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Making sense of time

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From the psychonomic point of view time is the conscious experiential product of the processes that enable the (human) organism to organize itself adaptively so that its behaviour stays tuned to the sequential contingencies afforded by its environment. This paper reviews some recent insights into the functioning of the timekeepers – clocks and regulators, organic and virtual – that make up the human 'sense of time'.

The origin of chronopsychology

Chronopsychology counts among the most ancient branches of empirical psychology. It sprouted in the early years of the 19th century as a result of two fundamental insights gained in those days. The first was that mental action is not instantaneous but requires a finite stretch of time.[1] This gave birth to *mental chronometry*, the systematic analysis of the time-course of mental activity.[2, 3] The other motivating insight was that, although we seem to 'perceive' time, we do not have a genuine time sense. This gave rise to the question what exactly it is that we call the *perception of time*.[4]

The first century of chronopsychology – essentially covering the period 1860–1960 – may be characterized as the 'psychophysics of duration'.[5] Hundreds of experiments were carried out to establish the relation between subjective time and physical time.[6] Regrettably, however, early chronopsychology suffered from one pernicious weakness: it almost totally lacked a coherent theoretical framework to support the many empirical results. As a result it gradually disappeared from the psychological research agenda.

Around 1960, however, these matters took a positive turn.[7] Chronopsychologists began adopting the cognitive perspective that now prevails in psychological theory and chronopsychology became a mainstream research topic again.[8, 9]

Tuning

Almost invariably in animated cartoons, a *Tom and Jerry* episode say, a moment arrives when Tom, in full pursuit of his arch-enemy Jerry runs over the edge of a cliff. Too late Tom realizes that the ground is no longer affording him the required *terra firma*. What follows is too catastrophic for words and 'wovon man nicht reden kann, darüber muss man schweigen'.[10]

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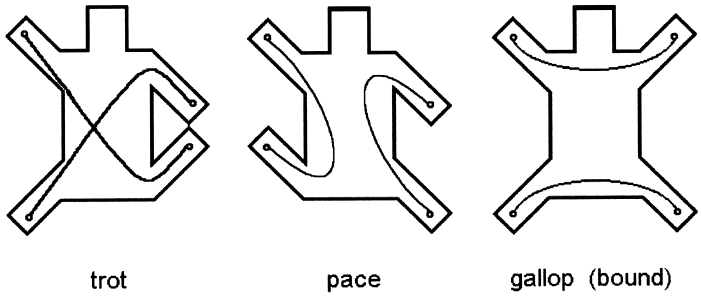


Figure 1. Elementary linkages for the principal gaits of quadrupeds: trot, pace and bound (gallop).[12]

It shows, however, that Tom is an evolutionary misfit, fundamentally out of tune with his environment. For Tom, there is no hope of redemption, no survival and no evolution.

It is not surprising, therefore, that in the course of their evolution, *real* animals have come to deploy a plethora of tools – let us call them timekeepers – for fine-tuning with some or another dynamic aspect of their environment. Many of these are universal and, accordingly, we find them on both ends of the evolutionary scale – in the humble sea urchin as well as in the President of Academia Europaea.

Most of these timekeepers are highly specialized adaptations. They accomplish only one thing, but that they do extremely well. An interesting example of such mechanisms is the gait control of the quadruped (Figure 1). It enables the animal to change gear without effort – from walk to trot, to pace, to gallop (bound) and back – by selecting the most adaptive linkage between the legs.[11, 12]

Importantly, these mechanisms work automatically and, given their evolutionary history, largely in isolation from one another. This does not imply, however, that the resulting behaviour is incoherent. On the contrary, a whole branch of artificial intelligence, known as Mobile Robotics, or Mobotics, is there to prove otherwise.[13]

One of the contraptions that have so far resulted from this line of research resembles an insect, in shape if not yet in intellect. Each of its six legs is endowed with some elementary intelligence, enabling it to do the simple reflex-like things a leg would normally do when left to itself, such as extending itself or withdrawing from touch.[14] Apart from a few linkage rules there is no shared cognitive functionality and no shared representation of the task environment that would keep these legs together. Yet the creature is capable of coherent task-oriented behaviour of some complexity. In the real world the possibilities for the emergence of complex behaviour would have remained somewhat problematic under such austere functional constraints. Fortunately, however, in the course of evolution a miraculous tool emerged: the general purpose representational memory that enables its owners to extract and use information about the world in totally unprecedented ways. Specifically, this kind of memory has made it possible to detect and use *temporal affordances*, cognitive anchors in a world of change and a necessary condition for learning from experience and for planning.

