Systems of Visual Identification in Neuroscience: Lessons from Epistemic Logic*

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The following analysis shows how developments in epistemic logic can play a nontrivial role in cognitive neuroscience. We argue that the striking correspondence between two modes of identification, as distinguished in the epistemic context, and two cognitive systems distinguished by neuroscientific investigation of the visual system (the "where" and "what" systems) is not coincidental, and that it can play a clarificatory role at the most fundamental levels of neuroscientific theory.

1. Introduction. While most work in neuroscience is conducted at the cellular and subcellular level,[1] brain research that catches the eye of philosophers is likely to come from a relatively recent interdisciplinary hybrid known as cognitive neuroscience. Explanations from cognitive neuroscience are of interest to philosophers since they offer the possibility of connecting brain and behavior through the specification of the information-processing properties of parts and processes of the brain. However, despite

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1. As John Bickle has recently noted, a brief "perusal of this year's Society for Neuroscience Abstracts volume (cataloguing the 13,000+ slide and poster presentations at the year's meeting) reflects how intracellular, molecular, and biochemical mainstream neuroscience has become" (Bickle 2001, 468).

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the prominence of the information-processing approach in the brain and behavioral sciences, it is difficult to know exactly what cognitive neuroscientists mean by 'information'. Historically, contexts in which this term has been given a precise definition include the so-called mathematical theory of communication, the theory of semantic information of Carnap and Bar-Hillel, and later the theories of informational complexity associated with Kolmogorov and Solomonoff. Most uses of the term 'information' by cognitive scientists and neuroscientists conform to none of these three contexts.

Philosophers frequently complain of a lack of precision in scientific uses of the notion of information. For example, Fred Dretske notes: "Its use in telecommunications and computer science gives [the notion of information] a tough brittle and technical sound, and yet it remains spongy, plastic and amorphous enough to be serviceable in cognitive and semantic studies" (1981, ix). Like Dretske, Ken Sayre points out that uses of the term in cognitive science are almost never connected with the mathematical definition of information as provided by Shannon and Weaver (1976).[2]

While the term as it is used in the brain and behavioral sciences is not well-defined, it plays a crucial role in scientific theory and practice. In addition to providing a putative theoretical connection between the goings on in the brain and intentional notions (belief, desire, representation and the like) assumptions with respect to the nature, function, and flow of information can also be seen as shaping the scientific investigation and characterization of those same goings on in the brain itself. This paper focuses on the concrete effect of presuppositions regarding information rather than the broader philosophical issues traditionally featured in discussions of information. Specifically, our argument suggests that errors at the conceptual level have consequences for the interpretation of empirical phenomena. While a wholesale revision of the way cognitive scientists have used the notion of information may be in order, our ambitions here are more modest. In this paper we focus on a particular research tradition in the brain and behavioral sciences, the so-called two-pathways approach to the visual system, and in so doing we argue that a mistaken conception of information has had a misleading effect on research.[3]

2. One crucial and often ignored aspect of the mathematical theory of communication is that it deals with the statistical characteristics of a collection of messages rather than with the informational content of messages themselves. According to information theorists, no message is informative by itself, insofar as informational content is the product of the relationship between a message and the probability of other messages. The problem of the holism of informational measures leads to basic difficulties for any attempt to apply the mathematical theory of communication to cognitive science insofar as it conflicts with the basic assumptions of the kind of hierarchical and modular models of perceptual structures traditionally employed in cognitive science.

3. It is difficult to underestimate the importance of the information-processing approach

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While the two-pathways model of visual identification features prominently in most introductory textbooks and is often lauded as one of the great achievements of cognitive neuroscience, the approach continues to be a topic of considerable disagreement in the scientific community. Our analysis should not to be read as an endorsement of any particular alternative to the textbook two-pathways model.[4] Rather than intervening in an ongoing debate in the cognitive neuroscience of vision, this paper presents a far more general lesson about the nature of the notion of information. If our analysis is correct then one of the basic assumptions in the brain sciences, namely the notion that the brain traffics in different 'kinds' of information should be scrapped.

