

Pupil Dilation Marks Decision Making

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The eyes may be the windows to the soul, but the simple pupil--the circular opening at the center of the eye that contracts and dilates to regulate the amount of light the eye receives--offers a remarkable portal to the inner workings of the brain. Such is the conclusion of neurobiologist Christof Koch of the California Institute of Technology and his colleagues, who have found that changes in pupil diameter correspond to the moment when a simple decision is made.

Koch, the Troendle Professor of Cognitive and Behavioral Biology and professor of computation and neural systems and the author of *The Quest for Consciousness: A Neurobiological Approach*, working with former postdoc Wolfgang Einhäuser of the Swiss Federal Institute of Technology and Olivia Carter of Harvard University, discovered the phenomenon in volunteers viewing ambiguous stimuli. These stimuli, or "percepts," consist of images or sounds that can be correctly interpreted in either of two forms, such as the famous optical illusion of a young girl wearing a feathered hat. The image morphs into a picture of an old crone, and vice versa.

Another, more straightforward example, used in the current study, is the so-called "Necker cube," a simple line drawing consisting of two connected but offset squares that form an interlocking cube. The cube can appear to either jut out from the page, or to be inverted into the page.

Either interpretation is correct, but because both cannot be seen simultaneously, our brains will flip back and forth repeatedly between

the two. "Essentially, the switch occurs so that our brain can check out the other one," says Koch. "Bistable percepts are fascinating because nothing changes in the real world. Everything changes in your head."

In their experiment, the researchers presented six volunteers with four types of ambiguous stimuli. Three were visual--including the Necker cube--and one was auditory (a sound that could be interpreted as either a single tone or two separate ones). The volunteers viewed or listened to the stimuli--and pressed a key on a keyboard when a perceptual shift occurred-- when the Necker cube flipped from inverted to outward, for example, or back again. At the same time, infrared eye-tracking software measured the diameter of the subjects' pupils.

The scientists found a significant increase in the diameter of the pupil at the instant preceding the perceptual switch. The pupil, which is about 2 mm wide in bright light, dilated by as much as 1 mm at that moment--a change that, in theory, could be noticeable to a casual observer. Koch and his colleagues also found that the more the pupil dilated, the longer the period of time before the switch from one interpretation to the other

Pupils dilate and contract not just in response to light levels, but also depending on the chemical state of the brain. For example, drugs such as opiates cause the pupil to constrict to pinhole size, while the drug MDMA, or "ecstasy," causes it to dilate. In the normal body, the pupils dilate largely in response to norepinephrine (or noradrenaline), the neurotransmitter responsible for our "flight or fight" response to dangerous situations. Because the subjects' pupils dilated at the moment their brains decided between one form of the ambiguous stimuli and the alternative, the scientists say, norepinephrine may also be important in rapid, unconscious, low-level decisions--including what we see from one moment to the next. The pupil-dilating effect also may explain the ability of some professional poker players to detect "tells"--information about their opponents' cards--by looking at the other players' eyes.

"The pupil is not only there to regulate light, but is linked to our emotional state. This may have evolved for us to monitor the emotional state of others, and may offer a very simple way to track decision-making in general," says Koch.

The paper, "Pupil dilation reflects perceptual selection and predicts subsequent stability in perceptual rivalry," was published in the early online edition of the *Proceedings of the National Academy of Sciences*.

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