Perhaps the term *affordance*, coined by the psychologist James Gibson[15] and literally

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meaning 'the capacity of providing', requires some explanation. An evolutionary niche experienced by an animal that dwells in it is frequently referred to as the animal's *Umwelt*.[16, 17] Affordances constitute the furniture of an Umwelt. They have been defined as the resources or support that the environment offers an animal, with the *proviso* that the animal, in return, must possess the capacities to perceive them and to use them. Affordances, in other words, offer opportunities. The lampshade in my bedroom affords *sit-on-ableness* to the well-fed mosquito. Similarly, the marble slabs in the ruins of an ancient city offer *sit-on-ableness* to the tired tourist.

Minding our time

Because we live in a world of change, many of the affordances in our Umwelt should be qualified as temporal. In this context, *tuning* is the process of optimally using the many temporal opportunities offered by the world around us. Temporal affordances control our attention – *what* we select from everything that happens around us, and *how long* we will keep it in focus.

The dynamics of attending have been studied at length and in detail by Mari Riess Jones and her group at Ohio State University.[18–20] On the basis of an impressive body of solid empirical data and using tools from non-linear dynamics, they have come up with a substantive theory of the ways we 'attune' to complex events. By doing so, they have, perhaps unwittingly, provided the most successful answer yet to a question that was first asked by Samuel Taylor Coleridge two centuries ago:

> And what if all of animated nature
> Be but organic Harps diversly fram'd
> That tremble into thought? [21]

Jones' answer, summarizing an intricate exposition of her work, sounds almost as poetic as Coleridge's question:

> When one is captivated by an amusing story, excited by a fast-moving soccer game, or inspired by a masterfully conducted symphony, one is engaged by distal happenings that project complex rhythmic flow patterns comprising multiple related temporal components… The coordination of attention with the pulsating flow pattern connects the attender to the originating events in a rather direct fashion… [T]hese events can be attended to more or less efficiently depending on their timing properties… [C]oordinated attending rhythms fashion a crude mime of an event's rhythm, an adaptive attentional cartoon of its shape in time. Thus, by virtue of dynamic mimicry, the attender 'participates' in the rhythm of a remote event. Parts of an attender literally 'match up' with certain time spans in the remote event, and in this sense attending is participatory. The resulting synchrony with temporally structured events functions as a form of direct knowing.[20]

Jones' perspective on dynamic attending reverberates in a press interview that two famed Dutch ballet dancers, Alexandra Radius and Han Ebbelaar, gave on the occasion of their retirement a few years ago. Asked why they had always rehearsed to the sound of music played by mediocre pianists on seriously out-of-tune piano's, instead of using reliable high-quality recorded performances, Mr. Ebbelaar answered that recorded music would have made the already strenuous job of lifting his partner over his head even more strenuous. It would have forced him to stay in tune with the music, rather than the *music* staying in tune with him and

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his partner. He would have risked a slipped disk. Worse, he could have dropped Alexandra – which would have been especially embarrassing as Alexandra happened to be not only his favourite dance partner but also his wife.

Timing our mind

The hum in the basement

The temporal affordances of ballet dancers and other creatures, including even Tom and Jerry, do not materialize in the 'absolute, true and mathematical time' which, according to Newton's famous one-liner, 'of itself, and from its own nature, flows equably and without relation to anything external.'[22] Quite to the contrary, temporal affordances are *embodied* in organic timekeepers in countless ways.

It is impossible to sum up all the mechanisms and processes that qualify as timekeepers. There are genes that express the circadian clock. There are various neuro-anatomical clocks and regulators; you find one right behind the eyes for instance, in the suprachiasmatic nucleus, and another in the cerebellum. The former plays an important role in the control of our wake–sleep cycle, the latter fine-tunes the movements of our limbs. Also, brain potentials, heartbeat, breathing and the biomechanical properties of our bodies contribute to the 'tremblings of our organic harps'.

These timekeepers normally do their work automatically and unawares. They constitute what has been described as 'the hum in the basement'.[23] We cannot be certain that this 'hum' will never penetrate into the drawing room of our conscious life but, like the hum from a central heating system that from our timekeepers is likely to call our attention only when something goes wrong.

