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The Eyes Wide Shut Illusion

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Abstract

The Eyes Wide Shut illusion uses a standard enlarging (shaving/make up) mirror. Close one eye and look at the closed eye in the mirror; the eye should take up most of the mirror. Switch eyes to see the other closed eye. Switch back-and-forth a few times, then open both eyes. You see an open eye. Which eye is it? To find out, close one eye. Whichever you close, that's the eye you see. How can this be possible? The brain is fusing two images of the two eyes! The illusion depends on: 1- Binocular fusion: the two eyes see different pictures, which the brain combines into a single percept; 2- Mirrors reverse forward-backward and not right-left, unlike the case of real-world objects that rotate in space and therefore reverse forward-backward together with right-left. Neither case affects appearance of left-right symmetric objects; 3- Symmetry: The eyes are sufficiently left-right symmetric for the brain to combine them. Why aren't the lingering asymmetries sufficient to prevent fusion? 4- Only vision with scrutiny affords conscious access to scene details. Consistent with Reverse Hierarchy Theory, vision at a glance grants conscious perception of the gist of the scene, integrating images of non-perfectly symmetric eyes.

“… together they sing for joy,
for they shall see eye to eye,
the return of the Lord to Zion”
Isaiah 52:8

Introduction: Seeing the illusion

Use a magnifying mirror, the kind used for makeup or shaving, about 10x power. Hold the mirror at eye level, about 15cm (6 inches) from your nose. Close one eye and look at the closed eye in the magnifying mirror. The image of the closed eye should be in the center of the mirror. Hold the magnifying mirror close enough so the image of the closed eye fills most of the mirror.

Now switch eyes so the other eye is closed and look at the now-closed eye in the mirror. You now see the other, closed, eye and its image fills most of the mirror. You should not need to move the mirror – or your head – when you switch eyes.

Switch eyes back and forth a few times, opening one and closing the other, then opening the other and closing the first. You always see the closed eye in the mirror. The question is, what will you see if you open both eyes?

Open both eyes, and you see an open eye in the mirror. Which eye is it? It's BOTH eyes! Each eye sees the other eye, and the brain fuses the two superposed images and integrates them. Figure 1 demonstrates schematically the three stages of the illusion: one eye shut, the other eye shut, and both eyes open.

The integration is accomplished even though eyes are not symmetric, so that the two eye images are not identical. Additionally, where is your nose in the mirror image? Surprisingly, it's on both sides of the eye. Each eye is seeing the other eye and the two images have a nose on opposite sides of the eye. This phenomenon has been presented to large numbers of observers at university classes and international conferences, including Vision Sciences Society (VSS, 2017) and Society for Neuroscience (SfN, 2017) with ubiquitous surprise, amazement and delight, except for people unable to close one eye at a time, or those with extreme eye dominance (Shneor & Hochstein, 2006).

Before we discuss what can be learned from the eyes wide shut illusion, we need a bit of background about mirrors and illusions, in general.

Background: Mirrors

The optics of mirror reflections are rather simple and well-known. However, there are still some aspects of the relationship between mirrors and perception which puzzle most people. One such issue is the simple question of why we experience a left-right reversal in mirrors but not up-down reversal. The physical world should have no preference for horizontal over vertical, so why and how do mirrors differentiate these two axes? In particular, why is writing seen in a mirror – mirror writing – reversed left right instead of up-down?

