Intellectica, 2000/2, 31, pp. 111-123

Israel ROSENFIELD

Consciousness and Subjectivity: Memory, Language and the “Body Image”

The place of consciousness in cognitive studies is important because several major properties of consciousness have to be taken into account in order to develop adequate theories of the cognitive functions, such as perception, memory and language. Two properties of experience are emphasized, and it is shown that they play a central role in perception as well as in memory. The fist one is the dynamic feature of the stream of consciousness. The temporal integration of this flow, carried out by consciousness, is a major property without which perception nor memory cannot be understood. Every conscious content, such as a perceptual content, is grasped in this flow in which it has its meaning, by means of the establishing of relations. The second main property of experience is the internalized body image associated with every experience. This internalized body image plays the role of a frame of reference, necessary for perception as well as for memory. Different disorders of this internalized body image, with severe consequences on perception and memory, prove this role. Because experience is a flow, the internalized body image seems to be the unique frame of reference for the different conscious activities, and hence the basis of our subjectivity.

Key words : consciousness, perception, memory, language, temporal flow, body image

Conscience et Subjectivité : mémoire, langage et l'"image du corps" : L'importance de la conscience pour l'étude de la cognition vient de ce que certaines de ses propriétés essentielles doivent être prises en compte pour développer une théorie adéquate des diverses fonctions cognitives telles que la perception, la mémoire, ou la production du langage. L'accent est mis en priorité sur deux propriétés de l'expérience consciente dont il est montré qu'elles jouent un rôle central dans la fonction perceptive comme dans la fonction mnésique. Il s'agit en premier lieu du caractère fluent et dynamique de la conscience. L'intégration temporelle du flux qu'opère la conscience est une propriété essentielle en dehors de laquelle ne peuvent être compris ni la perception ni les phénomènes mnésiques. Tout contenu de conscience, y compris perceptuel, est donc appréhendé dans un flux au sein duquel il trouve son sens, notamment par le biais des mises en relation qui s'y opèrent. La seconde propriété cruciale de l'expérience est la conscience du corps propre qui accompagne en permanence toute expérience, et qui joue le rôle d'un cadre de référence indispensable aussi bien pour la perception que pour la mémoire. Diverses situations pathologiques d'altération de la conscience du corps témoignent du rôle de cette propriété, par leur retentissement spectaculaire sur la perception et la mémoire,. En raison du caractère fluent de l'expérience, la représentation dynamique du corps constituerait le cadre de référence nécessaire des différentes activités conscientes et la base neurologique de notre subjectivité.

Mots clés : conscience, perception, mémoire, langage, flux temporel, corps propre

The distinction between memories as stored information and memories as conscious recollections has rarely troubled psychologists, philosophers and neuroscientists[1]. One exception was Sigmund Freud who suggested that consciousness could not be understood independently of the unconscious, and that conscious processes have a profoundly different structure from those of the unconscious. Freud noted that what he believed were stored memories rarely, if ever, become conscious in a form that is identical with their unconscious state. Freudian theory was an attempt to explain, in part, why conscious and unconscious memories are so different. Ultimately, however, it failed to explain to the nature of the "stored" memories.

It was Freud, too, who noted that when new theories replace old ones, certain central ideas are radically transformed, as in the case of the notion of the atom at the beginning of the twentieth century. And so too, he argued, modern psychology was built on ideas that would change in unpredictable ways. In 1914 he wrote:

"We have often heard it maintained that science should be built upon clear and sharply defined concepts. In actual fact, no science, not even the most exact, begins with such definitions. It is only after more thorough investigation of the field of observation that we are able to formulate its basic scientific concepts with increased precision, and progressively so to modify them that they become serviceable and consistent over a wide area. Then, indeed, the time may have come to confine them in definitions. The advance of knowledge, however, does not tolerate any rigidity even in

---

[1] For a more detailed account of the argument in this essay see my *The Strange, Familiar and Forgotten,* (1993) and the more recent revision (including a more extensive discussion of language) that appeared in French under the title *Une anatomie de la conscience* (1996) .

definitions. Physics furnishes an excellent illustration of the way in which even "basic concepts" that have been established in the form of definitions are constantly being altered in their content."[2]

Twentieth-century psychology, and the related neurosciences have not fulfilled Freudian hopes; most evident is the failure to explain the distinction between conscious and unconscious thoughts and memories, suggesting just how far we are from any new understanding of the "mind." Indeed, human memory may be unlike anything we have thus far imagined or successfully built a model for. And consciousness may be the reason why. For what makes consciousness puzzling and hard to talk about is its utter subjectivity, the uniqueness of each personal perspective. We can no more capture the essence of our subjectivity than we can capture that of others. For to say that consciousness is subjective is also to say that it is dynamic and ever changing; our subjective experience is made up of unreproducible, evolving mutually dependent states of mind, knowable only from our own unique perspectives.