2. The "Where" and "What" Systems. While they may have no real underlying theory of informational measure, there is one important point of agreement among cognitive neuroscientists. Modern theories of perception, especially modern theories of vision, can be found to place great importance on distinctions between *kinds* of information. But what precisely does this almost universally accepted approach to information mean?

To answer this question it is important to avoid the temptation of projecting treatments of information from cognitive science or philosophy onto the activity of contemporary neuroscientists. For instance, neuroscientists, as opposed to traditional cognitive scientists, equivocate on whether information specifies the content of information-processing activity. Similarly, in neuroscience it would be difficult to find a practicing scientist who believes in the kind informational encapsulation that we find in Jerry Fodor's work. Functional specialization in neuroscience has almost nothing in common with modularity in Fodor's sense (1983). Rather than arguing that functionally specific areas of cortex are informational modules, neuroscientists usually present the issue in far more modest, but perhaps more complicated terms. Functionally specialized regions of the brain are said to be sensitive to information of different *kinds.* So, for example a region of cortex might be described as being specialized for processing edge information or for information pertinent to face recognition.

to recent studies of the visual system. Historically, David Marr's work helped to orient the brain sciences towards the information-processing approach by seeming to provide a bridge between computational analyses and the neuroscience of the visual system. In the early pages of his classic text, David Marr spoke for a developing consensus in cognitive science with his claim that "[v]ision is, first and foremost, an information processing task" (1982, 3).

4. Given the vast literature, our history of the topic will inevitably remain incomplete. However, this shortcoming is irrelevant to the task at hand.

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While use of the term 'information' in neuroscience is certainly vague, we can assume general agreement on one point. This one relatively stable point is the notion that there are different kinds of information in the brain, and that the difference in kind is relevant to scientific investigation and explanation. So, rather than beginning with a philosophical account of information processing (like Fodor's) which has had only the most marginal influence on real neuroscience, a useful analysis of the concept of information as it actually functions in scientific theory and practice should begin from this basic point of consensus.[5]

To demonstrate the importance of this consensus it is useful to examine a real dispute in neuroscience. One of the most significant and well-accepted theoretical results in contemporary neuroscience is the idea that visual processing is split into two relatively separate functional processes, the "what" pathway and the "where" pathway. Roughly speaking, the "where" system governs such things as spatial orientation, location of objects in visual space (including prominently one's own body), as well as the relations of objects in visual space. The "what" system, by contrast, governs the identification of objects.

The "where" and "what" systems in visual perception came to the fore through the study of the effects of brain injuries of various kinds on the behavior of people and animals. The specific distinction between "what" and "where" systems was made largely on the basis of behavioral deficits in patients suffering from damage to the ventral and dorsal extrastriate cortex. These behavioral deficits have been characterized in roughly the same terms for almost one hundred years. So, for example, in the early part of the twentieth century, the Irish neurologist Gordon Morgan Holmes (1918) described patients who could perceive and identify objects while at the same time being unable to reach for, or properly locate, these objects in space.

Since at least the late 1960s researchers have noticed a relationship between these two cognitive functions and damage to particular anatomical locations.[6] Following Ungerleider and Mishkin (1984) scientists now

5. We are grateful to an anonymous referee for pointing out that for most neuroscientists, the term 'module' is more often associated with Mountcastle's (1980) work than Fodor's.

