of its retinal image. When a moving object is by an observer with eyes, head, and body fixed, ected image moves across the retina. In this in- it is natural to equate object motion with image . But much of the time, our eyes, head, and body motion, and this fact invalidates any attempt to object motion directly with image motion.

ge motion depends on both eye movements and motion. For example, eye movements produce motion even in a completely stationary environ- as the eye moves in one direction, the image s across the visual field in the opposite direction.[1] there is image motion when there is no object n at all. The opposite can also occur, as when a ng object is tracked by the eye: Its image on the will actually be stationary even though the object is in motion. For these reasons, it is important tinguish clearly between image motion and object on and to realize that perception of object motion ys depends on eye, head, and body movements as as image motion.

.1 The Computational Problem of tion

computational problem of motion perception is to get from the dynamic optical event on the retina he veridical perception of moving objects within a erally stationary environment. This is not a trivial blem, particularly when the complications of eye, d, and bodily movements are considered. The visual tem appears to solve it in at least two steps: an early cess of motion analysis concerned with the registra- n of 2-D image motion and a later process concerned h interpreting image motion in terms of 3-D objects ving in 3-D space, independent of how the eyes are ving. We will consider each process in turn.

The starting point for motion and event perception— deed, for *all* perception—is what Gibson called the namic ambient optical array: the flux of optical struc- re converging from all directions to a stationpoint (see ction 1.2.1, Figure 1.2.5). One useful way of con- ptualizing the information in the dynamic ambient

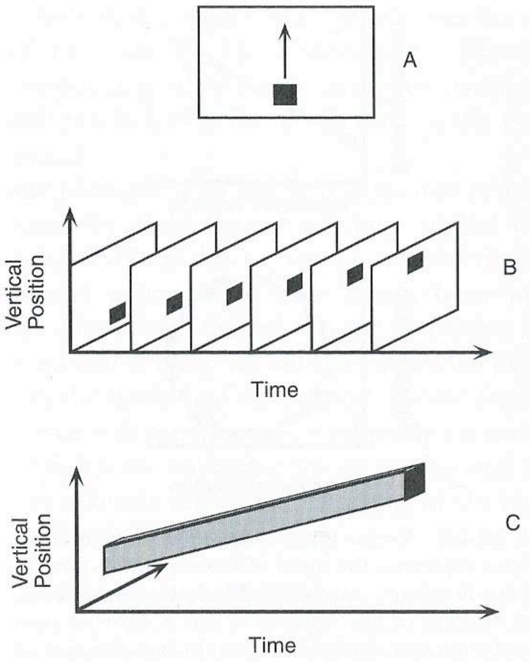

Figure 10.1.1 Space-time diagrams. The event of a square moving upward (A) can be sampled by a series of snapshots in which the position of the square changes discretely over time (B). This sequence approximates a representation of the continuous event in space-time (C) as the time between snapshots approaches zero.

optical array is in terms of **space-time diagrams** of image motion.

Space-time diagrams represent image structure as it changes over time. Because the sample of the ambient optic array that strikes the retina at each moment in time is a two-dimensional luminance structure, the additional dimension of time makes space-time representations of image motion three-dimensional. Consider the space-time diagram of the simple visual event shown in Figure 10.1.1A: a square moving upward at uniform speed. In the space-time diagram, the two spatial dimensions of the image are preserved in the vertical (y axis) and depth (z axis) dimensions, so each "depth slice" constitutes the image—a square at some position—at a particular moment in time (Figure 10.1.1B). The temporal dimension is represented along the horizontal (x axis) dimension, with later times to the right of earlier ones. Thus, the square moving upward results in the

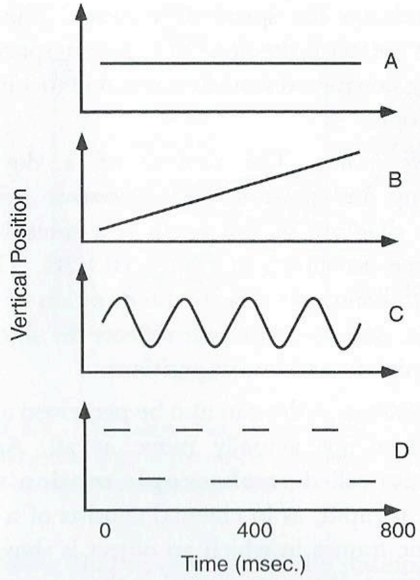

Figure 10.1.2 Space-time diagrams of four simple events. Each graph represents the motion of a single point along a vertical trajectory in the frontal plane: a stationary point (A), a point moving upward with uniform speed (B), a point moving continuously up and down in harmonic motion (C), and a point moving discretely up and down in a series of static snapshots, which produces the perception of apparent motion (D).

most recent one at the end. The primary difference is that the transparencies would be discrete samples of image motion (as in Figure 10.1.1B), whereas the structure of real motion in space-time diagrams is continuous (as in Figure 10.1.1C).

To simplify things a bit, we will now consider space-time diagrams for some simple motions of a single dot. In Figure 10.1.2 the vertical position of the dot is plotted as a function of time. Because the horizontal dimension of space is now irrelevant, it can be dropped from the space-time diagram so that motions can be presented as simple 2-D graphs with time on the horizontal axis and vertical position of the dot on the vertical axis. Figure 10.1.2 shows a few representative examples of space-time diagrams for simple visual events.

1. *Stationary dot.* The simplest case of all is an unmoving dot. Since its position does not change over time, its space-time diagram is a flat horizontal line, as shown in Figure 10.1.2A.