# 11

# Attention, Information, and Epistemic Perception

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Attention became a topic studied in experimental psychology by the end of the nineteenth century. With the subsequent development of psychology, interdisciplinary research on attention became an integral part of the cognitive and medical sciences (Posner and Raichle 1994; Parasuraman 1998; Wright 1998; Braun, Koch, and Davis 2001; Handy, Hopfinger, and Mangun 2001). Meanwhile, attention continues to raise a wide range of philosophical questions concerning, for example, sensory-motor control, perceptual reference, language understanding, social intentionality, and the neural correlates of consciousness. This chapter focuses on a question that is fundamental to bridging the gap between epistemology and biology: what is the role of attention in the acquisition of knowledge?

To address this problem, I will outline a theory grounded in what I call the *attentional constitution principle* (ACP). This principle asserts that attention is constitutive of humans' perceptual knowledge about individuals (i.e., objects and persons). The ACP expands research on perception and demonstrative identification, which originated in the writings of thinkers such as Peirce (1932–1935), Russell (1910), Sellars (1944, 1959), Dretske (1969, 1981, 2000), Evans (1982), Peacocke (1983, 1991, 1992), and Campbell (2002, 2004). Its method is grounded in the thought that the epistemology of empirical beliefs should mesh with the psychobiology of attention in order to explain how human agents navigate and analyze their environment. In contrast to the non-biological epistemology of knowledge or the nonepistemological psychobiology of attention, the ACP holds that the function of human attention is mainly to serve perceptual knowledge through the extraction of causal information.

Section 11.1 formulates the ACP. Section 11.2 introduces a concept of information that is useful and relevant to the theory. Specifically, I distinguish causal information from semantic information and information processing. Section 11.3 introduces the argument from cognitive access to lend support to the ACP. This argument relies on premises (justified in sections 11.4 and 11.5) stating that overt and covert forms of attention are necessary for establishing direct cognitive access to target individuals and for extracting causal information relative to such individuals while they are perceived. From this analysis, it follows that the use of attention is necessary for assessing the truth value of empirical beliefs and linguistic information reports about perceived individuals. This argument raises the challenge of discovering a theory whereby the *epistemic* use of attention is explained. Sections 11.5 and 11.6 suggest that the procedural theory of attention can explain the epistemic and pragmatic roles of attentional systems in the extraction of causal information. The procedural theory characterizes attention as a multicomponent system that controls sensory-motor routines for solving action and epistemic requests, and thus for seeking, extracting, and using causal information available in the organism's environment.

## 11.1 The Attentional Constitution Principle of Singular Perceptual Knowledge

This chapter studies singular perception and singular action. I employ the term *singular* to refer to acts that are directed at individuals. Here, the term *individual* is used to denote a particular material thing that persists, changes, or grows and is located in the spatiotemporal world. There are two classes of individual: inanimate *objects* (e.g., artifacts) and intentional *agents* (e.g., human persons). Such objects or agents follow continuous paths in space and time, have cohesive parts, and have the power to affect other individuals. We can not only perceive them at different locations, or moving to new locations, but we can also identify persisting individuals across changes in their appearance or location.

Individuals present a unique set of properties determining their fundamental ground of difference (i.e., the material ground determining their uniqueness, identity over time, and singular causation). This ground of difference is that which is to be known in singular knowledge and that which is causally relevant for guiding the performance of singular actions. The notion of a fundamental ground of difference of an individual has philosophical roots that go back at least to Spinoza or Leibniz.

In recent philosophy of mind and language, it is analyzed by Evans (1982) and Campbell (1993, 2002). We can link the idea that individuals have a fundamental ground of difference with the thought that material individuals possess singular causal powers, or singular causation (see, e.g., Ellis 2000; Shoemaker 1984). In section 11.2, I link this singular causation to causal information and suggest, in section 11.6, that the function of epistemic attention is to extract causal information relative to the singular causation of individuals.

I borrow this use of the term *singular* from the philosophy of language and the semantic theory of singular terms, in which the fact that the human mind is directed at particular things (individuals) has been recognized as a key factor to address in order to explain the intentionality of the human mind (see Bullot and Rysiew 2007; Frege 1892; Strawson 1956; Devitt 1974; Kripke 1980; Evans 1982).

In the study of perceptual knowledge, the term *singular* is useful to stress that perceptions and actions are usually directed at individual things, in the sense that they use mechanisms that point toward, track over time, or come into contact with particular persons or objects. This idea can be expressed in this principle:

**P1 dependence-on-tracking of true empirical beliefs and perceptual knowledge** **The acquisition of perceptual knowledge of (of nonaccidentally true empirical beliefs about) individuals depends on the tracking and perceptual-demonstrative identification of individuals.**

P1 expresses a condition admitted in various versions by the realist accounts of perceptual knowledge (Sellars 1944, 1959; Strawson 1959; Quinton 1973, 1979; Dretske 1967, 1969, 1995b; Evans 1982; Campbell 1993, 2002; Peacocke 2001, 2003). In philosophy, the notion of *perceptual-demonstrative identification* is traditionally understood as a mental act (a form of intentionality) in which an individual is identified on the basis of its current perception (McDowell 1984; Pettit and McDowell 1986; Woodfield 1982). For instance, this kind of identification happens when, on the basis of your perceptual experience, you identify that "this is your mother." In the phrase "perceptual-demonstrative identification," the term *demonstrative* is used to indicate that this kind of identification frequently occurs with a thought that contains a demonstrative term, which is labeled *demonstrative thought* in philosophy.

Perceptual-demonstrative thoughts have a form such as "This is *F*," in which "this" is a demonstrative term and "is *F*" is a predicate that refers to a concept or an attribute ascribed to the referent of the demonstrative term. Arguably, such thoughts are associated with the evaluation of propositions expressed by observations and information reports about what is perceived. Demonstrative thoughts can identify, locate, or describe the referents (or targets) of our perceptual experiences. For instance, if, at a crowded conference, your colleague points to a person and utters "This is Donald Broadbent," your grasp of the meaning of the demonstrative proposition depends on your ability to visually pick out and identify the referent of the demonstrative.

The condition of *tracking* is mentioned in P1 because perceptual tracking seems to be a necessary condition of perceptual-demonstrative identification. This notion of tracking refers to the ability to identify and reidentify an individual (as remaining the same individual) over a certain period of time, in spite of changes in its intrinsic or relational properties (e.g., aging or changes in appearances and location). For instance, the demonstrative identification of Donald Broadbent (in the situation described previously) requires you to succeed in visually tracking Donald Broadbent over a certain time and series of limited changes. In section 11.5, I will distinguish perceptual tracking from more epistemic forms of tracking. The theory that I propose posits that attentional systems integrate different forms of tracking through the extraction of and storage of causal information about the identity and location of target individuals. This form of tracking can be termed "integrated tracking" (for more on this, see Bullot 2006; Bullot and Rysiew 2007; Bullot and Droulez 2008).

I accept P1 and believe it corresponds to a relatively widespread view in the philosophical epistemology of perceptual knowledge. Here, I will focus on a more specific claim, which can be expressed in this principle:

**Principle of the attentional constitution of singular perceptual knowledge** **Attentional systems are constitutive of human agents' perceptual knowledge of individuals in their ecological environment.**

Because there are close ties between perceptual knowledge of individuals and action planning, the claim can be associated with this more comprehensive thesis:

**Generalized *attentional constitution principle*** **Attentional systems are constitutive of the links between singular perceptions (i.e., perceptions directed at individuals) and singular actions (i.e., actions directed at individuals).**

How are we to understand this notion of *constitutive* relation? The strongest form of constitutive relation would be identity. In such a case, the thesis would mean that some attentional processes in perception are identical to some knowledge-acquisition processes, or that the performance of some attention system is a necessary and sufficient condition of some perceptual knowledge. A weaker constitutive relation is a part-whole relationship. On this interpretation, the thesis would mean that some attentional systems are necessary parts of systems for the acquisition of perceptual knowledge. According to the ACP, in either its weak or strong forms, the study of attention is required to explain the genesis of agents' perceptual knowledge and its relations to their actions.