Troubled timing, troubled mind

Something may indeed be going terribly wrong for patients suffering from Attention Deficit and Hyperactivity Disorder – ADHD for short. ADHD is characterized by fidgeting, wandering attention and a pronounced inability to concentrate.[24, 25]

Clinical studies of ADHD have indicated a deficiency of the neurotransmitter dopamine accompanied by an involvement of various parts of the brain (prefrontal cortex, cerebellum and basal ganglia) that play a role in the cognitive control of behaviour. These have detrimental effects on the development of some of the patients' cognitive functions. The effects may initially be small and subtle, but unfortunately they tend to be cumulative and they may eventually result in a seriously maladaptive behavioural repertoire.

One characteristic of ADHD is a profoundly disturbed sense of time. Unable to wait for events to take their normal course, patients are likely to engage in impulsive behaviour. They find it difficult to make and accomplish plans. Finally, they have difficulties stopping an action once they have initiated it, which under some circumstances may result in seriously destructive behaviour.

How is ADHD to be coped with? Most experts recommend a mixture of medication[26] with

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cognitive and behavioural training. Such training should specifically address temporal regimentation, as one of these experts stipulates:

> Parents and teachers must aid children with ADHD by anticipating events for them, breaking future tasks down into smaller and more immediate steps, and using artificial immediate rewards. All these steps serve to externalize time, rules and consequences as a replacement for the weak internal forms of information, rules and motivation of children with ADHD […].[24]

This approach may work well, at least if it is initiated at an early age. When children get to the adolescent phase, however, they will already have found means of coping with time in their own way – a way that may turn out to be terribly inappropriate!

How inappropriate is illustrated convincingly in *Borderliners*, a novel in which the Danish writer Peter Høeg recounts the adversities of three highly gifted but seriously disturbed adolescents.[27] As students at *Biehl's Academy*, a prominent but very strict boarding school, they soon find each other in their shared hatred of time. For them, time emerges as the unacceptable, one-dimensional mould the school is applying to them in an attempt to socialize them. The three revolt – with dire consequences, as the reader soon finds out. Years later, looking back in resignation, one of protagonists muses:

> At that place only linear time was permitted, all life and teaching at the school was arranged in accordance with this – the school buildings, environment, teachers, pupils, kitchens, plants, equipment and everyday life was a mobile machine, a symbol of linear time.
>
> We stood on the edge, we had reached the limit. For how far you could, with the instrument of time, push human nature[27]

I have drawn your attention to ADHD because it illustrates how subtle tuning deficiencies may eventually turn into seriously maladaptive behaviour. But there is also another reason. ADHD is rapidly becoming an indiscriminate label for all kinds of boisterous behaviour – especially in the USA, although the trend appears to be spreading. The result is that countless children are put on medication for no valid reason. Recent estimates suggest that between 10 and 20% of children in elementary schools in the USA presently receive medication to calm them down.

I am convinced that most of these children are suffering less from their own hyperactivity than from that of their parents and educators. Parents (and teachers) are becoming so preoccupied with their own affairs that they find it increasingly problematic to pay adequate attention to the children in their care. The result is that, in the end, even a normally active child is considered a fidgeting, unruly rascal. Administering drugs only for the purpose of keeping children below the irritation threshold of the adults in their company remains irresponsible even when it is *à la mode*.

The plasticity of timing

Returning to our basement for one moment, there is one further characteristic of the 'hum' there that I should mention. This is the plastic, or opportunistic, nature of the tuning process. When task conditions change, or when fatigue or boredom sets in, the timing of the task at hand may undergo a drastic change.

As an example, teach a monkey to perform a simple temporal task. Teach it, for instance,

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to nod its head in anticipation of a light being flashed at regular intervals. Next, wrap the monkey in a straightjacket. Understandably, the animal's performance on the task will be seriously affected even though it may still be free to nod its head. The reason for its poor performance is that the animal can no longer make the so-called 'collateral' movements that enabled it to nod at precisely the right moments. After some delay, however, performance will recover when novel linkages between timekeepers unaffected by the straightjacket get established. This illustrates that tuning is indeed a flexible and basically opportunistic, enterprise.

