

Is there more to adaptation than meets the eye?

Solomon, Roach, Arnold

How would you explain adaptation to a five-year-old? We might say that adaptation is the way things appear to change, after long or repeated contact with them. Adaptation happens with just about anything, from loud sounds to bad smells and annoying siblings. Loud sounds may become less distracting. Bad smells may become less stinky, and siblings may become less annoying, especially if they no longer seem to be quite so loud or stinky.

With time, this explanation would likely lead to more questions. Does adaptation always reduce sensitivity? Does adaptation do anything else? My siblings are always around. Why do they still annoy me?

We would struggle to answer any of these questions with confidence, and that uncertainty motivates this special issue. Adaptation has been studied for more than a century, yet there is still no single account of what it does, how it operates across different levels of processing, or what functional role it serves. The contributions brought together here tackle these questions from multiple perspectives, using aftereffects as both tools and phenomena of interest.

Rather than offering a comprehensive review of the field, for which we direct readers to Webster (2015), this editorial highlights several themes that emerge across the contributions: suppression and facilitation, recalibration of perceptual norms, the functional consequences of adaptation, and the dynamics of adaptation over time.

Mechanisms of negative afterimages

Adaptation is often described as a redistribution of sensitivity across populations of neurons, most typically initiated by a reduction in responsivity in neurons tuned to the adapted stimulus. As a consequence, perception can shift toward stimulus features represented by other, unadapted neural populations. A familiar example is opponent coding, in which imbalances between channels tuned to different features can bias subsequent appearance. However, the existence of opponent mechanisms does not guarantee that changes in perception following adaptation can be fully predicted from their activity alone.

In this special issue, Sun et al. (*in press*) examined chromatic afterimages using a colour space constructed according to Hering's opponent colour theory. Despite clear evidence for colour opponency in the visual system, including in the retina, their results suggest this framework cannot fully account for the appearance of chromatic afterimages. To explain their findings, Sun et al. appeal to higher-order colour mechanisms, likely operating at cortical stages of processing. This interpretation contrasts with recent arguments by Witzel (2025), who proposes that colour afterimages can be explained entirely by adaptation at the level of cone photoreceptors. Together, these contrasting accounts highlight open questions about how opponent coding is integrated across levels of visual processing.

Facilitation of visual performance through adaptation

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A straightforward way in which adaptation could enhance an organism's sensitivity to a target is by reducing its sensitivity to everything else. Schwarz et al. (2026) provide a clear demonstration of this principle in the visual system of dragonflies. Repeated stimulation, stimulation that elicits stronger responses, or stimulation that was more consistent in contrast, direction, or trajectory, drove progressively reduced responsiveness in target-detecting neurons, accompanied by an increased behavioural preference for stimuli that activate other neurons. The authors reasonably conclude that adaptation strength is modulated by stimulus saliency. However, the term "saliency," may be misleading here, as it implies a role for perception. What Schwarz et al. have demonstrated more directly is a relationship between the magnitude of stimulus driven activity during adaptation and the degree of subsequent suppression. Such activity need not be accompanied by awareness, as illustrated by dissociations between adaptability and perceptual awareness in the magnocellular system, for example when flicker beyond the critical fusion frequency drives adaptation without a corresponding percept (Shady, et al. 2004, Jovanovic et al. 2025).

Wissig et al. (2013) exploited adaptation's attenuation of adapted detectors to facilitate the detection of targets that stimulate unadapted detectors in a visual search task. In this special issue, Shareef et al. (*in press*) extend this approach to blur perception, showing that adaptation can facilitate the detection of regions containing increased blur embedded in otherwise moderately blurred images. Notably, this facilitation was confined to targets near the adapted level and did not extend to regions that were already highly discriminable, such as those with extreme levels of blur. A further demonstration that adaptation can facilitate visual search is provided by Shareef et al. (*in press*). Ethnically White observers adapted to ethnically Asian faces, and were then required to search amongst a set of facial images for a target with the most ethnically White features and/or the least ethnically Asian features. In contrast to their results with blur, adaptation in this task produced a benefit in response time but not in accuracy. Although a full computational model of performance lies beyond the scope of this study, the authors suggest that this pattern might reflect a recalibration of perceptual norms, rather than a change in discriminability. This interpretation raises the possibility that ethnic features are encoded by opponent mechanisms at some stage of visual processing.