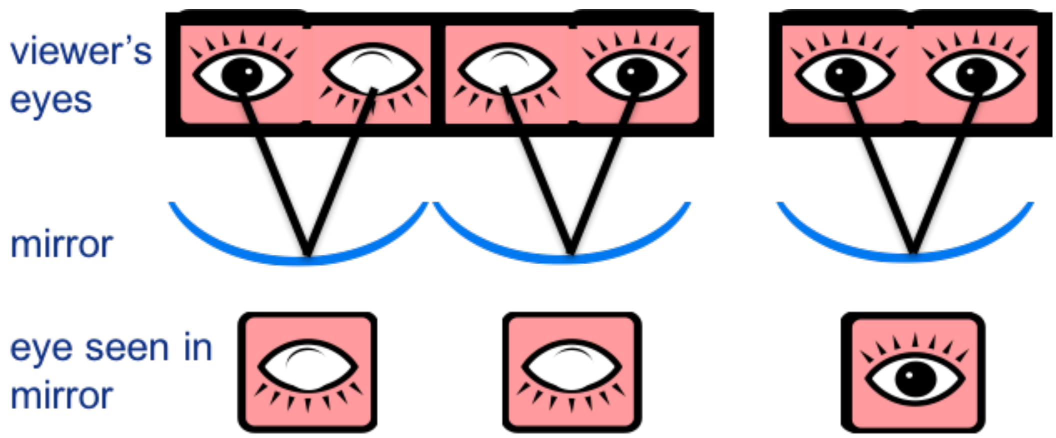

Figure 1. The eyes wide shut illusion. Look at a closed eye in a magnifying mirror. Switch eyes and you again see the closed eye. Now open both eyes. You perceive a single eye – but it's a composite of the two eyes since each eye is seeing the other eye. The brain is willing to perceive the two images as one, even though eyes are not symmetric and surprisingly, your nose appears on both sides of the composite eye.

The answer is, of course, that mirrors reverse neither up-down nor left-right. They only reverse forward-backward. Two objects which are between us and a mirror, one closer to us, the other closer to the mirror, will appear in the mirror image in reverse order: first the object further from us (closer to the mirror), then the item closer to us (further from the mirror) and finally our own image, the most distant. This is clear in Figure 2,left.

You	A	B	mirror	B'	A'	Your image
Archer	string	bow	mirror	bow	string	image of archer

That's the fact, but it doesn't explain why we think of mirror images as reversing left-right. And this part of the story depends on psychology and human experience. Real world objects can only rotate in space reversing two dimensions at a time. The person standing in front of us facing the same way we are, has his right hand on our right, his left hand to our left and his back to us (Figure3D). Similarly, the person behind us faces our back and is not reversed at all (Figure 3E). When he turns around so that he is facing us, he has reversed front-back (he is now facing us) and right-left, his right hand is to our left. So, to shake hands, we must cross arms across our bodies to shake right with right (Figure 2,right and Figure 3A). Of course, our friend could have done an up-down flip and ended up standing on his head, facing us. The he would have reversed front-back and up down, but not left right (Figure 3C). (There is a third rotation, doing a cartwheel, reversing left-right and up-down, but not forward-backward, ending with his back to us, but right-left and up-down reversed.) None of these occur with a mirror (Figure 3B). Here we see ourselves front-back reversed; we face our mirror image and it faces us, and it is not right-left (nor up-down) reversed. If we put out our right hand, the image puts out the hand on our right.

