2000). According to Debrun, there is secondary self-organization when a system reaches, by means of operations exercised upon itself, a higher degree of complexity. For secondary self-organization to occur, at least three conditions must apply: first, the elements must possess "a certain degree of autonomy;" second, the relations between the elements must be susceptible to alteration; finally, there occur processes of adjustment between the elements of the system as a result of learning.

As organization involves a universe of elements, relations, and functionality (Bresciani and D'Ottaviano 2000), self-organization is developed through the interaction of such elements in a nonmechanical fashion. As Debrun points out (2009: 32): "... these elements cannot be of such nature that its presence mechanically determines the process that will happen having them as a basis. If that were the case, the intuition that we have of 'self production' would be nullified."

Summarizing, secondary self-organization constitutes a process of adjustment and refinement that occurs, without a central controller, in a primarily organized system. It is our hypothesis that criteria of relevance, the directors of skillful action, emerge from the process of secondary self-organization by means of the actions of agents (internal or external to the system) who are embodied and embedded in specific contexts. It is in the pragmatic dimension of existence, and not by decree or by the establishment of rules imposed by a central controller, that criteria of relevance emerge and are established in the directing of skilled action.

Criteria of relevance are fundamental, in this perspective, for the characterization of the *parameters of order* that emerge from the dynamics of *parameters of control* generated by means of the spontaneous interaction among the elements that constitute a complex system (Haken 2000) and by the system's interaction with the environment. A game of soccer can help us illustrate the relation between parameters of order (which reflect, in our view, the organization of the system) and parameters of control. The players, the referees, the grass, the ball, and other elements constitute parameters of control, while the parameters of order will emerge from the pragmatic dynamics which are established among these elements during the game, expressing the presence of criteria of relevance. Even though parameters of control are necessary conditions for the realization of the game, habits establish the readiness to act in a certain way, molding the style of the game and directing (not necessarily in a determinate fashion) the action of the players. When this action is successful, we say that it is a case of "skilled action," which involves criteria of relevance. But, in the context of this interpretation, what would be the difference between skillful action and action that merely expresses a habit? How can we explain what occurs in the process of the generation of criteria of relevance? These are questions for which we have no algorithms available to serve as answers. However, in conclusion, we will now outline a proposal of investigation based on Peirce's reflections on the pragmatic nature of abductive reasoning.

4 Habit, Ability, and Abductive Reasoning

Habit, as we argued in the first section, has the conditional form *If A, then B*. Thus, we may conceive of a habit as a *relation between circumstances and behavior inscribed in the patterns of action of an individual*. Circumstances and behavior both being susceptible to analysis from a third person perspective, allow inference an operative habit *H* from the *frequency* with which an agent *S* adopts the course of behavior *B* given circumstance *C*.

Adopting the Peircean pragmatic approach, we may outline a distinction between *rational operative habits* and *degenerated operative habits*. As operative habits, both of them furnish a readiness to act in a certain way under the influence of certain circumstances. However, in the case of a rational habit, this readiness must be in conformity with a certain purpose. Thus, if we recognize that a habit is not in conformity with a goal or a purpose, we may be able to modify that habit. The failure in attempts to modify a habit (*in the absence of physical and/or physiological impediments*) points to a certain degree of degeneration (or crystallization) of this habit, characterizing it as degenerated. Be that as it may, a purpose *P* having been chosen, the decision to modify a habit that does not foster or bring about the achievement of *P* constitutes an important step in the restructuring of the behavioral system.

In a *system of behavioral habits*, a decision "[...] will be integrated in the process, contributing to give it meaning or vigor," but, "it is not known, however, how the previous phases of the process [in this case, the habit we wish to alter and its relation with other habits] will react to its beginning. The reaction can even be negative" (Debrun 2009: 34). That is, when we decide to alter part of our behavior, this decision, as a commitment we assume with ourselves, does not guarantee, in and of itself, that a restructuring will be successful.

The decision to alter part of our behavior can turn out to be weak, or even contradictory. What is really important, says Debrun (2009: 60), "is the sedimentation of 'something', which can be even the project itself [e.g., a commitment to modify our behavior], or something similar, that will have received the 'stamp' of interaction."

As we have suggested, behavioral organization, expressed as a system, constitutes a set of interconnected or interrelated habits. For us to be able to alter a habit *H*, we must also alter, to a greater or lesser degree, the habits {*I*, *J*, *K*, *L*, *M*, *N*, ...} associated with *H*. It may be that an initial process of behavioral change meets an obstacle, due to some kind of crystallization, in a habit *I* (that does not foster purpose *P*) associated with *H*. It may also be that the "subject" decides to insist on this line of conduct, being capable of impeding for a certain amount of time, but not in a definitive way, the actualization of the consequents that are (weakly) determined by habit *I*. It may even be that the alteration of a conduct should be redefined. Whatever the case may be, habits have to be interrelated among themselves in order for an alteration to reflect an adjustment among them. We arrive, now, at the following definition of *rational habit*: *X* is a *rational habit* for subject *S* in the instant t_1 *if and only if* (a) *X* brings about successful consequences for *S* in t_1 and (b) *S* can change *X* in t_2 if the consequences of *X* in t_1 become non-successful for *S*.

