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Chronesthesia: Conscious Awareness of Subjective Time

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One of the most remarkable capacities that nature has seen fit to bestow on us human beings is our sense of subjective time in which we exist. We do not think much about this subjective time; we take it for granted as we take for granted the air we breathe. But we can, if we decide to do so, reflect on the fact of our protracted existence in time that extends from the present "back" into the past and "forward" into the future. We can, if we wish, close our eyes and think about what we did minutes ago, or how we celebrated our last birthday. And we can think about what we might be doing tomorrow, or next year. This kind of sense of time makes a huge difference to what we are and how we live. If we retained all our other marvelous mental capacities but lost the awareness of time in which our lives are played out, we might still be uniquely different from all other animals but we would no longer be human as we understand humanness.

This chapter is about this human sense of time. To distinguish it from other time-related and time-dependent achievements of the brain/mind, I refer to it as *chronesthesia,* which is tentatively defined as a form of consciousness that allows individuals to think about the subjective time in which they live and that makes it possible for them to "mentally travel" in such time. In this chapter, I shall attempt to explicate the concept of chronesthesia, suggest what it is (and what it is not), contrast it with other kinds of time-related mentation, discuss the origin of the concept, and, the main reason for the chapter's appearance in the present volume, speculate on chronesthesia's relation to prefrontal cortex. I shall conclude the chapter by discussing the role of chronesthesia in human evolution and human affairs.

Chronesthesia is closely related to a number of neurocognitive functions that have to do with time, and that have been studied by brain/mind scientists for a long time. These include mental activities such as remembering (or recollection of) past happenings, thinking about the past, expecting, planning, and thinking about the future. To understand the relation between chronesthesia and these other time-related cognitive activities, which may sound indistinguishable from chronesthesia as defined above, it is necessary first to draw a distinction between two aspects of organization of the brain/mind, capacity and function.

CAPACITY AND FUNCTION

A basic conceptual distinction is that between *neurocognitive (brain/mind) capacities* that individuals possess, on the one hand, and *functions (manifestations) of such general capacities* on the other hand. A (general) neurocognitive capacity (sometimes also referred to as neurocognitive or brain *system*) allows an individual to engage in mental activities and attain goals that are not possible for an individual who does not possess the capacity. Each general capacity is a property of the evolved brain that serves specific organismically useful ends. Thus, for example, the visual capacity (*vision*) allows the individual to make use of optic signals provided by the environment, that is, to see objects in space. Similarly, the auditory capacity (*audition*) allows the individual to make use of acoustic signals, that is, to hear sounds. The episodic memory capacity allows one to remember one's personal past, that is, to re-experience at time 2 happenings experienced earlier, at time 1. The biological value of these capacities and their functions is indisputable.

Examples of some of the general capacities and their functions that interest brain scientists are listed in Table 20–1. Some of them (vision, audition, and other senses) are associated with special receptors, while others (learning, memory) have no such devices for registering changes in one's external environment. Some of the latter do involve "inputs" and "outputs," whereas the operations of still others (shown in Table 20–1 as various kinds of consciousness) somehow supervene on, and interact with, selected other processes in ways not yet completely understood.

The nature of the relation between general capacities and their specific expressions (functions) is one that is exceedingly common but has no common label. We can use the term *enabling* to designate it. Thus, a general capacity enables or allows the individual to engage in a large but circumscribed category of mental activities without specifically determining whether or how the capacity is used. A general capacity is just one of the necessary conditions of certain behavioral, cognitive, or consciousness-based achievements. The actual exercise of any capacity always depends on other factors as well.

All general capacities listed in Table 20–1 represent properties of the evolved brain, and are subserved by specific, usually widely distributed, neuronal centers and pathways. The capacities may vary among the species. Not all species have vision, and very few, perhaps only humans, have autonoetic consciousness, the kind of consciousness that allows people to be aware now of experiences of an earlier time. The capacities are also products of ontogenetic development, and usually grow, mature, and decay as an individual interacts with its physical and social environment. Being dependent on the brain, they are vulnerable to brain damage.

When a given brain/mind capacity is reasonably closely tied to known neuroanatomical structures and physiological mechanisms, we can talk about it as a neurocognitive "system": for example, the visual system, or the auditory system. When such a relation between the brain and the mind is less firmly established, as is the case for learning and memory, or as yet largely unknown, as is the case for different kinds of consciousness, we speak of the corresponding neurocognitive systems somewhat more metaphorically, simply as an expression of our faith that neural correlates of these capacities also exist even if they are not yet (or not yet completely) known.