In this subjectivity, oddly, we nonetheless feel or believe we are experiencing the objective truth about the world, and we call that knowledge; we usually think of knowledge as something that can be understood and also transmitted from one person to another. This in turn has given rise to the belief, widely held by scientists and philosophers, that our brains in some sense re-create images of the objects we perceive (though not necessarily in a "pictorial form").

However, if one thinks about the ordinary human experience of being conscious, of being aware and alert to the meanings of one's ongoing experiences, it seems unlikely that perceptions become conscious by these re-creations or representations in the brain, however complex they are supposed to be. This presupposes a static notion of brain function. But consciousness has a temporal flow. Our perceptions are part of a "stream of consciousness", part of a continuity of experience. A sense of consciousness comes precisely from the *flow* of perceptions, from the relations among them, from the dynamic but constant relation to them governed by one unique personal perspective sustained throughout a conscious life. Compared to it, units of "knowledge" such as we transmit or record in books or images are but instant snapshots taken in the flux of a dynamic flow of uncontainable, unrepeatable, and inexpressible experience. And it is an unwarranted mistake to associate these snapshots with material "stored" in the brain.

---

[2] The Freud passage comes from his paper "Instincts and Their Vicissitudes" (Standard Edition, vol 14, p. 117), though a similar passage can be found in "On Narcissism: An Introduction" (Standard Edition, vol 14, p. 77).

The profound difference between conscious knowledge as relations and information as stored, fixed items is underscored by the famous "phi experiment." Two spots of light slightly separate in space, one green and one red, are alternatively flashed on a screen. We do not see red and green spots lit in succession, but a sequence of events that does not actually occur; we first see the green spot, then a <u>moving</u> image of a green spot <u>changing</u> to red, and then the red spot. Though we are aware of a single moving image that changes color, we are in fact looking at two differently colored stimuli that are alternatively lit and that never move. When looking at motion pictures we are also looking at static images that never move; and yet we see motion that is not on the screen. The problem the brain is solving in the phi experiment and in motion pictures is the same one it confronts when we are observing any stationary or moving object. How do we know it is always the same object? How do we know that we are always observing the same light bulb? Or that the light bulb we have been watching for the past minute is the same bulb that has just been turned off? We know it is the same bulb because conscious awareness is based on the brain's establishing a <u>relation</u> between a set of stimuli at a given moment and those of an immediately preceding moment.

We see a green spot moving, and changing to red, because the brain relates the first arrival of red light to the immediately preceding stimuli, the slightly differently placed green spot, making us aware of the relation between the two sets of stimuli: a "moving green spot changing to red" is a relation, and this relation is consciousness. This is why motion pictures give us the illusion of moving images, when in fact we are watching a series of still photographs. We are not aware of the individual photographs, but of the relation of one photograph to another; and this relation is manifested as a conscious moving image. The sense of motion can exist only in consciousness, not in any representation in the brain.

The stream of consciousness, then, is a flow of relations: the connections between moments, not the moments themselves. Conscious perception is temporal; continuity derives from the correspondences that the brain establishes from moment to moment. If it were otherwise, we would perceive a collection of unrelated and unrelatable moments, and therefore we would be unable to acquire knowledge and understanding of the world. That is why conscious knowledge is so different from the information stored in computers.

Nonetheless, nineteenth and twentieth century neurology has taken for granted that there must be specific, reproducible memories stored in the brain that can be partially or completely destroyed. Most neurological difficulties, such as the inability to speak or understand spoken and written language have been taken as proof of this fundamental claim. Patients appear to lose specific memories and specific brain functions, just as a particular memory or program can be wiped out of a computer. Yet individual memories have never been successfully "located" within the brain; and even more surprising, the recollection of places and events are not necessarily lost following brain damage; they are profoundly altered.