The making of the present

Now, now, now …

With all these tools in place, how do we actually succeed in maintaining contact with our Umwelt? Sixteen centuries ago, Saint Augustine gave the answer: through the present, is the only part of time that is 'given'.[28] His arguments have had a deep and lasting effect on our philosophies of time.

The present, or 'Now' as some prefer to call it, is the privileged focus of human experience. The present is not a durationless, knife-edge between a past that is no more and future that is not yet. It has a certain width, variously estimated to last between, roughly, one-tenth of a second and half a minute. Events seem to 'materialize' in this *time window* and then to recede gradually into the past.[29]

The present allows us to *integrate* the various products of our information processing into coherent, meaningful parcels – scenes, events, frames or ideas. Memory storage and retrieval depend on such 'coagulated', or 'parsed', inputs and outputs. Artists have attempted to capture the coagulation phenomenon. Consider the fascinating painting by Marcel Duchamp, *Nude descending a staircase* (Figure 2).

Most certainly this is *not* how we perceive temporal reality! Or, is it? What for Duchamp was an artistic *trouvaille*, for some brain patients is a tragic reality. Patients suffering from *akinetopsia*, a possible outcome of stroke, are unable to perceive objects in motion. They will find it almost impossible, for instance, to pour a cup of coffee. They see the pot and they see the cup. They can even hold the pot, but what they can't see is the coffee filling the cup. Consequently they also remain unaware of the coffee spilling over the edge. In the company of others, such patients feel insecure because they will be unable to see others moving around.[30]

The present is not the fixed window on reality for which it has long been held. It is dynamically affected by the syntactic and semantic structure of the environment and the actions being performed. Taking these aspects into account, a flexible and dynamic present emerges that can be thought to operate in the following way.[29]

At some instant we are induced to pay attention to a stimulus event, a sudden sound, say, or a light being switched on. This marks the onset of the 'dynamic present', because at this point the process of dynamic attending as described by Jones[19, 20] will begin to evolve, parsing and interpreting events as they unfold. Essentially, this is a continuous process of guessing what will happen next, on the basis of the incoming stimulus information and aided by our experience and expectations. As long as the incoming information confirms these expectations

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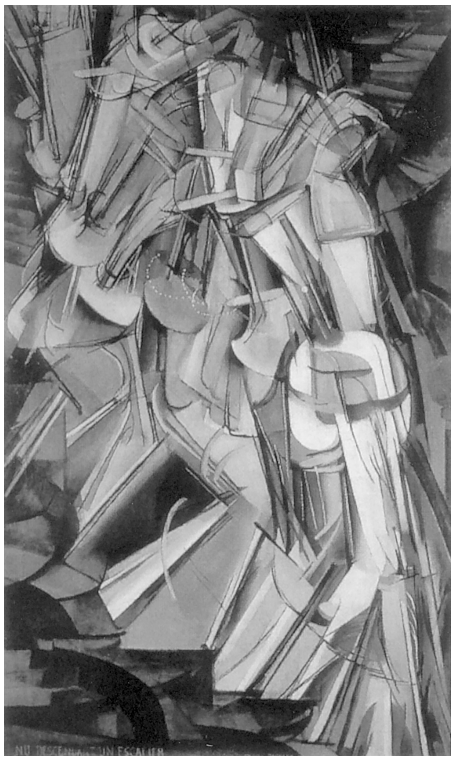


Figure 2. *Nu descendant un escalier* by Marcel Duchamp, 1912 (Philadelphia Museum of Art).

the evolving dynamic present will remain intact and continue growing. However, as soon as a serious mismatch between expectation and reality occurs, the parsing process is instantly interrupted and the current dynamic present is terminated. Its contents are transferred to permanent memory as an image, a phrase, a 'snapshot' of what just went by. At the same time the next present, a new search for interpretable information, is initiated.

Speech segmentation

Language is eminently suited to study this parsing process in minute, almost microscopic detail. Take speech, for instance. Despite its seemingly discontinuous character, speech consists of a continuous pattern of sound energy with no segmentation cues that would enable the listener to determine proper word boundaries.