The points just made about neurocognitive capacities, or systems, and their "expressions," or functions, are elementary, well known to and accepted by all practitioners. They are

Table 20–1. Selected Examples of General Neurocognitive Capacities and their Particular Functions

General Capacity	Function
Object vision	Seeing objects
Spatial vision	Seeing space
Color vision	Seeing colors
Motion vision	Seeing movement
Audition	Hearing sounds
Semantic memory	Knowing the world
Episodic memory	Remembering experiences
Noetic consciousness	Awareness of the world
Autonoetic consciousness	Awareness of self in time
Chronesthesia	Awareness of subjective time

mentioned here to place the concept of chronesthesia in the proper perspective.

CONSCIOUSNESS AND CHRONESTHESIA

The term *consciousness* has many different meanings. A very basic distinction can be made between the individual's general state of alertness or arousal, such as those accompanying wake–sleep cycles, or of the kind measured by the Glasgow Coma scale, on the one hand, and various cognitively and affectively experienced mental states that characterize a fully alert individual on the other.

Table 20–1 includes the reference to two particular kinds of consciousness of the latter category, noetic and autonoetic. Both have to do with experiential, or phenomenological, aspects of conscious awareness that accompany memory retrieval (recovery of stored information). Each has its own functions. *Noetic consciousness* is evolutionarily older and the more "primitive" of the two, and is the default mode of the semantic memory system. Noetic awareness accompanies an individual's memory-based interaction with aspects of its environment in the present. When individuals think about the "facts of the world," they are noetically aware of what they are thinking, as well as aware of such awareness. Noetic consciousness also provides individuals with access to their own past, but the mode of such access is one of "knowing," not "remembering" (Gardiner, 1988; Rajaram, 1993). *Autonoetic consciousness* has a more recent origin in evolution and is more advanced than noetic, because in addition to allowing people to know what happened in the past it also allows them to re-experience past experiences. Autonoetic awareness accompanies retrieval of information about one's personal past as well as projection of one's thoughts into the future. When individuals remember the past, they are autonoetically aware of what they did or thought at an earlier time, and they are also aware of such awareness. Thus, autonoetic consciousness includes but transcends noetic consciousness.

Both autonoetic and noetic consciousness are determined by the properties of the individual's brain and its general physiologic state at any given moment. A given kind of consciousness provides the individual with a potential for particular kinds of awareness; it determines what kinds of awareness or subjective experience the person *can* have. Consciousness as capacity is not directed at anything, whereas awareness is always of something. To be aware of something means to have a particular subjective experience that is determined by both the current (general) state of consciousness and the current (particular) stimulation from external and internal sources. In other words, awareness presumes consciousness, but consciousness does not imply awareness: consciousness is a necessary but not a sufficient condition of awareness. Within a given level of awareness, many particular kinds of subjective experiences may occur. We can think of (selective) attention as the primary process that determines the aspects of the stimulus situation of which the individual is aware.

Because chronesthesia is a kind of consciousness, everything that is said about consciousness in general also applies to chronesthesia. Chronesthesia is the kind of neurocognitive capability that expresses itself in individuals' awareness of the temporal dimension of their own and others' existence and that makes thinking about subjective time possible. It is a general precondition of many different kinds of *cognitive activity* that involve time. The most common and familiar expression of chronesthesia is remembering happenings from one's life, or thinking back to past events and situations. But the human time sense also extends to the future. Everybody can as readily think about the future and make plans for the future as they can think about and remember the past. I refer to the thought-about time in which one's personal experiences take place as *subjective time*. It plays a critical role in the definition of chronesthesia (on the various concepts of physical and psychological time, see Fraisse, 1963; Church, 1989; Block, 1990; Ivry, 1996; McCormack & Hoerl, 1999).

WHAT CHRONESTHESIA IS NOT

It may be useful at this point to briefly mention what chronesthesia is not, to minimize confusion and unnecessary argument. Numerous time-related concepts figure prominently in the existing literature that need to be distinguished from chronesthesia. Consider three categories of such concepts.

First, there are various behavioral and cognitive (mental) activities that clearly *depend on* chronesthesia but are not identical with it. They are the functions of chronesthesia, activities that chronesthesia makes possible. Examples are activities such as reminiscing about or recollecting past events, daydreaming, anticipation of future happenings, planning future activities (Owen, 1997; Koechlin, et al., 1999), and "prospective memory" (Mantyla & Nilsson, 1997; Einstein et al., 1999).

Second, as a special kind of consciousness, chronesthesia has properties that other forms of consciousness do not. Therefore it has to be distinguished from these other forms. For example, young children share many forms of consciousness with adults, but there is no evidence that those younger than 3 or 4 years "possess" chronesthesia (Wheeler et al., 1997).