Now, the ACP can be paired with the thought that the attentional capacities in our hominin ancestors evolved to have the function to efficiently keep track of, and act on, individuals present in their environment such as prey or predator animals, or even tools (Arp 2006, 2008), and that this evolution was an adaptative response to environmental pressures. Before presenting an argument (sections 11.4 to 11.6) and a procedural theory (sections 11.6 and 11.7) to lend support to the ACP, I will clarify the information-theoretic approach I propose to use (section 11.2), along with a few basic problems relative to the concept of attention (section 11.3).

## 11.2 Causal, Semantic, and Mathematical Notions of Information

Phenomenological descriptions of mental acts (e.g., de Biran 1804/1988; Hatfield 1998; Husserl 1995; Merleau-Ponty 1945) may support some version of ACP. However, the justification of this principle is probably more forcefully achieved if we combine phenomenology with an information-theoretic approach to attention. When the term "attention" is used in connection with perception in information-theoretic psychology, it frequently denotes the selection of information for further analysis. In neurobiology, this can be formulated in terms of the selection of information for global availability across neural networks in which modulation correlates with conscious attentive perception (Dehaene and Naccache 2001; Dehaene et al. 2006; Kastner and Ungerleider 2000; Posner 1994; Somers et al. 1999; O'Craven et al. 1997; Handy, Hopfinger, and Mangun 2001).

This concept of attention qua mental selection has been central in the descriptions of attention since at least the work of William James (1890) and other psychologists of the late nineteenth century (Helmholtz 1867; Ribot 1908; James 1890; Titchener 1908; Sully 1898; Hatfield 1998). However, a major step in the theoretical study of attention occurred with the description of mental selection in information-theoretic terms. This description originates in the research inspired by the mathematical theory of communication and carried out in England and the United States during and after the Second World War (Miller 1981, 2003). Information-theoretic approaches conceive of human persons, brains, and minds as information-seeking or information-processing systems. This focus on information has introduced a number of innovations in the understanding of perception. For instance, the information-theoretic approach provided researchers with a framework departing from behaviorist theories (e.g., Neisser 1967; Posner 1994) and the atomistic theories of sense-data or sensations (e.g., Gibson 1966; Miller and Johnson-Laird 1976). This has proven to be a useful move to study the cognitive and active dimensions of human perception.

Information-theoretic approaches in biological psychology, philosophy, and other fields of cognitive science have become remarkably diverse (Miller 1956; Broadbent 1958; Dretske 1981, 1994; Adams 2003). As a result, the variety of information concepts can generate methodological intricacies. For instance, talk about information is ambiguous when it does not specify whether the concept of information in use refers to an objective (or mind-independent) property of physical facts or a subjective (or mind-dependent) construction of the mind. As an attempt to prevent conceptual slips, I will distinguish three classes of information-theoretic concepts.

1. *Causal information* The first class is relative to causal, environmental (Gibson 1966) or material information (Bogdan 1988), or natural meaning (Dretske 1988; Grice 1957; Millikan 1984). I will use the concept of causal information to refer to an objective property of certain facts or structures of the material world, which is to have constant (or invariant) connections with other facts or structures of the world. If a particular component A is constantly connected to component B (or has the propensity to lead to B), A can be viewed as carrying causal information relative to B by virtue of its constant connection to B. One can, therefore, apprehend A as a *carrier* (or vehicle) of causal information relative to B, of which specific characteristics may vary according to ontological kinds (Bogdan 1988). Causal information refers to an objective connection between A and B in which existence is independent of, and prior to, the knowledge that one may obtain about A or B.

Depending on specific ontological levels and terminologies, such connected components A and B may be apprehended as events, individuals, facts, or situations. Their connections may be regarded as constant conjunctions, causal links, or laws of nature. Specifically, the concept of causal information can be accommodated to a variety of ontological accounts of causation—for example, causation qua singular causation, laws of nature, counterfactual dependencies, or statistical regularities (Ellis 2000; Israel and Perry 1990). Although this concept of information is in the spirit of important points introduced by Fred Dretske (1981, 1994), the notion of causal information is distinct from Dretske's notion of information, because the latter is primarily conceived of from the standpoint of Shannon's mathematical theory of communication (1948) and thus cannot be reduced to causation.

I will focus on the case in which the basic carriers of causal information are material individuals such as material objects, biological organisms, and human persons. Here, I will assume that the fundamental ground of difference of an individual depends on the singular causal powers of that individual, and that such powers carry causal information about numerous other facts. Consider the case of human persons. Objective facts involving human individuals carry causal information about other facts, because the former are constantly connected to the latter. For example, the fact that you are a living adult human person carries causal information about numerous facts relative to your biological organism, such as the causal facts that you were born, that your body is made of cells, or that your cells contain DNA. You remain a carrier of this causal information regardless of whether you cognitively access the specifics of that causal information, which is carried by your organism and your DNA. Such causal information is an objective property of the fundamental material ground of difference of your own particular biological organism.

One can conceive of human folk knowledge and scientific knowledge as the extraction and analysis of distinct sorts of information (e.g., Bogdan 1988; Dretske 1981; Israel 1988; Israel and Perry 1990). An argument that supports this information-theoretic approach is that human subjects continuously communicate their knowledge through what one can term, after Israel and Perry (1990), *information reports*.

Information reports are sentences about what certain causal facts indicate about other facts. Information reports are omnipresent in the communication about forensic evidence, archeological or historical archives, or clinical medical knowledge among many other forms of empirical inquiries grounded in the scrutiny of material individuals. For instance, given the regular connection between the fact that a human agent manipulates an object and the fact that fingerprints are left on the surfaces of the object, a human fingerprint on a knife carries causal information relative to the fact that the knife has been manipulated by a particular human individual. This can be expressed in these information reports: (1) this fingerprint indicates that somebody has manipulated the knife, and (2) the fact that this fingerprint has these specific patterns indicates that Jack has manipulated the knife.

Such reports have a specific structure (Israel 1988; Israel and Perry 1990). The referent of the noun phrase in (1) refers to the carrier of causal information (or a part thereof). The noun phrase used to describe the carrier of causal information can be the referent of a demonstrative phrase. The proposition introduced by the *that*-clause, which refers to the fact that is indicated by the primary carrier of causal information, can be thought of as the *informational content* of the linguistic report (Israel and Perry 1990).

2. *Semantic information* Information reports are paradigm cases of the building of singular knowledge through the conversion of causal information into semantic contents, or semantic information. One can use the concept of *semantic information* (or intentional information), which is distinct from causal information, to refer to the property of that which has the function to carry intentional content or meaning. Semantic information can thus be understood in teleological terms—that is, through an analysis of the functions of the carrier of semantic information—and comes in different varieties of natural or conventional carriers of semantic information (e.g., Bogdan 1988; Dretske 1988, 1995b; Millikan 1984). Numerous theories in cognitive science view phenomena such as experiences, emotions, thoughts, information reports, or cultural contents either as possessing or processing semantic information. This use raises the problem of specifying the ways minds convert causal information into semantic information, or extract semantic information from causal information.

3. *Formal-mathematical information* A third class of information-theoretic notions includes the formal concepts of information, which have been initially introduced as mathematical tools for measuring the performance of communicating devices. The classical notion, in this category, was introduced by the mathematical theory of communication of Shannon (1948) and Shannon and Weaver (1949). In the latter,

information is a measure of one's freedom of choice when one selects a message (the logarithm of the number of available choices or of probabilities).

The conceptual relations of the different classes of information-theoretic concepts are notoriously knotty. A number of thinkers have expressed concerns about the risk of conflating the colloquial notion of semantic information with the formal concepts of the mathematical theory of communication (see, e.g., Bar-Hillel 1955; Partridge 1981; Wicken 1987). In addition, the project of grounding the theory of meaning and intentionality in the mathematical theory of communication—which has tempted Dretske (1981), among others (see, e.g., Adams 2003)—remains contentious (Dretske 1994). Similar concerns have been expressed about the project of using the concept of information to describe genetic coding (Godfrey-Smith 1999, 2000a, 2000b; Griffiths 2001; Maynard Smith 2000). Moreover, methodological debates on the concept of information are also found in psychology. For instance, there is a striking contrast between the information-theoretic frameworks of Donald Broadbent (1958, 1971, 1982) and James Gibson (1966, 1979).

