Chapter 2
On Control and Communication: Self-regulation and Coordination of Actions

Abstract The term control is a loaded one and the term communication needs much clarification. In 1948 Wiener encapsulated the outcome of discussions about feedback loops and circular causality in self-regulating systems in his book *Cybernetics: or Control and Communication in the Animal and the Machine* and this was formally the beginning of cybernetics as a discipline. The name comes from the Greek for steersman (the equivalent in Latin is gubernatur), a term that Plato used to describe the art of steering ships; much later, in the nineteenth century, the French scientist Ampère, used it in reference to the science of government. In the second edition of his book, Wiener added a few chapters showing the relevance of cybernetics to learning, artificial intelligence, adaptation and language. Today feedback mechanisms are ubiquitous; they happen whenever part of the output of a system returns as its input, which is thereby changed. This is the case of a normal heating system and any servo-mechanism ranging from missiles to robots. It is also the case of complex systems, which depend on memory to learn; feedback is happening when input information is affected by the output of the previous observation. As for communication we understand it as coordination of actions, going beyond making sure that the message has been received; only when we manage to produce coordinated actions we can claim that communication has been achieved.

During the last years of the Second World War, the Office of Scientific Research and Development of the USA focused most of its efforts and resources on finding solutions to two strategic problems: the first one was the development of the atomic bomb, the second was the construction of an antiaircraft cannon to attack German bombers. While the research for the first problem was carried out at Los Alamos as the Manhattan Project under the direction of Robert Oppenheimer, the antiaircraft project was assigned to Norbert Wiener, a brilliant mathematician who was working at the Massachusetts Institute of Technology (MIT) (Heims 1987).

Wiener was a mathematician prodigy and at the age of ten wrote his first paper entitled 'The Theory of Ignorance', when he was sixteen he got a degree in mathematics and philosophy from Harvard University and at nineteen received a PhD in philosophy from the same university. With this impressive background, it was no surprise that he was appointed to lead the project at MIT.

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The main problem was to predict the position of an aircraft. This was so because given the limited speed of the cannon's projectiles, the operator of the cannon should not point it directly towards the plane. If he did so, when the projectile reached its intended target, of course, the aircraft would not be there anymore. In addition, pilots surely will move randomly to avoid being destroyed. Wiener's approach was to develop a mathematical theory to predict future events by extrapolating incomplete information from the past which, in passim, was the basis of modern statistical communication theory (Heims 1987, p. 184). Working with a young engineer, Julian Bigelow, they built an antiaircraft machine by connecting a cannon to the recently developed radar. Figure 2.1 shows the operation of the machine.

When the radar first detected the plane, it followed it for a few seconds gathering information about its course. Then, by using the mathematical theory developed by Wiener, a possible position of the plane was estimated. This information was fed on to the cannon mechanism which used it to set the target position and fire. If the plane was not destroyed, the radar gathered additional information and adjusted the prediction mechanism to calculate the new probable position of the plane. Again the information was passed on to the cannon that adjusted the firing mechanism and so on. As soon as the plane would follow a pattern, almost certainly it would be destroyed.

But notice that this was an entirely automatic process, nobody was controlling the cannon! Imagine the generals' astonishment when Wiener was showing this