The third category of time-related mentation that has to be differentiated from chronesthesia has to do with behavioral and cognitive activities of everyday life, and their artifactual analogues in the laboratory (*cognitive tasks*) that may appear to involve awareness of subjective time. This third category is most troublesome, because in many cases the temptation is great to think of them as dependent on chronesthesia. Examples of these include the following: *(1)* many non-episodic forms of memory whose function is to allow the organism to benefit at time 2 from what happened at time 1 (see Tulving & Markowitsch, 1998; Tulving, 1999, for further discussion); *(2)* various kinds of "serial learning" in humans (Crowder & Greene, 2000) or in nonhuman animals (Gower, 1992); *(3)* genetically programmed ("instinctive," "purposeful") evolutionary adaptations, such as rodents demonstrating temporal 'entrainment' of behavior by environmental rhythms (Moore-Ede, et al., 1982) or crows dropping walnuts to get at the fruit (Zach, 1979), *(4)* "estimations" of temporal durations in tasks (e.g., interval reinforcement) where the duration serves as a discriminative stimulus (Church, 1989); *(5)* matching sensory-motor rhythms (e.g., finger tapping) to external sources of rhythmic stimulation (e.g., Jäncke, et al. 2000); and *(6)* the kinds of "generalized timing functions" in whose control the cerebellum plays an important role (Ivry & Fiez, 2000). Even semantic knowledge that humans possess about physical time (*chronognosia*) and expressions of such knowledge linguistically need not imply the involvement of chronesthesia.

The exclusion of these and other similar behavioral/cognitive activities as expressions of chronesthesia does not mean, of course, that they have nothing to do with chronesthesia. Indeed, it makes sense to assume that all or some of the many ways in which evolved brains deal with temporal aspects of the world represent evolutionary precursors of chronesthesia. The exclusion of these activities also does not mean that chronesthesia could not be usefully deployed in many of these activities. The hypothesis is simply that chronesthesia is not necessary for them.

CHRONESTHESIA AND RELATED CONCEPTS

If none of these other time-dependent or time-related forms of behavioral or cognitive activities are to be identified with chronesthesia, what kinds of time-related activities are? How do we know that a given bit of an individual's behavior involves or directly relies on chronesthesia?

In the first instance, of course, we can rely on individuals' telling us what they do consciously recollect of their personal happenings, that is, on their verbal reports of their past experiences and future intentions. We can also rely on their claims that they are consciously aware of the existence of subjective time, and that they understand what it means to "mentally travel" in such time.

But what do we do about nonverbal organisms, such as young children or nonhuman animals? Here we have to rely on inferential reasoning based on our extant knowledge of the world. Thus, when we observe an organism engaged in an activity that we suspect might involve chronesthesia, we ask: Would it be possible for this activity to occur without the capability of consciously thinking back to the past, or forward to the future? If the answer is positive, we act on the principle of parsimony and refrain from invoking chronesthesia; if it is negative, we postulate that the activity in question is an expression (function) of chronesthesia. Although we may not be able to achieve universal consensus on the answers to all instances of such questions, it is reasonable to expect that sufficient agreement would exist in the matter to make at least the beginning of the scientific study of chronesthesia possible. More refined approaches to chronesthesia will be worked out in the natural course of the development of cognitive neuroscience.

Although the sense of time has seen less coverage in psychology and cognitive neuroscience than has the sense of space, time-related ideas rather similar to that of chronesthesia have been proposed and discussed. These include ideas proposed by David Ingvar who, in his pioneering work on the measurement of regional cerebral blood flow, noticed chronic hyperfrontal activity and attributed it to the individual's conscious thoughts about the future (Ingvar, 1985). His prescient sentiments have been echoed in recent work in functional neuroimaging (Andreasen et al., 1995). Some time ago, Joaquin Fuster, on the basis of his findings of differential firing patterns of individual neurons (Fuster, 1973), proposed a general theory of prefrontal cortex in which temporal organization of behavior and cognition plays a central role (Fuster, 1995). Fuster's concept of "prospective set" (Fuster, 2000), one of the two major cognitive specialties of the dorsolateral prefrontal cortex in his theory (working memory is the other), designates the brain's capability of anticipating future sensory and motor acts on the basis of neurocognitive events in the present (Fuster, 2000). Prospective set can be thought of as closely related to chronesthesia. In other studies it has been observed that some patients with brain damage can respond well to questions about the impersonal past and future, but are quite deficient on comparable questions pertaining to their own personal past and future (Dalla Barba, et al., 1997; Klein et al., 2002 [in press]). The impairment of personal temporal orientation described in these studies can be seen as possible instances of defective chronesthesia. Disturbances in consciousness of time brought about by cerebral damage have been documented by Knight and Grabowecky (1995, 2000). Finally, in developmental psychology, Haith (1997) has been engaged in a systematic research program aimed at elucidating the development of future-oriented thinking in children. Haith's concept of "future thinking" is in many ways quite similar to chronesthesia (see also Haith et al., 1994).