Figure 3 shows the sound spectra of two Dutch sentences that are homophonic, except for two extra word boundaries in the second sentence: *Voor mij is er geen* ***luisteraar*** (meaning 'Nobody is listening to me') and *Voor mij is er geen* ***luis te raar*** (meaning 'To me no bug looks funny'). Experiments have proved that word boundaries are perceived because the ongoing speech flow simultaneously activates all relevant entries of the mental lexicon. All

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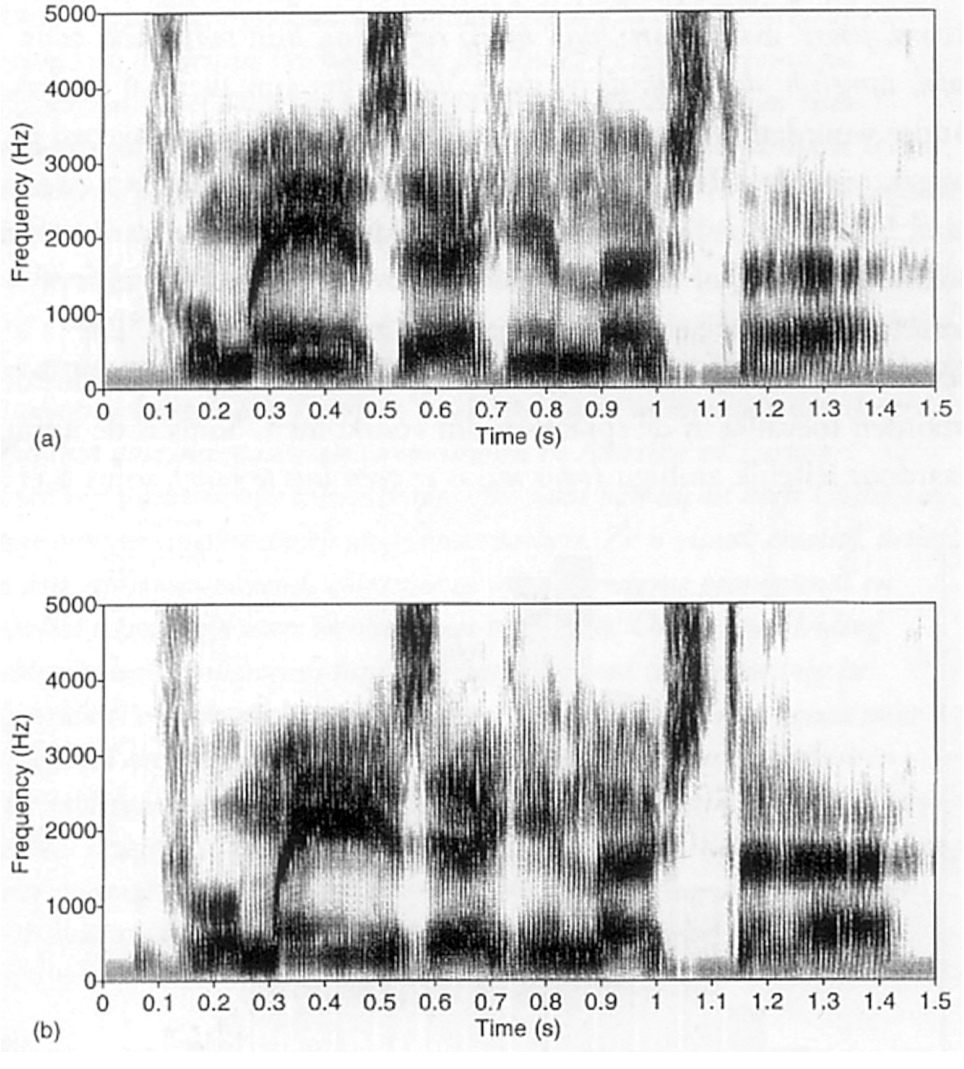


Figure 3. Sound spectra of two homophonous sentences in the Dutch language. (a) *Voor mij is er geen* ***luisteraar***, meaning 'Nobody is listening to me'; (b) *Voor mij is er geen* ***luis te raar***, meaning 'No bug looks too funny to me'.

entries that fail to match this flow will be eliminated one after the other, until a point is reached where a positive identification can be made and the word boundaries fixed. This is illustrated for the word *elephant* in Figure 4.