It is a cliché that the contemporary neurosciences owes to the nineteenth century its "central dogma"--localization of function--the idea that specific functions have specific locations in the brain. And yet the very success of the nineteenth century dogma of localization of function is odd because, though neurologists were describing breakdowns in linguistic functions caused by brain damage, they had not addressed themselves to issues of "meaning," "understanding," or even consciousness and the relation of these to memory. Equally odd was the subsequent claim that the visual centers of the brain had been discovered, as if perception were an activity no different from that of a camera taking pictures. No one addressed the problem of how we become aware of what we see.

Typical of the studies that have so profoundly influenced the contemporary neurosciences was H. Munk's 1881 study of a dog with brain damage that had "psychic blindness" (Seelenblindheit). The dog could see objects, but could not recognize them. Subsequently Paul Flechsig suggested that the brain had "primary" cortical areas directly connected to the sense organs and "association" areas in which "psychological qualities" were associated with sensory information[3]. Thus one can see a chair without understanding what it is; knowing it is a chair requires information from the association area of the brain. Clinical studies appeared to justify the assumption that "understanding" and "perception" were two separate functions. Like Munk's dog, humans too, could see and yet not "know" what they were seeing (agnosia). But is the ability to see form, to see shapes really independent of understanding?

Recently an area of the brain was discovered that is essential for seeing colors but that is not part of of what Flechsig called the primary cortex. Patients whose "color center" has been destroyed do not merely lose the ability to see colors; they cannot remember what colors are, or what it was like to have seen a world in color. A painter who had become color-blind because of brain damage said that he could no longer go to the museum to look at the Impressionist paintings he had formerly known so well. He could no longer

---

[3] For an excellent discussion of Munk and Flechsig see Semir Zeki, *A Vision of the Brain* (Oxford, 1993), pp. 50-56.

understand the paintings and he could not recall what they had been like--indeed, he could no longer imagine what a color was. His linguistic abilities were intact and he still knew there was something that was called "color." He just did not know what it meant[4].

So too, patients who have become blind because of brain damage (destruction of the visual centers), still use the word "seeing," but they clearly have no idea what it means, or what it had been like when they had sight. One patient sat in front of a television set for hours and when told that the speaker could "see" a man running across the screen of the television would, in response, confabulate "seeing" all kinds of odd events on the television screen. He apparently thought that "seeing," or "watching television," meant making up stories about the voices and sounds coming out of the television. So the effect of localized brain damage is not a loss of either the ability to perceive or to understand, but of the ability to perceive and understand; specific memories are not lost, but rather the recollection and knowledge of a particular kind of experience is no longer possible--one no longer remembers, understands, what "seeing" is or what "colors" are. The loss of the ability to see following brain damage (be it colors, or seeing in general), destroys the understanding of what seeing is as well. The structure of the patient's knowledge is altered following brain damage[5]. Hence what appear to be losses of memory following brain damage--the inability to see colors (the "memory images" of the colors have been destroyed) or understand specific words--are quite different from our everyday failures of memory. When I say to a person. "I'm sorry, but I don't remember your name," I am saying: "I *know* you have a name and I *know* what it means to have a name, but I cannot bring it forth at the moment." Though temporarily irretrievable, it is still, in some sense, a part of my knowledge in general. After all, when you tell me your name, I will instantly recognize it. "Memory" losses owing to brain damage are quite different. Patients do not know that they once

[4] The story of the color blind painter is told in Sacks, O. and Wasserman, R. *The New York Review of Books* **34,** 193-226.

[5] It is our linguistic usage that divides the unified nature of memory, perception, subjectivity and consciousness into independent activities. R.C. Collingwood made a similar observation about the study of language itself: "we think that the grammarian, when he takes a discourse and divides it into parts, is finding out the truth about it, and that when he lays down rules for the relations between these parts he is telling us how people's minds work when they speak. This is very far from the truth. A grammarian is not a kind of scientist studying the actual structure of language; he is a kind of butcher, converting it from organic tissue into marketable and edible joints. Language as it lives and grows no more consists of verbs, nouns, and so forth than animals as they live and grow consist of forehands, gammons, rump steaks, and other joints." (R.C. Collingwood, 1958, p. 257)

knew a particular name or fact; for them the memory does not and never did exist, they experience it not as something that has been forgotten but as something that was never known *and that is not knowable*; it does not and cannot make any sense; it cannot exist. The patient cannot learn the name or the fact; it does not fit into the structure of his or her knowledge of the world.