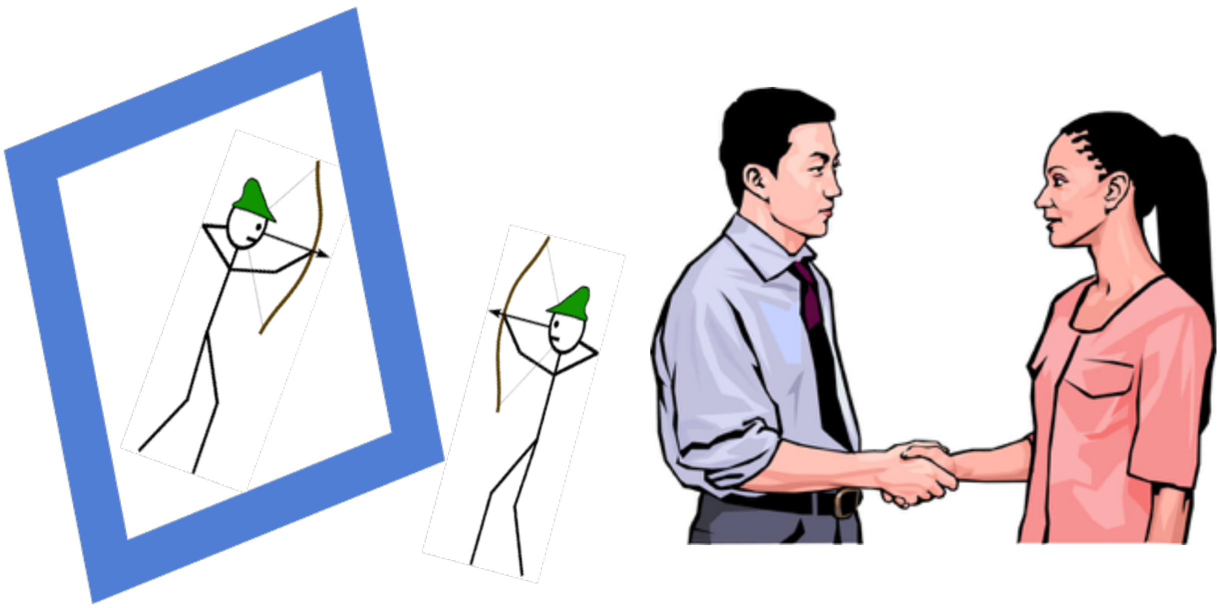

Figure 2. Mirror reflections. Mirrors reverse front-back but not right left, unlike our usual experience with real-world objects which can rotate but not reflect so that they always reverse both front-back AND another axis, usually left-right – as in shaking hands with a friend.

The most common of all these rotations in space, whether when facing a friend (or enemy), or when looking at a clock or reading a book, is the rotation that reverses front-back together with right-left. Another circumstance to consider is the car in front of us versus the car coming towards us. The drivers are on opposite sides of the cars; they and we are all on the inside of the road. People just don't stand on their heads very often, nor do we see upside-down cars. Thus, the unusual thing about mirrors is that they <u>don't</u> reverse right-left, as do real objects (Figure 3B). Therefore, they are perceived as, interpreted as, reversing right-left.[1] These and other issues

[1] There's an old story about two acquaintances meeting on a train. "Where are you going?" askes the first. "To Minsk," is the reply. To which the first responds, "You say you are going to Minsk

are discussed by Gregory (1966, 1998) in his usual clear, brilliant style in his classic book, “Mirrors in the Mind”.

