theguardian

Search

A stopwatch on the brain's perception of time

Research by neuro-physiologists shows that our emotions affect our awareness of the passing of time

Marc Gozlan
Guardian Weekly, Tuesday 1 January 2013 14.04 GMT

Steady hands? Time appears to pass more quickly when we are busy than when we are bored. Photograph: David Sillitoe

Our perception of time changes with age, but it also depends on our emotional state. Research is steadily improving our understanding of the brain circuits that control this sense, opening the way for new forms of treatment, particularly for Parkinson's disease.

Time is an integral part of our daily life, regardless of whether we are in a hurry, relaxed, gripped by an emotion or bored stiff. We may be walking, driving, listening to music, hearing the phone ring, taking part in a conversation or doing a sport, but time is always there, omnipresent and immaterial. Whereas all our senses – sight, touch, hearing, smell and taste – bring into play specialised sensory receptors, there is no specific receptor for time. Yet it is present in us, our brain being a real timing machine.

"From infancy onwards babies must come to grips with a world marked by recurrent time patterns, learning the length of time, or duration, associated with the various actions they experience every day," says Professor Sylvie Droit-Volet, at the Social and Cognitive Psychology Laboratory (Lapsco) at Blaise Pascal University, Clermont

Ferrand, France. "They react, become agitated or cry, when something they expect does not occur on time: when the mobile over their bed stops turning earlier than usual, when their mother takes too long preparing a feed," she adds.

Very young children "live in time" before gaining an awareness of its passing. They are only able to estimate time correctly if they are made to pay attention to it, experiencing time in terms of how long it takes to do something. "For a three-year-old, time is multifaceted, specifically related to each action," Droit-Volet explains. At the age of five or six a child is able to transpose the duration it has learned to associate with a particular action (pressing a rubber ball) to another (pulling on a lever). "They begin to realise that a single time continuum exists separately from individual actions," she adds.

The awareness of time improves during childhood as children's attention and short-term memory capacities develop, a process dependent on the slow maturation of the prefrontal cortex. To gauge the time required for a task they must pay attention to it. But they must also memorise a stream of time-data without losing concentration. So children suffering from attention-deficit hyperactivity disorder find it hard to gauge time correctly.

One way of improving accuracy is by counting time. "A five-year-old cannot count the passing of time, but can do so if prompted by an adult. But their counting does not really keep pace with the seconds. At the age of eight, children start counting time on their own, keeping cadence, but not till they are 10 will they count time regularly and of their own accord, without input from an adult," Droit-Volet says.

On the basis of our early ability to estimate passing time, researchers suggested in 1963 that time as perceived by our brains (subjective time) was synchronised with the ticking of an internal clock, in much the same way as our daily life is governed by the ticking of our watch (objective time). They modelled a mechanism for measuring time, a sort of internal clock. It consists of a pacemaker, continuously emitting pulses (ticking), which are stored in an accumulator. The subjective duration of time depends on the number of pulses that have accumulated (since the beginning of the stimulus). When the internal clock speeds up, the number of pulses increases, creating the impression that time is passing more slowly.

Furthermore, if you stop paying attention to time, the pulses are blocked and no longer reach the accumulator. As these pulses are not counted, time will appear shorter than it really is. Although the internal-clock model is useful for predicting the behaviour of subjects taking part in psychological research, it is only a metaphor and does not stand up in terms of brain physiology or anatomy.

At the beginning of the century, Professor Warren Meck, at the Duke Institute for Brain Science, North Carolina, developed a more physiologically realistic model. According to the striatal beat-frequency model of interval timing, the representation of time is underpinned by the oscillatory activity of brain cells in the upper cortex. The activity of each oscillator cell is characterised by a specific rhythm. The frequency of oscillations is detected by certain cells in the dorsal striatum, a substructure of the basal ganglia, located at the base of the forebrain.

"Each of these brain cells has up to 30,000 connections with a series of cells in the cortex oscillating at various frequencies. The neurons in the striatum can read time codes emitted by oscillator cells in the cortex. They come into action when oscillatory activity corresponds to previously detected patterns, stored in memory," Meck explains.

Alongside this model, in which estimates of time intervals originate in neuronal activity, the brain structures involved in processing time-related data differ depending on whether they are estimating the duration of a stimulus (explicit timing) or gauging the lapse of time, or interval, separating us from an event expected to occur in a few seconds or minutes (implicit timing).

"For durations ranging from a few milliseconds to several minutes, the processing of explicit and implicit timing does not bring into play the same neuroanatomical regions," says Jennifer Coull, a senior research fellow at the Cognitive Neuroscience Laboratory, at Provence University in Marseille. These differences are due to the fact that "implicit-time processing is almost always used to achieve a motor-task goal – 'Do I have time for a coffee before my meeting?' – whereas explicit-time processing aims to estimate a duration as such", Coull explains. Studies of explicit timing show that two cortical structures, the supplementary motor area, which co-ordinates complex movements, and the right prefrontal cortex, are constantly activated.

