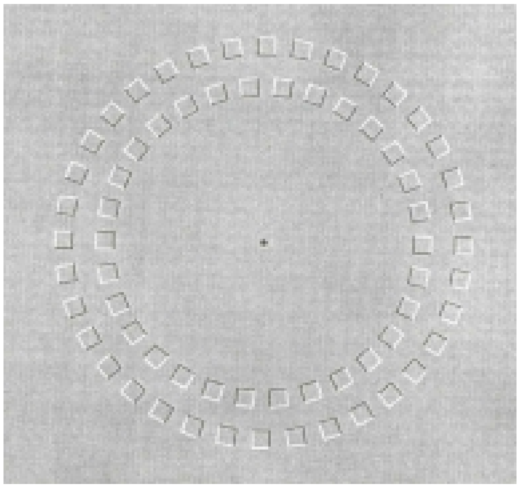
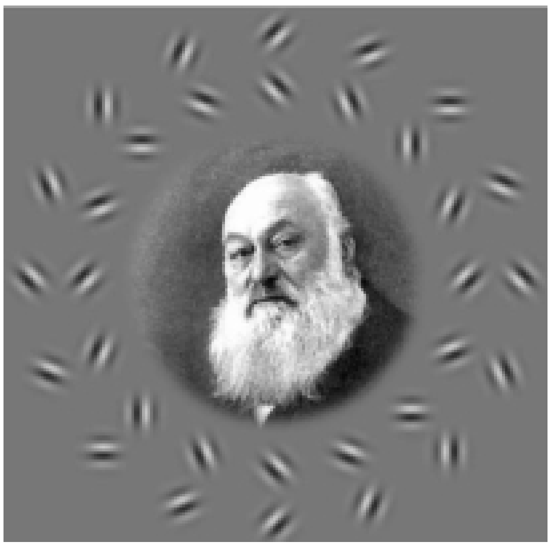
The Rotating Wheel Phenomenon

The original version of this striking figure was described by Baingo Pinna and Gavin Brelstaff (Pinna, B & Brelastaff, G.J. 'A new visual illusion of relative motion', Vision Research, 2000,40,2091-2096). It is shown in their version below:



Pinna and Brelstaff point out that the dominant Fourier Components in the squares are along the diagonals, and are thus oriented at 45 deg to the direction of movement when the pattern expands/contracts. I therefore decided to replace the squares by patches of tilted grating:



The photograph in the middle is of Sigmund Exner, who was the first to say that there are specialised micro-circuits in the periphery of our vision for detecting movement.

A movie (Quicktime Movie) of the figure expanding and contracting also shows the effect but not so strongly. In the following, I argue that this is because self-movement cancels the expansion component of the 45 deg local signals, making the rotation component more obvious.

Running Rings Round the Brain

The famous *Phonogrammarchiv* in Vienna has an excellent Web site from which you can download, amongst other things, a song of the Ai-Khoë bushwomen, recorded in 1908. It also has a photograph of its founder, the physiologist Sigmund Exner, who was the first to suspect that the brain contains specialised microcircuits for attracting our attention to movement. Look fixedly at Exner's nose while rocking your head backwards and forwards to change the distance of the picture from your eyes. The rings around the picture will appear to rotate. But where does the rotation come from? Explaining visual phenomena like these, which take place in our brains rather than in the eye, is a fascinating exercise in logic. The brain uses many different tricks to understand the world outside, so we have to use many tricks to understand the brain. Here goes for the 'rotating wheel' phenomenon.

The brain analyses movement in several stages. The whole process can be compared to an intelligence network in which spies scattered around the world send their messages to a central controller who puts together their fragmentary reports to discover the 'big picture'. In the visual brain, the spies are millions of small nerve cells, each of which is connected to the retina and responds to movement of lines in its own very small area of the image. We have learned from Neurophysiology that each motion detector prefers a particular tilt of the line to the vertical. Because they look at only a very small area of the image these detectors cannot uncover the 'true' direction of movement within their area. A moving line tilted at 45 deg to the vertical stimulates 45 deg detectors more than, say, 25 deg detectors, even if it happens in reality to be moving along a 25 deg path.

So what is the 'true' direction of movement of the patches in our figure when we bring it nearer to our eye? As the picture approaches the eye its image on the retina expands and the patches fly apart, like galaxies after the Big Bang. As with expanding Galaxies all the patches fly apart from each other and from the centre of the image. This is simple optics, which explains the movement but not the rotation. The important thing about the patches is that they have been designed to have stripes which are angled at 45 deg to the local direction of expansion. This causes our unintelligent spies to report movement at 45 deg to the true direction. More accurately, we should say that all the spies are responding, but that those reporting 45 deg motion are sending the strongest messages.

Enter the Spymaster MST (Medial Superior Temporal cortex). The millions of confusing signals from the field have to be put together to make some sort of sense. First of all, the reports of movement are coming from points around a circle. The report from each point on the circle is indicating a direction of movement at 45 degrees to the line joining that point to the centre of the circle. What real object could rise to such a pattern? The answer is: a set of points on a circle that is simultaneously expanding and rotating. And this is why we see the pattern rotating. The location of the nerve cells that perform this inference in the brain is not known exactly, but patterns like the one we are examining cause strong neural activity in MST, and individual nerve cells there are known to respond best to complicated movements like expansion and rotation.

But the explanation is not quite finished yet. If our image is made to expand by zooming it on a TV screen, the impression of rotation is still there, but most people think it is not as strong as when we move our heads. This is puzzling because the same movement is present on the retina in the two cases. This problem can be linked to another: why does the distance between Exner's eyes not seem to increase when we move towards his image? Apparently the brain disregards signals of expanding movement when they are produced by movement of our own body, because they are anticipated. It is another general Axiom of vision that if a given signal from the retina is habitually correlated with our own movement in space, it is ignored. The reason the rotating ring is so powerful when we move towards it is that it is not mixed up with expansion.

Acknowlegments: I am grateful to Baingo Pinna for permission to reproduce the figure, and to Nick Wade for pointing me to the *Phonogrammarchiv*. Jeremy Wolfe first drew my attention the Pinna & Brelstaff article and Peter Thompson suggested changes to the article above.