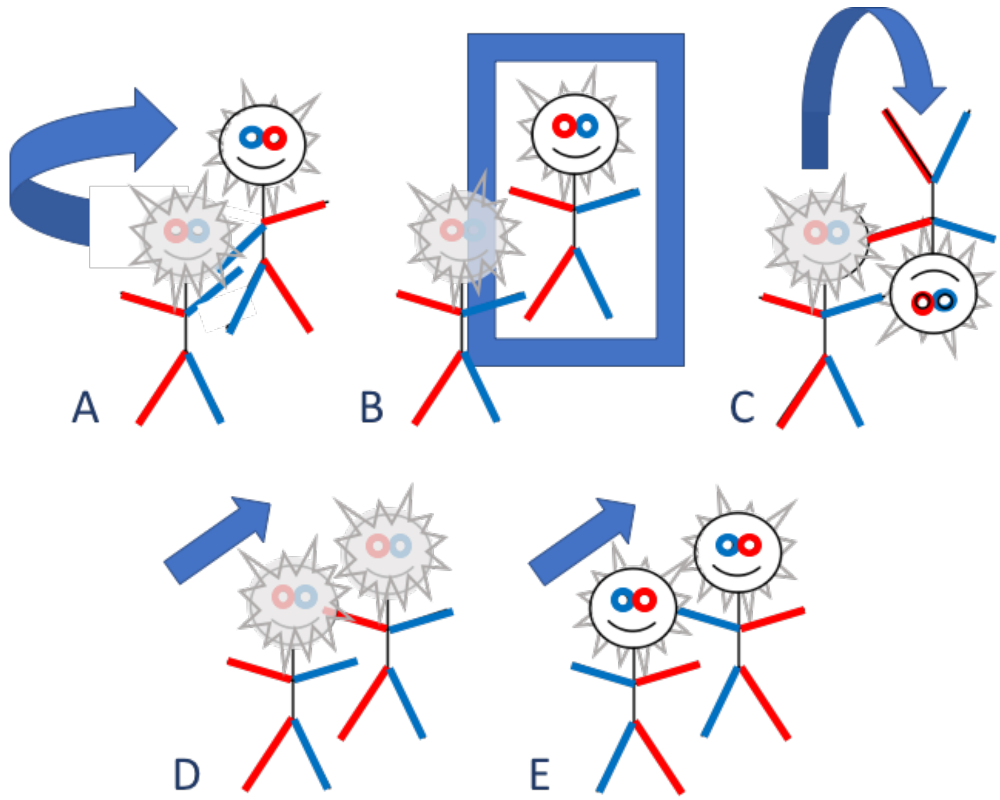

Figure 3. Translations, rotations and reflections. Translation: when facing the same direction as a friend, they can stand in front of us, and we see their back (D) or behind us and they see our back (E); there is no reversal of right (blue arm, leg, eye) versus left (red arm, leg, eye) nor front (bright) versus back (darkened). Rotations: When a friend turns around on his feet to face us, we now see his face, and he sees ours, but his right hand, leg and eye are on our left, so we have to cross over our bodies to shake hands (A; see also Figure 2,right). If, instead he would stand on his head and face us, his right hand, leg and eye would be on our right side, but he would be upside down (C), an unusual rotation, and uncommon state of affairs. How do you shake hands, converse with a friend doing a head-stand? Mirror Reflection: Looking at our own, or a friend’s reflection in a mirror leads to a very different percept. Now the image is facing us, but there is no right-left reversal (as in A) nor an up-down reversal (as in C); just forward backward. We can touch right hands (at the mirror) without crossing over our body.

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so that I’ll think you are going to Pinsk, but I happen to know you are really going to Minsk, so why are you lying?” When expecting reversal, non-reversal seems like reversal compared to expectations.

Methods: Visual Illusions

What is a visual illusion? The visual system is constantly bombarded with an immense amount of information. Our eyes' 100 million photoreceptors receive different levels of light at each instant. Clearly, it's too much to grasp and retain all the time. The brain must use tricks and shortcuts to condense this information and interpret the scene in a useful manner. Sometimes, a usually useful and appropriate algorithm of interpretation is used in an inappropriate circumstance. When this happens, the result is called an illusion. As Richard Gregory (2009) wrote, "Though seldom taken seriously by science – as errors are generally nuisances to be avoided rather than phenomena of interest – explaining why illusions occur can reveal how perception works and secrets of brain and mind."

One example is the Hermann Grid (1870), demonstrated in Figure 4,top-left. The precise "explanation" is a subject of debate, but suffice it to say that the visual system generally – appropriately – goes from perceiving absolute illumination intensity to relative brightness, so that it is the <u>difference</u> between light and dark that is perceived. This is useful, for example, so that objects, faces, or texts seem more-or-less constant over a range of general illumination levels. In the Hermann Grid, seeing gray intersections results from their being less different from their surroundings, which include 4 white "streets", than are the streets themselves, with only 2 white street extensions.

Similarly, the Ebbinghaus illusion demonstrates that size of an object is generally perceived relative to the sizes of surrounding similar objects, as shown in Figure 4,top-right (see Roberts, Harris & Yates, 2005).

A third example is Shepard's (1990) rotating table top illusion (Figure 4,bottom-right) where 3D perspective interpretation makes two identical shapes look very different, when rotated and seen as table tops in depth. And finally, a fourth illusion is the floating frankfurter illusion (Figure 4,bottom-left; Sharp, 1928), which is seen when staring at two nearly-toughing index fingers held in front of the eyes.