It has also been shown that the cerebellum plays a key role in motor tasks requiring perception of implicit timing. Other parts of the brain may be involved in implicit-timing estimates: for example, the left parietal cortex, which manages intended movement, and the left premotor cortex, which plans and organises movement. Sometimes the right prefrontal cortex, usually involved in explicit-timing estimates, is activated for implicit estimates, for instance, when an event does not occur as soon as expected: a traffic light stays red for longer than foreseen. The brain updates its time forecasts, once again anticipating the interval.

In addition, "the regions of the brain involved differ depending on the context, particularly if the stimulus only lasts for a very short time, less than 200 milliseconds," says Coull. The visual cortex is activated when we estimate the duration of a visual stimulus. In the same way, the primary motor cortex comes into play when a timing estimate is associated with an action, whereas the auditory cortex has a part in estimating the length of a sound stimulus.

Above all, the brain's perception of time involves processes linked to memory and attention: witness the impression that time is passing more quickly when we are busy, or doing something amusing or exciting. Time flies even when we are in love. In contrast, a watched pot never boils. Minutes drag by when we are bored.

"On account of the joint contribution of memory and attentional processes, processing by the brain of time-related data can only be based on a functional network, rather than a single region. This certainly explains why there are no neurological or psychiatric disorders characterised exclusively by temporal processing deficits," Coull says.

Dopamine is the main neurotransmitter involved in time processing. Dopamine agonists – compounds that activate dopamine receptors – tend to speed up our perception of time, which passes more quickly. This is also the case for certain drugs, such as cocaine, which enhances the effect of dopamine. On the contrary, the neuroleptics used to treat schizophrenia inhibit its effect, creating the impression that time is passing more slowly.

Recent research by neuro-physiologists and chemists working on time processing is beginning to show how emotions may speed up or slow down our perception of time. In 2011 Professor Droit-Volet and Sandrine Gil, a lecturer on cognition and learning at Poitiers University, France, published a study of how changes in the emotional state of subjects caused by watching films affected their sense of time. The psychologists showed students extracts from films known to induce fear (horror movies such as The Blair Witch Project, Scream, The Shining) or sadness (drama such as City of Angels, Philadelphia or Dangerous Minds). A third category of "neutral" footage (weather forecasts or stock market updates) was also shown. They then asked students to estimate the duration of a visual stimulus.

"Fear distorted time, the stimulus being perceived as longer than it really was," says Droit-Volet. Fear prompted a state of arousal that speeded up the rate of the internal clock. This state also involved dilated pupils, higher pulse rate, increased blood pressure and muscular contraction. It reflects a defensive mechanism triggered by a threatening situation, as the body prepares to act either by attacking or running away. The psychologists observed a similar tendency to overestimate time in three-year-old children exposed to a threat.

But, "quite unexpectedly, sadness does not affect our perception of time, no doubt because the emotion felt when watching a sad film is not strong enough to slow down physiological functions," Droit-Volet explains. However, she adds, work is needed on the profound sadness associated with periods of severe depression. Her team is currently looking at whether the internal clock may slow down in healthy subjects who practise meditation and relaxation. Is it possible they may step outside time in this state?

Gil and Droit-Volet have also worked on the perception of time when the face of someone close expresses a secondary emotion such as shame. Seeing someone looking ashamed prompts the observer to understand the cause of this feeling. "This reflective activity distracts attention from time-processing, so that estimated time seems shorter than it really is," Droit-Volet says. Only after the age of eight, when children have learned the meaning of shame, does this tendency to underestimate time appear.

The theory of embodied mind (or cognition) helps explain how the perception of other people's emotions changes our sense of time. Embodied cognition hinges on an internal process that mimics or simulates another's emotional state, enabling us to tune in and understand their feeling. Accordingly, when a teenager spends time with a senior who speaks and walks more slowly, the young person's internal clock slows down. There is also a subjective slowing of time, which enhances social interaction between the two people.

Droit-Volet and her colleagues have shown that inhibiting this mimicry process by freezing the facial expressions of the observer – simply by putting a pen in their mouth – prevents this empathetic shift. The internal clock remains steady, regardless of the emotion perceived in the other. Other studies have shown that a person who has been "botoxed" has greater difficulty recognising other people's emotional expressions and is less empathetic towards them.

"Our perception of time is very revealing of our emotional state," says Droit-Volet, pointing out that temporal distortion caused by emotion is not the result of a malfunction in the internal clock, but on the contrary an illustration of its remarkable ability to adapt to events around us. She adds: "There is no single, uniform time, but rather multiple times which we experience. Our temporal distortions are a direct translation of the way in which our brain and body adapt to these multiple times, the times of life."

In Durée et Simultanéité, A propos de la théorie d'Einstein (Duration and simultaneity, with reference to Einstein's theory) the French philosopher Henri Bergson explained that "we must put aside the idea of a single time; all that counts are the multiple times that make up experience". In other words our perception of time is always relative.

• *This article appeared in* Guardian Weekly*, which incorporates material from Le Monde*