In his seminal book *Perception and Communication*, Broadbent (1958) borrows the term *information*, with a constellation of other notions, from the mathematical theory of communication (e.g., information source, channel, signal, noise, and capacity). However, it seems fair to view Broadbent's approach (1958, 1971, 1982) as a global strategy to analyze psychological activities relative to semantic information (or content) empirically rather than an attempt to develop Shannon's mathematical theory of information or the theory of causal information. The key concepts originating from Broadbent's school in psychology are the notions of information processing and of processing levels (e.g., Kosslyn 1994; Newell 1990), which are theoretical concepts used to analyze the semantic processing of information. Through the concept of information processing, attention can be defined as analysis for further detailed processing (Kosslyn 1994; Treisman 1969, 1988). The notion of information processing performed by psychological faculties is primarily used to model the functional architecture of the mind/brain activities that underpin the possibility of semantic information. Its use is aimed at naturalizing semantic information.

In contrast to Broadbent (1958), Gibson (1966, 1979) develops an approach to perception that explicitly departs from the mathematical theory of communication and focuses on what Gibson terms *environmental information*, which is a concept roughly equivalent to the concept of causal information. He holds that "the information for perception is not transmitted" and "does not consist of signals, and does not entail a sender and a receiver" (1966, 63). Gibson's concept of environmental information refers to invariant regularities, structures, or specificities, which are present in the organism's environment and which can be extracted in perception and action. These invariant regularities are found in a variety of "ambient arrays" of energy, such as the ambient optical array (Gibson 1979, 65–91) or the acoustic array, which are fully objective and described by physical laws (also see Stoffregen and Bardy 2001). He maintains that "when we say that information is conveyed by light, or by sound, odor, or mechanical energy, we do not mean that the source is literally conveyed as a copy or replica" because "the sound of a bell is not the bell and the odor of cheese is not cheese" (Gibson 1966, 187) and the perspective projection of the faces of an individual is not the individual itself. However, in all these cases "a property of the stimulus is univocally related to a property of the object by virtue of physical laws" (Gibson 1966, 187), and this is what Gibson labels environmental information.

Gibson's environmental information, therefore, is a form of causal information. It describes the invariant or law-like structure of the physical world. For instance, in light structured by the environment, "the information lies in the *structure* of ambient light, that is, in its having an *arrangement* or being an *array*" (Gibson 1966, 208; also Gibson 1979, 47–64). The ecological psychology of perception develops the idea that, in perceptual exploration, the organism "picks up" causal information (Gibson 1966, 250–265) in the sense that it detects and explores the invariant structure of its environment.

There is a discrepancy between Broadbent's and Gibson's approaches to information: Broadbent's information-processing view primarily accounts for the mental operations performed on semantic information (e.g., storage in memory systems), and Gibson's ecological approach holds that the function of perception is to extract causal information. In spite of this apparent dilemma, I will suggest that the information-theoretic insight of each approach can be resolved by considering that attention is a key component of the translation of causal information into semantic information via the control of information-processing routines.

## 11.3 Common Assumptions about Attentional Systems and Information

In this chapter, the main idea I wish to convey is that attention is fundamental in the acquisition of perceptual knowledge because of its role in the conversion of causal information into semantic information. Support for this thought is found mainly in the theories that consider attention to be a faculty of selection for further information-processing. The early research on such an approach to attention has been primarily carried out in Broadbent's school, which hypothesized that the need for selective attention arises from certain basic limited processing capacity in the brain. This conception was developed by Broadbent (1958, 1971, 1981, 1982) and other pioneers of cognitive psychology such as George A. Miller (1956), Ulric Neisser (1967), Anne Treisman (1969), Neville Moray (1969), and Michael Posner (1978; also Kahneman 1973; Parasuraman and Davies 1984; Cowan 1995; Parasuraman 1998; Pashler 1998; Wright 1998; Braun, Koch, and Davis 2001).

In this view, the selective character of attentional operations is a consequence of global information-processing limitations. This approach is usually combined with closely related assumptions, which have been critically pinpointed by cognitive scientists, such as Allport (1993) and others (e.g., Desimone and Duncan 1995; Gibson 1966, 1979; Neisser and Becklen 1975). The defining assumptions of the early models of information processing (I follow Allport's analysis with a few changes) are, primarily, these statements about computational resources and control:

**A1 The concept of *attention* refers to a processing resource, which is limited in quantity and must be allocated selectively. This conception originates in Broadbent's notion of attention as a "selective filter" that feeds a "limited capacity channel" (Broadbent 1958; Treisman 1969; Pashler 1998; Desimone and Duncan 1995; Duncan 1984, 1996; Humphreys, Duncan, and Treisman 1999).**

**A2 Attention is a necessary condition for certain kinds of processes, which are *controlled* processes; attention is not necessary for other kinds of processes, which are *automatic* processes (Kahneman 1973; Posner 1978, 1982, 1994; Shiffrin 1997; Shiffrin and Schneider 1977).**

In addition, these early models usually endorse a set of assumptions about the problem of the unity and variety of attention, which can be expressed as follows:

**A3 As a limited processing resource, attention is unitary.**

If one rejects the unity of attention, the attempt to characterize cognitive processes in terms of those that (discretely) do, or do not, require attention becomes an ambiguous enterprise. In spite of giving some credence to A3, the early theories usually recognize that the division or scission of attention was possible, and thus tend to accept this statement:

**A4 Attention is a unitary resource that can, in some circumstances, be "divided," but such a division demands a specific effort (it costs more resources; see Pashler 1998).**

It cannot be taken for granted that the propositions A1 to A4 are compatible, as the ostensible tension between A3 and A4 may illustrate. Although such propositions pertain to controversial debates, they have oriented psychological research toward a series of traditional questions (Allport 1993; Findlay and Gilchrist 2003). A first question is the problem of the spatial or temporal "location" of selection: what is the *locus* (or place, stage) of attentional selection? Does the intervention of attention take place in or at an *early* or *late* stage in the (temporal or sequential) ordering of information processing? The debate opposing psychological theories of the early and late selection presupposes the idea that there is a specific location in which, or where, the "unitary" attention intervenes. Another problem, raised by A2, is this: what are the processes which do, or do not, require attention?

There are reasons to approach propositions A1 to A4 with caution. Consider A3 as an example. There might be good reason to describe the phenomenology of attentive perceptual experience as being unitary. However, A3 is neither a phenomenological claim nor a reductive claim about phenomenology. It is a psychological claim about the functional architecture of attention and the human mind/brain. It maintains that there is a single attention mechanism in the brain that is independent of other cognitive systems, such as sensory-motor control and memory. As such, A3 is debatable. Alternative approaches hold that *the* faculty of attention depends on *multiple selection* systems, and show that attention is reducible to the performance of a variety of sensory-motor and cognitive systems that can carry out a variety of mental procedures, acts, or routines.

The aim of the basic research strategy in biological psychology is to analyze the faculty of attention in terms of functional units and, thus, in terms of *multiple* mechanisms or systems (e.g., Parasuraman 1998; Parasuraman and Davies 1984; Posner 1994; Kahneman 1973; Posner

1978, 1982, 1994; Shiffrin 1997; Shiffrin and Schneider 1977). For instance, in a statement that reflects a common approach in psychology and neurobiology, Parasuraman affirms that "attention is not a single entity but the name given to a finite set of brain processes that can interact, mutually, and with other brain processes, in the performance of different perceptual, cognitive, and motor tasks" (1998, 3). Although there is no completely established taxonomy of attention, Parasuraman proposes the relative independence of three components of the attention faculty, which are selection, vigilance, and control. Given its focus on naturalistic approaches to attention, I will use phrases such as "attentional systems" or "systems of attention" to convey the idea that, at least in naturalistic accounts, the theoretical understanding of the faculty of attention requires the examination of a varied hierarchy of functional units or mechanisms.