The concept that is most closely related to chronesthesia is *autonoetic consciousness* (or *autonoesis*), already mentioned above. It is defined as a form of consciousness that allows individuals to apprehend their subjective experiences throughout time, and to perceive the present moment as both a continuation of their past and as a prelude to their future (Nelson, 1997; Suddendorf & Corballis, 1997; Wheeler et al., 1997; Tulving, 2001; Stuss et al., 2001). Because the essence of what I attribute here to chronesthesia has previously been associated with autonoesis, one may wonder whether yet another esoteric concept such as chronesthesia is needed. I think that it is. Although both autonoesis and chronesthesia imply awareness of self in time, the emphasis on self versus time is different in the two concepts: in autonoesis the emphasis is on awareness of *self*, albeit in subjective time, whereas in chronesthesia the emphasis is on awareness of *subjective time*, albeit in relation to self. The distinction may be subtle but it is necessary, because time can be dealt with, and usually is dealt with, independently of the self, and self can be dealt with independently of time, as shown by behavioral (e.g., Gallup, 1982; Povinelli et al., 1996; Stone et al., 1998; Keenan et al., 2000) and functional neuroimaging (Craik et al., 1999; Kircher et al., 2000) research on self-recognition and self-face recognition.

CHRONESTHESIA AND THE CASE OF K.C.

The evidence supporting the postulated existence of chronesthesia is as yet scant, and what exists is largely indirect. Indeed, when relating the hypothetical ideas about chronesthesia to empirical facts, it would be pretentious to talk about evidence as such. It would be more appropriate to talk about ideas, observations, and facts that are related to the ideas concerning chronesthesia, and that can be seen as encouraging speculations about the kind of sense of time I refer to as chronesthesia.

Some relevant evidence comes from clinical cases of brain-damaged patients, such as those cases already mentioned (Dalla Barba et al., 1997, Klein et al., in press). One such case, indeed, gave rise to the concept of autonoetic consciousness, the predecessor idea of chronesthesia (Tulving, 1985). (Note: N.N. in that article is the same patient that in subsequent publications is referred to as K.C.). The case is that of a man known as K.C., now 50 years old, who at the age of 30 suffered traumatic brain injury, as a result of which he became densely amnesic. Various aspects of his case have been published previously (Tulving et al., 1988, 1991; Tulving, 1989a, 1989b, 2001; (Hayman et al., 1993; Rosenbaum et al., 2000; Westmacott et al., 2001). As shown in Figure 20–1, he has multiple cortical and white matter lesions in anterior and posterior regions, and his hippocampus and other medial–temporal lobe structures, more in the left than the right hemisphere, are also largely dysfunctional (Rosenbaum et al., 2000).

In many ways K.C.'s intellectual capabilities are comparable to those of healthy adults. His intelligence and knowledge of the world (premorbidly acquired semantic memory) is normal, language is normal, he reads and writes, his thought processes are clear, he has a good sense of self here and now, he plays the organ, can play chess and various card games (indeed, he spends a lot of time playing these games on the computer), he has no problem with immediate memory (his digit span has been measured at 8 digits), his social manners are exemplary, and he possesses a quiet sense of humour.

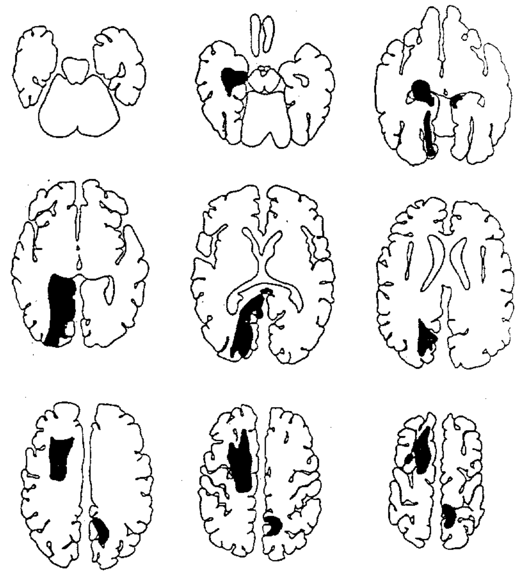

Figure 20–1. Schematic presentation of K.C.'s brain lesions, estimated from magnetic resonance imaging (MRI), rendered on axial slices of the template from Damasio and Damasio (1989). Most lesions are seen in the left hemisphere limbic, cortical, and white-matter structures, although some also appear on the right, in the medial temporal and median parietal (cuneus and precuneus) regions. (*Source:* Courtesy of Dr. Paul J Eslinger)