Therefore, a rational habit is a habit that, given a goal, tends to bring about successful consequences in conformity with such a goal, or a habit which is weak or transformable, that is, one which can participate in a process of secondary self-organization in the generation of abilities which can contribute to the realization of this goal.

Even though the subject cannot impose habits that are representative of an alternative version of him or herself on his or her own behavioral organization, this does not imply that a change of habits is not possible. It is possible, and the weak connection between the antecedent and the consequent of a habit guarantees this. However, it is reasonable to claim that the alteration of habits admits possible variations in directionality, which may include a return to the earlier version that the subject wishes to overcome, as well as a return to the path toward the desired alteration. In the development of the process of the alteration of habits, the earlier version of the subject will always be there (potentially), and there will not be a precise break in continuity between the earlier version and the alternative one in construction. Sometimes the subject may be much more like what it was earlier and much less like what it would like to be alternatively. The course of time will show what (and to what degree) the agent has been capable or incapable of changing with regard to his or her behavior. In both cases, however, action develops as the result of criteria of relevance pragmatically established.

Changes in circumstances, such as structural, functional, or environmental changes, among other things, can occasion a temporary disorganization in systems of habits, allowing for the appearance of doubts regarding the relevance and efficiency of certain habits. Such doubts, for their part, can make way for the generation of new criteria of relevance in the establishment of goals or purposes. In a certain sense, the evolution of the behavior of an agent may reflect the evolution of his or her reasonableness. If, in the application of behavior *B* to circumstance *A*, there is concordance between a hoped-for result *R* and what has in fact resulted, then the habit *If A, then B* is reinforced as efficient.

According to Peirce, habits "[. . .] guide our desires and shape our actions." Belief (understood as a strong habit) is an "indication of there being established in our nature some habit which will determine our actions" (Peirce, CP, 3: 370). On the other hand, doubt can "paralyze" behavior (the functionality of the system). If, in the application of consequent *B* of habit *If A then B* to antecedent *A*, there is no concordance between the hoped-for result *R* and what is in fact the result, then a doubt is established in the behavioral system. The agent will not know what to do when a similar antecedent appears again. In virtue of its not offering support for behavior (and fostering instability), the doubt must be eliminated.

We are assuming that the behavioral system seeks stability. Thus, under the influence of a doubt, there will occur an attempt by the agent to restructure the set of habits within which the doubt has arisen. According to Peirce (1958), persistent doubt initiates a process of thought which does not cease until belief, or habit of action, in the form an explicative hypothesis, is established and the doubt is eliminated. The process of the generation of hypotheses constitutes the essence

of abductive reasoning (or abduction). Abduction may be described as having the following form:

(a) A surprising fact C is observed.
(b) But, if A were true (a true hypothesis), C would follow as a matter of fact.
(c) Therefore, there exist reasons to suspect that A is true.

We would like to propose an interpretation (adaptation) of Peircean abduction to deal with the generation of criteria of relevance in the search for hypotheses explicative of a surprising fact. According to this interpretation, *surprising fact* is equivalent to "the consequent of habit H (a behavior) produces result R_1 (which does not lead to purpose P), and R_1 is different from hoped-for result R, which fosters purpose P." Furthermore, "true hypothesis" (which presupposes correspondence between theory and fact) is interpreted as "correspondence between a potential result R (which fosters purpose P) and the real result R' (identical or similar to R, and also fostering purpose P); R' is derived from the application of behavioral sequence S_b to circumstance C_1." The proposed interpretation/adaption is presented below:

1. A behavioral sequence S_b, frequently experienced as efficient when applied to circumstance C_1, has been experienced as inefficient; Doubt D is established.
2. An alternative behavioral sequence S_{ab} is created as a hypothesis of action.
3. If the alternative behavioral sequence S_{ab} were to be applied efficiently to circumstance C_1 (in place of the earlier behavioral sequence S_b), then the instability generated by D would probably be overcome.
4. Therefore, there exist reasons to apply the alternative behavioral sequence S_{ab} to circumstance C_1.

In this pragmatic context, criteria of relevance can emerge in the form of parameters of order which make possible the establishment of new goals, as well as the restructuring of the system of habits of action which, when successful, are transformed into abilities.

