Neural adaptation helps maintain image quality and perceptual constancy in aging eyes

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in Barcelona

VISUAL neuroadaptation effects can strongly change judgements of image focus and thus may be important for understanding the perceptual consequences of refractive errors, the correction of these errors, and how vision changes with aging, according to Michael Webster PhD.

"Almost any stimulus you can think of will induce a change in visual coding. Conversely and more importantly, if the observer changes while in the same environment, which is just what happens in aging, there are compensatory adaptive changes to balance that out. Visual coding is not a static system, but highly adaptable," said Dr Webster at the Congress of the International Society of Presbyopia.

Adjustments in the brain's visual coding to changes in the environment or the observer fundamentally determine how the world ‘looks’ to the observer. Perceptual adaptations result from changes in the highly adaptable visual coding mechanisms, and are best illustrated by visual ‘after-effects’, such as motion-, tilt-, and figural- after-effects.

A well-known motion after-effect occurs when watching the movement of black and white spiralling curves. The outward spiralling motion seems to continue even when the lines have stopped moving and represents an adaptation of the visual system. Similarly, if you stare at a tilted line and then at a vertical one, visual compensation mechanisms actually cause the vertical line to appear somewhat tilted in the opposite direction, after having adjusted and gotten used to the original tilted line. After just a few seconds’ exposure to a new stimulus, there will be dramatic changes in how the brain processes visual information, Dr Webster observed.

Adaptation occurs at all levels of the visual system, from the retinal photoreceptors to the motor neurons. In fact, adaptation is an intrinsic property of neurons. Chromatic adaptation reflects peripheral sensitivity changes, for instance, while adaptation to faces may involve neural response changes at high levels of visual coding.

Adaptation in the aging eye

Dr Webster noted that the visual system corrects intrinsic and external errors, essentially recalibrating the visual system, to allow us to see the world as a stable place in spite of changes in neural sensitivity. A adaptation may compensate for a mismatch between visual responses and expectations about the environment. Perceptual constancy provides stable perceptions despite variations in the observer (eg, during aging), he said.

"Observer changes that occur with age include changes in lens pigmentation, due to density changes that come about in increments throughout life. We have increasingly less sensitivity for short wavelengths as we age, therefore, what seems white when you’re younger should appear yellow when you’re older," he noted.

However, a recent study showed that observers of all age groups did not in fact see white any differently or any more yellow than one might expect, thanks to adaptive changes. Despite large changes in spectral sensitivity, the perception of white remained nearly constant during aging.

Similarly, the perception of white following cataract surgery reveals a slow renormalisation to the environment as patients’ eyes adapt to their new lens. The results reflected the fact that our eyes continue to adjust to changes and create images that are ‘constant’, whether the changes are external or occur in the observer.

Dr Webster noted that in his investigations on visual adaptation and the perception of image blur, evidence was yet again strongly supportive of the brain’s adaptive capability. He explained that natural images have a characteristic spatial structure to which the visual system is matched. Mismatches between visual sensitivity and the spatial structure of scenes are more likely to arise from changes in the observer, due to refractive errors, neural sampling and developmental changes, he said.

"What people perceive as focused changes following adaptation to a blurred or sharpened image. Staring at a blurred image causes a ‘correctly’ focused image to appear to sharp, while sharpened images causes focused images to appear blurred. This may reflect a change in how the visual cortex codes spatial information, so that what is perceptually focused is the amount of blur you are currently exposed to. Perceived focus of an image can also be affected by whether the surrounding context is blurred or sharpened. This blur induction, in fact, may underlie the photographic technique of using a narrow depth of focus in portrait photography. By surrounding something physically focused with a blurred background, it appears sharper. Interestingly, images appear better focused to the observer when filtered by his own specific optical aberrations, according to one study by Dr Pablo Artal. People with higher order aberrations preferred to see stimuli according to their own aberration, and adapted more easily to see images according to the imperfections of their own eyes."

Dr Webster noted that adaptation to blur had some interesting functional consequences. A study suggests that induced blur, or defocus, caused improved vision through neural adaptation. Changes in perceived blur were very robust across study participants, he noted.

However, changes in thresholds are small and less consistent than the changes that adaptation produces in the perception of focus. This highlights the fact that the adaptation may be more important for maintaining perceptual constancy than for optimising visual acuity.

Dr Webster noted that visual adaptation could maintain constancy for image focus throughout the patient’s lifespan, in the same way as chromatic adaptation maintains colour perception.

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Interestingly, the strength of blur adaptation is similar in older and younger observers. Also, corrected presbyopes tend to judge near stimuli as ‘too sharp’ compared to younger observers, he said, perhaps reflecting an adaptation in older observers to increased blur in near viewing. Consistent with this, a recent study found that blur adaptation may be contingent on the perceived viewing distance, as the after-effects differed when subjects were adapted to different levels of blur in ‘near’ and ‘far’ objects.

Current research suggests that the processes of adaptation remain stable across the lifespan and may be important for maintaining subjective image quality and perceptual constancy despite large losses in visual sensitivity with aging.