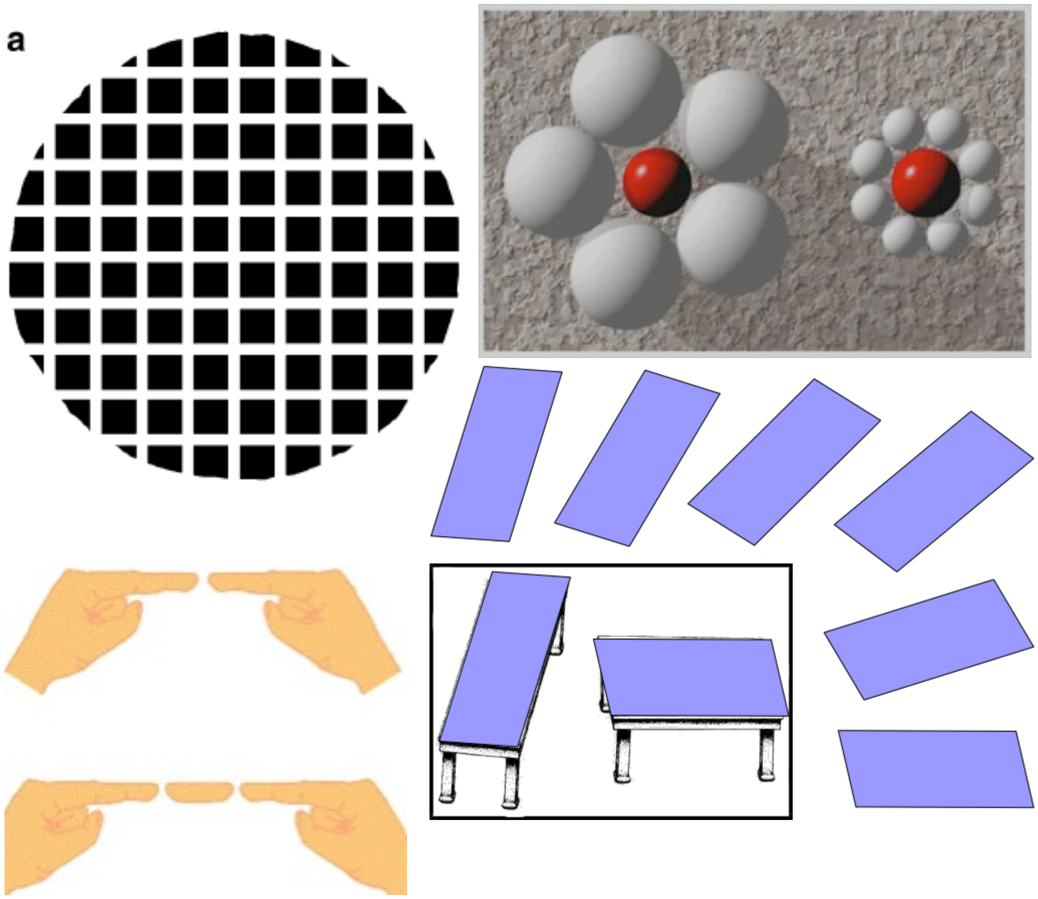

Figure 4. The Hermann Grid (top-left) and Ebbinghaus (top-right) illusions demonstrate inappropriate use by the visual system of usually appropriate mechanisms that allow us to perceive relative, rather than absolute illumination and size, respectively. The Hermann Grid intersections are not dimmer than the “streets” connecting them, and the red balls are of equal size, but relative to their surroundings, they are different and appear different to most viewers. The Shepard rotating table illusion (bottom-right) plays on our 3D depth interpretation of a plane parallelogram, and the floating-finger frankfurter illusion (bottom-left) occurs when the eyes cannot fuse two views.

Discussion: Perceiving the gist of the scene

Many perceptual conditions have been studied where observers, following limited viewing, are able to report only the gist of the scene. We require lengthy viewing with scrutiny to obtain fine scene details. Examples of limited early vision-at-a-glance include change blindness (Rensink, O’Regan & Clark, 1997; Rensink, 2002; Sampanes, Tseng & Bridgeman, 2008), repetition blindness (Kanwisher, 1987), the attentional blink (Raymond, Shapiro & Arnell, 1992), crowding (Korte, 1923; Levi, 2008) and boundary extension (Intraub & Richardson, 1989).