This admission of the plurality of attentional systems opens the path to a wide range of questions. These questions originate in the attempt to understand attention systems as a *hierarchy* of selection and control procedures that shape tracking and action. Such control procedures may include the agent's endogenous selection of intentions and goals, of individuals to be tracked or of features to be analyzed. They may also include the selection operated by mechanisms that can prioritize the perception of salient unexpected events, which are usually termed *exogenous attention* to indicate that they are not deliberately or endogenously controlled by the attentive agent. The distinction between endogenous and exogenous factors in the control of attention is another fundamental assumption, which can be expressed as follows:

**A5 The faculty of attention can be controlled by endogenous or exogenous mechanisms.**

This assumption distinguishes between endogenous and exogenous shifts of attention (A5 should not be conflated with A2). It has long been described by phenomenological analyses that attention can undergo involuntary shifts (see, e.g., Hatfield 1998). This has led to the distinction between *automatic*, or *reflex*, and *voluntary*, or *willed*, attention, within various lexical idioms (James 1890; Wundt 1897; Titchener 1899; Folk and Gibson 2001; Driver and Spence 1998, 2004; Spence 2001). The distinction supports the naturalist stance about the plurality of attentional systems because endogenous and exogenous controls may be distinct with respect to their phenomenology, psychological mechanisms, and neural correlates.

Another assumption, which can serve as a guide for the study of attention systems, can be expressed as follows:

**A6** The faculty of attention encompasses *overt* and *covert* forms of selection.

In psychology, the concept of *overt attention* refers to gestures and actions associated with observable activities of attentive tracking such as listening, touching, smelling, tasting, or looking (see, e.g., Posner 1980; Spence 2001; Findlay and Gilchrist 2003). Paradigmatically, overt attention coincides with the displacement or adjustment of a sensory organ to explore target individuals in the organism's environment. As pointed out by Gibson (1966), each perceptual system (i.e., the basic orienting system, the auditory system, the haptic system, the taste-smell system, and the visual system) uses specific modes of overt attention. With respect to the visual system, overt attention is the activity of looking at individuals, which is performed by observable eye movements (patterns of saccades and fixations). Eye fixations are usually tightly bound to cognitive operations under progress (Yarbus 1967; Kowler 1995; O'Regan 1992; Ballard et al. 1997; Triesch et al. 2003; Findlay and Gilchrist 2003). In contrast to overt attention, the concept of *covert attention* refers to the internal and cognitive consequences of the selection that are not so readily observable.

## 11.4 An Argument from Cognitive Access in Support of the ACP

Although the information-processing approach has provided a fundamental impetus to a functional description of the faculty of attention, a theory grounded in the assumptions A1 to A4 does not explain how humans acquire knowledge of individuals from the extraction of causal information. To provide such an explanation alongside a foundation for the ACP, I will propose an argument from cognitive access and outline a more appropriate theory of attention.

The argument from cognitive access in support of the principle runs as follows: humans' empirical beliefs and perceptual knowledge about target individuals depend on having direct cognitive access to such individuals in order to track and identify them through direct perceptual acquaintance (see P1 in section 11.1). The act of directing attention at a target individual is a necessary condition of having direct cognitive access to this individual (for the orienting of attention at a target provides access to causal information relative to such target). Therefore, attention is a necessary condition of the perceptual knowledge of individuals.

The crux insight of the argument is that selection by perceptual attention institutes direct cognitive access to targets of de re epistemic attitudes, such as perceptual identification, demonstrative thoughts, and empirical beliefs. Such a cognitive access is made possible by specific information-processing procedures performed by attentional systems. Only such attentional procedures can retrieve causal information available in the organism's environment.

To be consistent with naturalist constraints, this argument must be grounded in a biologically plausible account of attention and cognitive access. For this, I propose to ground the argument in the distinction between overt and covert attention (see A6, section 11.3). On that basis, the argument from cognitive access can be expressed as follows:

**P2 Perceptual tracking and perceptual-demonstrative identification of an individual *i* necessarily require a direct cognitive access to *i*'s properties (i.e., some of *i*'s intrinsic or relational properties that carry causal information).**

**P3 To obtain direct cognitive access to *i*'s properties, an intentional agent must perform search actions and acts of *overt attention* (or overt attentive tracking) in order to introduce and maintain *i* into at least one of his or her sensory fields and track *i*.**

**P4 To obtain direct cognitive access to *i*'s properties, an intentional agent must track *i* and select *i* by *covert attention* to analyze some of *i*'s properties and assess propositions (e.g., expressed by information reports) about *i*.**

From the fact that demonstrative identification depends on direct cognitive access (premise P2), and that direct cognitive access depends on acts of overt (premises P3) and covert attention (premise P4), we can conclude that

**P5 Acts of overt and covert attention are necessary conditions of the perceptual tracking and demonstrative identification of an individual *i*.**

Arguably, given P5 and P1 (see section 11.1), which states that human perceptual knowledge depends on perceptual tracking and demonstrative identification (the form of which is "This *i* is *F*"), it is possible to conclude that ACP is true. Attentional systems are constitutive of agents' perceptual knowledge of individuals. This reasoning concludes that attention is a necessary condition of perceptual knowledge, because of its necessary contribution to the assessment of propositions (expressed by information reports or beliefs) grounded in the perceptual-demonstrative identification "This *i* is *F*."

Proposition P2 expresses a commonly received epistemological thought. Perceptual-demonstrative identification of an object is usually defined—in a sense related to Russell's notion of knowledge by acquaintance (1910)—as an identification whose success depends on the actual perception of the individual to be identified. Such perceptual identification may be performed, by excellence, through its localization and analysis in the visual field, or in some other sensory field (Dretske 1969; Evans 1982; Clark 2000, 2004a, 2004b; Rollins 2003; Kaplan 1989a, 1989b; McGinn 1981; Wettstein 1984; Reimer 1992; Siegel 2002). According this tradition, perceptual-demonstrative identification cannot occur in the absence of veridical perception of the target individual, and to perceive in a veridical manner, an individual requires having direct perceptual access to some of its properties. This direct access possesses a cognitive value, because it determines the cognitive significance of the representation of the target individual (e.g., Campbell 2002). In perceptual-demonstrative identification, perceptual access serves the epistemic goals of the agent—such as to verify an empirical belief expressed in information reports such as (1) and (2) in section 11.2.

Premises P3 and P4 and my comments on P2 refer to the establishment of a proper direct cognitive access to a target individual. How are we to understand this notion? I will follow the common understanding of cognitive access in terms of global availability for mental acts such as recognition, reasoning, and the rational guidance of action and speech (Evans 1982; Baars 1988; Block 1995, 2001). I am using the term "direct" to restrict the discussion to perception and the perceptual retrieval of causal information. Hence, in this use, we can declare that a human agent *a* has direct cognitive access to an individual *i* when, in virtue of *a*'s current perception of *i*, some properties of *i* and their related causal information are available to *a*'s mind/brain for use in identification, localization, reasoning, and the rational guidance of *a*'s action and speech.

Two kinds of analyses may appear as conflicting accounts of this perceptual access. As a first kind, the conceptualist and intentionalist accounts stress the roles of conceptual capacities for individuating the target of perception (Wiggins 1997, 2001; McDowell 1990, 1996; Kaplan 1989a; Reimer 1992; Siegel 2002). For instance, a few of them emphasize the role of sortal concepts in the spatiotemporal delineation of the demonstrative's referent (Wiggins 1997, 2001). In another kind of analysis, the explanation of cognitive access is conducted in an analysis of the nonconceptual mechanisms or contents that allow the perceiver to be "anchored" onto the target via sensory-motor skills (Cussins 2003a, 2003b; Clark 2000, 2004a, 2004b; Gunther 2003; Pylyshyn 2003).

If an account of cognitive access for identification is restricted to only one of the two types of explanation, it may be at risk of circularity with regard to the analysis of access, because access might then be conceived as a purely conceptual/descriptive process without grounding in external individual, or as a purely sensory-motor anchoring without grounding in conceptual thought (see Strawson 1959; Peacocke 1992; Pylyshyn 2003; Bullot, Casati, and Dokic 2005). I suggest that the interest in studying overt tracking and covert attention in this context is that the faculty of attention is likely to explain the missing link between the two explanations. It should help us have a better understanding of how conceptual and nonconceptual abilities interact to determine direct cognitive access. Thus, in the argument from cognitive access to preclude any circularity in the analysis, attention is viewed as a mediating faculty of control that articulates the conceptual and nonconceptual conditions of the cognitive access to individuals.

## 11.5 Cognitive Access and the Tracker's Goal-Directed Movements (Justification of P3)

Let us focus on proposition P3, which asserts that the perceptual and cognitive access to an individual is dependent on *overt* attention. The statement can be justified on the ground that (1) the preparation and initiation of cognitive access is dependent on a wide spectrum of spatial actions and motor behavior needed for tracking a target (for reaching the situation where searched causal information can be made available), and that (2) such actions can be viewed as sequences of information-seeking acts of overt attentive tracking.