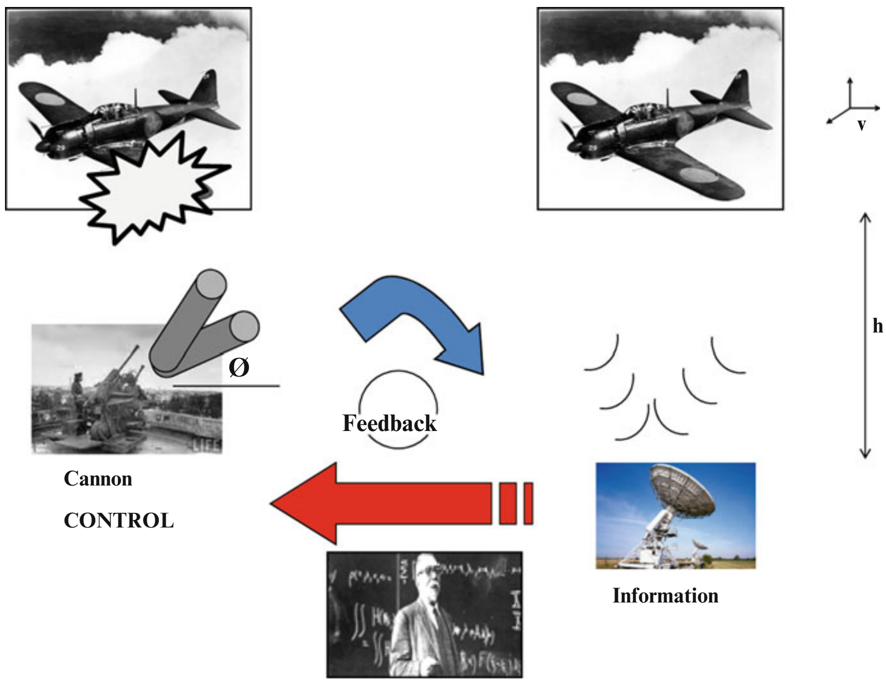

Fig. 2.1 Antiaircraft cannon built by Norbert Wiener and Julian Bigelow

invention to them. What they saw was an antiaircraft device that was activated as soon as a plane came into the range of the radar, they then saw that the cannon started to shoot automatically following and anticipating the movements of the target. It seemed as if the mechanism had an in-built purpose: to shoot down enemy aircraft. We will come to this point later on.

The mechanism was very successful though, of course, many people died, regardless of being enemies or not, Wiener publicly proclaimed that he would not participate in military projects again (Heims 1987). He moved towards the philosophy of science and organized several congresses about the subject. Here he met Arturo Rosenblueth who had been working for several years in understanding the nature of ataxia, a neurological disorder that, among other manifestations, led patients to an erratic and oscillatory movement of their arms when they wanted to pick up an object. During the course of their conversations, Wiener soon realised that it was possible to explain this biological disorder by applying the same ideas used for the construction of the antiaircraft machine.

What made it possible for the antiaircraft cannon to reach its goal (i.e., to shoot down the plane) was the feedback mechanism built into the operation of the system. Information gathered from the radar was fed onto the control mechanism of the cannon, the outcome of its operation led to gather additional information from the radar that was fed back again to the cannon and so on. This feedback loop that allowed the interlocking of communication and control in real time was the common explanatory device that Weiner recognised.

With this insight, Wiener and Rosenblueth suggested that the reason why persons suffering from ataxia started to move their arms in an oscillatory manner was because there was a delay in this feedback mechanism. Indeed, when a person tried to pick up an object (i.e., fixed a goal) and started moving his arm towards it, he initiated this feedback loop. If he observes that his arm is moving in the wrong direction, his brain will signal his muscles to correct the movement. But if they do not respond, a reinforcement signal will occur. When the muscles finally respond, the arm will pass on and move wrongly in the other direction. When the person notices this, he will promptly react to correct in the opposite direction. But if the delay continues, the outcome is that the arm will swing back again to the previous incorrect movement. In other words, an oscillatory movement will occur.

It turned out that further research found that persons suffering from ataxia had this delay in their sensory-motor system. Wiener and Rosenblueth wrote together with Bigelow a joint paper inspired by these ideas (Rosenblueth et al. 1943). The paper proposed that feedback mechanisms could be used as explanatory devices to understand phenomena either pertaining to the mechanical realm (as the operations of an anti aircraft cannon) or to a biological realm (as in ataxia). The paper was a hit because it showed an alternative way to the old debate between mechanistic principles and vitalism. The former claiming that all phenomena could be explained in terms of the operation of physico-chemical laws and the latter claiming that biological phenomena needed an additional category, that of the intrinsic purpose of the being, its soul, that regulates its behaviour.