K.C. differs from other people primarily in two ways. First, he has no functional episodic memory: for all practical purposes he cannot remember anything that has ever happened to him. However hard he tries, and however powerfully he is prompted, he cannot mentally travel back into his past in the way that healthy people can. He has no conscious awareness of a single event, happening, or situation that he has witnessed or in which he has participated. This *global episodic amnesia* covers the period from his birth to the present day. Second, he has serious difficulties learning and retaining new information. Although he has been taught some new factual information (Tulving et al., 1991; Hayman et al., 1993); and although he has incidentally acquired some other new knowledge about the world as well as himself (Tulving, 1993; see also Klein et al., 1996), he can be classified clinically as a typical dense anterograde amnesic patient.

K.C.'s autonoesis is largely dysfunctional, or perhaps even nonexistent. He lives in a timeless world—that is, in a permanent present. When he is asked to try to "travel back in time" in his own mind, back either a few minutes or many years, he says he cannot do it. When he is asked to describe the state of his mind when he tries to turn his mind's eye towards the past, the best he can do is to say that it is "blank." Nor can he think about the future. Thus, when asked, he cannot tell the questioner what he is going to do later on that day, or the day after, or at any time in the rest of his life, any more than he can say what he did the day before or what events have happened in his life. When he is asked to describe the state of his mind when he thinks about his future, whether the next 15 minutes or the next year, he again says that it is "blank." Indeed, when asked to compare the two kinds of "blankness," one of the past and the other of the future, he says that they are "the same kind of blankness" (Tulving, 1985). Thus K.C. seems to be as incapable of imagining his future as he is of remembering his past.

It is important to note that K.C. has no greater difficulty with physical time than he has with physical space. He knows and can talk about what most other people know about physical time, its units, its structure, and its measurement by clocks and calendars. But such knowledge of time in and of itself does not allow him to remember events as having happened at a particular time. It is necessary but not sufficient. Something else is needed, and this something else—the awareness of time in which one's experiences are recorded—seems to be missing from K.C.'s neurocognitive profile. He thus exhibits a dissociation between knowing time and experiencing time, a dissociation that parallels one between knowing the facts of the world and remembering past experiences.

It was this striking pattern of K.C.'s mental life—his largely conscious thoughts about the impersonal world contrasted with his essentially nonexistent conscious thoughts about his own past and future—that first suggested the distinction between noetic and autonoetic consciousness (Tulving, 1985). K.C. possesses the former, and does not possess the latter. Because he is perfectly well aware of his timeless self—self in the present—it seems reasonable to attribute his difficulties with personal past and personal future to deficient, perhaps largely lacking, chronesthesia.

CHRONESTHESIA AND PREFRONTAL CORTEX

What is the connection between chronesthesia and prefrontal cortex? What do we know in general about the neuroanatomical correlates of chronesthesia?

One reason for suspecting the involvement of prefrontal cortex in chronesthesia lies in the following general principle: If *X* represents a "higher"—subtle, sophisticated, intricate—form of neurocognitive capability, then chances are that frontal lobes in general and prefrontal cortex in particular figure prominently in its neural substrate. The principle was originally supported from neuropsychological studies of patients with frontal damage (Stuss & Benson, 1985), and is now further bolstered by electroencephalographic (EEG) and functional neuroimaging studies (Knight & Grabowecky, 1995, 2000).

A second reason lies in neuropsychological and functional brain imaging findings of the involvement of prefrontal cortex in many tasks that, one way or another, involve chronesthesia (e.g., Baker et al., 1996; Okuda et al., 1998; Burgess et al., 2001).

A third reason has to do with the close relation between chronesthesia and autonoesis. Autonoesis has been seen as critically dependent on prefrontal cortex, as discussed at some length by Wheeler et al. (1997). With the further refinement of the concept of autonoesis in terms of self *and* time, it would be difficult to imagine that the temporal dimension of autonoesis, that is, chronesthesia, would not critically depend on prefrontal activity.

