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Timing your mind and minding your time

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Prologue in Hell

Since we humans find the problem of time perplexing and the problem of the mind excruciatingly difficult, it is safe to say that the problems born from the conjunction of time and mind, the theme of this Sixth Conference of our Society, are simply diabolical. Let us therefore go to Hell for enlightenment. And let our guide be that latter-day Dante Alighieri, Stanley Elkin, whose masterly *The Living End* offers a revealing view of life after death (Elkin, 1979).

Burning in Hell is Lesefario, a man to whom, as the author tells us, “life had not signified.” But Lesefario has changed. He wants to make something of his death. He now strives for mortality, whatever that may mean for someone in his position. While thinking of ways to achieve his goal in the midst of all the senseless suffering that is surrounding him, suddenly the truth dawns upon him: “The meaning of death is how long it takes!” Drawing the only possible conclusion from this insight, Lesefario begins to count time, and soon he finds himself followed by the trillions of other denizens of Hell.

Meanwhile at God's in Heaven they are having a garden party. And, being in a really relaxed and talkative mood, the Lord starts explaining to His guests what the universe is all about. He reveals, among other things, what the real causes of inflation are and why dentistry is ultimately a purer science than astronomy. At that point the counting from down below attracts His attention. And instantly realizing the peremptory trick Lesefario is playing on Him, He pronounces Doomsday and the Last Judgment, in the process annihilating the universe with everything that is in it.

Now, for good understanding, the point of this allegory of apocalyptic allure is not that there is no time in Hell. Actually we are informed that indeed “they had time; they had minutes, seconds, hours, years.” They simply did not have structured time, no *duration*. And so, when Lesefario came to recognize the significance of duration, Hell and suffering suddenly became meaningful and, consequently, vanished.

In my view this infernal episode epitomizes a fundamental connection that exists between time and mind: it points out the distinction between a non-reflective, if not passive, adaptation to the course of events on the one hand and an active, deliberate effort to make events “signify” on the other—the distinction between damnation and redemption, between being and becoming or, indeed, between timing your mind and minding your time.

Time, Reality, and the Mind

That a relation exists between time and mind is rarely denied, although many discussions have been phrased in exclusive terms: time is (a) real and, therefore, in principle at least, a property of the physical world, independent of the presence of a natural (or supernatural) spectator; or it is (b) “all in the mind” and therefore, in principle at least, unreal. The simplest way to avoid the dilemma of a physical as opposed to a mental origin of time is to acknowledge hat there is a fundamental duality and to look at both aspects as complementary but equally important manifestations of the structure of reality.

Although most philosophers of time have attempted, somehow, to accommodate both aspects, the problem took a more serious turn when Immanuel Kant showed that there is no access to uncorrupted knowledge of the world around us. The inaccessibility of the world-in-itself might not have caused so much epistemological distress as it actually did, had Darwin been around at the time when Kant formulated his Critique of Pure Reason. Evolution—and Kant would certainly have acknowledged—must have tuned us to the world as it really is or we would not be here and now. Although we may not have direct access to the world-in-itself, we have evolved to be functionally tuned to it, just as my radio is tuned to the electromagnetic spectrum in such a way as to make it a radio. Similarly, time is real although it requires a mind to be aware of temporal relations.

‘Time and Mind’ as a Psychological Dilemma

Leaving aside these ontological concerns, I simply note that time is a prominent and variegated feature of human experience and that it is, therefore, upon psychology to provide an explanation for both that prominence and the various appearances of time. This, however, is not yet a workable formulation of the problem; it all depends on what is meant by “explanation.” just what this task actually entails became clear to me during a workshop on “Scientific Concepts of Time in Humanistic and Social Perspectives,” convened by Dr. Fraser in 1981, at the Study Center of the Rockefeller Foundation on Lake Como. One afternoon, David Park and I, while walking the gardens of the Villa Serbelloni, discussed what psychology might contribute to what he saw as a fundamental problem of time in physics: defining the characteristics of a conscious observer in a not quite deterministic universe.

It was then that I realized that, with respect to time, psychology is essentially facing a design problem, namely, and here I quote from my 1981 notebook:

> “How to demonstrate that the human mind operates in such a fashion that it can cope with the sequential contingencies of its natural and self-created (cultural) environment and at the same time produce the experiential appearance (phenomenology) of time which conscious reflection reveals. The latter includes such aspects as the conscious experience of the present, past, or the subjective flow of time, and such pathological phenomena as déjà-vu. Some of these products of experience may themselves serve as strategies of negotiating the temporal contingencies of the world outside.”

What I distilled from our discussion was that

> “...one should eventually be able to provide the design specifications for an intelligent system that, by dealing with a dynamic environment, could succeed in timing its mind and also, by explicitly manipulating its temporal experience, might be said to be minding its time.”

A Psychological Frame of Reference

At this point I feel it is necessary to make a slight digression into psychological theory. It is common, nowadays, to consider the human mind-brain as a material information processing system (Reed, 1982; Reed and Jones, 1982; Anderson 1985). Whatever the exact nature of this system, a distinction must be made between two functionally different and complementary ways of processing information: the automatic (or habitual) and the controlled (or conscious) mode of processing. Examples of automatic information processing include, in the first place, such largely innate abilities as maintaining an upright position, recognizing a hand when you see one, or scratching an itch; and in the second place learned automatic behaviours like juggling with six empty beer bottles while maintaining equilibrium on a tightrope, or the ability to grind out “golden oldies” on the piano in a hotel lobby while at the same time figuring out how to renovate the bathroom at home. Controlled processing, on the other hand, is characteristic in situations that are new or unusual: deciphering Kanji characters when you are three weeks into a Japanese language course, or learning how to set your new high-tech digital watch with its forty-three timing and calendar functions.