Hochstein and Ahissar (2002) suggested Reverse Hierarchy Theory to help understand this "gist before details" phenomenon. According to this theory, visual information processing begins with an implicit, unconscious process that integrates information from representations at lower-level cortical areas to form global higher level representations. However, at first, only these higher-level representations are accessed by consciousness. Then, if there is time and need, consciousness includes scene details through a top-down guided return to access lower-level representations. Thus, conscious, reportable, remembered perception works in the reverse-hierarchy direction, and we perceive first the higher-level represented gist, with global attention, and only later, given time, desire, and focused attention, do we perceive scene details. This theory is demonstrated schematically in Figure 5.

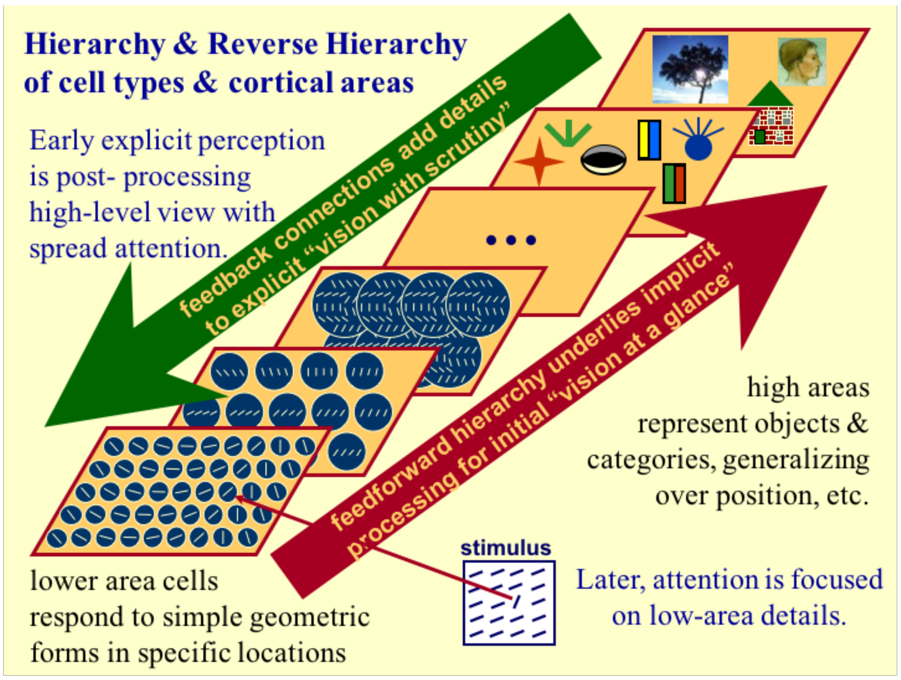

Figure 5. Reverse Hierarchy Theory. There is a hierarchy of visual information processing so that lower cortical level neurons represent local details of the scene, lines of specific orientations, spots of specific colors, and so on, while higher cortical level neurons are specific to more complex forms such as objects and faces, generalizing over location and orientation. According to Reverse Hierarchy Theory, this integrative processing is accomplished implicitly. "Vision at a glance", the first conscious perception, is awareness of the result of this unconscious processing, the higher-level representations of the "gist of the scene." Later "vision with scrutiny" is a gradual return in reverse hierarchy direction to lower-level representations, which already contain scene details.

Conclusion: Eyes Wide Shut Illusion as demonstrating gist-first Reverse Hierarchy Theory

We come to the important issue of what we can learn from the eyes wide shut illusion. As stated above, illusions are the result of the visual system using mechanisms that are usually appropriate but are inappropriate in the illusion-creating circumstance. It is certainly strange and inappropriate to see the two eyes fused into one image, and it is equally inappropriate to see them as one symmetrical eye, since eyes are not fully symmetric, and the surprise is compounded when we suddenly notice our nose on both sides of the unified eye. Why then does the brain form one image of an apparently symmetric eye?

The answer depends on two important principles of perception.