Millard et al. (2026) also examined whether adaptation can enhance sensitivity, by focusing on the aftereffects of dark adaptation on size distance scaling. Specifically, they asked whether dark adaptation's putative enhancement of depth perception in low-lighting conditions would translate into a more proportional relationship between an afterimage's apparent size and distance. Dark adaptation produced a modest improvement in this relationship, but the scaling remained far from the near veridical performance observed for real objects.

Perceptual recalibration

Returning to the first of our hypothetical five-year-old's questions, we can now be confident that adaptation does not always reduce sensitivity. Several papers in this special issue highlight the visual system's capacity to maintain, and in some cases

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enhance, sensitivity to differences around the adapted level. Karjack et al. (2025), for example, report enhanced sensitivity to differences in motion direction following bidirectional adaptation. They interpret this effect as evidence for a form of perceptual recalibration. Related insights come from studies of motion aftereffects, which can remain striking even when discriminability is unaffected by adaptation. Morgan et al. (2011) attributed this dissociation to the subtraction of signal from the adapted half of the opponent mechanism thought to mediate direction discrimination. Addition of signal to the unadapted half seems an equally good model. Perhaps the bidirectional adaptation studied by Karjack et al. (2025) adds signals to both halves of an opponent mechanism. Sensitivity enhancements would then be expected if those signals helped the mechanism to exceed some kind of sensory threshold.

The opponency attributed to directionally selective neurons might have analogues in spatially selective neurons, such that imbalances in stimulation appear as a boundary between different visual stimuli. As with the directionally opponent pair, prolonged stimulation of half the spatially opponent pair might result in signal added to the unadapted half. If this “filling-in” were sufficiently strong, the boundary could completely disappear. A phenomenon of this nature was studied by Otten et al. (2026), who (like Morgan et al., 2007) reported psychophysical correlates of filling-in, after the restoration of uniform stimulation. Adaptation to different textures in central and in peripheral vision caused the boundary between these textures to disappear, and the peripheral texture was found to resemble the centre’s adapting texture several seconds after that texture had been replaced by the periphery’s adapting texture.

Another form of perceptual recalibration, audiovisual temporal recalibration, has become increasingly relevant in everyday experience, not least through exposure to asynchronous online media. Coupled with the different conduction latencies of auditory and visual signals in the human body, these delays mean that veridical perception of audiovisual timings would require continual adjustment. Without such adaptive calibration, apparent asynchronies might be pervasive, unless the expanse of physical timings across which asynchrony can be discerned is considerable. Wang and Ichikawa (2025) used auditory and visual stimuli with durations that allowed clear discrimination between onsets and offsets. They found that recalibration of onset asynchronies did not transfer to offset asynchronies, and vice versa, implicating separately adaptable mechanisms. Moreover, recalibration was observed only when changes in the auditory signal preceded corresponding changes in the visual signal. The authors suggest that this asymmetry might reflect on the greater conduction latency of visual signals, such that attention to audiovisual asynchrony is required for recalibration to occur. If so, temporal recalibration may differ from motion adaptation, which appears to be largely insensitive to attentional factors (Morgan, 2011; Wolgemuth, 1911).

Recalibration of visual space

Another aftereffect that does not seem to depend on attention, or even awareness, is discussed by Jovanovic et al. (2025). They report evidence for a compression of visual space following magnocellular stimulation by flicker, including flicker that is invisible, or nearly so. Their evidence comes from an experiment in which participants were required

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to estimate the separation between a pair of dots. As the authors note, “adaptation reduces the value of the metric in an analogous way to the reductions seen in perceived contrast.” This finding implies that the computations used to estimate spatial separations may share common mechanisms with those used to encode other quantities influenced by flicker, raising the possibility that such metrics are more generally adaptable.

The separation between stimuli in visual space is famously labile, even when those stimuli are confined to the fronto-parallel plane. One manifestation of this is “pseudoneglect” (Bowers & Hellman, 1980), whereby targets to the left of the vertical meridian are perceived as further from it than equidistant targets to the right. Tyson et al. (*in press*) show that this perceptual bias can be modified by fixation position during adaptation. Following 30 seconds of fixation on a target to the left of the observer’s midline, pseudoneglect is exacerbated, whereas fixation on an equidistant target to the right reverses the bias. Notably, both adaptation stimuli produce similar retinal images, consisting simply of a fixation spot in an otherwise dark room.