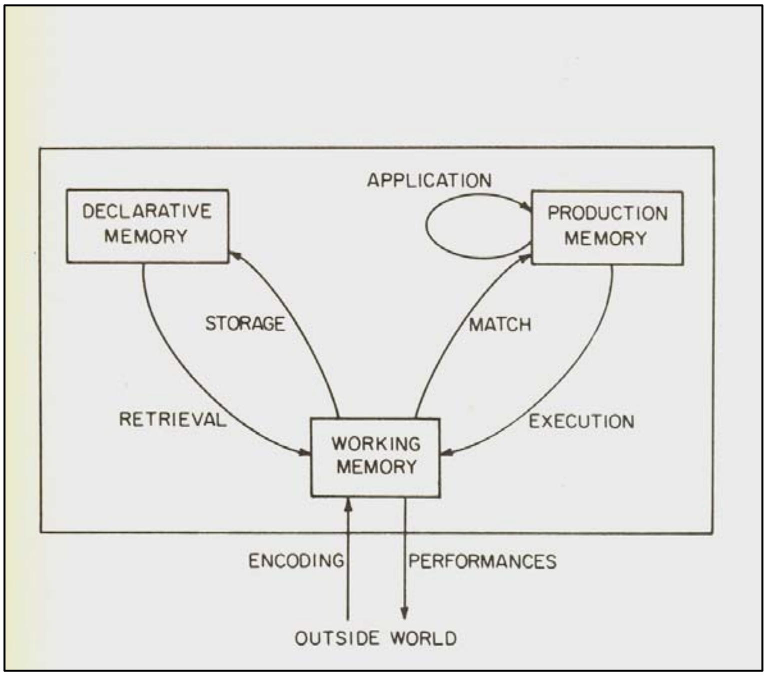

Figure 1. Summary diagram of the information processing model of J. R. Anderson. Communication between the actual world and the mind is established through a process known as “working memory.” The useful life time of information in working memory is of the order of 1 to 30 seconds and may be identified with the specious present or Now. There are two information processing modes—as described in the text. One deals with declarative (fact-oriented) knowledge, the other with procedural (skill-oriented) knowledge. Declarative knowledge is explicitly stored and accessible through consciously controlled retrieval strategies. While new knowledge is initially stored as declarative knowledge, repeated usage in working memory will sooner or later create more condensed procedural rules for applying this knowledge. Such rules, known as productions, can be formally characterized in terms of conditional statements: *if* the light is red, *then* stop. Proceduralized knowledge is a matter of tuning (viz. matching with some external event or situation) and automatic execution. (From Anderson, 1983, p. 19; reproduced by permission of The Harvard University Press, Cambridge, MA).

Functionally these two processing modes, automatic and controlled, are intimately related. The acquisition of skills, for instance, involves a gradual shift from controlled processing to automatic processing. Novel information is initially processed and stored under conscious control as, what is frequently called, declarative knowledge (Anderson, 1983). Declarative knowledge—-knowing what—remains consciously accessible and is easily updated in the light of additional information; we can talk about it. With repeated usage declarative knowledge tends to be increasingly transformed into procedural knowledge—a matter of knowing how. Procedural knowledge is immediate but almost inaccessible to conscious manipulation and therefore difficult to change deliberately (See Figure 1).

This functional interdependency of the two processing modes also works the other way around. The memory blackouts suffered occasionally by performing artists, or that particularly scenic road to Auntie Janet's Highland cottage you knew so well last year but need a map for this time, characteristically trigger a reverse transfer of action control from automatic to controlled processing. What normally comes smoothly and without noticeable effort suddenly requires hard thinking and as a deplorable result may proceed only haltingly.

Although functionally there is this intimate relation, theoretically there seems to be a tremendous conceptual gap. For a long time information processing theory has been dominated by two opposing movements; let me call them direct realism and constructivism. Both fail by wishing to account for the human mind in terms that are essentially applicable to one mode of processing only. This problem, in my view, is similar, in a nontrivial sense, to the wave/particle duality that took physicists such a very long time to accept. Today psychologists do not (yet) recognize the dual nature of their distinction between automatic and controlled processing. If they did, however, they would conceptually come quite close to some recent trends in physics. The automatic/controlled duality seems to correspond, for instance, to the distinction implicate/explicate made by the physicist Bohm. That is, the distinction between a description of the world in terms of potential fields, wave fronts, and energy distribution on the one hand, and discrete (particulate) matter, sharply defined events, and dynamic trajectories on the other. It is, metaphorically, the distinction between the distributed world of the hologram and the focused world of the lens (Bohm, 1980).

In the remainder of my address I wish to expound the following two assertions derived from the argument thus far:

(a) *Timing your mind* is primarily, if not exclusively, a matter of automatic processing of external (perceptual) as well as internal (stored or represented) data; timing your mind enables you to stay in tune with an intrinsically temporal world but, as I shall, argue, not necessarily by explicitly representing time as a point or an interval in time, that is, as the variable t in mathematical equations.

(b) *Minding your time,* on the other hand, is primarily, if not exclusively, a consciously controlled way of coping with those aspects of the world to which we cannot directly tune ourselves because we are not geared to those aspects by evolution or learning.

Incidentally, I must warn you that, if I call controlled processing conscious, I do not in the present context mean the awareness of personal identity which we also call consciousness or self-awareness.

Timing Your Mind: Tuning to Reality

Tuning

Consider this question, posed by Coleridge more than a century and a half ago, in his poem *The Eolian Harp*:

> And what if all of animated nature
> Be but organic Harps diversely fram'd
> That tremble into thought?

