Dispatches

Vision: When Does Looking Bigger Mean Seeing Better?

A recent study shows that our ability to discriminate the orientation of a visual pattern improves if the pattern appears larger.

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Imagine having an eye examination, and the optometrist gives you a choice: you can have your visual acuity tested using either a large eye chart at the back of the room, or a chart half the size and placed at half the distance. Reasoning about geometry as Euclid might have, you correctly conclude that the size of the retinal image of either chart will be the same (Figure 1A) and, therefore, that the two options will produce the same result…but then again you can *see* that the far chart is truly bigger…and you would like to get a good score. At this point, you would really appreciate some experimental data.

It turns out that relevant results were obtained a century and half ago by the German physiologists Hermann Aubert and Richard Förster [1]. They would advise you to choose the bigger chart, because they found that visual acuity gets better with distance. But the improvement is small, and even smaller once the effects of pupil size and focus are eliminated. In 1951 Louise Sloan [2], reviewing what by then was a substantial and somewhat inconsistent literature on the Aubert–Förster phenomenon, concluded that "While it is probable, therefore, that there is some factor which reduces acuity at short distances less than 1 meter, further investigation is needed to determine the cause of the phenomenon".

What could the cause be? In the 1960s, several authors suggested that the improvement in acuity with distance might be related to 'size constancy' — our visual system's ability to estimate the physical size of an object across changes in distance [3,4]. For example, in Figure 1A, even though the two eye charts project the same image on the retina, we would readily perceive the larger/distant chart as being physically larger. Because distance information is lost in the two-dimensional retinal projection, size constancy necessarily involves neural processes beyond the retina. Somehow our visual system extracts distance information from a variety of cues and transforms angular size information to estimate an object's physical size.

One important distance cue is that our eyes converge more strongly for near than for the far objects (Figure 1B). In fact, around the same time as Aubert and Förster, Charles Wheatstone noticed that if the two eyes are made to converge more (using mirrors or prisms to simulate a closer view), the object *appears* smaller, even though neither the object nor its image on the retina has changed. This illusion makes sense considering the fact that increasing binocular convergence is similar to changing fixation from the large eye chart to the smaller/closer one. In other words, the visual system 'thinks' that it is looking at a closer object and scales the percept in the direction of the object's physical size. This phenomenon can be easily appreciated by looking at the two spheres in Figure 1C: both spheres project the exact same retinal image size, but our perception of their apparent size is biased away from the retinal image size in the direction of their physical size in the environment.

As they report in this issue of *Current Biology*, Schindel and Arnold [5] adapted Wheatstone's mirror technique to show that human orientation discrimination improves with an *apparent* increase in the size of the target. This finding is important because it demonstrates that changes in apparent size have fundamental implications for visual performance. By using an orientation, rather than acuity, task, they reduced the impact of optical factors that had complicated studies of the Aubert–Förster phenomenon. Moreover, given that orientation tuning is most finely represented in primary visual cortex (V1), the results suggest an early cortical integration of distance information (as conveyed by convergence) and retinal image size. Until recently, this conjecture would have seemed highly unlikely. V1 is characterized by a fine-grained representation of visual space organized as a 'retinotopic map'. Recalling our imagined eye charts, this implies that the 'neural images on V1' of the far-large and near-small charts would be identical, because their retinal images are identical. However, consistent with Schindel and Arnold's [5] results, recent fMRI studies using stimuli similar to Figure 1C have shown that the spatial extent of activity in V1 does increase with perceived size [6,7].

Is distance information combined with retinal size information to solve the problem of size constancy in V1? In theory, V1's representation of object size could increase with distance through changes in receptive field sizes or shifts in the receptive field positions of V1 neurons. The idea that early visual receptive fields change size as a function of distance is not new and has been somewhat controversial [4,8]. More recent claims of a 'flexible retinotopy' have also been hard to interpret [9,10].