Sentence comprehension resembles word recognition in many ways, although as a cognitive task it is considerably more complicated. Specifically, if an expected sentence structure is not confirmed, the listener must 'backtrack' and try to restructure the sentence so that it matches the information received so far. This is illustrated by the following two examples:

[1a] The ship sailed to Portsmouth

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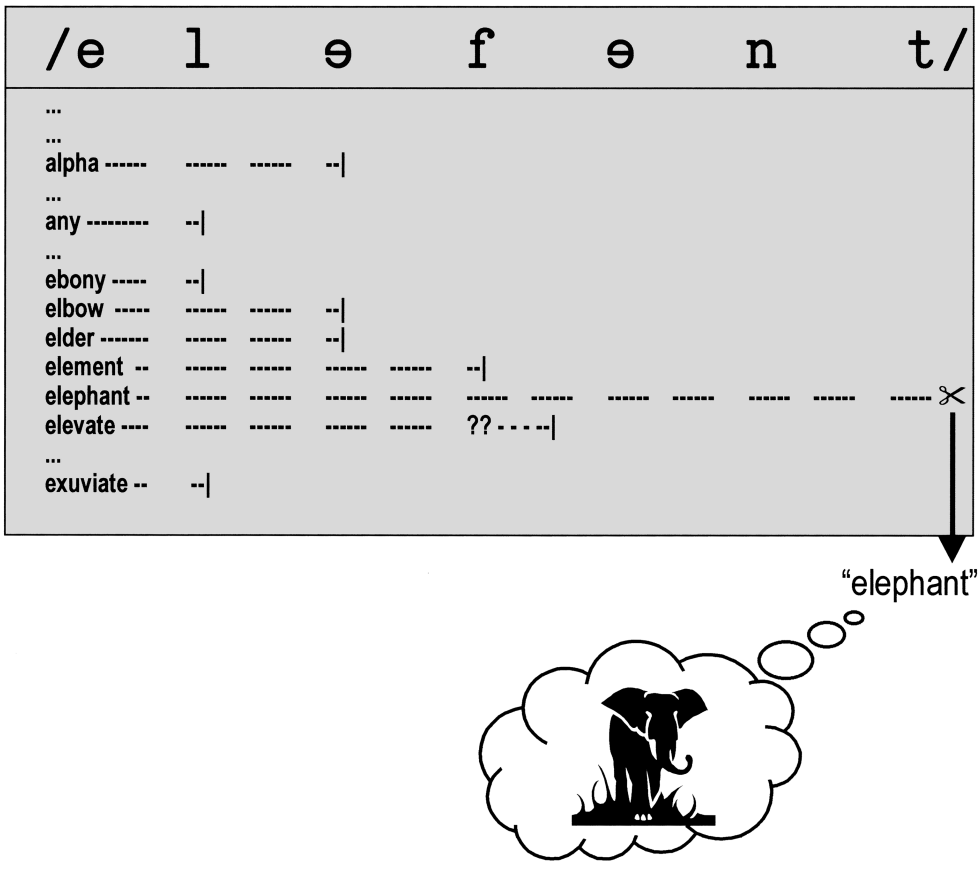


Figure 4. Successive cancellation of lexical entries that do no longer match the ongoing stream of speech sounds pronouncing the word *elephant* (/eləfənt/).

[1b] The ship *sailed to Portsmouth*/sank
[2a] The horse raced past the barn
[2b] The horse *raced past the barn*/fell

The first sentence of each pair simply consists of subject and predicate only. Listening to the second sentence of each pair raises the same expectation as listening to the first, up to the point marked by the slash (/). The expectations are frustrated by the actual predicates – *sank* and *fell* – that follow at the end of these sentences. Thus, the listener is forced to attempt a reinterpretation of the original predicates (the italicized parts of 1b and 2b). These should now be taken as qualifiers (adjuncts) for *ship* and *horse*, respectively.

The time course of the present

The temporal parameters of the dynamic present can be estimated on the basis of a variety of empirical data.[29] Starting from the zero-point at which a dynamic present begins to evolve

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in response to a triggering event, parsing appears to begin as early as 20–25 ms after stimulus onset. At 250–300 ms, the parsing attempt will be aborted if no plausible interpretation has been discerned. This will be the case if the input information is essentially random, or if a lack of relevant knowledge, stress, or other distracting factors prevent a person from properly attending to the input. The upper limit of the dynamic present is set by the capacity of our working memory. To retain information in working memory it must be recycled every 20 to 30 s, which is nearly impossible if, at the same time, we go on attending to newly arriving information.