Consider the case of a person who is looking for another individual *i* (e.g., a partner, a lost artifact, a building), to act upon *i* or verify an information report about *i*. Call the former agent the *tracker* and the latter the *target*. By the former definition of *direct cognitive access*, if, as a tracker, one intends to obtain direct cognitive access to *i*, one must put oneself in a situation of directly perceiving *i* and extract causal information relative to *i*. Assuming the existence of the target, a tracker can be presented with approximately two cases.

The first case can be termed *sustained perceptual absence*: the target *i* is apart or very distant from the tracker's perceptual field and cannot be perceived at the moment. The second case can be termed *perceptual proximity*: the target *i* is either present within the tracker's perceptual fields or present in the region surrounding the tracker's body, that is, its peripersonal space (Maravita, Spence, and Driver 2003).

In a situation of sustained perceptual absence of the target, in which the tracker maintains the intention to obtain direct cognitive access to *i*, the tracker must move its body (and, thus, the sensors thereof) in order to track down *i*'s present location until *i* is reached, found or caught. This spatial search may require small-scale spatial actions (e.g., performing a saccade) or large-scale spatial actions (e.g., displacements in case of migrations or pilgrimages). These spatial actions can be described in different frames of reference.

For example, in the case of a pilgrimage, the pilgrim, as tracker, may have to move across lengthy territories before finally reaching a particular holy target. In this example, a useful description of the tracker's move to *i*'s location may be made according to allocentric reference frames, for example, by means of a map. The initial phase of the tracker's search corresponds to bodily movements initiated toward a still imperceptible target. Prior to a successful end of the search, the tracker's behavior is not grounded in the direct perception of *i*, although it may use, of course, the perceptual tracking of clues relative *i*'s location (e.g., the perception of maps or of signs that carry causal or semantic information relative to the target location). Thus, this kind of search can be termed *epistemic tracking* (Bullot 2006; Bullot and Rysiew 2007) because it aims at reinstating the perception of a target via epistemic means, which may use memories, reasoning, and communication about the target's identity and location.

Notice that epistemic tracking is organized to prepare cognitive access associated with the direct perceptual-attentive tracking of *i*, although in epistemic tracking, the tracker's target may not at all be available in the tracker's peripersonal space. Still, there may be concrete, perceptual clues or signs within that space (e.g., Bullot and Droulez 2008; Sutton 2006) that might eventually lead the tracker to a location where the target *i* can be directly perceived. In this case, some of the evidence that leads the tracker to its target is still perceptual (and therefore not just epistemic in a nonperceptual sense) although the target *i* itself is not directly perceived or within the tracker's peripersonal space.

Consider, now, the case of clear perceptual proximity with the target. To prepare cognitive access to *i*, when the tracker is sufficiently close to *i*'s location and *i* is available within its perceptual fields, the tracker must perform another class of bodily movements, which are the typical tracking actions described by the concept of overt attention (see A6, section 11.3). It includes movements such as the displacement and orientation of the sensory organs (e.g., eyes, hands, ears) in order to focus on the properties of the target. In addition to these movements, the preparation and optimization of direct cognitive access imply attention:attention and inhibition of the movements the inhibition or modification of competing movements. For example, when the tracker arrives in the target's proximity, the tracker may suspend its locomotion or change its way of breathing. The description of these preparatory movements has been developed in the theories of sensory-motor consequences of attention since the end of the nineteenth century.

In addition to James (1890, 434–438), this reference to the motor and overt consequences of attentional selection is found in a number of other authors. Sully (1898, 82) describes attention as an active mode of consciousness that affect certain motor process. Ribot (1908, 3) writes that the mechanism of attention "is primarily motor, i.e. [attention] always acts on muscles, mainly in the form of a stop." Similar assumptions are held in contemporary theories of vision such as the motor (or premotor) theories of visual attention, which describe spatial covert attention as a preparation of saccadic eye movements (e.g., Rizzolatti, Riggio, and Sheliga 1994). A comprehensive classification of the possible acts of overt attention for each perceptual system can be found in Gibson (1966).

William James, for instance, analyzes the overt and organic phenomena that accompany the procedures that seek for causal information through the attentional tracking of a target. He noticed that when we look or listen we accommodate our eyes and ears involuntarily, and we turn our head and body as well. Similarly, when we taste or smell we adjust the tongue, lips and respiration to the target. James concludes that in all these acts of overt attention "besides making involuntary muscular contractions of a positive sort, we inhibit others which might interfere with the result—we close the eyes in tasting, suspend the respiration in listening, etc." (1890, 435).

We can conclude from all these examples that various classes of tracking actions and attentional movements prepare perceptual access to a target (and to related causal information) and, consequently, prepare the target's perceptual tracking and demonstrative identification. This appears to be a sufficient reason to admit P3.

## 11.6 Cognitive Access, Epistemic Attention, and the Procedural Theory (Justification of P4)

This section is a justification of proposition P4, which states that an agent must track and select an individual *i* by covert attention in order to obtain direct cognitive access to *i*'s properties. Here, the rationale is that the description of overt attentive tracking is insufficient to explain direct cognitive access to an individual, because the description of overt attention does not fully account for the epistemic uses of attentional acts.

In spite of their complementary status, overt and covert attention must be kept distinct (see Posner 1980; Findlay and Gilchrist 2003). For instance, the description of overt and goal-directed attentional behavior in vision is mainly the description of eye movements. There is an emerging consensus to acknowledge that, in an unconstrained context, the description of eye movements cannot unambiguously reveal the covert cognitive tasks performed by the tracker (Ballard et al. 1997; Findlay and Gilchrist 2003). For instance, the fact that a tracker is looking in the direction of an individual *i* does not necessarily imply that the tracker is currently paying attention to *i* to identify *i*. Empirical evidence supports this point, and, subsequently, the distinction between overt and covert attention.

The seminal psychological argument for the distinction originates from a series of experiments conducted by Michael Posner and collaborators (Posner 1978, 1980; Posner, Nissen, and Ogden 1978; Posner, Snyder, and Davidson 1980). They have found convincing evidence that human trackers can shift covert visual attention independently of their eye movements (i.e., overt visual attention). Specifically, they demonstrated that reaction times to visual targets selected by covert attention were faster for spatial locations that had been previously cued in a context of unchanged fixation. These experiments are usually interpreted as evidence that covert and overt attention can be uncoupled in vision.

In addition, other experimental findings indicate that directing the eyes at an individual does not imply the identification or memorization of this individual. As described in perceptual phenomena such as *attentional blink* (Shapiro 2001; Shapiro and Terry 1998), *change blindness* (O'Regan, Rensink, and Clark 1999; Simons and Rensink 2005a, 2005b), or *inattentional blindness* (Mack and Rock 1998), a sensory organ can be directed precisely toward a target without this target being consciously noticed, identified, or recalled. For instance, the concept of inattentional blindness (Mack and Rock 1998) refers to the failure to detect the presence of an entirely visible stimulus (such as a red square or a mobile bar) presented in the region of fixation. To study this phenomenon, Mack and Rock used a paradigm based on the principle of situating the subjects in a position where they would neither pay attention to nor expect to see an individual thing—termed *critical stimulus*—but nonetheless would look at the region within which this thing is presented. Inattentional blindness illustrates a case in which directing the gaze toward a target does not imply the target's identification or, more weakly, does not imply the capacity to submit a verbal report on its identity.

Taken together, these findings suggest that overt attentional behavior and covert attentional information-processing are two distinct, but (jointly) necessary, conditions of direct cognitive access. Overt attentional selection, such as the action of looking at *i*, does not necessarily imply an epistemic analysis of *i*'s properties aimed at identifying or locating *i*. Therefore, the nature of covert mental procedures must be elucidated in order to account for the epistemic dimension of the access to *i*'s properties. However, what is the nature of covert acts of attentional selection, and how do they relate to overt attentional tracking? To answer these questions, I will introduce the concept of *epistemic attention*.