Neuroanatomical correlates of chronesthesia, of course, are difficult to identify, for the same reason that consciousness of any kind is difficult to pin down in the brain (Moscovitch, 2000). But some suggestive evidence does exist. A relevant case is that of M.L., a patient studied at the Rotman Research Institute by Brian Levine and colleagues (Levine et al., 1998). M.L. is a young man who suffered traumatic brain injury in a traffic accident that caused a severe 'focal' retrograde amnesia (Kapur, 1993; 2000; see also Kopelman, 2000) for both episodic and semantic information. Because he had not lost his ability to acquire new semantic information, M.L. was able not only to re-acquire much of the semantic knowledge he had but also to relearn many facts about his pre-accident life. But he cannot autonoetically recollect any past happenings, possibly because of deficient chronesthesia (Levine et al., 1998). M.L.'s loss of autonoesis is accompanied by a seriously diminished affect and difficulties of self-regulation. The relevant observation is that the only magnetic resonance imaging (MRI)-detectable brain damage is a lesion in the uncinate fascicle in the right hemisphere, a fiber tract connecting prefrontal and temporal cortical regions.

Other clinical evidence suggests that patients who have suffered right anterior brain damage have difficulty in autonoetically reminiscing about their premorbid personal experiences. Thus, Calabrese and colleagues (1996) have reported the case of a post-encephalitic patient, with brain damage mainly in the right temporofrontal region, who showed a severe and enduring loss of the ability to recollect premorbid personal experiences, and less severe loss of general knowledge. Baron et al. (1994) did a position emission tomography (PET) study of a 60-year-old woman during the early recovery phase of an episode of transient global amnesia during which she exhibited severe inability for autobiographical recollection. The imaging results showed reduced cerebral blood flow and oxygen consumption over the right lateral prefrontal cortex, together with a (smaller) reduction in ipsilateral thalamic and lentiform nucleus metabolism, in the absence of any involvement of the hippocampal region. These findings suggest that the transient global amnesia in this case resulted from a metabolic dysfunction of right prefrontal cortex and consequent disturbance of retrieval, possibly because of interference with chronesthetic functions, similar to cases of lasting amnesia (Markowitsch et al., 1993; Markowitsch, 1995; Calabrese et al., 1996). A particularly revealing PET activation study was reported by Fink et al. (1996). In critical conditions of the study, subjects were scanned while they listened to two kinds of critical sentences. One kind consisted of sentences that were taken out of the subjects' own autobiographical musings that the experimenters had recorded previously. These were assumed to bring back to the subjects' minds 'affect-laden' earlier episodic experiences. The other kind consisted of comparable sentences (taken from other subjects' musings) that the subjects had been exposed to previously in the experiment. Listening to these sentences was also assumed to evoke episodic recollection, but of a type less personally relevant and less affect-laden. Fink et al. (1996) found that listening to own-life sentences was associated with largely right hemispheric activation that included temporal lobes, posterior cingulate insula, and prefrontal regions, in close proximity to M.L.'s lesion reported by Levine et al. (1998). An observation rather similar to that of Fink et al. (1996) has been described by Markowitsch and colleagues (Markowitsch et al., 1999). This was a functional imaging study with normal healthy volunteers, comparing neural networks involved in the retrieval of personal autobiographical information with those involved in retrieval of similar fictitious material. The results showed that the retrieval of autobiographical information was associated with selective activations of the right amygdala and the right ventral prefrontal cortex, again in the vicinity of the uncinate fascicle.

All these and other similar case studies suggest that damage to the frontal lobes and connected brain areas disrupts autobiographical (episodic) recollection while recall of general (semantic) knowledge of the world remains intact, or is less severely impaired. The data fit well with suggestions that frontal lobes play a critical role in self-awareness (Ingvar, 1985; Stuss & Benson, 1986). Although, typically, in these earlier discussions self-awareness was not explicitly defined in terms of time-related (autonoetic or chronesthetic) consciousness, it makes sense to do so (Wheeler et al., 1997; Wheeler, 2000). A recent case study explicitly extends these ideas into the personal past and personal future (Klein et al., in press). The data also fit well with studies that show the involvement of the frontal lobes in "theory of mind" tasks (e.g., Stone et al., 1998).

FUNCTIONAL NEUROIMAGING

Perhaps the most promising, albeit still rather indirect, evidence on chronesthesia has been provided by functional neuroimaging research concerning the similarities and differences between episodic and semantic memory. It is well established that episodic memory is like semantic memory in many ways (Tulving & Markowitsch, 1998), including the fact that both depend critically on the intact limbic system, including medial temporal lobe and diencephalic structures (Squire, 1992). For some time it was also suspected that episodic memory depends on prefrontal cortex in a way that declarative and other forms of memory do not (Schacter, 1987; Squire, 1987; Tulving, 1989b). These early ideas have received good support from more recent functional neuroimaging (PET and FMRI) studies. Most informative have been studies comparing the neuroanatomical correlates of semantic and episodic retrieval. These studies show both similarities and differences in the functional neuroanatomy of the two systems (e.g., Dalla Barba, et al., 1998; Maguire & Mummery, 1999; Wiggs, et al., 1999; Nyberg, 2002).