6. See Vaina 1990 for a discussion of the history and prehistory of this distinction in the anatomical context. The "where" and "what" taxonomy for cognitive systems has had a long and fascinating history. However, we will confine our discussion of the history to the recent past, focusing on articulations of the two systems stemming from Ungeleider, Mishkin, and colleagues' work in the early eighties. We therefore cannot address earlier efforts to understand the distinction in neuroscientific terms. Most notably, in the sixties, researchers localized the "where" and "what" systems *primarily* in the geniculostriate and tectofugal structures respectively (see Schneider 1968 and Trevarthen 1968). This approach is now widely regarded as having been superceded by

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widely acknowledge (at least in very general terms) that lesions in the parietal cortex result in disturbances of the "where" system while lesions in the posterior and inferior temporal cortex result in disturbances of the "what" system. This correlation between functional and anatomical distinctions is, by and large, unproblematic. So, in a sense, the "where" and "what" distinction presents a clear instance of a successful functional correlation in neuroscience. Damage to particular areas of the brain predictably result in deterioration of certain patterns of behavior. However, neuroscience has a wider theoretical ambition than simply to generate a catalog of correlations. In the case of the "where" and "what" pathways, as in so many other instances of well-established functional correlations, the functional correlation itself becomes a phenomenon that demands an explanation.

Given the influence of cognitive science, it was natural that neuroscientists would turn to explanations of the distinction in terms of the flow and processing of information. The two pathways are thought of as conveying two different kinds of information. In much of the recent discussion of visual perception it has been assumed that "where" information and "what" information is conveyed along distinct neural pathways leading from the eyes to different centers in the cortex where the two functional systems seem to be implemented. The 'kinds of information' approach has had an important effect on the search for a neural mechanism to support the distinction.

One of the negative consequences of this approach to the "where" and "what" distinction is what we shall call the *P and M model* of visual identification. This choice of abbreviations is motivated by the widely accepted correlation of the "where" and "what" distinction with a division between retinal projections to parvocellular (P) and magnocellular (M) regions of lateral geniculate nucleus (henceforth, LGN). This is a controversial account of the mechanisms underlying the "where" and "what" distinction, however. It is not universally accepted; for example, Semir Zeki and others have already criticized what we are calling the P and M model on anatomical and physiological grounds (Zeki 1988, 1993). Of course, the present argument proceeds along different lines.

3. Two Systems and Behavior. Textbook presentations of the "where" and "what" pathways describe them as beginning at the third layer of cells in the retina: the ganglion cells. Axons from the ganglion cells form the optic nerve. These cells project to many different target regions of the brain.[7]

more recent work. Nevertheless, the lessons that can be drawn from an analysis of more recent work can also be taken to apply also to earlier efforts.

7. Milner and Goodale (1995) and Palmer (1999) describe the numerous connections

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However, for the purposes of the two-pathways discussion, the crucial retinal projections from the dorsal region of LGN are divided into those that end up in the magnocellular (M) and parvocellular (P) regions of LGN. M cells are most easily distinguished from P cells by their size; M cells are large while P cells are small. Beyond this, these cells are widely interpreted as informationally specialized for location, size, and spatial information in the case of the magnocellular ganglion cells, and for color and contrast in the case of the parvocellular pathway (Livingstone and Hubel 1987).

This initial division of informational labor has been understood as the beginning of a distinction that continues beyond the lateral geniculate nuclei and on into the cortical areas of the brain that subserve visual cognition. From here the pathways are thought to divide into dorsal and ventral streams. The ventral stream, going from striate cortex into the posterior temporal cortex is thought to be responsible for object recognition. The dorsal stream, going from prestriate cortex into the posterior parietal cortex, is thought to be responsible for the perception of spatial relations among objects. Mishkin, Ungerleider, and Macko's (1983) account of the distinction in the rhesus monkey provides the classic portrayal of this latter half of the information-processing stream. Their account of the distinction in the monkey served as the basis for the later extension of the distinction all the way back to the M and P cells by Livingstone and Hubel.