In fact, there is a deep link between the ways in which we acquire our perceptual skills, the ways in which we learn to see, to hear etc., and our understanding of our surroundings. Individuals who are born blind and later acquire sight will always see two-dimensional drawings as three-dimensional objects. They cannot understand how three dimensions can be "represented" on a flat two-dimensional surface. And they find it impossible to judge size or distance. Recently, a patient who had regained her sight reported that she found colors particularly distressing because they floated in space like amorphous clouds; they were never a part of any object or surface[6].

Cases of individuals who are born blind and later acquire sight illustrate that our recognition of three-dimensionality, of distance, size and shape is acquired when visual stimuli are integrated with touch and movement. The blind person who later acquires sight is severely handicapped in his ability to create new kinds of abstractions; his brain is incapable of making sense of two-dimensionality. Apparently the blind person's use of movement and touch to explore his surroundings makes it impossible for him to "understand" after he acquires sight anything but a three-dimensional world. And so too, the ability to see the relation between form and color is never acquired. The new sensations of color have no place in the only kind of world knowable to the blind; their knowledge and understanding have, in some sense, an unsurmountable rigidity. The brain is puzzled by the newly acquired abilities to see colors and the patient becomes depressed and confused.

Of course, normally our perception of colors is integrated into the physical explorations of our surroundings that begin in infancy. If during our childhood we are deprived of certain sensations (such as color in the case of blindness), the brain cannot, at some later date, simply integrate the new sensations into an "understanding" of the world that has been acquired during the early years of childhood. (In fact, people born blind, who acquire sight late in life, are probably <u>never</u> able to see colors as part of objects.) Apparently, movement, motor activity, is essential for our ability to perceive (and

---

[6] The original description (1737), in many ways still the best, of a patient born blind who later acquired sight can be found in R. I. Gregory (ed.), 1987, p. 94 ff.

understand) our surroundings. But the cases of individuals born blind who later acquire sight also tell us that perception and acquired knowledge, learning, are part of a larger whole; these individuals can never *see* two-dimensional drawings in two dimensions. They see three-dimensional objects. Is movement, therefore, crucial to determining what we know and think? Extra sensory deprivation experiments have shown that the denial of sensory experience, itself dependent on movement, causes, within hours, a total breakdown of coherent thought. If we could not move, we could not think.

But then what is the nature of this apparent "link" between knowledge and movement? Studies of patients with brain damage suggest an answer to this question as well as deep connections among our perceptions, knowledge and memories.

For example, people who have lost a part of their arm or leg because of physical trauma or surgery continue to have sensations in their missing limb (known as a phantom limb). But in all other respects their perceptions and memories are perfectly normal. Even more curious is the fact that children born without a part of an arm or a leg may also have sensations in the "missing" limb. We seem to be born with brains that have a capacity to create an internalized body image that because of physical injury or birth defects may not always correspond to our real body.

In sharp contrast to the phantom limb phenomenon is a neurological disorder in which a brain damaged patient with a perfectly intact body, will deny that an arm or a leg is his. He will declare that it is "alien," a "strange foreign object," and he will push the arm or leg out of his bed, telling a bystander "It's yours." [7] If he is then told that this means the bystander has three arms, he will shrug his shoulders and declare that there is nothing unusual about that. Nor will he recall ever having used the "alien" arm or leg. He will have forgotten that he had ever walked. He has acquired a completely new "understanding" of the world, an understanding that makes three-legged people seem perfectly ordinary.

That phantom limb patients (and children born missing a part of an arm or leg) have normal perception and recollections--though with paradoxical sensations from a limb they know they do not have--suggests that the brain creates a body "image" (a dynamic, abstract, unconscious representation) as a unique frame of reference for bodily sensations, and hence the basis of my subjective relation to the outside world. "Me" and "not-me" exist because of this relation.

[7] The first important discription of the alien limb phenomenon was published by M.J. Babinski, *Société de Neurologie,* 11, June 1914: 112-115. (For other studies see my book, *op. cit.*)

Phantom limbs occur because the intact internal body image is apparently necessary for normal perception and remembering. It is so essential that the brain ignores serious damage to the body.

Patients with alien limbs, on the other hand, have abnormal perceptions and recollections though their bodies are perfectly intact. Here there has been a neurological breakdown of the brain's representation of the "body image" causing a complete restructuring of the patient's patterns of thought. It is paradoxical that normal brain function requires an intact internalized body image, creating the phenomenon of phantom limbs, whereas a breakdown of brain function in a perfectly normal body distorts one's perception of one's own body and the world around one.