A remarkable empirical regularity that emerged from early studies (Shallice et al., 1994; Tulving et al., 1994) is that right prefrontal cortex is differentially more involved in retrieval of episodic than semantic information. Subsequent work reinforced this kind of hemispheric asymmetry, which has become known as one part of the hemispheric encoding/retrieval asymmetry (HERA) model (Tulving et al., 1994; Nyberg et al., 1996, 1997; Düzel et al., 1999 Cabeza & Nyberg, 2000). Under the circumstances, the question naturally arose as to the specific meaning of the right frontal activation so frequently observed in episodic retrieval but seldom in semantic retrieval.

It is known that memory retrieval is not a single process but rather consists of several subprocesses. One way of tackling the question about the theoretical meaning of right-frontal activation therefore lies in the analysis of the overall retrieval process into subprocesses, and in trying to find out to what extent these subprocesses are associated with right prefrontal cortex. A major distinction within episodic-memory retrieval process can be made between retrieval mode and recovery of stored information. *Retrieval mode* represents a mental (neurocognitive) state in which an individual attempts to remember earlier experiences, whereas *recovery* (also called *ecphory*) refers to the actual success of such an attempt. Given this distinction, it is possible to ask whether the right frontal episodic retrieval activation observed in PET and FMRI studies signifies retrieval mode or retrieval success. Although experimental evidence for both alternatives has been reported (Rugg et al., 1996, 1997; Schacter et al., 1996; Buckner et al., 1998; Nolde, et al., 1998; McDermott et al., 1999, 2000), the important fact in the present context is that right prefrontal activation has been consistently found under conditions where episodic retrieval mode is present but no recovery of previously stored information occurs (Kapur et al., 1995; Nyberg et al., 1995; Rugg et al., 1997; Buckner et al., 1998; Wagner et al., 1998). A recent multistudy analysis of PET data (Lepage et al., 2000) was undertaken to identify "retrieval mode" (REMO) sites in the brain. A *REMO site* was defined as a brain region (a cluster of voxels) that is significantly more active during episodic retrieval than during episodic encoding (or semantic retrieval), *and* that is equally so when recovery succeeds and when it fails. Semantic retrieval is usually indistinguishable from episodic encoding (Tulving et al., 1994; Cabeza & Nyberg, 2000). The data produced by this study could be regarded as especially convincing because of the large number of subjects providing the data ($n = 53$). There were six REMO sites, all of them in the frontal lobes. Five were in prefrontal cortex, three "strong" ones in the right and two "weaker" ones in the left hemisphere, and one was in the medial anterior cingulate. No similar sites were seen in any other part of the brain.

One or more, or a combination, of these prefrontal activations can be assumed to be associated with chronesthesia. The hypothesis is that they reflect the "mental time travel" (into the past) component of the recognition test. In order for subjects to be able to solve the problem posed by the task—determine whether a test item is "old" or "new"—they must be able to focus on a particular past segment of their lives, the event of studying the list. Only individuals who possess chronesthesia can "remember" such happenings from their own past. Others must solve the problem by relying on other processes, such as "knowing," or "familiarity" (or "novelty") detection (or assessment), processes whose results are expressed through noetic consciousness that does not involve chronesthesia (Mandler, 1980; Yonelinas, et al., 1998; Gardiner, 2000; Kelley & Jacoby, 2000).

CHRONESTHESIA AND EVOLUTION OF CULTURE

Living things in nature may be different from inanimate things, but they, too, exist in a physical world with its immutable laws to which everything in the world is subject. In order to come into being and to survive, all species must be able to not only fit into the world as it exists but also adapt to changes in it over time. Phylogenetic evolution tells the story of the successes and failures of such adaptation by millions of species over millions of years. The rule is simple and harsh—to live means to conform to the requirements of the world *as it exists.*

Human beings, as far as is known, are the only animals who have ever used a different, much more efficacious, solution to the problem of the fit between the species and its ecological niche: at some point in their evolutionary history, thousands of years ago, they discovered that they did not have to adapt to every feature of the world, and that one way of dealing with the physical environment was to change it to fit them. Other species exist that have used the same strategy for isolated purposes; humans learned to do it on a grand scale. The changes they have wrought on the natural world are staggering in scope and sophistication. We can use the term *culture* to collectively describe all the differences between the world—material and virtual, concrete and abstract—as it exists by virtue of human intervention and as it would have existed in the absence of such intervention, and ask the question: What kinds of events in human evolution made it possible for *Homo sapiens*, slowly but surely, to bring about the monumental achievement of culture? What prompted the initiation of cultural evolution, and what kept the momentum going?

