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PRESS RELEASE

How the Brain Builds the Present Through the Lens of the Past

A SISSA study identifies a cortical mechanism that integrates recent sensory experience with incoming information, shaping perception from moment to moment.



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Why does the same sensory stimulus sometimes feel different depending on what came before it? In a study published in Science Advances, a team of neuroscientists at SISSA-Scuola Internazionale Superiore di Studi Avanzati has identified a neural mechanism that helps explain how recent experience shapes present perception: a frontal cortical area carries a memory trace of previous sensory events and combines it with current sensory input. Crucially, recent experience shifted how neurons represented the current stimulus, matching the shift in how it was perceived, directly linking cortical activity and perception. The study reveals where and how the brain embeds the present within a broader temporal context, providing new insight into the neural basis of perception and decision-making.

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“Perception is often thought of as a direct mapping of the external world,” explains Mathew Diamond, cognitive neuroscientist at SISSA. “Yet what we experience depends not only on what is happening now, but also on what happened moments ago. In short, every percept is constructed against a backdrop of recent experience.”

One manifestation of this principle is a phenomenon known as serial dependence. “Imagine feeling a vibration with your fingertip (for instance, from the cell phone) and then feeling a second vibration shortly afterward,” Diamond continues “The second stimulus will not be experienced as an independent event; instead, perception is systematically biased by prior inputs. The brain, in effect, carries traces of the recent past into the present. Perception is not a photograph of the world,” the scientist concludes. "It is more like a film, in which the experience of each frame is influenced by those that came before."

Understanding where and how this integration between past and present occurs has been a longstanding challenge. Theories of predictive processing propose that the brain continuously combines incoming sensory information with expectations derived from prior experience. However, the neural mechanisms that merge these two sources of information have remained unclear.

To investigate this question, a group of researchers at SISSA, led by Diamond, recorded the activity of hundreds of neurons in rodents while they performed a sensory categorization task, judging tactile inputs as weak or strong. Trial by trial, recent sensory experience systematically influenced perceptual judgments: stronger previous stimuli biased subsequent judgments towards weak, weaker previous stimuli in the opposite direction.

“The key finding emerged from comparing two cortical regions,” explains Iacopo Hachen, first author of the study published today in Science Advances. “Activity in primary sensory cortex mainly reflected the stimulus currently being processed, a direct representation of the ongoing input. By contrast, neurons in a frontal cortical area carried information about both the current stimulus and recent sensory history. There, neural representations of the present were embedded within a context established by the past,” Hachen continues “Variations in this frontal-cortex activity predicted corresponding variations in perceptual judgments from one trial to the next, suggesting that while sensory cortex faithfully reports the ongoing input, frontal cortex integrates that input with recent experience to shape perception.”

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The researchers also identified a possible cellular mechanism underlying this process. Their results suggest that a specific class of inhibitory neurons helps the brain combine present and past sensory information, allowing context to shape perception. The work also revealed an unexpected transformation in how memories are stored. Neural representations in frontal cortex initially encoded a stimulus as an ongoing sensory event, but as soon as the animal committed to a judgment, the coding scheme shifted into a distinct memory-like format that persisted and influenced subsequent decisions. This transition suggests that the brain actively reformats experience as it moves from perception into memory.

"Our findings suggest that the brain does not treat each moment in isolation. Instead, the recent past becomes part of the neural representation of the present, a unitary construct that mirrors our experience," concludes Iacopo Hachen

More broadly, the study points to a fundamental principle of brain function: perception emerges from an ongoing dialogue between incoming sensory evidence and traces of the recent past. Understanding this interaction may help clarify how predictive processing normally supports behaviour and how it may become disrupted in neurological or psychiatric disorders.

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