From 1946 to 1953 there was a series of meetings in New York sponsored by the Josiah Macy Jr. Foundation to discuss the application of these ideas in different domains (Heims 1991). The meetings were led by Warren McCulloch, an American neurophysiologist, whose work in modelling the operation of the nervous system gave rise, among other things, to the modern theory of neural networks (McCulloch 1989; Bishop 1995); nowadays a field with many practical applications that goes from the design of robots to the understanding of customers' shopping behaviour in supermarkets via the use of data mining techniques (Berry and Linoff 1997)

In 1948 Wiener encapsulated the outcome of many of these discussions about feedback loops and circular causality in self-regulating systems in a book that he entitled *Cybernetics: Or Control and Communication in the Animal and the Machine* (Wiener 1948); this was formally the beginning of cybernetics as a discipline. This name comes from the Greek *κυβερνήτηζ* or steersman (the equivalent in Latin is *gubernatur*) a term that Plato used to describe the art of steering ships. In the nineteenth century the French scientist Ampère, used it for the science of government. In the second edition of the book, Wiener added a few chapters showing the relevance of cybernetics to learning, artificial intelligence, adaptation and language (Wiener 1961).

To understand control and communication mechanisms of these kinds of systems the Macy Meeting of the cybernetic group, as it was called (Heims 1991), developed a deep understanding of concepts like feedback, homeostasis and the black-box. Today feedback mechanisms are present in many applications; they are used to regulate certain variables (outputs) by a continuous observation of others (inputs) in such a way that the input is affected by the output of the previous observation. This is the case of a normal heating system and any servo-mechanism ranging from missiles to robots.

A special case of a feedback system is called a homeostat. Here a set of variables are maintained among expected values regardless of the nature of perturbations that may affect them. An interesting mechanical example, known as the centrifugal governor, is shown in Fig. 2.2. It was designed by the Scottish inventor James Watt to regulate the speed of a steam engine in 1765. Given the maximum expected speed (***w***), Watt arranged a couple of solid balls weighing ***m***, as shown in Fig. 2.2. If the amount of steam increases, the balls will move up because of the centrifugal force over them. This, in turn, will move up the valve (***v***) reducing, in this way, the amount of steam going into the engine. But this reduction in steam will force the balls to fall down (as the centrifugal force will decline) making the valve move down as well. This will allow the entrance of more steam and so on. Notice that as long as the regulating mechanism does not break down, the governor will regulate the speed of the steam engine regardless of the nature of perturbations that may affect it. This special characteristic of certain control systems is commonly known as ultrastability (Ashby 1964). This is a nice example of a self-regulating system, that is, of a system that has intrinsic control. In the biological realm the internal mechanism of the body to maintain the inner temperature within a steady range (around 36–37°C for an adult) regardless of being in Alaska or near a furnace is

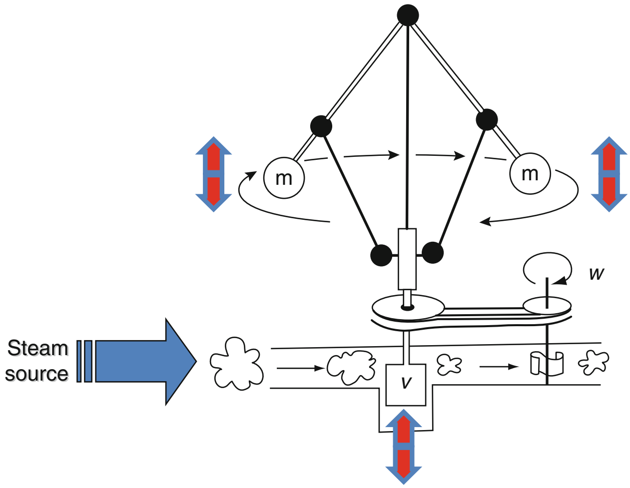

Fig. 2.2 The centrifugal governor of James Watt

another example of a homeostat. In the domain of organizations, we used the same concept at the end of Chap. 4.