The first principle depends on the fact that the two eyes commonly receive different views of the world; they have different points of view. This difference in viewpoint is used for stereo depth perception, but only for objects within a limited range of depths. Outside this range we see double vision, especially for objects that are too close to us, and generally for objects that are significantly closer than the object of our current fixation. This phenomenon is so ubiquitous that we don't generally notice it. Interestingly, double vision in amblyopia often leads to disuse and blindness of the non-dominant eye, but this does not occur more generally because the views of the two eyes are similar enough, especially for distant objects, that the scenes may be fused, or perceived by stereo-selective neurons. The exception to our not noticing this type of double vision is when it leads to obvious illusions. For example, if you point to a distant object, it doesn't disappear behind your finger, because the other eye fills in the view. The edge of our laptop computer screen shifts left-right versus the scene behind it as we shift between eyes; (this may be part of the source of the boundary extension phenomenon; Intraub & Richardson, 1989). This phenomenon is made obvious, again by an illusion, the floating-finger "frankfurter" illusion (Sharp, 1928), shown in Figure 4,bottom-left.

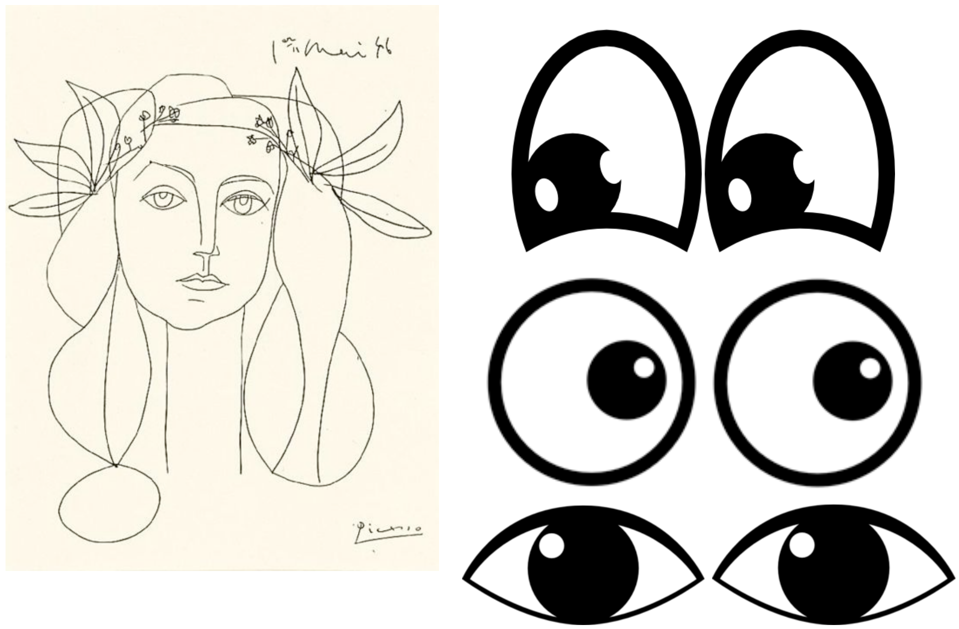

Figure 6. Examples of symmetric eyes in Picasso and graphics.

The second principle is that early “vision at a glance” is satisfied with the “gist of the scene” and discounts any superfluous, perhaps confusing details. Eyes are indeed not quite symmetric, but they are close to symmetric, and it’s good enough to see a symmetric almond shape to recognize it as an eye. Note that in line drawings of eyes, even those by Picasso, they are often depicted as symmetric – as I did in Figure 1, and is shown in Figure 6.

This is the essence of Reverse Hierarchy Theory. Conscious vision begins with a “quick and dirty” bottom-up analysis of the scene, discounting discrepancies, to get at a rapid, most likely interpretation of what’s going on and what’s important for rapid response. Corrections are left to the following return, down the reverse hierarchy, guided by this early gist, to find the details already represented there. When discrepancies are found, the visual system surveys alternative interpretations, but in this case, none is found.

Acknowledgements.

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