Motion Perception

Visual Motion:
Visual motion, at the most basic level, is a change in the position of a luminance pattern over time. The velocity is expressed in degrees of visual angle/second. Humans are very sensitive at detecting motion in visual images. The smallest motion that humans have been reported to detect is about 10 arc seconds, which is similar to the best threshold for vernier acuity. Motion detection is therefore like other hyperacuities, the threshold for the smallest detectable shift is much less than the size of a single cone.

Motion is a correlation across space and time:
In order for us to see visual motion, our brains have to compare the activity of individual receptors across space and time. One cone cannot see motion! One cone can only see light increasing or decreasing at its location. Motion comes from a comparison of two or more detectors at different locations, with activity that is a little delayed from one to the next. See the demo GratingThroughHoles.avi to illustrate what individual cones see when a grating drifts across the retina.

Apparent Motion:
Although objects in the world move continuously across our visual field, continuous real motion is not required for the perception of motion. When two stimuli appear with the correct separation in time and space, our brains link them together into “Apparent Motion” and we see them as a single moving object. The phenomenon is variously called Apparent Motion, Sampled Motion, Phi-phenomenon and/or Beta-phenomenon. The last two terms were coined by Max Wertheimer in his 1912 studies of motion perception. See demo of Phi phenomenon at http://www1.psych.purdue.edu/Magniphi/SimpliPhi.html

Motion Aftereffect
Our motion perception shows adaptation effects similar to color, orientation, brightness and even faces. Stare at a strong stimulus for a period of time, it will seem less strong. Look away at something neutral, and it will appear to have the opposite sign. For motion, this means you adapt to one motion for a long time, and when you look away you will see stationary things appear to move. The existence of specialized motion sensitive units is dramatically illustrated by the spiral motion aftereffect. Steady objects will appear to contract after watching an expanding spiral. Adaptation to the moving stimulus causes an aftereffect of perceived motion where there is actually only stationary images.
A rotating spiral provides a strong stimulus for adapting motion detectors. Stare at the center of a rotating spiral for about one minute to fatigue motion mechanisms that respond to the expanding pattern. Then shift gaze to some stationary object and watch it appear to contract without getting smaller! See the demo DriftingSpiral.avi

**Motion Can Break Camouflage**
Our sensitivity to motion can allow us to see things that otherwise would blend in with the surroundings. Many creatures have colors and patterns that make them blend in with their background, but when they move our visual system is able to see the shape clearly.

In the laboratory, we can make stimuli that are perfectly camouflaged except for motion by using completely random colors in the object and the background. These stimuli are called Random Dot Kinematograms. An example is in the demo movie RandomDotUHCO.avi

**Global Processing in Motion Perception**
Our perception of motion in the world is built up from individual detectors at each location in the visual field. A single local detector may often have ambiguous motion information, but higher-level mechanisms are usually able to combine all the local motion signals into a unified percept. There are long range interactions across the visual field that “bind” local motions together into a single large object moving in one direction. See the demos DiaMovieG.mov and DiaMovieW.mov for an example of local and global motion perception being very different.

In the demo movies, the diamond moves left and right behind some occluding bars. If the bars are visible, the brain connects the four parts of the diamond and sees one object. If the bars are less obvious, the brain sees four independent lines moving in different directions.
Motion perception requires the brain to put together local motion signals into one sensible global motion pattern, and sometimes this is ambiguous.

**The “Aperture Problem”:**
The individual parts of the moving diamond are seen by neurons in the cerebral cortex as isolated line segments moving through the cell’s “receptive field”: that part of the visual field that activates the particular cell. Seen through this small aperture, the motion always appears to be going perpendicular to the line. Only by combing the activity of many such cells can the brain extract the whole pattern motion.

The white circle represents the receptive field of a hypothetical neuron in primary visual cortex. This neuron is not sensitive to areas outside the circle (in gray) but only that part of the visual field that falls inside the white circle. When a straight line or edge moves through the visual field, the cell sees the direction of motion as perpendicular to the orientation of the line, regardless of the true direction of the pattern. On the left, the line moved vertically, on the right it moved horizontally, but the one cell cannot tell the difference.

**First Order and Higher Order Motion processing**
Our brains are wired to see motion. In some species, even cells in the retina respond to moving objects specifically. In primates, motion is extracted in the primary visual cortex, and processed further on in other visual areas. When a bright/dark edge moves across the retina, it excites particular cells in the cortex and inhibits others, allowing the brain to identify the edge’s orientation and direction of motion. This sort of motion, based on luminance edges, is called **“first order”** because it is very basic.

Our brains are able to see much more subtle patterns as well. Consider the “amber waves of grain” phenomenon, where you perceive patterns of moving waves across a field. The individual plants are moving back and forth, not really going anywhere. But the pattern as a whole seems to drift across the field. This example is called **“motion-defined motion”** and it is one example of **“higher order”** motion.

The video “LumConOrienMotStereoMotionDemo.avi” illustrates several levels of motion.
Motion processing in cortex:
Area V1 (also called “Area 17”) in primary visual area, and has cells with selectivity, but they cannot solve the problem. The Middle Temporal area (MT) in the Temporal lobe collects responses of all those V1 cells and has cells that respond to the whole pattern, rather than small pieces. Experiments suggest that this area has the closest association to our perception of motion in complex displays.
Damage to this part of the brain leads to a condition of “motion blindness” or Akinetopsia. Patients with this condition will see objects clearly, and be able to indicate position, but are unable to smoothly follow moving objects or judge their speed. A nearby, related area called the Middle Superior Temporal area (MST) has similar sensitivity to global motion, but also includes information about the rotation of the eyes to help us track moving objects.