In the remainder of this chapter, the phrase *(perceptual) epistemic attention* will refer to the capacities to identify or locate individuals that are currently perceived, and to disclose facts about them through the extraction of causal information from their perceived properties. In this usage of the term "epistemic," I conform to a tradition in the epistemology of perception represented mainly by Dretske's concepts of *epistemic seeing* (1969) and *meaningful perception* (1995a). In the following analysis, an example of the use of epistemic attention is the primary epistemic seeing in Dretske's (1969, 72–93) sense, which refers to knowledge that "(this) *i* is *F*" based on direct perception by the perceiver of the fact that *i* satisfies a perceptual predicate *F* (and the perceiver is justified in thinking that *i* is *F* because he or she perceives the fact that *i* is *F*). The perceptual reidentification of an object is another example (Strawson 1959; Treisman 1992).

In contrast to the epistemic tracking carried out when the target is not perceived, by definition, an act of perceptual epistemic attention requires the analysis of some properties of a perceived individual. Thus, perceptual epistemic attention can be performed only while the target individual is being tracked within a sensory field. How shall we analyze the acts of epistemic perceptual attention?

Given its definition, the central requirement for epistemic attention is this: to qualify as "epistemic," an attentional system must be necessary to the acquisition of knowledge. Thus, in perception, epistemic attention must contribute to the ability of the tracker to form nonaccidental true beliefs (e.g., Nozick 1981) and information reports (Israel 1988; Israel and Perry 1990) about perceived individuals. Consequently, epistemic attention must bestow on the tracker an ability (1) to flexibly assess the truth value of perceptual and demonstrative beliefs and (2) to revise, or update, such beliefs as a function of information made available through perceptual analysis of the target's properties.

When assessed with regard to this epistemological constraint, the early models of selective attention—those that accept A1, A2, and A4—appear limited. Their explanatory scope is too narrow, because they do not account for anything like an ability to assess whether a perceptual-demonstrative proposition is true or false. Models associated with this tradition—such as "attention-as-a-filter" (Broadbent 1982; Eriksen and St. James 1986; Brefczynski and DeYoe 1999; Driver and Baylis 1989; Valdes-Sosa et al. 1998), "visual-attention-as-a-spotlight" (Broadbent 1982; Eriksen and St. James 1986; Brefczynski and DeYoe 1999; Driver and Baylis 1989; Valdes-Sosa et al. 1998), or "attention-as-a-spatial-window" (Treisman 1988; Kosslyn 1994)—restrict their descriptions to early stages of perceptual selection, which would not qualify as vehicles of truth-assessable mental states or truth-assessing mental processes. Furthermore, they may not view attention as a system that functions to extract causal information.

There is also another substantive reason why the early models fail. To explain perceptual verifications or falsifications, you need to analyze the control of sensory-motor procedures used to perform perceptual verifications, such as directing your eyes toward *i* to verify whether *i* is *F*. Arguably, to account for procedures of perceptual verifications, one must have an account of the *executive control* of sensory-motor systems as performance systems for verification procedures. However, as a matter of historical fact, early cognitive models of selective attention were developed in relative independence from the theories of motor control. The executive control for epistemic/cognitive purposes is not an important theme of the early theories of the "locus" of attention selection. For instance, Broadbent's (1958, 297–301) early-selection theory identifies attention to a selective filter that feeds a single limited-capacity information channel and would not directly control the system's effectors—see the information-flow diagram in Broadbent (1958, 299). As a result, this kind of model does not offer predictions about the control of sensory-motor systems for epistemic purposes.

Can one provide a biologically plausible conception of attention that accounts for the perceptual verification or falsification of propositions expressed by empirical beliefs and information reports? My proposal is that a positive answer is possible within the framework of the "procedural/executive" theory of attention (e.g., Ballard et al. 1997; Campbell 2002; Cavanagh 2004; Gray 2000; Logan 1985; Miller and Johnson-Laird 1976; Posner 1994; Tomasello, Carpenter, and Liszkowski 2007), which has different foundational principles from that of early models of attention.

The *procedural*[1] or *executive* theory I propose hypothesizes that attention-driven perceptual processing corresponds to strategies[2] built by each tracker for satisfying requests about individuals. Specifically, perceptual epistemic attention uses perceptual analyzers to generate semantic information about perceived individuals from the cognitive processing of causal information. The semantic information-processing guides the acquisition of singular perceptual representations and the performance of singular actions. (Singular representations are sometimes termed "object files" or singular event "files."[3]) Consistent with the attentional constitution principle (section 11.1), attention is identified with procedures constitutive of singular perceptions and singular actions. Although this account incorporates the semantic concept of information processing, it does not restrict attention to the mere process of filtering out information as suggested by the attention-as-a-filter model (Broadbent 1958).

The core principles of this procedural theory (PT) of attention can be formulated as follows:

**PT1 The faculty of *attention* encompasses a set of executive and cognitive systems whose function is to perform singular perceptions (e.g., tracking and identifying a currently perceived individual through the use of a mental file) and singular actions (e.g., acting on a presently available individual).**

As a component of the faculty of attention, one can isolate the faculty of perceptual epistemic attention as follows:

**PT1′ The faculty of *perceptual epistemic attention* is a system of executive and cognitive procedures that can implement exploratory strategies in order to (1) extract semantic information from causal information; (2) track and identify individuals in perception; and (3) assess the truth value of information reports and empirical beliefs about such individuals and their relations.**

In PT1′, the reference to the ability to assess the truth value of propositions expressed by reports and empirical beliefs is what justifies the use of the adjective "epistemic." Perceptual epistemic attention is at the root of epistemic perception understood as the ability to perceive facts, form perceptual-demonstrative beliefs, and express linguistic information reports. The nature of attentional control can be specified as follows:

**PT2 Perceptual epistemic attention is a control system that builds *attentional exploratory strategies,* which are hierarchical procedures of information-processing that combine (1) instructions that can be termed "epistemic requests" and "action requests"; and (2) specialized information-seeking operations termed "perceptual routines," "motor routines," or "sensory-motor routines" that allow the tracker to solve or satisfy the epistemic and action requests (as a function of specific context- or task-dependent combinations).**

An *epistemic request* is a control procedure—that is, an instruction or command—that instructs a sensory-motor system or perceptual analyzer to extract semantic information about a perceptually tracked individual(s) from available causal information. As a component of a way to come to believe a particular perceptual-demonstrative proposition, the aim of an epistemic request is to solve a specific problem about perceived individuals. A paradigmatic example of the resolving of an epistemic request is the evaluation of perceptual predicates embedded in a demonstrative proposition.

Think about this task: imagine that a human person must act as a tracker and place a dozen eggs that are spread out on a table crowded with other kinds of objects inside a box. To perform the task, the tracker must iterate and solve an epistemic request that may be expressed in public language by the question "Is this an egg?" The procedural theory proposes that human trackers solves this request by assessing whether a perceptual predicate—which one may term EGG(*i*)—is satisfied by the objects they are looking at in a serial fashion. Thus, the ability to verify perceptual-demonstrative propositions depends on an ability to assess the truth-value of mental structures built from perceptual predicates ascribed to individuals. An examples of such predicates is OVOID(*i*), which is satisfied when the target individual *i* is egg-shaped. OVOID(*i*) is procedurally assessed as satisfied by the current target of attention if the tracker's perceptual epistemic attention can extract from the analysis from *i*'s faces the fact that *i* is egg-shaped. Perceptual predicates can relate to any other perceivable aspect of the target, such as its spatial relations with neighboring individuals—for instance, ABOVE(*i*,*k*) is satisfied when *i* is above *k*; COLLINEAR(*i*,*k*) is satisfied when *i* and *k* are collinear, and so forth.[4]

Similarly, in the action domain, to account for the fact that the trackers' actions are singular (i.e., are directed at individuals), an action request can be represented under the form of an action-predicate assigned to an individual. An *action request* is a procedure that controls motor routines through the use of a repertoire of action predicates, which may be initiated in the context of the performance of a hierarchy of actions. An action predicate can be represented as GRASP-A(*i*), in which the structure GRASP-A( ) refers to a sensory-motor mechanism that can control the grasping of the individual *i* in argument position (see Rizzolatti and Arbib 1998, 192).