If timing our mind is resonance-driven, as Coleridge suggested, what kind of tuning forks are we? Do organic harps evolve? And why would the capacity for tuning develop in the course of evolution in the first place? Actually, if you come to think of it, animals have pretty good reasons to behave like organic harps or resonators. Their major concern is to maintain their internal structure irrespective of highly variable outward conditions and, even more importantly, irrespective of a large variety of goals. To achieve this internal stability they must stay sharply tuned to their environment (Michon, 1985).

The prototypical example of these internalized tuning mechanisms is the circadian rhythm (Moore-Ede, Sulzman, and Fuller, 1983; Aschoff, 1984; Groos and Daan, 1985). But chronobiological research has also brought to light numerous other “clocks” and “timers” from which the organism can almost always select one or more that suit its tuning needs (Richelle and Lejeune, 1980). Especially important are the regulatory processes in the range between one-tenth of a second and ten seconds that govern the tuning to most common behavioural phenomena. Speech rate is a good example: voice recognition and speech comprehension, for instance, depend critically on the temporal characteristics of the speech signal. My favourite illustration of this dependency is an experiment (Dooling, 1974) in which subjects are presented with a series of simple sentences, all with an identical stress pattern, say, a trochaic pattern as in “this is a happy p6rson.” After eight such sentences a change in stress pattern is suddenly introduced: the ninth sentence to be presented may be iambic, as for instance in “this is a rem6te contr6l.” The comprehension of this last sentence turns out to be dramatically worse than that of the earlier sentence simply as a result of the change in temporal structure from trochaic to iambic. In a similar way, highly automatic motor skills, such as the athletic long jump (Lee, Lishman, and Thomson, 1982) or handwriting (Thomassen and Teulings, 1985) entail a very complicated and highly idiosyncratic internalized temporal organization which is extremely difficult to change or imitate. The relevance of studying the intrinsic temporal organization of such skills is illustrated by a recent investigation ordered by the Netherlands Government to establish the authenticity of the diary written by Anne Frank (Nederlands Instituut voor Oorlogsdocumentatie, 1986). It being one of the most important *documents humains* of the Holocaust, its authenticity has over the years been questioned by a number of people, mostly for rather unsavoury reasons. The recent investigation, to an important extent based on our latest insights into the temporal organization of handwriting, has finally put the issue to rest. The diary of Anne Frank is authentic, scribble for scribble, letter for letter, and word for word.

Patterning

Resonators, the category of entities to which "organic harps" and tuning forks belong, may be broadly conceived as pattern detectors. As such they pick up (and represent) regularities or recurrences in their environment. Tuning in the human organism may be defined as the matching of patterns of symbolic events in the mind-brain to patterns of events in the external world. In this context a pattern may be understood as a relatively compact, efficient description of the structure of a state of the world, say a series of events. Such pattern descriptions are always in terms of a code; that is, a set of symbols and a set of rules for combining these symbols. When I call a pattern relatively compact and efficient, you will perhaps think of the number m, which seems a most compact and efficient way of writing the digit sequence 3.14159. . . . If that is indeed what you think, however, you are on the wrong track. The symbol π does not qualify as a pattern description because it is not a recipe for generating 3.14159 . . . . unlike, for instance, a description such as "n squared for increasing $n > 0$" which tells us how to generate the digit sequence 1 4 9 1 6 2 5 3 6 . . . .

Pattern descriptions are always in terms of a code, that is, a number of symbols and a set of rules for combining these symbols. In the past fifteen years the art of defining clever codes that allow descriptions of all kinds of perceptually relevant patterns—visual, auditory, linguistic—has made considerable progress (Restle, 1970; Simon, 1972; Leeuwenberg and Buffart, 1979; Jones, 1985), but an important question remains: to what extent are such coding theories psychologically relevant? To what extent do codes which describe sequential or temporal patterns reflect internal tuning processes?

Patterns are what they are by virtue of the context in which they appear. In isolation they can have no meaning and no structural significance. A wedge-shaped symbol V will be different as an element of the set of consonants (B, V, F, S), than when it belongs to the set ($\neg$, $\vee$, &, $\rightarrow$) of familiar logical symbols (meaning not, or, and, and if-then, respectively). An important question that proves very difficult to answer is what, or should we say who, determines the context that will specify the meaning of a given pattern or set of patterns. This difficulty is a matter of considerable dispute in contemporary cognitive psychology as well as in the philosophy of mind (Goodman, 1984).

In these discussions it is pointed out that coding theories remain incomplete and arbitrary as long as it is not made clear why some pattern structures appear to invite or to “afford” one particular interpretation rather than another. Some interpretations of a pattern-a melody or a situation-make sense to us, and others simply do not. As the philosopher Nelson Goodman observed, humankind makes versions of the world, and true versions make worlds (Goodman, 1984, p. 34). But how do we know which versions do make true worlds? How does an event sequence evoke in the observer just that special interpretation of context, let us call it mood, in which the sequence occurs, so that we can understand and later on recognize or even reproduce it?

Could it be that some patterns carry the key that will unlock their “true codes”? Do these things-in-themselves dictate the way we should perceive them? Several authors have observed that certain strings of events seem to invite us to follow and participate in changing relationships over time, or to derive their appropriate interpretation from the temporal aspects in their structures (Jones, 1985). Attending to various aspects of a series of events is primarily guided by temporal relations (e.g., tempo, rhythm, and meter in music) that are suggested or afforded by the structure of the pattern. Temporal structure is thus indicative of what to listen for when a piece of music is heard for the first time. It is also guiding later recollections of that piece (Jones, 1985; Shaffer, 1985).

Unpatterned Patterns

Not all patterns to which humans attend are actually patterns. We cannot help seeing patterns in a completely uniform checkerboard tessellation. More significantly, we cannot resist seeing symmetries in irregular checkerboard tessellations, just as we cannot help seeing faces and animal shapes in clouds, inkblots, or wallpaper. Indeed if we consider the world of unpatterned patterns we begin to appreciate how clever evolution has been giving us the broadest possible means of tuning to the world. Although Albert Einstein claimed that the Good Lord does not play at dice, it is clear that Nature herself was not so sure about that: as a precaution she has endowed us with ‘resonators’ that indeed allow us to tune to non-patterns in our environment. Only quite recently is it becoming clear why this may be so.