Other members of the cybernetics group were John von Neumann, a Hungarian born (but later American nationalized) mathematician who, after participating in the Manhattan Project, developed the conceptual framework that allowed the construction of the first electronic computer (called ENIAC) in 1947 (von Neumann 1946); Gregory Bateson an English anthropologist who later developed (from notions of feedback) the theory of the double bind as a major contribution to understanding schizophrenia (Bateson 1972); Margaret Mead, then wife and fellow anthropologist of Bateson, who studied the behaviour and culture of tribes in Samoa (Mead 1961); and Heinz von Foerster, an Austrian physicist who was the secretary of the Macy Conferences and founder, many years later of the Biological Computer Laboratory at Illinois for studying the dynamics of observing systems or what he called second-order cybernetics (von Foerster 1984).

In 1959 Stafford Beer wrote his first book making a connection between cybernetics and management. This novel discipline, called management cybernetics, studies the design of communication and control mechanisms in organizations (Beer 1959). These are two crucial concepts for the purpose of this book. Let us explore in more detail the meaning we ascribe to them here.

Controlling a system is usually associated with the idea of reducing the uncertainty about its operation. It is believed that by increasing the knowledge we have about the specific operation of a system, we increase the chances of its effective regulation. However, this can be misleading because uncertainty is part of the natural dynamic of any complex system (see Chap. 1). From one of the control aphorisms proposed by Beer in *Diagnosing the System for Organizations* we can conclude that *given particular constraints* it is always possible to regulate a black box even if we do not know its internal operation (Beer 1985). But what exactly do we mean by a black box?

A black box is a cognitive device used to describe the operation of a system based on the relation between a set of inputs (controlled and uncontrolled variables) and a set of outputs (observed variables). It is the operation of an invisible mechanism transforming inputs into outputs. For instance, when we use our mobile phone we are able to operate it (i.e., to control its operation) without any need to know how it actually works. We manage all technology at our disposal today exactly in the same way; we treat them as black boxes. But what about the control of an organization?

In the examples just mentioned there was a person externally controlling a system (a piece of technology, for instance), but in the domain of organizations, managers are part of the organizational system themselves. Organizations, as we advanced in Chap. 1 and will further develop in Chap. 5 are human communication systems where people are observer participants producing their system by engaging in recurrent communication networks.

Therefore, control in organizations does not refer to its naïve interpretation as a crude process of coercion, but instead it mostly refers to self-regulation, a homeostatic process similar to the ones explained before. A general model for a self-regulating mechanism in an organizational context is shown in Fig. 2.3.

This is a feedback mechanism whose operation demarcates the purpose of the organizational system. Once this purpose is defined, it is possible to identify a set of aspects (sometimes called critical success factors – CSF) relevant to observe the behaviour of the system vis-à-vis this purpose. These are called indices in the diagram. Because the organizational system is not static, external and internal events will occur that affect the value of indices. When these risks materialize we

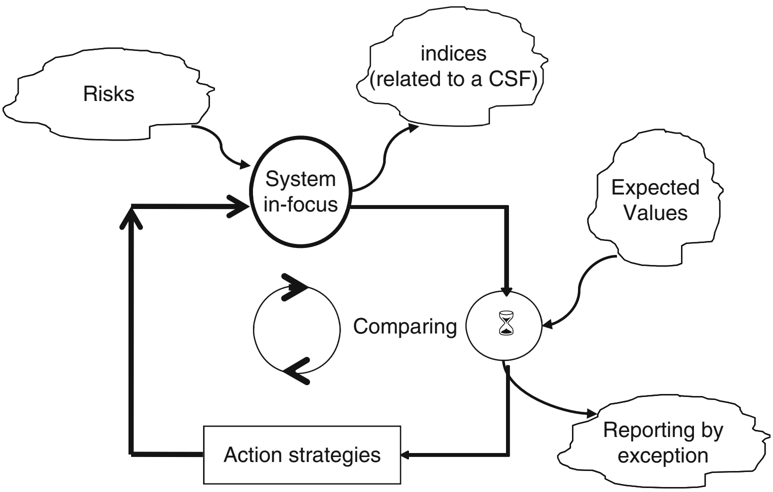

Fig. 2.3 A general model for self-regulation in an organizational system

need to work out a set of strategies to define a new course for action. The effects of its implementation will be observed in the on-going reading of the indices. The loop goes on and on and can be seen as the basis for learning mechanisms. We will go back to this point in Chap. 10.