In summary then, the dynamic present is bounded by the *minimum* time needed for guessing what is happening and the *maximum* period during which we can keep information active in working memory without refreshing it. In everyday circumstances, a dynamic present will usually last between 2 and 5 seconds before it is superseded by the next. Many naturally and culturally determined events have an internal structure, with components or constituents that fall within this range and rhythm, and these are the events that we most easily attend to.

Time regained

Having parsed the incoming stream of information into 'snapshots' that we can retain in memory for later use, we are left with one final question: how do we recover temporal relations from these snapshots?

It is possible these days to give a detailed account of the connection between 'snapshots' and the temporal affordances contained in them. *Shape* is used to recover the past and, as such, constitutes the basis for memory. Michael Leyton has formulated the rules by which the conversion from (present) shape to (recalled) history takes place.[31] In his view, the mind assigns to any shape a causal history explaining how that shape was formed. According to Leyton this process of *history-recovery* is a primary drive, independent of any other goal in life. It implies, for instance, that we cannot help but perceive a deformed beer can as a dented can, a can that once left the beer can factory in pristine, symmetric and a-historical condition.

History-recovery is, in fact, a very common cognitive activity. Archaeologists and historians do it all the time.[32] Chess players of some standing are pretty well able to recover a game by looking at the present arrangement of pieces.[33] Snapshots of windswept trees, of people jumping off fences, portraits, all reveal a host of details of the history that eventually led to the situation they depict.[12, 34] The many self-portraits Rembrandt composed during his lifetime provide the materials for a remarkable illustration of event-history recovery.

So consistent remained the eye of the master over the years that it is possible to recover almost the entire ageing process of the painter. This can be achieved by projecting these self-portraits in chronological order, with the pupils of the eyes and the tip of the nose calibrated.[35] The results are truly stunning. Unfortunately they cannot be reproduced in a convincing way in static images, as Figure 5 painfully shows.

Explicit representations of time

Not all tuning should be attributed to the implicit mechanisms and processes I have emphasized

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thus far. We also use a rich variety of explicit cognitive representations to supply us with a dynamic worldview, a temporal lifestyle.

These explicit representations come in three varieties. First, there are *scenarios*, descriptions of generalized episodes that guide our common behaviour such as, for instance, 'How to walk a dog', 'How to cook a meal when in a hurry' or, perhaps somewhat less common, 'How to win an Olympic gold medal'. Then there are *metaphors*.[36, 37] Some temporal metaphors are as dead as a doornail, such as Ovid's image of Time as the 'devourer of all things',[38] or that of the great popularizer of astronomy Camille Flammarion who saw Time 'pushing the earth towards an ever more remote future'[39] (Figure 6). Other metaphors, however, such as 'Time is money', are alive and kicking.

Finally there are explicit representations that have reached a level of respectability as scientific theories of what goes on in reality. 'People make visions and true visions make worlds', the philosopher Nelson Goodman once wrote.[40] Other speakers at the symposium on *Concepts of Time* have offered lively and pertinent descriptions of some of these 'true visions'. They give me the opportunity to conclude my contribution with a rather extraordinary example, illustrating what may happen if people make a vision that they then try very hard to make true, and by doing so expect to turn it into a world.

Around his twentieth birthday, in 1884, the Dutch novelist and literary critic Lodewijk van Deyssel decided, as he wrote at the time:

> … to impose on myself an iron temporal discipline and to document in minute detail all the mechanical aspects of my intellectual functioning; one and the other with the aim of collecting the building bricks for a science concerning the properties and functioning of my brain. Like the workings of my body (…) the temporal performance in the course of the days of my life may be investigated, in order to achieve as much as possible, an uninterrupted and desired state of mind. I now feel in this existential bureaucracy not more and not less than a (relative) omnipotence.