One of the most fascinating developments in modern mathematics—already from an aesthetic point of view—is the fractal geometry of Benoît Mandelbrot (1983). Fractal geometry deals with the formalization of irregularity, that is, with spatial and temporal patterns whose irregularity (or fragmentation) appears the same, irrespective of the scale at which they are considered. Imagine, for example, that you are descending over the coast of Norway in a Montgolfière and that you are looking straight down at the shoreline below. You would see fjords, gradually

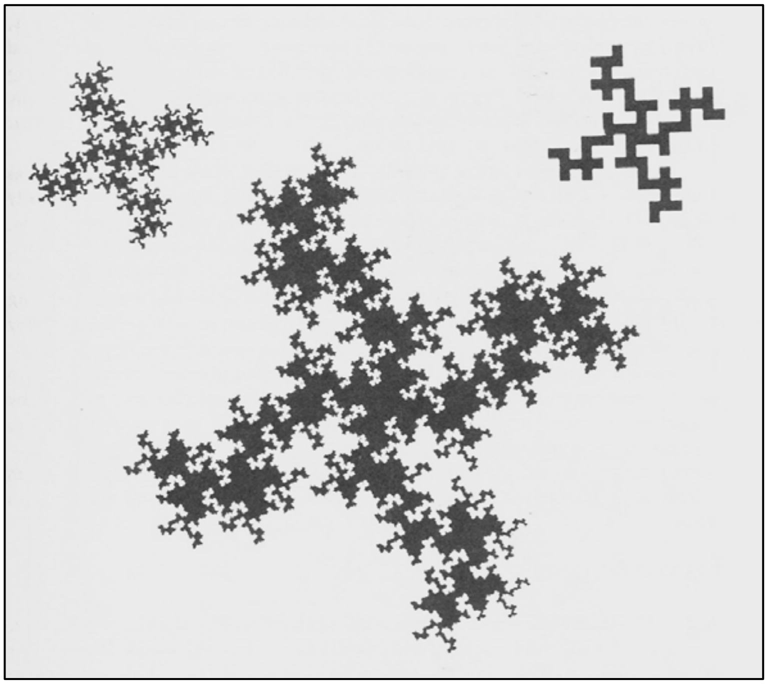

Figure 2. A fractal pattern showing the scaling property: the overall characteristic of the pattern remains the same for the three levels of complexity. The pattern in the upper right-hand corner constitutes the limiting condition: further enlarging its scale will no longer retain the characteristic shape. (From Mandelbrot, 1983, p. 53. Reproduced by permission of Freeman & Company, San Francisco, CA.)

dissolving into smaller and smaller but geometrically similar fjords, until at perhaps a hundred meters altitude or a little less, individual rocks and boulders would begin to dominate (see Figure 2).

This self-repeating quality of fractals is called their scaling property. It turns out that a good many natural phenomena possess this property, and it seems plausible that evolution has made us particularly sensitive to the way it is revealed in the edges of clouds, in mountain ridges, inkblots, and wallpaper designs.

Apart from producing many extremely attractive spatial configurations (Peitgen and Richter, 1986), fractal geometry has a lot ‘to say as well about temporal unpatterned patterns. Below the lowest level of structural coherence, well below the grammars of counterpoint and harmony, for instance, may be described in terms of fractal properties. As Mandelbrot (1983) has pointed out, 'musical compositions are, as indicated by their name, composed. First they subdivide into movements, characterized by overall tempos and/or levels of loudness. The movements subdivide further in the same fashion. And teachers insist that every piece of music be “composed to the shortest meaningful subdivisions” (p. 375).

Barring a few trivialities such as Brahms’ command of orchestral instrumentation, the scaling property is what makes a Brahms symphony a Brahms symphony, from the time span of the whole work down to the single bar. Studies by two American audiologists, Voss and Clarke (Voss and Clarke, 1975; Voss, 1978) have shown that pitch, loudness, and timing variations of several musical genres-classic as well as popular—indeed conform the fractal scaling assumption. They have also shown that sequences of notes that are stochastically tailored to this fractal property sound more like “real” music than do sequences that are generated under other stochastic rules.

Our sensitivity to fractal patterns, wherever they occur in nature, indicates that already at a very deep stochastic level many things in this world are internally coherent: fractals retain their overall character globally as well as locally. And so, coming back to the question of why we pick up some kinds of unpatterned patterns, the answer is that the randomness of a large class of relevant natural phenomena is highly constrained and that the human mind-brain has developed means of tuning to this kind of randomness. The fractal scaling property, it appears, is a very fundamental aspect of whatever is capable of attracting and holding attention. Unpatterned patterns outside this rather limited range of fractal scaling seem to lack internal structure. Such non-patterns can only be encoded and retained by human beings in a long process of explicit memorization, of the sort required to commit such abominations as the number π to memory (Chase and Ericsson, 1982). Einstein notwithstanding, Nature decided at an early stage in evolution to endow us with a defence against the rock-bottom indeterminism of the world in which we live.

Affordances

Although I am dealing here mostly with the temporal aspects of the tuning process, tuning involves a much more general relation to the external world. In particular James J. Gibson (1966, 1979) has repeatedly pointed out that tuning is, in a very general sense, a matter of extracting invariant properties from the environment. In his view, the geometry of our perceptual environment provides what he had called “affordances.” Nature “affords” such complex information as the looming of a hawk approaching a newly hatched chick, the sit-onableness of a slab of marble to a tired visitor of the Forum Romanum, or indeed the land-onableness of the landing strip at an airport (see Figure 3).