From the perspective of an effective management of complexity (see Chap. 4) control in organizational systems should mean, to a significant degree, self-regulation. However self-regulation is not the only form of control. In organizations we distinguish between intrinsic control or self-regulation, and extrinsic control or control from outside. Examples of intrinsic control, like the thermostat or the Watt's governor, have the constraints built into the control process. However, it is always possible to change externally the desired temperature or speed thus changing the nature of the control process from intrinsic to extrinsic control. Unfortunately, with extrinsic control it is always possible that a necessary change in expected values does not take place simply because those responsible can be out of the loop when a necessary resetting of parameters is necessary. We will discuss the complementarity of intrinsic and extrinsic control while discussing the Viable System Model in Chap. 6.

But in operational terms, as we saw from its origin in cybernetics, it is not possible to separate control from communication. How then do we understand communication in this context?

We normally understand communication as a process of information transmission. Even more, we usually have in mind a model to describe this process as the one shown in Fig. 2.4. This model, broadly extended today, comes from the early work by Claude Shannon during the late 1940s (Shannon and Weaver 1949). In his Mathematical Theory of Communication, Shannon developed a basic model that has been regarded as a paradigm ever since.

According to the model, after choosing a message, a sender uses a codifier to translate it to a form that could be sent without losing its integrity through a noisy channel. The receiver, at the other end of the channel, will use a de-codifier to translate the message back into its original form. Shannon formulated and demonstrated a beautiful theorem in which he proved that given that we know the nature of the noise in the communication channel, we can always find a codifier such that the

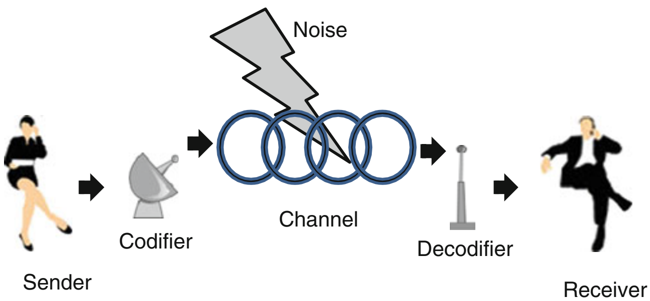

Fig. 2.4 Shannon's model of communication

codified message will go through the channel successfully. This is known as Shannon's 10th Theorem of Communication and has been used to develop many of our current devices and communication mechanisms from the telephone to radar and from satellite systems to mobile technology. This same theorem is also underpinning Ashby's Law of Requisite Variety (Ashby 1964) that we will use in Chap. 4 when we develop the concept of complexity management.

But the model has been used also in other areas. It is behind the design and implementation of modern computer networks, including the Internet, and psychologists have used it to study communication problems among individuals. Even biologists used this model to solve one of their hardest problems, the question about inheritance: how is it that certain characteristics of living beings go from one generation to the next? In fact, the well-known double-helix model of the DNA was developed because a famous physicist pointed in this direction when many scientists were looking for explanations somewhere else. In his book *What is Life*, Erwin Shrödinger suggested that this problem could be better understood if approached from the point of view of a communication mechanism at the molecular level from one 'individual' to the other (Shrödinger 1944). This is precisely the reason why nowadays scientists talk about the genetic 'code' and of being able to break this code to reveal the 'language' of the human genome (Marshall 1997).

This short historical detour should make evident the importance of Shannon's model to the current and broad understanding of the phenomenon of communication. The model's dictum is: *communication is information transmission*. However, as Weaver himself pointed out when presenting the implications of the model (Shannon and Weaver 1949), the problem of communication can be approached from three different questions emerging from the model itself. The first question is: How can we manage to send successfully a message from a sender to a receiver through a noisy communication channel? As we mentioned above, this is precisely the problem generally solved by Shannon's mathematical theory. But, there are two other problems to be solved.

