Helix Rotation: A New Twist on Pulfrich and Hess

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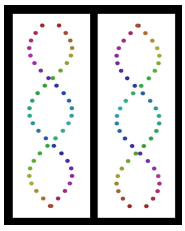
Introduction: In Virtual Reality (VR) and Augmented Reality (AR) displays, the perception of a third dimension is created by binocularly fusing images that simulate the perspective of each eye; depth is thought to be conveyed primarily through a combination of binocular disparity and monocular pictorial cues. However, the visual system can also create depth from differences in local adaptation (Pulfrich, 1922) and local contrast (Hess, 1904). To better investigate how local adaptation and local contrast affect the perception of depth in VR and AR environments, we created the Helix Rotation, in which changes in local adaptation and contrast stimulus transform simple harmonic motion into a three-dimensional rotating helix. Here, we show five examples that illustrate the power of these techniques.

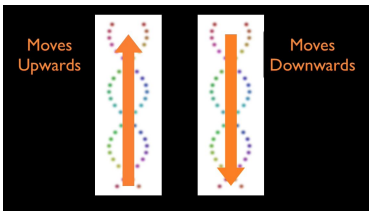
The five videos are posted on youtube as unlisted links:

Shapiro Video 1, Basic Helix: https://youtu.be/4MgR_ekgoZM
Shapiro Video 2, Distance Between Dots: https://youtu.be/Z2VQwCJpaoM
Shapiro Video 3, Global and Local Information: https://youtu.be/g3EjuclnLxM
Shapiro Video 4, Hess Helix: https://youtu.be/lm9OsEAQ5bk
Shapiro Video 5, Helix Rotation in VR: https://youtu.be/zb4Dmy19OEo

Video 1, Basic Helix. The display consists of two columns of dots that move horizontally back and forth as a temporal sine wave. The timing of each dot is offset from its vertical neighbor so that dots in each column form a standing sine wave. The standing wave whose top is on the left is offset by 180 degrees from the standing wave whose top is on the right.

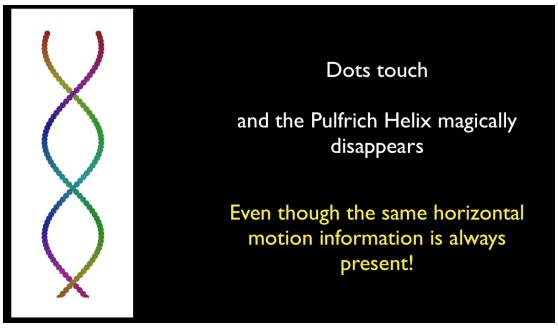
What to do: Put a dark filter over one eye, and keep both eyes open.



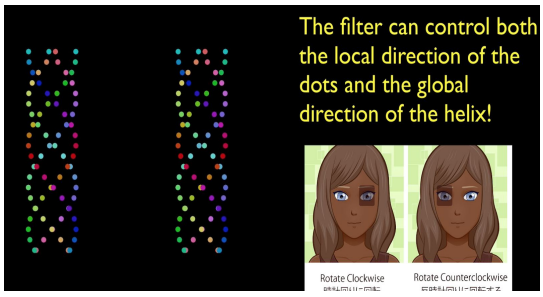


Three points to notice: 1. The dots look like a three-dimensional helix. 2. When the dark filter is over the left eye, the helix rotates clockwise; when the filter is over the right eye, the helix rotates counterclockwise. 3. When the viewer uses no filter but blurs the image by squinting both eyes or by using a defocusing lens, motion is upwards for one helix and downwards for the other. This response is a puzzle since there must be neurons tuned to low frequencies that respond to the upwards and downwards motion all the time, but that motion is suppressed when the video is not blurred.

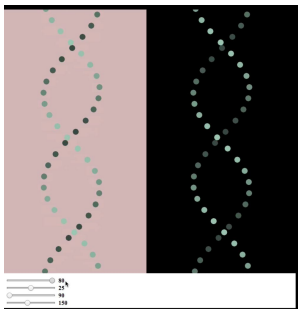
Video 2, Distance Between Dots. In this video, more dots are added so that the vertical distance between each dot becomes smaller.
What to do: As with Video 1, put a dark filter over one eye, and keep both eyes open.
What to notice: Pulfrich motion occurs when the dots are close to each other but not touching. When the dots touch each other, they no longer appear as separate elements, but instead appear to be part of a continuous vertical sine wave that shifts upwards. In this condition, the Pulfrich motion disappears even though the same horizontal motion is present.

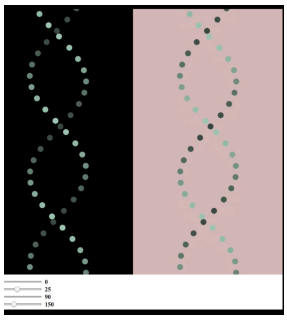


Video 3, Global-Local Motion. In this video, the helix formed by the dots also moves sinusoidally back and forth, creating a global framework for the motion of the dots.
What to do: As with Video 1, put a darkening filter over one eye, and keep both eyes open.
What to notice: The location of the filter (left eye or right eye) determines both the direction of rotation of the dots and the direction of the helices.



Video 4, Hess Helix. In this video, the dots change luminance as they move from right to left and are placed against light and dark backgrounds.
What to do: First, watch the movie without any filter (sometimes it is best to close one eye). Second, rewatch the movie with a dark filter over one eye.
What to notice: 1). The direction of motion is determined by the contrast between the dots and background. So, depending on the background and the phase of the dots, the helices can appear to rotate towards or away from each other. 2) With a filter over one eye, the helices rotate in the same direction. The direction is unaffected by the contrast, so the rotation will continue in the same direction as the background and phase change. It is as if--in this condition--rotation determined by Pulfrich motion is more important than rotation determined by local contrast (Hess).





Video 5, Helix Rotation in VR
The video shows someone looking at the Pulfrich helix in a virtual reality environment. When the viewer looks at the dots from one angle, the dots appear to be in a 3-d space even though the dots move along a single plane in the VR space.