Based on Gibson's ideas an extremely interesting line of research has developed that goes under the name of kinematic geometry. An excellent example is the research program of Roger Shepard and his colleagues (Shepard and Metzler, 197 Shepard and Cooper, 1982; Shepard, 1984). Shepard has shown that people are quite capable of mentally representing the movements of a solid object through three-dimensional space (see Figure 4 on page 12). Among other things he has demonstrated that complicated simultaneous movements of an object and an observer in three-dimensional space are always perceived and represented according to a unique, minimally complex trajectory which preserves the solid

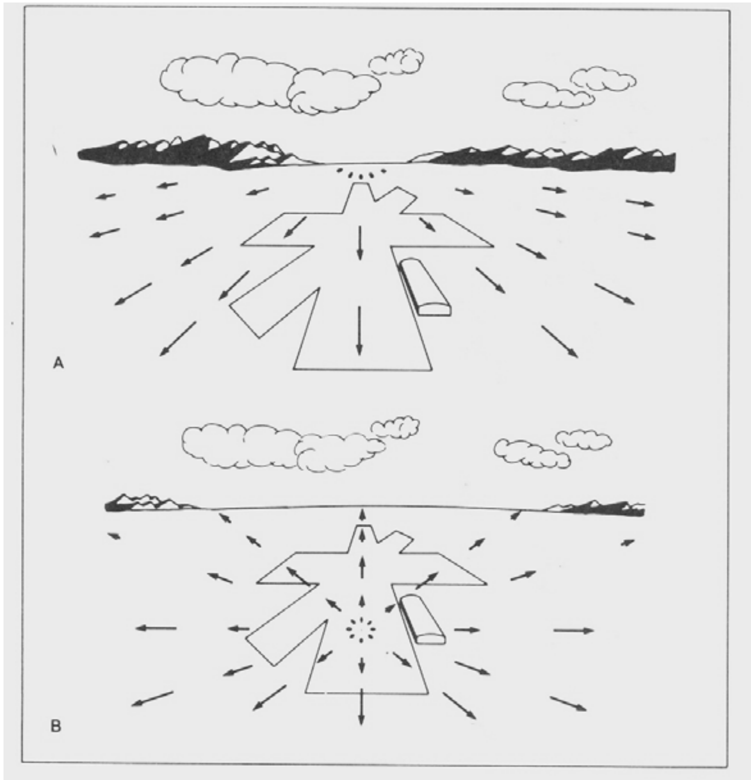

Figure 3. Schematic representation of perspective flow when approaching the landing strip of an airfield. The flow pattern affords the “land-onableness” of the strip. (From Reed and Jones, 1982; reproduced by permission of Erlbaum Associates, Hillsdale, NJ)

character of natural objects. In a similar way, imaginary movement of some object will instantiate “the continuing existence of the object by means of the unique simplest rigid motion that will carry the one view into the other, and it does so in a way that is compatible with a movement either of the observer or of the object observed” (Shepard, 1984, p. 423).

When we watch and attempt to hold in mind the tortuous trajectory traversed by, say, a failing autumn leaf, we set up a simplistic physics-of-the-failing-leaf mental model which preserves the characteristic rocking movements of such a familiar object. In the most general terms, the perception and mental representation of kinematic information are largely based on the principles of minimal effort, continuity of movement, and object permanence. We retain an idealized trajectory and omit disturbances due to, say, wind gusts or failing rain drops. Special effects in movies require an extraordinary amount of sophistication to fool all the people all the time, because of this sensitivity to ‘natural’ movements.

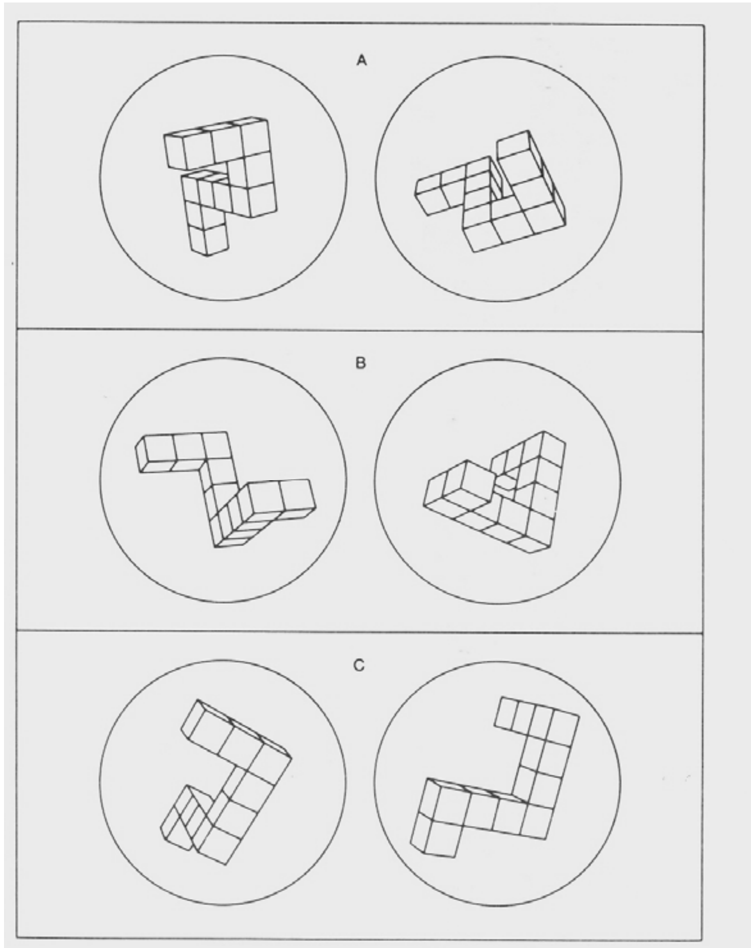

Figure 4. In a series of experiments by Roger Shepard of Stanford University, subjects were shown pairs of pseudo-three-dimensional pictures as in A, B and C. The subjects were asked to decide if the two pictures of a given pair are identical. An answer to that question requires mental rotation of at least one of the objects. It will be seen that the pairs A and B do in fact match, whereas in the case of pair C no such match can be obtained (From Shepard and Metzler, 1971, p. 701.)

