The brain's data compression mechanisms: Neurons subtract images and use the differences

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Data compression in the brain: When the primary visual cortex processes sequences of complete images and images with missing elements – here vertical contours – it “subtracts” the images from each other. Thereby, the brain computes the differences between the images. Under certain circumstances the neurons forward these image differences (bottom) rather than the entire image information (upper left). Credit: © RUB, Bild: Jancke that's the information volume transmitted every second with every quick eye movement from the eye to the cerebrum. Researchers from the Ruhr-Universität Bochum (RUB) and the University of Osnabrück describe the way those data are processed by the primary visual cortex, the entry point for the visual information into the brain, in the journal *Cerebral Cortex*. Deploying novel optical imaging methods, they demonstrated that the brain does not always transmit the entire image information. Rather, it uses the differences between current and previously viewed images.

Efficient reduction of data volumes

Researchers have hitherto assumed that information supplied by the sense of sight was transmitted almost in its entirety from its entry point to higher brain areas, across which visual sensation is generated. "It was therefore a surprise to discover that the data volumes are considerably reduced as early as in the primary visual cortex, the bottleneck leading to the cerebrum," says PD Dr Dirk Jancke from the Institute for Neural Computation at the Ruhr-Universität. "We intuitively assume that our visual system generates a continuous stream of images, just like a video camera. However, we have now demonstrated that the visual cortex suppresses redundant information and saves energy by frequently forwarding image differences."

Plus or minus: the brain's two coding strategies

The researchers recorded the neurons' responses to natural image sequences, for example vegetation landscapes or buildings. They created two versions of the images: a complete one and one in which they had systematically removed certain elements, specifically vertical or horizontal contours. If the time elapsing between the individual images was short, i.e. 30 milliseconds, the neurons represented complete image information. That changed when the time elapsing in the sequences was longer than 100 milliseconds. Now, the neurons represented only those elements that were new or missing, namely image differences. "When we analyse a scene, the eyes perform very fast miniature movements in order to register the fine details," explains Nora Nortmann, postgraduate student at the Institute of Cognitive Science at the University of Osnabrück and the RUB work group Optical Imaging. The information regarding those details are forwarded completely and immediately by the primary visual cortex. "If, on the other hand, the time elapsing between the gaze changes is longer, the cortex codes only those aspects in the images that have changed," continues Nora Nortmann. Thus, certain image sections stand out and interesting spots are easier to detect, as the researchers speculate.

"Our brain is permanently looking into the future"

This study illustrates how activities of visual neurons are influenced by past events. "The neurons build up a short-term memory that incorporates constant input," explains Dirk Jancke. However, if something changes abruptly in the perceived image, the brain generates a kind of error message on the basis of the past images. Those signals do not reflect the current input, but the way the current input deviates from the expectations. Researchers have hitherto postulated that this so-called predictive coding only takes place in higher brain areas. "We demonstrated that the principle applies for earlier phases of cortical processing, too," concludes Jancke. "Our brain is permanently looking into the future and comparing current input with the expectations that arose based on past situations."

Observing brain activities in millisecond range

In order to monitor the dynamics of neuronal activities in the brain in the millisecond range, the scientists used voltage-dependent dyes. Those substances fluoresce when neurons receive electrical impulses and become active. Thanks to a high-resolution camera system and the subsequent computer-aided analysis, the neuronal activity can be measured across a surface of several square millimetres. The result is a temporally and spatially precise film of transmission processes within neuronal networks.

More information: N. Nortmann, S. Rekauzke, S. Onat, P. König, D. Jancke (2013): Primary visual cortex represents the difference between past and present, *Cerebral Cortex*, DOI: 10.1093/cercor/bht318

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