Our simplified account of the "where" and "what" systems might give one the impression that the actual order of discovery was reversed. It is important to note that Ungerleider and Mishkin's correlation of the anatomical and functional distinction came before Livingstone and Hubel filled in the story from the retina to V1. So, in a sense, the P and M model looks like a natural extension of proposals that resulted from Ungerleider and Mishkin's studies of the "where" and "what" pathways in the rhesus monkey (1982).[8]

In order to complete our account of what we have called the P and M model of the two modes of identification in visual cognition it is necessary

and projections that retinal cells make to the rest of the brain. While the most widely studied projections that the retinal cells make are to the lateral geniculate nuclei, there are important connections to the superior colliculus, the pulvinar nucleus of the thalamus, etc.

8. In their famous studies, Mishkin and Ungerleider systematically damaged the brains of rhesus monkeys in search of the areas of the brain responsible for different aspects of visual identification. Their investigations followed on prior work in Rhesus monkeys by Pohl and others who laid the anatomical groundwork for the proposals by Mishkin and Ungerleider. By 1972, Mishkin had already understood work like Pohl's as proof that the inferior temporal cortex participates mainly in the acts of noticing and remembering an object's qualities, not its position in space. (For some useful historical dis-

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to examine the most problematic extension of Ungerleider and Mishkin's analysis: namely Livingstone and Hubel's proposal that the "where" and "what" pathways are distinguishable all the way back to the retina. The basic idea is that the two pathways that Ungerleider and Mishkin identified have their origins in the distinction between magnocellular (M) and parvocellular (P) retinal ganglion cells. As described above, the magno system, according to Livingstone and Hubel, is sensitive primarily to moving objects and carries information about spatial relations in the visual world. The parvo system is thought to be important for analyzing the visual scene in detail (Livingstone and Hubel 1987). It begins in the third layer of the retina and ends in the P layers of the lateral geniculate nucleus (LGN). Livingstone and Hubel base their assertion that the P system picks out details on the principle that it has characteristics making it more suitable for form and color vision. Since the P and M layers of LGN project to V1, Livingstone and Hubel concluded that the "where" and "what" distinction is best understood in terms of the distinction between the P and M pathways.

The principal argument for the extension of the two-pathways doctrine back to the earliest stages of the visual system is the notion that something like the P and M model is the only way to preserve the informational independence that the "where" and "what" distinction is thought to require. The idea is that by tracing the origin of the two pathways back to the distinction between the parvocellular and magnocellular pathways from the retina to the lateral geniculate nucleus, one can clearly distinguish the two kinds of information that are thought necessary to the possibility of distinguishing from each other the two modes identification that the "where" and "what" contrast involves.

However, as mentioned previously, the P and M model is quite controversial. For example, Zeki has shown that P type pathways are not exclusively tuned for color and form (1993). Likewise, M type cells are sensitive to color and form in addition to motion. He concludes that the extension of the two-pathways program is untenable. In support of Zeki's objections it can be argued that the informational distinction is the result of a misguided construal of the nature of visual identification. In particular, the idea that different modes of identification rely on different kinds of information is subject to conceptual criticism in addition to empirical counterevidence.

4. Two Kinds of Information? In his "On the Logic of Perception" ([1969] 1975) Jaakko Hintikka outlined a very similar distinction to the one under consideration here. That work systematically distinguished *physical* from

cussion of this topic see Bechtel and Mundale 1999.) Conversely, the posterior parietal cortex seems to be concerned with the perception of spatial relations among objects, and not their intrinsic qualities (Mishkin 1972).

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perceptual methods of cross-identification. The same distinction could be characterized as a contrast between subject-centered and object-centered modes of identification. As we shall see, Hintikka's treatment of the logic of this distinction, which he later referred to as a distinction between *public* and *perspectival* modes of identification, is directly relevant to visual identification.

In the case of vision, consider the totality of visual stimuli a certain person (or automaton) receives at a certain moment of time. Inevitably, this stimulus will not specify a unique scenario as to what the situation is in the perceiver's visual space. Instead, it leaves a number of alternatives open as to what is the case. Thus the identification that is being considered here concerns the identity of an object (in the wide sense of any kind of entity) in the different scenarios that the perceiver's visual information leaves open. These alternatives are the scenarios between which the identification is to take place. Philosophical logicians often misleadingly call these scenarios "possible worlds." Instead we will simply call them the perceiver's visual alternatives at some given moment.