Recalibration of other visual features

Adaptation has been described as the psychophysicist’s microelectrode (Frisby, 1979). Whereas physiologists can infer a neuron’s preferred stimulus by directly measuring its responsivity with a microelectrode, psychophysicists can infer the properties of perceptual mechanisms from systematic biases following adaptation. One such bias reported by Kudaka et al. (2026) is particularly striking. After adapting to a set of moderately happy faces and moderately angry faces, subsequently viewed sets of very happy faces and very angry faces appeared even more extreme. This pattern suggests the existence of a mechanism tuned to intermediate levels of variance in facial expressions, consistent with the results of conceptually similar investigations that have examined adaptation to other facial features, such as facial identity and gender (e.g. Storrs & Arnold, 2015). This result is noteworthy not simply because expression variance is a dimension infrequently studied in visual perception, but because mechanisms preferring moderate levels of variance in other visual dimensions seem to be absent. For example, Georgeson (1985) did not find any bias toward textures of more extreme luminance variance following adaptation to moderate levels of contrast.

Of course, aftereffects of adaptation might be subtle, and psychophysicists lack direct access to neural activity of the kind available to physiologists. The appearance of a stimulus must therefore be inferred from behaviour, and the most straightforward approach is to ask participants what they see. But subjective reports are vulnerable to non-perceptual influences such as expectation effects (Rosenthal & Rubin, 1978). The one sure-fire way of distinguishing perceptually based aftereffects from expectation effects is to adapt a roomful of undergraduates. If the aftereffect is accompanied by a loud gasp of surprise, it is fair to assume that the students were *not* expecting to see what they saw! Distinguishing perceptual aftereffects from decisional or strategic biases remains a central methodological challenge in this area.

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Mueller et al. (2026) explored the viability of a potentially more objective measure of aftereffect strengths using eye movements. Observers were tasked with discriminating between artificially compressed and artificially elongated celebrity faces. Although adaptation influenced fixation patterns, with longer fixations on compressed faces following adaptation to elongated faces, fixation durations did not closely track perceptual judgements. This dissociation echoes earlier demonstrations that perceptual judgements and motor behaviour can diverge (cf. Goodale & Milner, 1992). Nonetheless, the eye movement data provide useful insights into task strategy: for example, following adaptation to compressed faces, observers allocated less attention to the mouth region and more to the nose.

Sang et al. (*in press*) also examined aftereffects of artificial compression and expansion, extending this work beyond faces to whole bodies. Given the overrepresentation of thin bodies in visual media, such aftereffects may have enduring consequences for the perception of body shape, including one's own. A central aim of their study was to assess the longevity of these effects and to determine the extent to which they can be ascribed to changes in perception rather than to task demands, particularly those associated with binary "fat" or "thin" judgements.

This distinction is notoriously difficult to establish when each stimulus must be evaluated relative to an internalized standard (Morgan et al. 2012). Sang et al. appeal to the incomplete transfer of aftereffects across changes in body orientations and retinal position (Brooks, et al. 2018) as evidence for a perceptual component. We agree that retinotopically specific aftereffects are more plausibly perceptual in origin. At the same time, such spatial specificity sits uneasily with accounts that place these effects at high levels of visual processing, and there is no logical reason why people could not possibly maintain sets of distinct subjective criteria that are selectively applied to inputs from different regions of visual space.

Dynamics of adaptation

From their study of blur adaptation and visual search, Shareef et al. (*in press*) inferred that adaptation saturates quickly. Although prolonged adaptation (up to 20 minutes) benefitted search performance, more than half of that benefit was obtained with just 12 seconds of adaptation. Complementary findings were reported by Morgan & Solomon (2019), who observed maximal improvements in search for unadapted targets after only 12 consecutive trials, each containing two seconds of adaptation.

The rapid saturation of adaptation is reassuring for experiments that assume a relatively stable visual system. At the same time, it raises the possibility that adaptation may continue to evolve over long timescales in ways that are not always captured by standard experimental designs. Motivated by this concern, Surkys et al. (*in press*) examined whether measurements of the Oppel-Kundt (OK) and Müller-Lyer (ML) illusions might be influenced by ongoing adaptation, both within and between experimental sessions. Their analyses revealed gradual changes in the magnitude of the OK illusion over time, whereas no consistent changes were observed for the ML illusion.

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Concluding remarks

This special issue extends our understanding of visual adaptation by highlighting the diversity of its mechanisms, timescales and perceptual consequences. Across domains, the contributions show that adaptation cannot be reduced to a single process or function, but must instead reflect a set of flexible adjustments that shape sensitivity, appearance, and performance in context-dependent ways. Together, they underscore the continuing value of visual aftereffects as tools for probing perceptual coding. Perhaps, in some future special issue, we may even be able to explain to a 5-year-old why their sibling remains annoying despite prolonged exposure.

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