The rituals that Van Deyssel used to achieve a totally regulated, mechanical life were supported

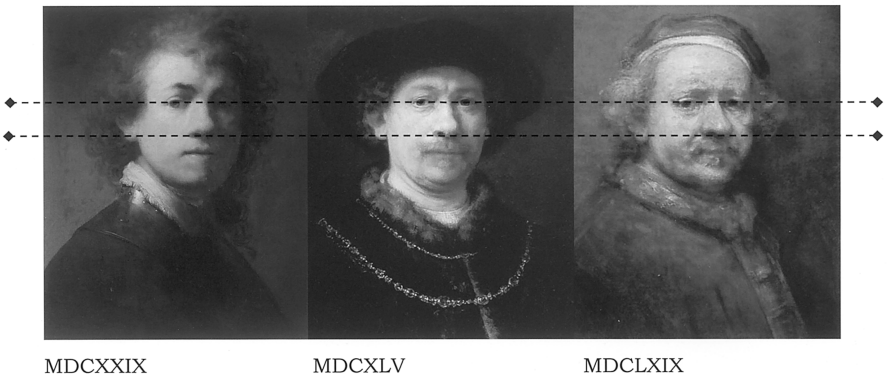


Figure 5. Three self-portraits of Rembrandt, dating from around 1629 (Nürnberg, Germanisches Nationalmuseum), 1645 (Karlsruhe, Staatliche Kunsthalle) and 1669 (London, Kenwood House), respectively. A movie sequence of the (many) known self portraits of the master creates a vivid impression of 'history recovery' applied to the human face.

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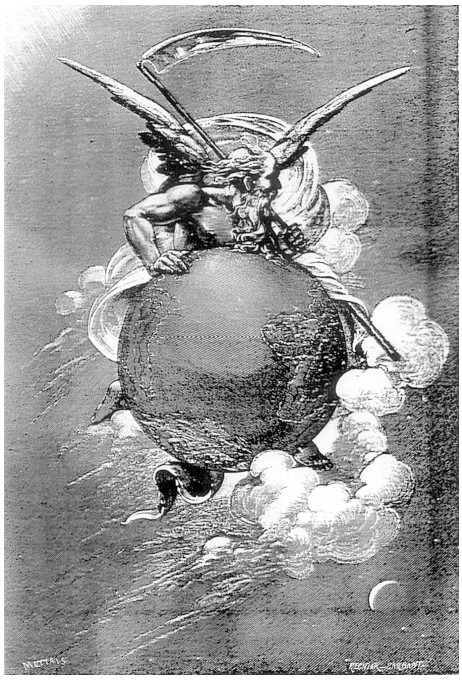


Figure 6. '*Emportée par le Temps, poussée vers un but qui fuit toujours, la Terre roule avec rapidité dans l'espace …*' [39]

by alarm clocks, printed routine orders and memoranda tacked to the bedposts. Yet Van Deyssel's rules and regulations were not immune to failure. And so, in spite of eight impressive precautionary measures taken on the previous night, he succeeded in oversleeping on 29 June1891. 'Among other things,' he wrote, 'because my spouse has neither awakened me, nor told me to rise.'[41]

Epilogue

In 1981, I had the privilege of participating in a very illustrious event that some of the participants will remember as the 'Time Summit'. It was convened by Julius T. Fraser, founder of the International Society for the Study of Time[42] and it took place in the Villa Serbelloni on Lake Como in Italy, once the residence of the poet Pliny the Elder. Among the participants was John Fowles, famed author of *The French Lieutenant's Woman*, *The Magus*, and other novels in which time plays a prominent role.

John didn't say much during the sessions, which lasted all week. Only on the very last morning did he offer an opinion. 'You academics sounded to me like a bunch of no-good boys chasing a little kid,' he said, 'and when you had finally driven him into a corner, you gave him the thrashing of his life.' At the time, this struck me as a devastating criticism of our scholarly attempts at explaining some of the intricacies of Time. Only years later did an appropriate reply occur to me: perhaps we *had* given Time the thrashing of its life, but so

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what?… Isn't Time constantly striking out at *us*, thereby forcing us to find ways of striking back?

What eventually such ruminations will lead to, I don't really care. 'Time the enemy' is only one of the many metaphors we use for making sense of time.[43] There are others that, to me, seem vastly more relevant and it is on understanding what makes these work that we should focus our research.[37, 44] I have tried to convince you of one thing only: *Timekeepers may serve us to keep time, but there is a lot more to time than just keeping it.*

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41. Lodewijk van Deyssel is the *nom de plume* of Karel J. L. Alberdingk Thijm (1864–1952). The quotations and details from Van Deyssel's unpublished diaries were taken from an article by H. G. M. Prick, which appeared in *Hollands Diep*, **1**(5), 28 February 1976.
42. Information about the International Society for the Study of Time can be found at the society's website http://www.studyoftime.org/.
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