Similarly, patients with an inability to understand the form of objects (agnosia) have difficulties that suggest a breakdown of an internalized body image. One patient, for example, was unable to orient himself with his eyes shut, and was unable to say <u>where</u> his arm was when he was blindfolded. And patients with movement disorders (apraxias), like patients with alienated limbs, feel that their movements do not "belong to" them. Indeed, they are unable to perform simple mechanical acts without an <u>external</u> point of reference. One patient was able to hammer a nail into a wood panel, but if the panel was removed while he was hammering, his arm froze in mid-air. This suggests these patients lack an internal body image, an internal frame of reference; though they are able to perform certain acts given an external guide, they nonetheless do not consider the acts their own.

Hence consciousness, memory and perception would not be possible if the brain were not using movements as the basis of its integration of sensory experience. And to do this the brain must establish an unconscious, dynamic "body image"--a unique frame of reference which makes our feelings of subjectivity and continuity possible.

Our linguistic abilities too are related to these motor functions. Patients with language disorders (the aphasias--difficulty speaking or understanding spoken language) often cannot understand spatial relations. The English neurologist Henry Head reported that many of his aphasic patients were able to follow familiar routes from home to hospital, but were unable to name the streets they took, or give any general description of their itinerary. One of his patients said that he could not establish a "starting point, but that once it was given him everything was much easier."

Some aphasic patients have difficulty with the words "right" and "left" and "above" and "below." A striking example of the aphasic's difficulties with space was reported many years ago by Van

Woerkom: "The patient cannot draw the main lines of orientation (to the right, to the left, upward, downward), nor place one stick parallel to another. This disturbance also affects his body; he has lost the schema (the imaginative notion) of his body . . . " (Revue neurologique, 35, 1919, pp. 113-19.)

Some of the subtlety of this relationship between language and motor activity has been revealed by very recent studies of children who have difficulty learning to read (dyslexia). They appeared to have difficulty remembering. In fact, these children are unable to produce, or hear complex combinations of sounds essential to language (for example, *ba, da*). If, on the other hand, the speech sounds are uttered very slowly the patients can make sense of them--and eventually can learn to understand normal speech and to read without difficulty. The rapid rhythms, so characteristic of speech, that are essential for motor coordination within the vocal apparatus, (or the equally rapid motor acts of sign language), are beyond the capacities of these patients. It is interesting that the inability to produce the rapid motor acts leads to an inability to read and to understand normal speech[8].

The motor skills that are essential to language cannot be acquired easily. Children deprived of human contact never learn to speak, and their awareness of the world must therefore be quite different from that of youngsters who have been more fortunate. Speech arises when children try to imitate the sound productions (a complicated motor act) of each other, or that of adults. Children who have contact with their peers but lack an adult model of language will learn to gesticulate and babble among themselves. They will eventually develop a form of communication we might call "gestural" language. But lacking an adult model, this will not develop into a true language, with symbols and a fully developed grammar. Normal children can, over time, abstract the symbolic and grammatical nature of language from adult speech. Without such a model, children have to create the notions of a grammar and symbols among themselves; and the process of abstracting gestures into symbols, and relations among symbols into grammar, is very long. Generalized linguistic patterns take several years to emerge, and they cannot, evidently, do so after puberty. In fact, it is impossible for one generation of children to accomplish the task; only a second generation, whose model is the "gestural" language invented by their older comrades, can create a true grammatical language with

---

[8] The importance of "temporal processing" in understanding spoken and written language can be found in articles by Paula Tallal and Michael Merzenich in the *Annals of the New York Academy of Sciences* , vol. 682 and in *Science,* January 5th, 1996, pp. 77-84.

symbols. One generation is building on, abstracting from the behavior--the motor acts--of the previous generation.

For example, deaf children with no adult model of sign language will nonetheless develop a “gestural” language among themselves. Younger deaf children, noticing these exchanges, will begin to sign among themselves as well and will develop a full grammatical language, with a syntax equivalent to those of modern sign languages. A similar pattern has been observed in the development of creole from pidgin languages. Pidgin languages arise when immigrant workers from various linguistic backgrounds are forced to create a system of communication in their common second language. It is similar to gestural sign language in that its grammar is primitive or nonexistent. Children of pidgin speakers develop a creole language (a true grammatical language), just as second generation deaf children develop a mature sign language.