The second one could be established as follows: given that a receiver successfully received a message, how can we assure that the meaning she or he ascribes to it is the same as the one ascribed by the sender? The third problem could be stated in the following way: given that a message successfully reached a receiver and given that she or he ascribes the same meaning as the one originally ascribed by the sender, how can we ensure that the receiver of the message responds to the sender's expectations? This last problem, of course, arises when the sender expects an effective response from the receiver.

Weaver is quite clear in stressing that Shannon's model only deals with the first problem and the reason for this is quite evident. Without solving this problem, there is no way to solve the other two. However, the importance of realizing this fact is that we suddenly become aware of the huge limitations of the model in understanding human communications. Certainly, the first problem covers most of the technical aspects of communication but the most pervasive problems in human communications are triggered by the last two, precisely the ones Shannon left consciously aside. However, as we explained before, the model has permeated all realms of communication from computer science to biology, from engineering to psychology and organizational theory and, most importantly, it is now part of our common sense in this matter.

With this in mind, we can go back to explore the implications of communication in organizational systems. It is often believed, as we said before, that communication is information transmission, which implies that whenever a message is successfully transmitted and received by the receiver the communication has been successful. We claim that this way of understanding communication is not enough in an organizational context for the reasons mentioned above. The problems of interpretation and coordinated action are left aside. In this book, we are using a rather different understanding of communication, one whose dictum could be expressed in the following way: *communication is coordination of actions*. It refers to the structural coupling (Maturana and Varela 1992, p. 75) of organizational actors, that is to their structural adjustments in a history of recurrent interactions. Communication, in this way, is a concept that belongs to the operational domain of the organization rather than the informational domain of sending messages (see Chap. 5).

Notice that communication, in Shannon's terms, implies a 'one way' process in the sense that it is effective when the message arrives successfully. On the other hand, communication as coordination of actions implies a *circular process*, a continuum of 'negotiation' between the sender and the receiver until their actions are coordinated. Once this coordination is achieved, we can say that the communication has been successful. A common metaphor to characterize the former model of communication is one of a conduit through which messages are delivered. A useful metaphor to characterize the latter model is one of an on-going dance between sender-receiver-sender.

It should be apparent that embodying one or the other when we engage in relations with others has important consequences. In terms of accountability, for instance, communication as information transmission implies that my responsibility in communicating effectively with others ends whenever I am sure that they got the message. This is perhaps one of the reasons why it was so common in many organizations (especially in public ones) to hold a signed copy of a message as evidence that the receiver had 'got it'. Today there are electronic equivalents of this practice. If there is a breakdown in the communication the one to be blamed is the receiver not the sender and the evidence is used to 'prove' that the message had been successfully communicated.

On the other hand, if we truly understand communication as coordination of actions, then in an analogous situation as before, my responsibility for effective communication goes beyond making sure that the message has been received. Only when I manage to produce a coordinated action can I claim that the communication has been effective. It is too easy to blame the others for our lack of competence in getting commitments from others. This understanding of communication has implications for our understanding of control; control emerges from the mutual adjustments, negotiations, dynamic stability of persons, groups, units in interaction and not from the unilateral impositions of one over the other. Of course control may also be achieved by unilateral impositions but, in general, this is an ineffective control.

Most of the main themes of this book revolve around the concept of communication. Therefore, from now on, whenever we talk about communication we will be referring to communication as coordination of actions and not simply as information transmission. Notice that this approach to communication clearly takes into account the two problems left aside by Shannon's model. In fact, we recover the full complexity of human communication by going beyond the technical aspects; emotions, for instance, play a fundamental role in human communication. To develop this line of thought even further, we would say that communication requires more than conversations; it also requires sharing cultural contexts. Here, we understand a conversation as the braiding of language and emotions in recurrent interactions with others (Maturana 1988). In other words, the language we use (verbal, written, signs, body language, etc.) and our emotions constitute our conversations. When these recurrent interactions produce meanings that go beyond the particular people in interaction then the affected community is sharing a cultural context. This is further elaborated below.