This being the case, the next time that a circumstance similar to C_1 appears, the system/agent will tend to test the hypothesis S_{ab} that was established in accord with the new criteria of relevance or parameters of order. Although still under the influence of the old system of habits, the hypothesis S_{ab} can be *accepted, rejected, corrected, adjusted, and incorporated*. What will be the case depends on the interaction between S_{ab} and the habits already present in the system, now under the influence of new criteria of relevance. In cases where S_{ab} is progressively and inductively reinforced by experience, a reevaluation of competing hypotheses that are inconsistent with S_{ab} will be required. Thus, the acceptance and or rejection of S_{ab} will require the adoption of a new criterion of relevance that will direct an organizing adjustment in at least some of the ordered pairs of antecedents and consequents pertaining to the different habits present in the system.

But perhaps most important, in relation to the possible transformation of a hypothesis of behavior into a habit, is the following: What is presented as a *hypothesis* must, in the presence of a circumstance which generates doubt, instantiate a

successful action in relation to the goals currently established. Successive efficient applications of such a hypothesis (a type of inductive evaluation that reveals the extent of its range of application) end up transforming it into a habit, making explicit the criteria of relevance emerging from the process of secondary self-organization that here incorporates abduction.

In sum, a doubt can stimulate the formation of new habits resulting from the emergence of new criteria of relevance in the system. But beyond this, the transition from doubt to habit can result from a process of secondary self-organization. In the first place, such a transition occurs within an already constituted system according to established criteria of relevance. Second of all, different from a transcendental subject, the embodied and embedded subject *S* realizes (pragmatically) the task of the creation, adjustment, and incorporation of a hypothesis of action. Finally, the creation of a functional habit applicable to a circumstance experienced as problematic suggests a complexification (in a greater or lesser degree) of the system of habits of an agent according to new criteria of relevance.

5 Final Considerations

Our reasonability and functionality as embodied and embedded pragmatic agents find an impressively wide range of possibilities of action in the establishment of criteria of relevance which foster goals or purposes on diverse planes of experience. Once certain criteria of relevance have been adopted and a purpose *P* established, habits which foster *P* can be identified, strengthened, and refined. We can also exert ourselves to change and weaken habits which are manifested as obstacles to achieving *P*. In extreme cases, new criteria of relevance can emerge in processes of secondary self-organization with the consequent abandonment of earlier goals and habits. Despite the fact that in the flux of life (or experience) great changes are not frequent, they can signal changes in the criteria of relevance incorporated in skilled action, the remaining activity being the mere repetition of habits.

In conclusion, the hypothesis and the arguments elaborated here attempt to show that criteria of relevance may emerge spontaneously in the form of parameters of organization and are manifested through abilities, making possible the maintenance of self-organized systems. In pragmatic contexts, criteria of relevance especially stand out when instabilities threaten the equilibrium, maintenance, and development of systems which encounter doubt. As Dascal (1990) points out, the main characteristic of intelligence is the ability to adapt pragmatically to changes in the context in which one is immersed. This pragmatic ability seems to be present in all living creatures. One great difficulty, which was noted by Dascal in the 1990s and which continues up to the present time, resides in the question of whether it is possible to model such pragmatic ability in artificial systems. Only the passage of time will give us indications about the capacity of artificial systems in the generation of such abilities. At the moment they appear to be a central characteristic of living beings embodied and embedded in a social environment.

Acknowledgments We would like to thank Len Olsen, William Pickering, and our research fellows from the Self-Organization Group and GAEC for their suggestions and support during the preparation of this paper. We would also like to thank FAPESP and CNPq for funding this research. Last, but not least, we dedicate this paper to Marcelo Dascal, in honor of his 70th young and lively years.

References

Bresciani, F.E., and I.M.L. D'Ottaviano. 2000. Conceitos básicos de sistêmica. In *Auto-organização: estudos interdisciplinares*, Coleção CLE, vol. 30, ed. I.M.L. D'Ottaviano and M.E.Q. Gonzalez, 283–306. Campinas: Unicamp.

Dascal, M. 1990. Artificial intelligence as epistemology? In *Information, semantics and epistemology*, ed. E. Villa Nueva, 224–241. Oxford: Blackwell.

Debrun, M. 2009. Identidade nacional brasileira e auto-organização. *Coleção CLE*, vol. 53, ed. I.M.L. D'Ottaviano and M.E.Q. Gonzalez. Campinas: Unicamp, Centro de Lógica, Epistemologia e História da Ciência.

Gonzalez, M.E.Q. 2005. Information and mechanical models of intelligence: What can we learn from cognitive science? *Pragmatics and Cognition* 13(3): 565–582.

Haken, H. 2000. *Information and self-organization*. Berlin: Springer.

Peirce, C.S. 1958. *Collected papers of Charles Sanders Peirce*, vols. 1–8, ed. C. Hartshorne, P. Weiss, and A.W. Burks. Cambridge, MA: Harvard University Press.