The crucial fact for our purposes here is that identification of objects in these visual alternatives can happen in at least two different ways. In the most general terms possible, to identify a person or an object is to place him, her, or it in some framework or "map." In perspectival visual identification this framework is provided by the subject's visual space. Thus, while the *perspectival* or *subject-centered* mode of identification employs, as it were, a coordinate system defined by reference to a particular perceiver or knower, there is nothing subjective or private about it. Instead, it relies on objective general principles and on the possible situations between which the world lines of identification are drawn. To illustrate this, consider what a person, Jane, sees at a particular moment of time. Let's assume that she sees a man standing in front of her, but that she does not see who the man is. The man standing next to Jane occupies a particular slot in Jane's visual space and can be individuated in such a way as to allow Jane to track him through various visual alternatives. In this case, we can call him one of Jane's perspectival visual objects, even though this locution has to be used with caution.

Of course, this man happens also to have a name, a social security number, and many other features of his public persona by means of which he can be identified. Persons and other objects so identified can be called *public objects.* Public identification thus uses in such a case as the requisite framework something like the social organization of the people in question.[9] Public identification constitutes another way to track a person

9. In other cases the framework of public identification almost reduces to geography, as in the typical Finnish family names which originally indicated the location of a

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through possible scenarios, namely by reference to who that person is. Let's imagine that this man standing in front of Jane happens to be the mayor of El Paso. Jane may have numerous beliefs and opinions about the mayor without being able to identify the man standing in front of her with the dignitary. She cannot identify, solely by means of the visual information, the perspectivally individuated object standing before her as the publicly individuated celebrity whose name regularly appears in the newspaper and for whom she voted twice. This means that in some of the scenarios that are compatible with Jane's visual information the good mayor is elsewhere in her visual space or even outside it. This does not exclude the possibility that she knows who the man in front of her is on the basis of other kinds of information, for instance by having been told who he is. It is also compatible with Jane's knowing who Mr. Cabarello is outside the particular visual situation, for example, with being able to identify Mr. Cabarello as a public object which in this case comes close to knowing which public official he is. She can track him through political history, she holds opinions about his policies, and is happy that he is her mayor.

What makes it possible to speak of just two modes of identification is the role that the visual (or other) stimulus plays for the subject at a particular time. Stimuli contribute to reducing the set of alternative scenarios; the more information one has, the more narrowly restricted is one's set of alternatives. For instance, when the set of alternative scenarios is so narrow that in all of them a term picks out the same person, it becomes true to say that the perceiver sees who this person is or sees this person depending on the mode of identification. In contrast, the identificatory relations between two different scenarios are independent of the factual information an agent happens to possess.

In more general terms, one can say that in public identification one takes a visual object and places him, her, or it on one's map of public figures in a wide sense of the expression. When this happens by means of one's momentary visual information, we can say that the perceiver *sees who* or *what* the visual object is. In contrast, in perspectival visual identification the perceiver takes a public object and places him, her, or it among one's visual objects. The colloquial expression for this kind of feat of identification is to say that the perceiver *sees* the (public) object in question, thus illustrating the semantical import of the direct object construction with perceptual verbs.

To sum up, the distinction between *public,* or *object-centered*, and *perspectival*, or *subject-centered*, modes of identification is thus clear in the

person's homestead. Vintanen was a person living next to a stream or vinta, Mäkinen one who lived on a hill or mäki and so on.

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case of visual perception. There one can use as one's identificatory framework the perceiver's visual space. Persons and bodies occupying the same slot in this visual space (in the different situations compatible with what the person sees) can be considered identical, even if that person does not see who they are. This results in a perspectival, or subject-centered, identification system. Please note that by identity, two different (but interrelated) things can be meant, either identity within a scenario ("possible world") or identity across the boundaries of scenarios. What is being referred to here is the latter, which might more explicitly be called cross-identity.