Other, similar research suggests that people possess a very delicate capability for recognizing the gait and gestures of other people, including their vocal mannerisms. The skill of successful impersonators and cartoonists is based on their ability to extract just those high-order invariances that make Margaret Thatcher unmistakably Margaret Thatcher and J. T. Fraser unmistakably J. T. Fraser.

I should add at this point, without further commentary, that such studies all point to the fact that time need not be, and indeed rarely is, encoded directly. Several authors have pointed out that time is not likely to be encoded in the motor command structures controlling complex body or hand movements. Instead, temporal precision seems to be a natural outcome of well-tuned, smoothly performing output systems (Thomassen and Teulings, 1985).

Some Intermediate Conclusions

It appears that tuning to the temporal contingencies of the world is dependent on the availability of a large number of preattunements ("affordances," resonators, internal rhythms), partly learned during the individual's lifetime, but mostly the result of eons of evolutionary development.

If all this worked flawlessly, you would be able to time your mind to perfection. If anything, you would resemble one of the windowless monads envisioned by Leibniz, and you would not need to know the difference between you and the world. In other words, there would be no need for self-awareness. Generally, however, your mind and the world are not quite so perfectly tuned, a fact that will from time to time induce shifts from the automatic to the controlled mode of information processing. Frequently the correlation between you and your world will be so low as to make you painfully aware of this fact. The following peculiar case may help to illustrate this.

Intermezzo: The Discovery of Slowness

Some people appear to suffer from conditions that prevent an easy and successful timing of their minds. They may be dyslexic or dyspraxic and thus have difficulties reading or performing, and there is dysrhythmia, the incompetence to keep the beat.

Rarely, however, will one find a condition as strange as that which seems to have afflicted the British arctic explorer, Commander of the Fleet and His Majesty's Governor of Tasmania, Sir John Franklin (1786-1847). Very strange indeed, if we are to believe the German novelist Sten Nadolny, author of a somewhat fictional biography of Sir John, *Die Entdeckung der Langsamkeit* (1983).

The Discovery of Slowness portrays its protagonist as an initially extraordinarily clumsy and sluggish boy. His rate of information processing—if you permit this bit of jargon—was so low that even at the age of ten he could not catch a ball or climb a tree. The ball would be gone long before he realized how it bounced, and when climbing a tree he was far too slow even to reach to a branch if losing his foothold. To cope with his handicap Nadolny's John Franklin decided to learn the world by heart, reviewing and memorizing at night what went too fast for him by daytime. He studied *rapidity* "the way other people study the Bible or the footprints of animals." And John Franklin, having joined the Royal Navy as a midshipman, succeeded.

> "Whole fleets of words he had learned by heart, and batteries of answers, to build his defence. He had to be prepared for everything that might be asked, every question, every action. And... he managed! A ship, restrained by the sea, could be learned... He paid careful heed to every conceivable route from every place on the ship to every other place, he had even drawn maps,

> and he had been rehearsing them every night for two full weeks. Now everything went automatically, as long as nothing unexpected happened. Then there was no recourse, and things would have to be accomplished without fine control. But... his excuse formula had been practiced too!" (transl. JAM)

The finite universe that is a ship could be mastered with everything that happened on it. Although this achievement made life manageable for him, it was only many years later that John Franklin eventually discovered in the Arctic a world where things happen slowly enough for him to feel really at home—and in tune.

It appears to me that Sir John's handicap—at least on Nadolny's account—must have been an extremely slow acquisition of procedural knowledge. In his case the transition from *knowing that* to *knowing how* must have demanded an unusually long and intense cognitive effort. In other words, John Franklin succeeded in timing his mind only by laboriously minding his time. As an 'organic harp' John Franklin was clearly a misfit!

Minding Your Time: In Search of Useful Metaphors

Conscious or Automatic?

Like John Franklin, however, we too must adopt the controlled mode of information processing in situations for which we have no automatic behavioural procedures. In fact, I am convinced that all conscious time experience is a consequence of controlled processing, and that "temporal information is not processed unless noticed, and not noticed unless meaningful" (Michon and Jackson, 1984, p. 305; see also Jackson, 1986). The term *temporal information* implies all relations that specify the order, duration, or position of events in a series, or the apparent rate of temporal flow; in short, all relations that define our conscious experience of time and that have been studied by time psychologists for well over a century with varying degrees of success (see Michon and Jackson, 1985, for a recent overview). People can understand, remember, and reproduce temporal relations between objects and events if and only if they succeed in generating some encoding strategy (see in particular Jackson, 1986). People must, in other words, find some kind of language, or semantics, in which they can express what, otherwise, would be an unmanageable mumbo-jumbo of impressions—unmanageable, because people lack the means for directly tuning in. It seems that there is no natural vocabulary for thinking about, or verbally expressing relations of order, duration, and temporal position. Like wine-talk, time-talk essentially relies in a very principled way on the availability of suitable metaphors.

Representations

The claim that minding your time, your conscious dealing with the temporal contingencies of a world of change, is dependent on metaphor, is not without support. There are, for instance, those who maintain that "metaphor is pervasive in everyday life, not just in language but in thought and action. Our ordinary conceptual system, in terms of which we both think and act, is fundamentally metaphorical in nature" (Lakoff and Johnson, 1980; p. 3).