There are computational arguments against the idea of V1 providing a single spatial map that gets passed on to later areas. If V1 is the primary cortical gateway to later visual processing, one would expect it

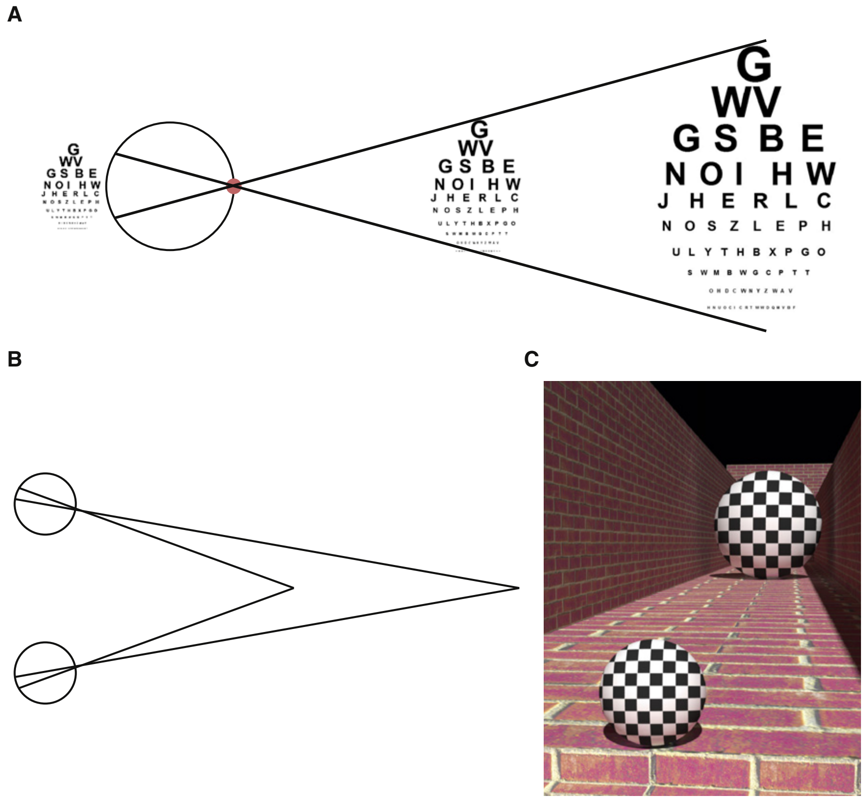

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Figure 1. Apparent size and visual acuity.

(A) If simple optics were the only factor limiting visual acuity, a small chart should be as easy to see as a chart twice the size at twice the distance. (B) The convergence of the two eyes is one source of depth information. (C) Depth can also be conveyed by monocular cues such as perspective as in the 'Ponzo illusion'. The ball that appears farther away looks bigger than the closer one. They are actually the same size in the image.

to process spatial information to support multiple and possibly competing functions. For example, size constancy could be achieved by transforming object shapes into a common coordinate system [11–13], perhaps intermediate between a retinotopic and environmental map, and perhaps represented by the pattern of activity in V1. On the other hand, retinal image size can also be an important cue to an object's distance. One reason you know that a person is far away or close is based on their retinal size. It would, therefore, seem unwise for the visual system to completely abandon retinal image size early on. In addition, angular distance between two points as represented in a retinotopic map is also important information for eye movements. Thus, the way in which V1 is involved in spatial processing may depend strongly on the task, and thus on top-down information from extra-striate visual areas [14–16].

Why should you pick the large far eye chart? More than a century and a half of empirical evidence says that you should, but a solid understanding of the physiological basis remains elusive. Historically, the arguments for a central nervous system component to the Aubert–Förster phenomenon have reflected Sherlock Holmes' reasoning that "when you have excluded the impossible [peripheral factors], whatever remains [central factors], however improbable, must be the truth". There is now converging behavioral and neuroimaging evidence to support the idea that early visual cortical areas are involved in size constancy, consistent with a common underlying mechanism to support improved spatial discrimination. But the evidence is still very indirect, and there is a clear need for neural cellular recordings to look for shifts in receptive field position and/or size as a function of depth cues.

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