As already indicated, the two methods of cross-identification correspond roughly to the truth-conditions of two different kinds of linguistic expressions. A person, say *b,* is a perspectivally identified entity for a subject on the basis of his momentary visual information if it is true that

(1) Jane sees *b*

(For a minor qualification needed here, see below). Now, other propositional attitudes have analogous direct-object constructions, e.g.,

(2) Jane remembers *b*
(3) Jane knows *b*

Their semantics is parallel with that of (1) albeit a shade less obvious. In the case of (2), Jane's first-hand memories of past events provide a framework—a framework not unlike a play or perhaps rather a long-running soap opera—in which certain persons (objects, places, etc.) as it were play a definite role. They are the persons Jane remembers independently of whether she remembers who they were. It is in this sense that (2) is parallel with (1), likewise, Jane's first-hand knowledge, alias acquaintance, of persons, places, events, etc. creates a framework with which she can place certain people, objects, places, etc. but not others. In this way (3) receives a meaning which is perhaps less clear than that of (1)-(2) but in any case is parallel with what (1)-(2) express. For the public mode of cross-identification, the analogous identificatory statements are:

(4) Jane sees who *b* is
(5) Jane remembers who *b* is
(6) Jane knows who *b* is

The criteria of identification here are the same mutatis mutandis as in the case of (1).

5. Epistemic Logic and Cross-Identification. It is instructive to express the statement (1)-(6) and others like them in an explicit notation that brings out their logical form. This can be done by using the usual first-order

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quantifiers. Now, in any logic, the values of quantified variables must be well-defined individuals. Since we are speaking of them as elements of different scenarios, this presupposes that they can be identified between different scenarios, in other words, that some particular mode of cross-identification is assumed to be given. But this makes quantifiers, when used in the context of cognitive concepts like seeing, perceiving, remembering, and knowing, relative to a method of identification. Since we are dealing with two different modes of identification in the case of visual cognition, we must use two pairs of quantifiers corresponding to perspectival and public identification. Hence if the public quantifiers are $(\exists x)$, $(\forall y)$, and the perspectival ones $(\mathrm{E}x)$, $(\mathrm{A}y)$, then the formal counterparts to (4)-(6) are

(7) $(\exists x)$ Jane sees that $(b = x)$
(8) $(\exists x)$ Jane remembers that $(b = x)$
(9) $(\exists x)$ Jane knows that $(b = x)$

The last one of these will be abbreviated

(9′) $(\exists x)\ \mathrm{K}_{\mathrm{Jane}}\ (b = x)$

More generally, we obtain in this way an analysis of constructions of the form *knows* + a *wh*-clause (subordinate *wh*-question). For instance,

(10) Jane knows who won the election

has the counterpart

(11) $(\exists x)\ \mathrm{K}_{\mathrm{Jane}}$ (x won the election)

By contrast (1)–(3) are rough translations of the following

(12) $(\mathrm{E}x)$ Jane sees that $(b = x)$
(13) $(\mathrm{E}x)$ Jane remembers that $(b = x)$
(14) $(\mathrm{E}x)$ Jane knows that $(b = x)$
(14′) $(\mathrm{E}x)\ \mathrm{K}_{\mathrm{Jane}}\ (b = x)$

However, this correspondence between (1)-(3) and (12)-(14) is not the only possible one. For example in the 'translation' (12) 'seeing *b*' is taken to require *recognizing b,* that is, seeing *b* as *b.* In the weaker sense in which 'seeing *b*' simply means laying one's eyes on *b,* (1) should be expressed by