More closely connected to the subject matter of this volume, and essentially taking a similar stand, are the contribution of the late Nathaniel Lawrence in *The Study of Time V* (Lawrence, 1986) and my own paper in the same volume (Michon, 1986). Metaphors deeply influence the ways we think. They 'tune' our thoughts about an object or an event—our mental representations if you like—to the semantic domain from which the metaphor is borrowed. Thus, the metaphor "Time is Money," thoroughly established in Western society, allows us to think about and act with respect to time as something that is valuable, that can be saved, lost, or wasted. Choosing to speak and think about time in these terms highlights some characteristics, at the cost of others. It suppresses among many other things, the connotations that belong to other temporal metaphors; thus, in the context of Time is Money, time does fly only to the extent that one can conceive of situations in which money flies.

There is ample reason to assume that all metaphors are not created equal. Some are sporadically used or even invented for a special occasion. Other metaphors, however, perhaps between fifty and a hundred of them, occupy a central position in human cognition (Lakoff and Johnson, 1980; Ortony, 1979). Especially powerful among these are the metaphors that refer to semantic domains that can be "physically envisioned" (Carbonell, 1982; Johnson-Laird, 1983; Jackendoff, 1985).

The spatial metaphor is particularly pervasive. Temporal relations are, indeed, most frequently interpreted in spatial terms, which suggests, in the words of the psycholinguist Herbert Clark, "the availability of a thoroughly spatial metaphor, a complete cognitive system that space and time expressions have in common" (Clark, 1973, p. 62). I take this to mean that there are aspects of both space and time that are expressible in the abstract spatial terms that are used in measurement theory. This is exactly what I proposed in my contribution to the 1983 conference of our Society. In that paper I suggested that the means we have available for representing temporal relations are, foremost, the ordering properties and measurement scales as they can be derived from some of the basic metaphors that serve us to make sense of the world (Michon, 1986).

But how is this abstract space to be dressed up? Clark's analysis of temporal expressions suggested to him that the representation of time conventionally takes the form of imagining time as a straight arrow passing from back (the past) to front (the future) through our body (the present). But this metaphor is clearly too simple to cover all the subtleties needed for representing temporal relations of order, duration, or position. So, clearly a richer conceptual framework is required.

An important step in that direction was taken by Miller and Johnson-Laird (1976) who, starting, like Clark, from the prevalence of a quasi-spatial linear conceptualization of time, pointed out that ultimately we possess no genuine sense of time, and that there can be therefore, no natural correspondence between temporal relations in the world outside and our mind-brain representations of them. While colour, size, or tactile pressure directly trigger representations that can spontaneously be given verbal labels—“red”, “what a whopper!”, or “ouch!”—no such connection exists to help us minding our time, and we are forced to rely on such metaphors as the “arrow through the body.” Miller and Johnson-Laird then went on to consider what can be said about the mental representation of temporal relations if we treat them as formal rather than natural, as conceptual rather than as directly perceivable. For this purpose they chose an instant logic as their model frame. In the context of instant logic (Van Benthem, 1983) every elementary temporal proposition about an event is evaluated. It is determined if it was always, sometimes, or never true before an instant t, whether it is true or false at the instant t, and whether it will always, sometimes, or never be true after the instant t. Thus, for every elementary proposition, the person's working memory must carry the weight of 3 x 2 x 3= 18 truth values, to be evaluated upon input. The temporal meaning of the simple sentence: “The shop is open until seven” is completely determined by specifying that the assertion “The shop is open” is true for all instants $t < t_0$, false for the instant $t = t_0$, and false for all instants $t > t_0$. That this quickly becomes a task of prohibitive complexity is readily seen if you attempt to analyze the following sample sentences each of which contains only a few elementary propositions:

(1) With a flawless last set in the final match against Ivan Lendl, Boris Becker proved that his earlier victory at Wimbledon had been no accident.

(2) Mary got out some money to buy herself a cup of coffee during the intermission of Nabucco.

Think for a moment what it would be like to extract truth-table representations from such statements! Each would impose an inordinate burden on our memory. Or, even worse, take that exasperating back-page newspaper advertisement by Heineken Breweries, published when The Netherlands went on daylight saving time a year or so ago and shown in Figure 5.

Figure 5. Advertisement confusing a majority of the population when the Netherlands shifted to daylight saving time in the spring (... or was it the fall?) of 1986. By kind permission of Heineken Breweries, Amsterdam, The Netherlands.

Those of you who have got a bit rusty on your Dutch will probably need the following translation:

> (3) Basically this is a very simple matter: the clock is advanced one hour. So it seems one hour later. But it is one hour earlier. That is because one hour is taken away in the evening and therefore it stays light longer. But that time is added in the morning and therefore it stays dark longer . . .
> Well, now, what is time anyway?

This mind-shattering advertisement should leave me urgently in need of a glass of beer every time I see it. (Incidentally, I had it framed and mounted on the wall of my study.) It reveals the tremendous difficulties human beings are facing when two sets of intervals (or temporal scales) do not just entertain a temporal scaling relation, but a change in this relation must also be taken into account.

Something else is required to cope with such complex relations, and that is the insight that when people do indeed use spatial metaphors to encode temporal relations like order, duration, and position, they tend to do so in terms of intervals rather than instants. This insight coincides with some crucial developments in temporal logic: interval logic has come of age in the past decade (Van Benthem, 1983, 1985).

It now seems that minding our time may be represented, efficiently and in a psychologically plausible way, as a knowledge base consisting primarily of relations between intervals. This not only provides a richer set of elementary relations; it can also be given a natural perceptual interpretation. Instead of the three relations in instant logic—before, at, and after—interval logic has exactly thirteen of them. Of two intervals A and B, A may precede or be preceded by, meet or be met by, overlap or be overlapped by, start or be started by, contain or be contained in, terminate or be terminated by B, and finally A may also (uniquely) coincide with B (Allen, 1984; Allen and Kautz, 1985). Please note, however, that here the terms starting and terminating, as well as being started or terminated by, should not be given a causal interpretation.

