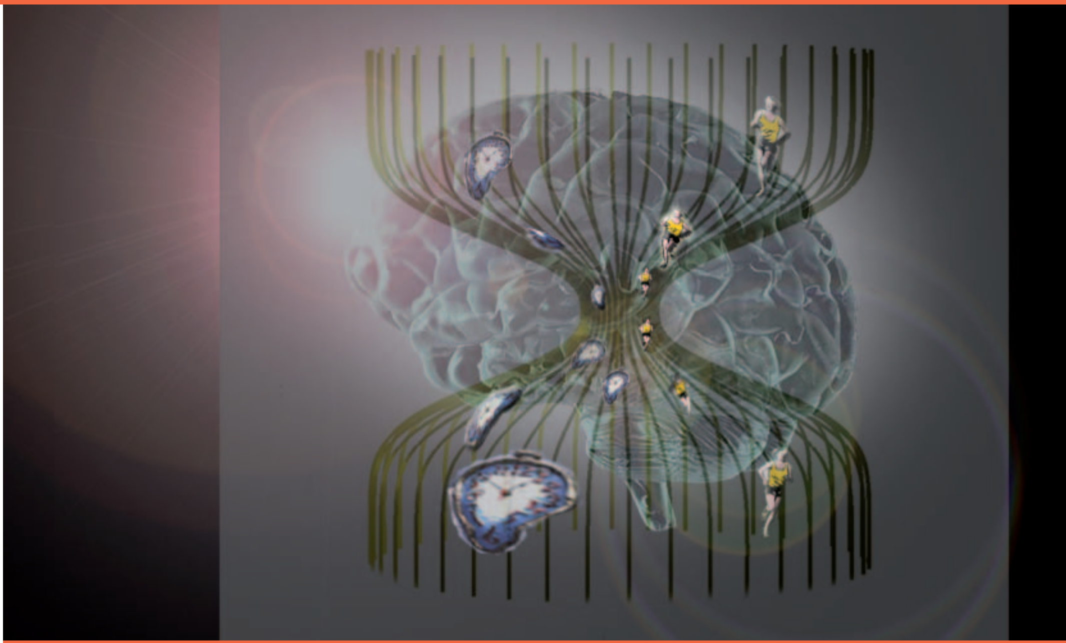
NEST Pathfinder

WHAT MAKES HOLES IN TIME?

MEMORY



When we view the world around us, we observe a stable image, despite frequent rapid body and eye movements. How the brain accomplishes this interpretation remains only partially understood, although it is known to involve short-lived perceptual distortions of space and time. The aim of MEMORY is to explore this complex mechanism and to reproduce it on a distributed computer system. The findings could lead to improved man/machine interfacing, and more sophisticated robots. MEMORY may additionally shed light on our understanding of the neuronal mechanisms, leading to the development of possible aids for diseases related to misperception of external space, such as in Alzheimer's and Neglect patients.

Watching a badly filmed video sequence shot with a camera that weaves, pans and zooms in a haphazard manner, can be an almost nauseating experience. Yet, although our own eyes roam about in much the same way when looking at everyday scenes, the brain automatically compensates for the shifting viewpoint and focus. We see a stable image, and can make valid judgments about the spatial relationships between the objects we see.

In observing the world, frequent small and jerky involuntary eye movements known as 'saccades' constantly change the images falling on the retina. Psychophysical studies by members of the MEMORY consortium and others, have shown that perceptual thresholds (particularly for motion) are raised during saccades, which implies a damping of the visual pathway at these times.

In addition, there is a transient distortion – by shifting or compression – of the objects in view. For example, locations may be spatially offset in the direction of the saccade target, and objects parallel to the path of the saccade appear squashed. The MEMORY team hypothesises that the effects are probably part of the process of neuronal integration of successive image captures.

More intriguingly, a phenomenon revealed by recent work is that time perception is also distorted in a similar fashion. A simple test of this fact is to look at your own eyes in a mirror, switching the gaze repeatedly between the left and right eye reflections. Each eye movement can take tens of milliseconds; although an observer can see the movements, you never will. What happens during the apparent gaps in time?

Cerebral relativity

The premise under investigation is that the distortions are relativistic – like consequences of the rapid remapping of neurones to compensate for the changes in retinal position produced by eye movement.

> “An integrated environment that combines real-life perceptual information with the virtual cyberworld.”

Experiments conducted on macaque monkeys reveal that the receptive fields of some neurones in the lateral intraparietal area (LIP) of the brain change position before each saccadic eye movement, effectively anticipating its consequences. Subsequently, the same LIP neurons have been strongly implicated in encoding time when the monkeys are performing cognitive tasks. This remapping is surprisingly fast compared with neural transmission time, but not instantaneous. The postulated relativistic effects may occur when the speed of remapping approaches the physical limit of neural information transfer.

In a parallel to Einstein’s landmark theory of physics, it appears that the brain treats space and time as strongly interdependent, and that the neural coding of time may vary with spatial location. Confirming the responsible mechanisms is crucial in understanding how visual stability is achieved.

MEMORY brings together four partner institutes representing Italy, Germany and Switzerland. Italy’s Libera Università ‘Vita Salute S.Raffaele’ (UHSR) and Philipps-University in Germany specialise in neuroscience, while the University of Applied Sciences of Southern Switzerland and the Italian National Research Council specialise in Information and Communication Technology. Under the coordination of UHSR, they will collaborate by performing direct psychophysical and electrophysiological measurements on monkeys and humans, and then carry out computer modelling of the findings on networked control systems (NCSs).

Visual perception is considered to be a distributed function, rather than under the control of a central bodily clock. The use of NCSs for modelling is therefore particularly appropriate since these, too, are distributed systems operating in real time with interacting sensors, actuators and controllers connected by wired or wireless networks.

Strong analogies with human perceptive errors can be seen in such systems, because transmission and processing speed limitations result in time-dependent aberrations, such as delays, jitter and information losses. The sophisticated and modern methods used in this field could thus prove equally useful in investigating the basis of visual stability.

Time perception over fine scales is fundamental to many aspects of our lives, including speech recognition and production, motion perception, sound localisation and motor coordination. A common framework of measurement techniques for the neurosciences, pervasive computing, communications and robotics would also be adaptable to the study of these and other multidimensional phenomena, which are mediated by human interpretation and perception. It has further relevance to the understanding of attention and memory.

Merging the real- and cyber-worlds

Ultimately, the goal is to define an integrated environment that combines real-life perceptual information with the virtual cyberworld. It could then become possible to devise models that compensate for human decisional errors in virtual support environments. Conversely, computerised analysis of the neural processes may provide ideas for innovative communication protocols, leading to more human-like machines and robots.

AT A GLANCE

Official Title
Measuring and Modelling Relativistic-Like Effects in Brain and NCSs

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Einstein showed that for physical systems moving near the maximum speed of information transmission, space-time becomes distorted. Recent studies show that similar effects may occur in the brain: when neural representations are moved near the maximal speed of neural information transfer, space-time in the brain becomes distorted, manifested in weird perceptual effects.