(15) $(\mathrm{E}x)$ $(x = b$ & $(\mathrm{E}y)$ (Jane sees that $(x = y)))$

In the corresponding sense, (2)-(3) should be translated as

(16) $(\mathrm{E}x)$ $(x = b$ & $(\mathrm{E}y)$ (Jane remembers that $(x = y)))$
(17) $(\mathrm{E}x)\ (x = b\ \&\ (\mathrm{E}y)\ \mathrm{K}_{\mathrm{Jane}}\ (x = y))$

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For instance in (17) *b* is one of Jane's acquaintances even though she need not know *b* as *d.* Both pairs of quantifiers behave among themselves in the same way. For instance, from

(18) K_{Jane} S[*b*]

(where S[*b*] does not contain any intentional operators) we cannot infer either

(19) ($\exists x$) K_{Jane} S[*x*]

or

(20) (E*x*) K_{Jane} S[*x*]

These inferences can be vindicated however, by an additional premise which for (19) is (9′) and for (20) is (14′). This treatment of the interplay of quantifiers and epistemic operators is easily generalized. A similar analysis can easily be given of the identification of general concepts instead of individuals.

6. Formal Analysis Vindicated by Evidence. Applying this analysis of the two modes of identification to the context of actual visual cognition is relatively straightforward. To identify *b* in the perspectival sense means finding a slot for *b* among our visual objects, in other words, locating *b* visually. This means in effect being able to answer a "where" question. In contrast, identifying *b* in the sense of public cross-identification means being able to put *b* on the map of abstract impersonal knowledge. It means being able to answer a "who" or "what" question. This suggests strong parallels between the distinction between the two cognitive systems and the distinction between perspectival and public identification. This consilience can be extended *a fortiori* to the formal representations (7)-(20).

The appropriateness of this analysis can be seen from the fact that the functional manifestations of the two cognitive systems are precisely what we are made to expect on the basis of our analysis of the two methods of identification. This is shown vividly by subjects suffering from disturbances in the one or the other system. This identity of the semantical distinction between the two methods of identification and the two cognitive systems is so strong that such disturbances can be used to teach and to internalize the logical distinction between the two kinds of quantifiers. The most common type of disturbance is a failure to identify objects of a certain kind, for instance faces (prosopagnosia) or colors (color agnosia). When in (fortunately rare) cases a subject loses spontaneous visual object identification in general, the result is a patient like Oliver Sacks' "man who mistook his wife for a hat." This is precisely what the general-object counterparts to (1) and (12) express. Sacks' sensitive account of Dr P.'s

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affliction captures the difficulties faced by an otherwise normal man who is unable to determine the identity of common objects or familiar faces.

> By and large he recognised nobody: neither his family, nor his colleagues, nor his pupils, nor himself. . . . In the absence of obvious "markers" he was utterly lost. But it was not merely the cognition, the *gnosis,* at fault; there was something radically wrong with the whole way he proceeded. For he approached these faces—even those near and dear—as if they were abstract puzzles or tests. He did not relate to them, he did not behold. (12)

Dr. P. was unable to visually recognize common objects, but he could make inferences based on certain clues that eventually led him to correctly identify the object in question. Again Sacks' account strikingly captures the affliction:

> I had stopped at a florist on my way to his apartment and bought myself an extravagant red rose for my buttonhole. Now I removed this and handed it to him. He took it like a botanist of morphology given a specimen, not like a person given a flower.
> "About six inches in length," he commented, "a convoluted red form with a linear green attachment."
> "Yes," I said encouragingly, "and what do you think it *is,* Dr. P.?"
> "Not easy to say." He seemed perplexed. "It lacks the simple symmetry of the Platonic solids, although it may have a higher symmetry of its own . . . I think this could be an infloresence or flower."
> "Could be?" I queried. . . . "Smell it," I suggested, and he again looked somewhat puzzled, as if I had asked him to smell a higher symmetry. (12)

The smell of the rose prompts Dr. P.'s recognition. In another powerful example, Sacks describes Dr. P.'s complete inability to recognize a glove. Dr. P. offers sophisticated geometrical descriptions of the glove, but utterly fails to recognize the "continuous surface infolded on itself with five *outpouchings*" as a glove.