These sorts of questions have been around for some time, and a variety of answers have been suggested. These answers have been guided by generally accepted facts about the intraspecies human evolution that occurred after the hominid species separated from the pongids some five or six million years ago. Among these facts, as revealed by available fossil evidence, one of the most telling is that for long stretches of this very long time, human culture changed exceedingly slowly. It was only in the last few tens of thousands of years (Eldredge & Tattersall, 1992) that the curve of cultural evolution began inching upward on its relentless march towards its present explosive acceleration. Thus, in addition to the questions posed earlier, we have another one: Why did this cultural evolution occur so recently?

There is good agreement that the human brain/mind has played a critical role in human evolution in general and cultural evolution in particular. Richards (1987) has noted that early evolutionists and later Darwininians alike embraced the idea that behavior and mind "drove" the evolutionary process. Thus, in addition to the gain in intricacy of neuronal organization (Tobias, 1971) and the "disproportionately large" prefrontal cortex (Deacon, 1997) that figure as candidate "drivers" of human cultural evolution, there are also obvious mental factors such as manual signaling, language, and especially speech (Donald, 1991; Lieberman, 1984; Corballis, 1998); literacy, numeracy, and abstract thought (Donald, 1991, Deacon, 1997); social learning and efficient transmission of information from one generation to the next (Boyd & Richerson, 1985); explicit instruction of others by those who had special skills and knowledge (Premack, 1984); and development of an enquiring or meditative ability exceeding simple knowledge (Santangelo, 1993).

The reason for raising the question of cultural evolution in this volume is this: I would like to propose that chronesthesia, and specifically *proscopic* (forward-looking, future-oriented) chronesthesia, was yet another "driver" of human cultural evolution, perhaps even a crucial one. The idea is simple: consciously apprehended awareness of the existence of future is a necessary, even if not a sufficient, precondition for massively changing one's environment. More specifically, the hypothesis—call it the hypothesis of chronesthetic culture—is that the development of civilization and culture was, and its continuation is, critically dependent on human beings' awareness of their own and their progeny's *continued existence* in time that includes not only the past and the present but also the future. An animal that cannot think about what might happen at a time that has not yet arrived, and that therefore does not exist, is unlikely to initiate and persist in any activity whose beneficial consequences will manifest themselves only at that physically nonexistent time. Such an animal's behavior is governed completely by the physical and biological laws of the world. These laws operate in linear time: the past can influence the present, and the present can influence the future, but there is no way in which the future, which does not yet exist, can influence anything that happens in the present—no way, except one: through a future that exists in one's conscious awareness of the world, the kind of awareness that chronesthesia makes possible. Chronesthesia is a trick that nature invented to circumvent its own most fundamental law of unidirectionality of time.

To the extent, then, that chronesthesia depends on prefrontal cortex, and to the extent that chronesthesia, once it began to evolve as a property of the human brain, became critical in the initiation and continued support of the evolution of human culture, the conclusion follows that the human prefrontal cortex, undoubtedly in collaboration with other areas of the brain, is directly responsible for the cultured world as it exists today, a world in which not only human survival but human satisfaction and happiness are no more a matter of nature but rather depend on human beings' own wisdom, or lack of it.

PROBLEMS WITH CHRONESTHESIA

In this chapter I have outlined some ideas about a human neurocognitive capability that I have called *chronesthesia*. I have proposed that it is a kind of consciousness involving subjective time that serves many time-related behavioral and cognitive functions as a critical enabling condition. All mature humans possess chronesthesia and critically depend on it for their existence. Prefrontal cortex is probably one of the central components on the neuronal circuits that subserve chronesthesia. I assume that chronesthesia is a recent appearance in human evolution, and that it played a critical role in the evolution of culture and civilization as we know it.

There are many problems with this story (or theory) of chronesthesia. Indeed, I myself find it much easier to criticize it than find supportive ideas and evidence for it. Does it really exist as a separate neurocognitive capacity? If so, in what sense does it exist? Why classify it as a form of consciousness? Wherein lies the advantage of this assumption? In what sense is consciousness, any kind of consciousness, a neurocognitive capacity? The list of these kinds of vexing questions is long. Perhaps the most basic one of them all is this: Given that there are no easy answers to these questions, why bother to ask them? Speculation may have a legitimate role to play in science, but if it gets to be too much, does it not become counterproductive?

I am well aware of the problems that the theory of chronesthesia faces. But just because there are many problems with an idea does not necessarily mean that the we should not even try to think about it. Remember Michael Faraday and his ideas about electricity; when asked what this new thing that he called electricity was good for, he is said to have responded: "Madam, what good is a newborn baby?" Chronesthesia may not be electricity, but it does share with electricity, and all other new ideas, the feature of having a kind of future promise that nonexisting ideas do not.

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