

Systematic examination of the ploidy of differentiated tissues across the plant and animal kingdoms is likely to uncover additional examples and functions for which increased ploidy provides an advantage, as well as potential limitations. In addition to these developmental insights, the field is now poised with powerful new tools to answer key mechanistic questions, such as why does increased ploidy cause an increase in cell size? Is there a minimal karyoplasmic ratio and, if so, why? How are transitions into the endocycle or endomitosis controlled in different developmental contexts? And what are the mechanisms and roles for differential DNA replication? It will be exciting to watch the answers to these questions emerge in different organisms.

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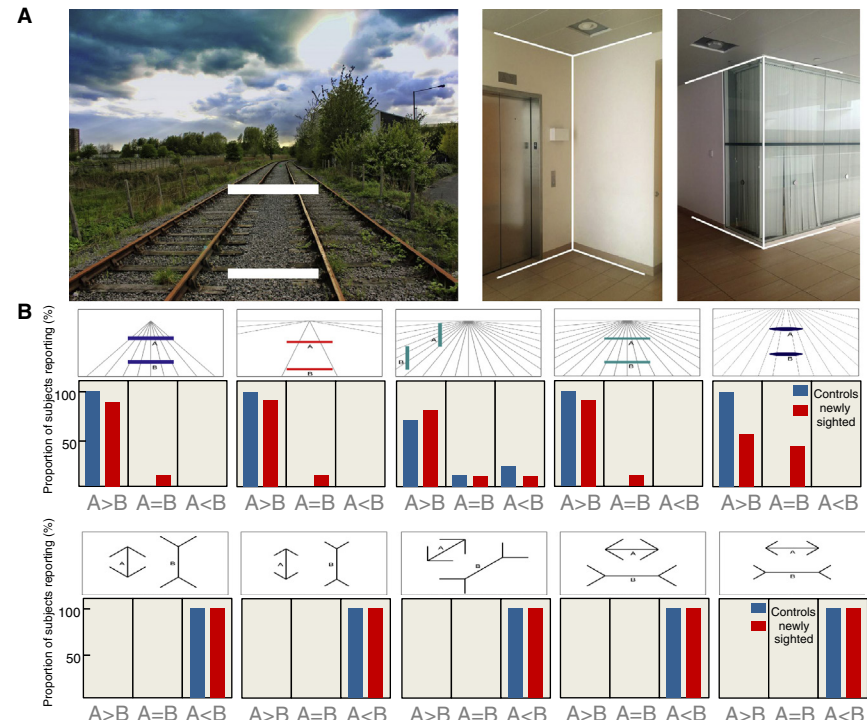
# Immediate susceptibility to visual illusions after sight onset

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The dominant accounts of many visual illusions are based on experience-driven development of sensitivity to certain visual cues. According to such accounts, learned associations between observed two-dimensional cues (say, converging lines) and the real three-dimensional structures they represent (a surface receding in depth) render us susceptible to misperceiving some images that are cleverly contrived to contain those two-dimensional cues. While this explanation appears reasonable, it lacks direct experimental validation. To contrast

it with an account that dispenses with the need for visual experience, it is necessary to determine whether susceptibility to the illusion is present immediately after birth; however, eliciting reliable responses from newborns is fraught with operational difficulties, and studies with older infants are incapable of resolving this issue. Our work with children who gain sight after extended early-onset blindness, as part of Project Prakash, provides a potential way forward. We report here that the newly sighted children, ranging in age from 8 through 16 years, exhibit susceptibility to two well-known geometrical visual illusions, Ponzo [1] and Müller-Lyer [2], immediately after the onset of sight. This finding has implications not only for the likely explanations of these illusions, but more generally, for the nature-nurture argument as it relates to some key aspects of visual processing.