Since perspectival identification in the case of visual cognition relies on a subject's visual space, disturbances of such perspectival identification amount to failures to articulate one's visual space. Such disturbances have been described for generations (see, e.g., Holmes 1919).

But the disturbances of perspectival identification may be subtler, pertaining predictably not so much to the subject's ability so to speak to construct a visual space, as to the subject's ability to use it as a framework of identification. This kind of failure may mean for example difficulties in using the concepts *left* and *right,* difficulties to use one's own body as a

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reference point, difficulties in pointing (ostension), and in some rare cases misplacing oneself in one's own visual space.

7. Implications for Neuroscience. All this provides strong cumulative evidence for the identity of the distinction between the "what" system and the "where" system, and the distinction between the two kinds of identification exemplified by the distinction between two kinds of quantifiers. And this identity is in turn significant in that it enables us to read off conclusions concerning the two cognitive systems from their logical representations. In other words, we are now ready to tackle the question as to how the conceptual results outlined here are related to the anatomical findings and other neuroscientific results discussed previously. Clearly, the cortical differentiation that corresponds to the functional difference between the two systems is not really open to serious criticism at this point. This correlation between the two functional systems and cortical differentiation is by and large very strong.

However, there is more to be said here. Conceptually speaking the most remarkable feature of the analysis of the two modes of identification is that only one notion of knowledge is involved in the two. This is true in more than one sense. As has been shown, all the different constructions in terms of knowledge can be analyzed without evoking more than one sense of knowing, viz., knowing that. This can be considered a major accomplishment of Hintikka's epistemic logic, in combination with the two-modes-of-identification principle. Moreover, the distinction between the two kinds of identification does not turn on any distinction between different sentences S in the construction $K_a\ S$, of course except for the presence of different kinds of quantifiers. Here, an important interpretational point is seen directly from the use of appropriate notation. The distinction we have here is a distinction between two principles of identification, not between two kinds of knowledge or information. It is not even a distinction between two different constructions involving knowledge, such as the distinction between *de re* and *de dicto* knowledge. It is a distinction between two kinds of identificatory frameworks to which one's visual knowledge can be related.

A fortiori, the information provided by different neuronal pathways to different cortical areas need not be differentiated in order for two modes of identification to be applied. This result is extremely consonant with Zeki's empirical objections to the two-pathways doctrine. What the univocity of knowledge suggests is that knowledge "where" and knowledge "what" are both extracted from the same, or at least overlapping, information. This is eminently compatible with Zeki's suggestion, according to which

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> perhaps a far better way to look at this system is to accept that each area will draw on any source to undertake its specialized task. (1993, 194)

If we accept that the same kind of knowledge or information is involved in the two distinct identificatory frameworks, then our research programs in neuroscience will have to be reconsidered. One would expect, for example, the identificatory systems to draw on any available clues, rather than being restricted to one particular source or kind of information. One would also abandon the idea that different aspects of the stimulus to the visual array should be such that they can be traced through distinct neural pathways in the brain. As we have seen, the two streams should probably not be construed as two largely separate informational routes running all the way through the visual system. Instead, different areas will call on different components of input processing most useful for the kinds of action being initiated. Later areas in the system are dedicated to solving specific sorts of problems (e.g., coordinating limb movements) and extract from relevant earlier processes information relevant to those respective tasks.

8. Conclusion. The foregoing analysis has shown that conceptual investigations can potentially have a nontrivial role in neuroscience. In the case of the visual system, we have argued that the striking correspondence between two modes of identification, as distinguished in the semantical context, and two cognitive systems distinguished by neuroscientific investigation of the visual system (the "where" and "what" systems) is not coincidental, and that it can play a clarificatory role at the most fundamental levels of neuroscientific theory.

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