It is useful to distinguish, when communicating with others, among different types of conversations (Flores 1982). We may distinguish, for instance, between a conversation for possibilities and a conversation for action. The former is intended to open up new alternatives, perhaps bringing forth fresh insights into the topic being discussed; the latter is intended to generate commitments and produce actions. We will mention conversations for possibilities in Chap. 4 when talking about creating new distinctions as the outcome of our interactions (i.e., conversations) with others. In an organizational context, making new distinctions is a necessary condition for people to invent and re-invent their organizations; it usually implies questioning the assumptions, values and norms we normally take for granted. On the other hand, in the same context, conversations for actions are the building blocks of individual's relations. A simple model of such a conversation is shown in Fig. 2.5 (Winograd and Flores 1986, p. 65).

In this model we can appreciate the circular structure of a communication process that we mentioned before. A conversation for action is effective if, and only if, the loop is closed by a declaration of satisfaction from the person who made the request. Of course, before reaching this point, the loop can iterate many times. In a broader organizational context many people can participate in closing a single conversational loop and many different conversational loops are going on all the time. It is precisely in this sense that an organization can be visualized as a closed network of recurrent individual relations. Notice that although the conversation model here is based on a *request* made by A to B, the same structure holds in a conversation where A makes an *offer* to B.

It should be clear by now how recurrent conversations among individuals may produce stable relations, which, in turn, may produce relationships as we will explain in Chap. 5. But, notice that at the same time, the values, norms and beliefs emerging from these relationships, and shared by individuals, define their cultural context and provide a powerful influence on the way individual conversations take place in the organization. This is, again, an illustration of the circular causality between human relations and organizational relationships. A consequence of this

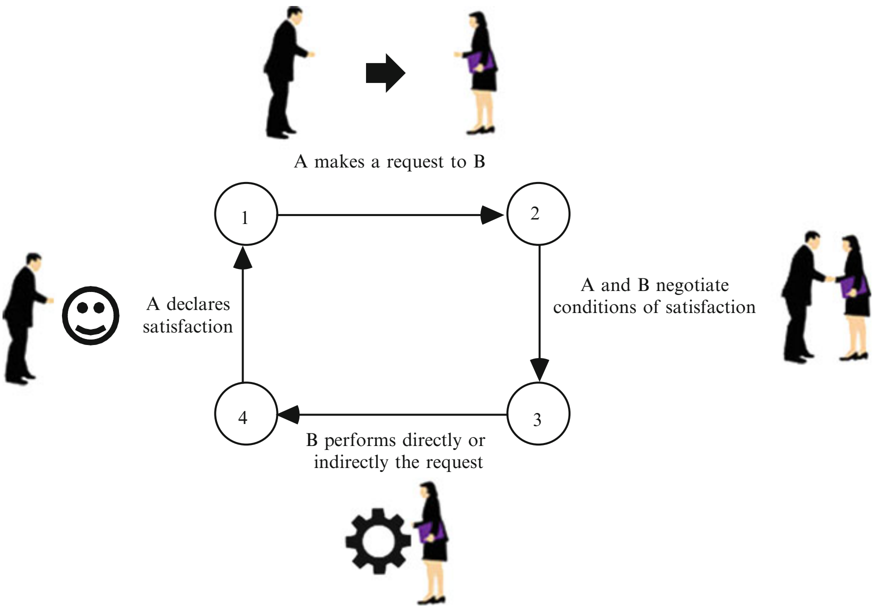

Fig. 2.5 A model of a conversation for action

circularity, as is mentioned in Chap. 5, is that the stronger the cultural links between organizational members (i.e., the stronger their relationships) the larger the capacity of the communication channels supporting their conversations (Espejo et al. 1996), which, in turn, may reinforce the organizational relationships.

Control, understood as self-regulation and communication as coordination of actions along with the meanings of complexity, systems, institutions and organizations that are given in the following chapters are necessary conditions to develop a methodological approach to study and design communication and control processes in viable complex organizations. The final chapters of this book unfold this methodological approach.

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