Requests presuppose the activity of a control system that can assess the semantic information obtained from the performance of a command. Their study relates to the cognitive aspects of sensory-motor control.[5]

An additional key concept in PT2 is the notion of routines. Epistemic and action requests can be solved through the uses of a variety of sensory-motor and cognitive routines. The concept of *routines* refers to hierarchical information-processing systems of elementary mental analyzers or sensory-motor operations that must be carried out to resolve epistemic or action requests—the notion of "perceptual analyzers" has been introduced by Treisman (1969). Routines are structured and hierarchical abilities, in which the iterated retrieval of information in familiar tasks does not impose extreme demands on the tracker's capacities. The routines constitute the basic elements of the repertory of the practical aptitudes of a tracker, and these elements are regarded as stable once acquired after training. The development of some routines is likely to be driven by innate mechanisms. The routines are selected during the action according to the demands of the ongoing task and are controlled by hierarchical structures of goals.

This concept of routine is to be understood with regard to the theories of the sensory-motor capacities.[6] It presents a kinship relation to other notions such as sensory-motor primitives (Ballard et al. 1997), functional routines (Ballard et al. 1997, 735–737; Kosslyn 1994), sensory-motor contingencies (O'Regan and Noë 2001), scripts and microscripts (Schank 1996, 1999), or procedures of haptic exploration (Klatzky and Lederman 1999, 171–172, 174–177)—the aim of which aim is to understand the formation and structure of the skills that allow trackers to carry out epistemic perceptions and actions.

The procedural theory can be summarized by this hypothesis of tracking by epistemic attention:

**H A human tracker must carry out exploratory strategies of epistemic attention (i.e., assemble epistemic and action requests with relevant routines) directed at an individual *i* in order to seek for task-relevant information, build a singular representation of *i*, and verify or falsify empirical beliefs and linguistic information reports about *i*.**

If H is correct, it provides a relatively new way to justify P3 and P4, and, subsequently, the attentional constitution principle. Direct cognitive access to an individual (see P3 and P4) depends on overt (P3) and covert (P4) attention. On the procedural theory, the cognitive and epistemic processes of covert attention are analyzed as procedures performed by epistemic perceptual attention: cycles of hierarchically organized requests and routines, which are constitutive of the tracker's perceptual verifications. Specific perceptual and conceptual routines explain the extraction of task-relevant causal information related to targets' properties such as shape, color, or acoustic activities. The procedural theory predicts that human agents, as epistemic and perceptual trackers, have routine recourse to probing behaviors and perceptual verification about causal information and individuals in their environment.

In contrast to the nonbiological epistemology of knowledge or the nonepistemological psychobiology of attention, the procedural theory can address epistemological problems in a conceptual framework that is consistent with a naturalist philosophy and a biological investigation. One further advantage of this theory is that it can accommodate the seminal insights of both Broadbent's and Gibson's schools (see section 11.2). Broadbent's school insists that one must account for semantic information in terms of activities of functional information-processing units of the perceiver's brain. The procedural theory addresses this point in its account of information-processing routines. Gibson's school states that perceptual knowledge derives from exploratory actions performed by perceptual systems that seek for and pick out (causal) information in the environment. The procedural theory addresses this point in its account of the epistemic exploratory procedures. The procedural theory can thus reconcile the two approaches in its suggestion that the attentional control of sensory-motor systems and perceptual analyzers provide human trackers with direct cognitive access to individuals qua carriers of causal information, and with the means for extracting semantic information from causal information.

## 11.7 Biology and the Procedural/Executive Theory of Epistemic Attention

One may object that the procedural theory of epistemic attention cannot be grounded in biology. This concern can be set aside for at least two reasons. First, the theory raises specific biological questions. Second, it leads to hypotheses that can be (and have been) assessed via methods of experimental psychobiology.

To establish the first point, it should suffice to mention a few prevalent questions. A popular issue belongs to neurophysiology: what are the neural bases of executive attention? The question is now an integral part of the biological sciences of attentional control, which use of a variety of methods for specifying the neural correlates of attentive experience and the role of the prefrontal cortex in executive control (e.g., Duncan 2001). For instance, Posner and his collaborators (Bush, Luu, and Posner 2000; Posner 1994; Posner and DiGirolamo 1998; Posner and Raichle 1994) suggest that the neural bases of executive attention involve frontal structures, including the anterior cingulated, that act on different brain areas and account for attention as a control system.

Furthermore, the procedural theory also raises the biological question of determining the evolution of human attention systems in phylogeny and ontogeny. The ontogenetic development of attention systems is studied through specific experimental methods in developmental psychology and neuroscience. Some studies have investigated the relation of attentional systems to heritable traits (e.g., Fan et al. 2003; Rueda et al. 2005).

With respect to phylogeny, the problem of understanding the effects of evolutionary pressure on the evolution of attentional systems remains, to the best of my knowledge, to be further investigated. The attentional systems specific to some of our human ancestors may have been primarily selected to keep track of individual agents and objects. Specifically, a reliable attentional ability for tracking animate individuals is advantageous in terms of ecological fitness, because it provides the tracker with efficient ways to hunt prey and to detect predators (e.g., New, Cosmides, and Tooby 2007). The attentional tracking of animate individuals is also crucial for understanding the biological bases of social cognition, because this kind of tracking is a requirement of learning social hierarchy, participating in collective actions, and learning language by means of joint attention (e.g., Bruner 1983; Tomasello 1995; Tomasello et al. 2005).

Second, the procedural theory can be, and has already been, developed and assessed through the methods of experimental psychobiology and neuroscience. This point can also be illustrated with behavioral research on the deployment of executive attention in the interactive tasks of daily human life. A good example of this kind is the experimental research associated with the "deictic theory of vision" proposed by D. Ballard and collaborators (Ballard 1997; Ballard et al. 1992, 1997). The core thesis of the deictic theory is that the eyes are used deictically. Their use of the term "deictic" refers to the ability of certain sensory-motor mechanisms and actions to serve as a means of direct cognitive access to (causal) information available in the organism's environment.

Ballard et al. (1997, 726–730) use the term "pointers" to refer to this mechanism of direct cognitive access. They argue that the use of pointers is essential to the performance of cognitive and epistemic procedures. Eye fixation is conceived as eye pointing directed at a referent (a target for the cognitive access to causal information in the tracker's environment), and illustrates the use of pointers in the sensory-motor domain. In addition, selection by covert attention is a neural pointer that interacts with eye fixations (Ballard et al. 1997, 725–726). Eye fixations are known to be particularly important when vision interfaces with cognitively, or epistemically, controlled action. This deictic theory is a procedural theory, in the sense defined by principles PT1 and PT2 (section 11.6), of singular perceptions and actions. With its enhanced visual resolution that occurs through foveal vision, the fixation on an external individual serves singular perception. Moreover, a fixation presents this advantage to allow "the brain's internal representations to be implicitly referred to an external point" (Ballard et al. 1997, 724), which can serve in the control of singular actions.

The deictic theory rests on the concept of deictic strategies. Fixations are parts of more overarching hierarchical structures termed "deictic strategies" or "do-it-where-I'm-looking" strategies (Ballard et al. 1997, 725). In a way consistent with PT2, the deictic theory stipulates that a *deictic strategy* is a sequential combination of routines, which use discreet deictic pointers to solve epistemic requests and activate action requests. The paradigm example of a pointer in the sensory-motor domain is eye fixations. Fixations serve singular cognition and action, because they provide direct cognitive access to the referent of the pointing and an addressing mechanism to control motor routines directed at the same referent. Furthermore, Ballard et al. (1997, 729–730, 735–737) distinguish two basic routines combined in deictic strategies to serve the tracking of individuals through the performance of singular perceptions and actions: the "identification routine" (e.g., trying to identify the target of an eye pointing) and the "location routine" (e.g., trying to locate in the environment the target of a pointer in memory). Therefore, in a summary consistent with the procedural hypothesis H, a deictic strategy employs eye fixations to select the individuals who must be targets of identification or location routines in order to solve epistemic request and fulfill action requests. In agreement with PT2, the binding of each fixation's referent with properties or motor instructions is usefully represented in a predicative form that ties a target individual with a general category or concept (in the case of singular perceptual knowledge) or a motor instruction (in the case of singular action).