In the Ponzo illusion (Figure 1A, left), first demonstrated over a century ago, two identical stripes, placed on a background of converging lines,



**Figure 1. The susceptibility of newly-sighted individuals to visual illusions.**

(A) The Ponzo and Müller-Lyer illusions superimposed on real images to indicate how learned perspective cues, as proxies for distance, may be the source of the effects. (Images after [5]; the railroad tracks image is by Darren Lewis and is in the public domain). (B) Results from normally sighted and newly sighted subjects on multiple displays. In each of these displays, the two lines being compared (denoted 'A' and 'B') are actually of identical length. Data are represented as the proportion of subjects (%) reporting each type of response.

appear to be of different lengths. According to an influential account [3,4], this anomalous percept arises from our learned association of two-dimensional perspective cues with the distances they represent in the three-dimensional world. On the basis of our past visual experience, we come to interpret the Ponzo display as depicting two objects at different depths in the three-dimensional scene, with the stripe closer to the point of convergence seen as being further away. To reconcile this three-dimensional interpretation with the two-dimensional display in which both stripes subtend the same visual angle, the visual system is led to infer that the distant stripe must be physically longer. This inference is believed to influence perception, making the 'distant' stripe appear longer in the display.

A similar account has been offered for the even older Müller-Lyer illusion [2] (Figure 1A, middle and right). The perceived disparity in line lengths is thought to be an outcome of our experience with the three-dimensional world [4–6], with the fins conveying a sense of lines advancing or receding in depth. Results from cross-cultural studies have provided support to experience-based explanations [7]. Although alternative accounts have been suggested [8], there has thus far been no direct test of the necessity of visual experience for engendering susceptibility to these illusions.

Experience-based explanations predict that susceptibility to the Ponzo and Müller-Lyer illusions will not be evident in observers who are visually naïve, such as newborn infants. As mentioned above, it is difficult to obtain reliable responses from neonates, and the issue cannot be resolved by studies with older, visually experienced infants. Our work in India with children who gain sight after extended congenital blindness [9] provides a potential way forward.

We tested nine children, ranging in age from 8 to 16 years (mean 12.2 years), who were treated for blindness due to dense bilateral congenital cataracts that limited their pre-operative vision to the perception of hand movements close to their face. Given the remote rural domiciles of the patients, formal medical reports of their ophthalmic status at birth were not available. Assessments of cataract congenitality were based on multiple factors including parental

reports, presence of nystagmus and nature of cataracts (see Supplemental Information). The children underwent cataract removal surgery and an intraocular lens implant. All children were tested within 48 hours after first eye surgery. As only one eye had been treated at the time of the experiment, the patients had had no exposure to binocular depth cues. Nine normally-sighted children (age range 6–18 years; mean 11.9 years), with similar socio-economic status as the patients and drawn from a local municipal school, participated as controls. The stimuli comprised variations on the basic Ponzo and Müller-Lyer displays (as shown in Figure 1B), subtending 50 degrees of visual angle at a viewing distance of 30 cm. In each display, the subjects' task was to point to the line that appeared longer or say that the lines were of equal length. No feedback was provided to the subjects.

As shown in Figure 1B, control subjects showed a reliable susceptibility to the illusions. If the illusion is driven by a learned appreciation of perspective cues, we would expect the newly-sighted children's responses to be physically veridical and, hence, inconsistent with the control subjects' choices. However, the data reveal that the newly-sighted behave akin to the control group in their choices. The pattern of responses exhibited by the Prakash children is unlikely to arise by random chance (binomial test, Ponzo illusion:  $p < 0.05$  for six of the nine children individually; Müller-Lyer illusion:  $p < 0.01$  for all nine children individually.  $p \sim 0.0$  for pooled data across all children for each of these illusions). Thus, even at the very outset of their visual experience, the Prakash children already exhibit susceptibility to the Ponzo and Müller-Lyer illusions. These results are especially interesting in the context of past studies of late sight onset which have shown that the newly sighted have difficulties with spatial perception of scenes [9]. This suggests that susceptibility to the Ponzo and Müller-Lyer illusions likely does not depend upon a sophisticated spatial analysis of the scene. It is also worth considering the possibility that susceptibility to these visual illusions may be engendered by prior haptic experience. Although we cannot definitively rule out this explanation, the

lack of transfer from touch to vision that we have previously observed in newly sighted patients [10] argues against this possibility.

These results argue that the susceptibility to these two classic illusions is based not on an individual's learned contingencies about the visual world, but rather on processing mechanisms that do not depend on visual experience.

## SUPPLEMENTAL INFORMATION

Supplemental Information includes experimental procedures, and one table and can be found with this article online at <http://dx.doi.org/10.1016/j.cub.2015.03.005>.

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