It turns out that complicated expressions such as (1), (2) and (3) can easily be represented in this formalism. Sentence (1) generates three intervals: Wimbledon, the men's single final, and the final set. The first interval contains the second, which in turn contains the third interval, and the last set of the final terminates simultaneously both the men's single final and Wimbledon. By implication sentence (1) also generates a similar triad for the preceding tournament at Wimbledon. Adding new information, such as the following sentence

(1*) Perhaps the brief spell of sunshine during the early part of the game had inspired the players.

to the temporal knowledge base already available, is straightforward if the semantics of words such as 'during' in sentence (1*) are understood. A occurs *during* B if and only if B *contains* A, or B *equals* A, or B *starts* A. The information contained in the facts that there was only a brief sunny spell and that it occurred early in this year's men's final, imposes certain constraints on the total set of possible temporal relations. Adding further propositions will eventually fix the network of temporal relations that together provide the chronology of the set *Wimbledon 1986*. A similar analysis of sentence (2) shows that here too the temporal relations are not quite determined by the information contained in the sentence. No doubt, you will appreciate that I am not going to bring up the statements (3) from the Heineken advertisement for further discussion right now, concerned as I am for your mental stability.

On the basis of a straightforward set of rules for encoding temporal expressions in terms of relations between intervals, it has been possible to construct models for parsing and integrating all such complex temporal relations as you may find in narrative and real life alike. Although their psychological relevance is not entirely clear yet, these models may be considered as important steps toward a formal theory of the way intelligent entities-and that presumably includes reader and author-are minding their time. Such is the case even though the prime motivation for the development of these models lies in a growing interest in automated knowledge systems that will be able to comprehend temporal relations and, as a result, to plan and execute complex sequences of actions (McDermott, 1982, 1985; Allen, 1984; Georgeff and Lansky, 1987). There is considerable practical value in an expert system or a robot that is able to mind its time without our having to time its mind in advance.

Epilogue: Can We Construct a Time-Experiencing Robot?

Having established (a) that the timing of our mind relies on the ability of the human organism to attune to highly complex temporal relations in a dynamic environment, and (b) that the minding of our time is a rule-driven, conscious act of intelligence, requiring one or several specific modes of abstract representation, metaphorical and formal, we should finally consider our chances of designing an intelligent system that really understands time. That was, as you will recall, the task I defined following my discussion with David Park in the gardens of the Villa Serbelloni.

In order to keep fantasy within reasonable bounds I will, for the sake of my present argument, restrict myself to the vastly simpler task of building a computer that can really appreciate music. Since music is the ultimate temporal art anyway, I am certain that this simplification will appeal to most people.

Of course, there are already computers that compose some sort of not quite trivial music, and in recent years we have indeed come a long way toward highly intricate forms of synthesized musical performance. The problem, therefore, must be phrased even more specifically: Will a computer ever compose or perform really masterly music; that is, will it ever move us in the way Bach, Brahms, or Bernstein can move us? And what about that twin computer still to be designed, a listening automaton that is really moved as we are when we are listening to great music? Will that ever see the light of day? The answer, in my view, is that both will indeed materialize sooner or later, but that we may never know if and when we have really succeeded (Dennett, 1978; Michon, 1984). The reason is simple enough: some domains of experience are extremely difficult to tackle, though not because we might not be able in principle to simulate in an artificial system the feeling of pain or the joy of listening to a Mozart piano concerto. We could easily let it beep or weep. It could produce drops of an isotonic saline solution from a pair of tubes on its front panel according to some scale ranging from bliss to distress. But what would be needed to make such a system *really* feel pain or enjoy music?

Upon further reflection that question turns out to be meaningless. People are quite aware of the fact that they react very differently to pain, as well as to music. Your headache is not my headache, and your appreciation of music need not at all be consistent with mine. In fact, my music may even be your headache! Now, if as human beings we differ already so fundamentally among ourselves, if a single person even can stand some pains and some music at some time that he or she cannot stand at other times, how then could we ever agree on precisely what properties to build into one computer to make it *really* suffer pain or *really* love Brahms? Music, along with pain, dreams, love, and some other important domains of experience, is a product of mental activity with such a rich phenomenology that we cannot formulate a consistent set of design requirements for a music-loving computer. If we ultimately accept a computer, or any other non-human intelligence, as really understanding music, it must be by act of faith. That will be the case when, and only when, we are prepared to accept an alien intelligence as a person, as one of us.

Some reflection on the troubled communication with autistic people seems relevant here. Music frequently appears to be one of the few gateways to the otherwise inaccessible world of autistic individuals; they may seem to appreciate music a great deal, and they may show emotional reactions to it. But do they really understand music? Are they really moved? The answer is that they do to the extent we believe them to share a musical semantic or meaning with us. And the sad fact is that we may not be unconditionally convinced that such is really the case.

And so, yes, ultimately we shall build a computer that really creates or understands time. But we will only know if we have been successful when we are prepared to believe that we have been successful, that is, when we are prepared to accept such a contraption as an equal, as a consciousness, as a person. Isaac Asimov considered what would have to happen in his novelette *Bicentennial Man* (Asimov, 1976).

Unfortunately one needs only to think of the very inhumane ways in which human beings may treat humans, to know that the probability of this ever being the case is arbitrarily close to zero. But this consideration returns me to my infernal point of departure, which suggests that I have swung full circle. This way I am paying the tiniest possible tribute to a totally different representation of time, and one that I have chosen to exclude altogether from this address although I recognize the importance of that other time—circular time.

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