To assess the principles of the deictic theory, Ballard and his colleagues (Ballard et al. 1992, 1997) used an artificial manipulative task carried out by mouse-controlled modifications of a computer screen display. In this "block assembly" task, the subjects acted on elements presented in computer display of colored blocks and had the task of assembling a copy of the Model (a top left area of the screen with a few colored blocks) in the Workspace (bottom left area of the screen). The experimental set up allowed the authors to keep a detailed record of both the manipulative actions and the eye scanning of the subject carrying out the task. The data collected from the block assembly task supported a deictic characterization of the underlying cognitive operations. Blocks were invariably *fixated* before they were operated on. Furthermore, there was clear evidence that the preferred strategy involved making minimal demands on any internalized memory.

In the block assembly task, as has been found in other tasks, many more saccades were made than what would seem necessary. The most common sequence observed in the block assembly task was eye-to-model, eye-to-resource, pick-from-resource, eye-to-model, eye-to-construction, drop-at-construction. It is referred to as a Model-Pickup-Model-Drop or MPMD strategy. The first eye-to-model shift would be to acquire the color information of the next block to be assembled, then a suitable block is found in the resource space. The second look at the model informs, or confirms, the location of this block in the model, which is then added to the construction. This second look could be avoided if the location information is also stored on the first look.[7]

It is possible to describe this MPMD deictic strategy in terms of a sequence of demonstrative thoughts, such as: "What is the color of the next square to be moved?" (epistemic request about an individual's color); "This is a green square." (demonstrative proposition about information obtained by a fixation and a color-recognition routine); "Pick a green square in this area up." (action request); "What is the location of the green square in the model?" (epistemic request about the relative location of the element in the model); "It is located at the bottom right location" (demonstrative proposition supported by a location routine).

Another group of studies that accords with the procedural theory has been published by Michael Land and his collaborators. Land used a head-mounted video-based eye tracking system, which enabled a record to be built up of the fixation positions adopted by an observer during a variety of actions. Tasks studied include: driving (Land and Lee 1994), table tennis (Land and Furneaux 1997), piano playing (Land and Furneaux 1997) and making tea (Land, Mennie, and Rusted 1999). The results, obtained during cognitively controlled actions, demonstrate the strength of the principle that the gaze is directed to the points of the scene where causal information is to be extracted (Land, Mennie, and Rusted 1999, 1328).

The aim of Land's analysis of tea making (Land, Mennie, and Rusted 1999) was to determine the pattern of fixations during the performance of a well-learned task in a natural setting, and to classify the types of monitoring action that are associated with eye movements. They used a head-mounted eye-movement video camera, which provided a continuous view of the scene ahead, with a dot indicating foveal direction with an accuracy of about 1 degree. A second video camera recorded the subject's activities from across the room. The authors analyzed the actions performed during the task as a control hierarchy in which the largest units describe the goals and subgoals of the operation. The hierarchy comprises these levels: (L1) main goal: "make the tea"; (L2) subordinate goals: "put the kettle on," "make the tea," "prepare the cups"; (L3) intermediate actions: "fill the kettle," "warm the pot"; (L4) basic actions, object-related actions: "find the kettle *k*," "lift the kettle *k*," "remove the lid *l* of *k*," "transport *k* to sink," and so forth; (L5) eye fixations "fixate *k* at time *t*."

To analyze the fourth level, the authors introduced the concept of "object-related action" units, which they regard as the basic elements of an action sequence. These units, with very rare exceptions, are carried out sequentially and involve engagement of all sensory-motor activity on the relevant individual object or set of individuals. The eyes move to the object before the manipulation starts. In general, the eyes anticipate the action by about 0.6 sec. During a single object-related action, saccades move the gaze around the object, but when shifting between one object-related action and another, very large saccades can occur. The eye movements could, with only occasional exceptions, be placed into one of the following categories of procedures: "locate *x*" (locate an object to be used later in the task), which may be represented with a deictic perceptual and action predicate such as LOCATE(*x*); "direct *x*" or DIRECT(*x*, *l*) (directing the hand or object in the hand to a new location); "guide *x*" or GUIDE(*k*, *l*) (guiding the approach of one object to another such as lid and kettle); "check *x*" or CHECK(*w*, *k*) (checking the state or property of an object such as water level in a pot). The description on these control functions is consistent with the procedural theory, in which they are described as epistemic requests (about the location or identity of certain individuals) or action requests, the aim of which aim is to control the action performed on a contextually relevant individual.

## 11.8 Concluding Remarks

This chapter formulated the attentional constitution principle (ACP). It introduced both the argument from cognitive access to support this principle and the procedural theory of epistemic attention. The procedural theory accords special epistemic importance to attention, due to its role in the perceptual tracking and demonstrative identification of individuals. It conceives of attention as a system that controls sensory-motor routines to satisfy action and epistemic requests—and, thus, to seek or extract semantic information from causal information available in the organism's environment. Hence, through the deployment of epistemic attention in singular perception, human attentive trackers can "navigate" the informational structure of the world to follow individuals and discover truths about them. Concurrently, through executive attention, trackers can perform singular actions on individuals as a function of their dynamical knowledge of the informational structure of the world.

## Notes

1. According to the criteria mentioned in the text, one may consider as possible antecedent versions of the procedural theory the contributions of Miller, Galanter, and Pribram (1960) on plan; Miller and Johnson-Laird (1976) on the relations between perception and language and the evaluation of the perceptual predicates; Dretske (1969, 78–139) on epistemic primary seeing; Evans (1982) on demonstrative identification; Posner on executive attention (Posner 1978, 1994; Posner and DiGirolamo 1998); Ullman (1984) on visual routines; Ballard, Hayhoe and collaborators (Ballard et al. 1997) on the deictic strategies; Campbell (2002, 80, and chaps. 2, 3, 4, 5) on attention in reference; Pylyshyn (2003) on focal attention and visual reasoning. One may also include some theories of cognitive control (Allport 1993; Allport, Styles, and Hsieh 1994; Gopher 1993; Logan 1985; Shallice 1994) and some theories of joint attention (Tomasello et al. 2005; Tomasello, Carpenter, and Liszkowski 2007). Although they differ in many important aspects, the aforementioned works tend to analyze the contribution of perceptual attention to singular knowledge and singular actions, and to describe strategies or methods necessary for the acquisition of knowledge on individuals. In addition, such works may account for the fact that acts of identification by perceptual attention can be of a greater or lesser sophistication (Campbell 2002; Clark 2000, 135; Millikan 1984, 239–256), and can be revised and built from increments added to the singular knowledge already available to the tracker (Dretske 1969, 78–139; Pylyshyn 2001, 135–139).

2. The notion of strategy and of perceptual strategies is used in the executive/procedural theories of attention and action planning; see, for instance, Miller, Galanter, and Pribram 1960, Logan 1985, Gopher 1993, or Ballard et al. 1997.

3. See Kahneman, Treisman, and Gibbs 1992, Hommel et al. 2001, and Bullot and Rysiew 2007 for reviews of the literature on mental singular (object, agent, event) files.

4. The notion of perceptual predicate is used by Minsky and Papert (1969), Miller and Johnson-Laird (1976), Ullman (1984, 1996), Pylyshyn (1989, 2003), Peacocke (1983, 1992), Clark (2000, 2004a), and Hurford (2003). There are, of course, different ways to view the neural or behavioral implementation of perceptual predicates, and I remain neutral about this question. The point of the discussion is that something like perceptual predicates is needed to account for the epistemic dimension of perception, and it is likely that these predicates are assessed by attentional procedures.

5. Some directing ideas of control theory applied to cognitive science originate from electrical engineering (e.g., Craik 1947; MacKay 1951; Poulton 1952). They have been developed in the theory of eye movements (see, e.g., Kowler 1995) and other domains.

6. The concept of routines has been used in cognitive psychology to analyze the architecture of practical skills (Gopher and Koriat 1999; Gray 2000; Kirsh and Maglio 1995; Klahr and Wallace 1970; Monsell and Driver 2000; Schank 1996).

It refers to primitives used in sensory-motor and interactive abilities and perceptual abilities such as visual recognition and analysis (Ballard et al. 1997; Hayhoe 2000; Kosslyn 1994; Ullman 1984) or haptic/tactile recognition (Klatzky and Lederman 1999; Lederman et al. 1990). It has also been used in the analysis of understanding, reasoning, and memory (Bower, Black, and Turner 1979; Schank 1996).

7. On occasions, the second look was omitted, indicating that such use of memory was an option. However, these sequences were much less common than the sequences in which a return was made to the model.

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