At the heart of language learning, then, is the acquisition of the ability to create a complicated *sequencing* of motor acts, as has been demonstrated by the studies of dyxlexic childred already mentioned; and it is the acquisition of these motor capacities that determines the recognition and understanding of speech and the ability to read. Ultimately, memory, too will be structured by these motor capacities. Even visual memory in humans with speech is not independent of our verbal descriptions of remembered images. Once we have acquired language we can have no idea what it is like to “remember” in a purely visual sense. Hence understanding in a broad sense depends on our motor skills.

Just how deeply understanding is related to our linguistic productive capacities is suggested by the development of the vocal system in children. Only at the age of seven does the vocal tract of a child attain its mature shape and it is also only at this age too, that the child begins to accurately produce all vowel sounds, including [i] and [u] which are essential to the accurate perception of all human languages. These vowels are virtually never confused with other linguistic sounds. (Parents often convince themselves they are hearing the correct sounds in much younger children, but accoustic studies show that younger children produce only approximations of the mature vowel sounds.) It is also at this age that children begin to understand abstract thought. Hence the changes in the child's vocal tract and related linguistic capacities may parallel its intellectual development.

Among the deep implications of these studies is not only the importance of motor activity in the organization of our sensory and linguistic experience, but the importance of timing, temporal flow (an essential element of all motor activity), in the brain's making sense of what we hear, see and touch--*including every aspect of our linguistic abilities*. We know the world not as a series of disconnected, isolated moments, but as a continuous flow of events and perceptions. What we see at any moment is not independent of what we saw a moment before, just as our more general awareness of our surroundings is the consequence of individual histories. And language is the most developed form of this “continuous flow”; language is not a collection of individual words that can be remembered or forgotten, but a structured “flow” of perceptions and productions. It is an integral part of human consciousness as are our recollections that we only can know consciously: it is fundamentally a motor activity. The subjectivity of language, like the subjectivity of our perceptions in general depends upon the brain’s creation of a unique frame of reference for all sensory and motor activity (including our speech and writing)--the internal dynamic body image. If brain damage alters the structure of this frame of reference it alters both the ways in which we see and understand our surroundings and our recollections of the past. There is no “place” in the brain where memories are stored any more than there is a place were language is stored. Language and memory are part of a larger process that, for the moment we do not understand, namely consciousness. But it is because consciousness is a process that conscious knowledge differs in kind from reproducible information, such as photographs, or information stored in computers.

The dynamic body image, then, is a unique frame of reference for all brain activities and is the neurological basis of our subjectivity. What gives our constantly evolving memories continuity is this frame of reference. Subjectivity, perceiving and remembering are all part of a complex set of brain mechanisms that are inevitably distorted when studied individually.

So there appears to be an intimate relation between our ability to speak and our ability to think abstractly. "L'appetît vient en mangant" goes the well-known proverb, and equally accurate is "La pensée vient en parlant".

* * * *

references

Babinski, J. (1914) Contribution à l'étude des troubles mentaux dans l'étude l'hémiplégie organique cérébrale (anosognosie). *Société de Neurologie,* 11, June 1914: 112-115

Collingwood, R.C. (1958) *The Principles of Art* , New York, Oxford University Press

Freud, S. (1914) Instincts and Their Vicissitudes in *The standard edition of the complete psychological works of Sigmund Freud* , vol 14, 1953, London, Hogarth Press

Freud, S. (1914) On Narcissism: An Introduction in *The standard edition of the complete psychological works of Sigmund Freud* , vol 14, 1953, London, Hogarth Press

Gregory, R.I. (ed.) (1987) *The Oxford Companion to the Mind*, Oxford, Oxford University Press

Rosenfield , I. (1993) *The Strange, Familiar and Forgotten : an anatomy of consciousnes,* New York : Vintage Books. Trad. Franç.: *Une anatomie de la conscience*, 1996, Paris , Flammarion.

Sacks, O. & Wasserman, R. (1987) The Case of the Colorblind Painter, in *The New York Review of Books,* 34, 193-226

Tallal, P. & Merzenich, M. (1996) Temporal information processing in the Nervous System : Special References to Dyslexia and Aphasia, in the *Annals of the New York Academy of Sciences* , vol. 682 and in *Science,* January 5th, 1996, pp. 77-84.

Zeki, S. (1993) *A Vision of the Brain*. Oxford, Blackwell Scientific Publications