INSTRUMENTATION & TECHNIQUES

A revolving X-Y plotter for studying the perception of rotational motions

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A new apparatus for studying the visual perception of rotational motion is presented. The revolving X-Y plotter allows the observer to directly affect changes in the motion parameters of a revolving stimulus as it is being viewed. The advantages afforded by this apparatus over previously used response measures is discussed followed by a description of its design and utilization. The primary value of the apparatus is that it makes possible a precise response measure of the perceived center of any rotating stimulus.

First introduced in the psychological literature by Rubin (1927), the perception of rotational motions has been of lasting interest to perceptual psychologists. In the Gestalt tradition, the perception of wheel-generated motions has been an exemplar of the priority of higher order invariants. It is easily demonstrated that the perceived motions of a revolving configuration are often not obviously manifested in the absolute motions of its individual parts. When viewing a rolling wheel, for example, the motions that are seen are circular rotations and linear translation; however, only the center of the wheel manifests the translational component as its absolute motion, whereas all other points follow motion paths that are members of the family of cycloidal curves. A second reason for psychologists' interest in rotational motions follows from the first. Many researchers feel that an understanding of how observers extract motion information from rotating events may serve as an important step toward discovering general principles of perceptual organization applicable to the whole domain of motion perception.

Studies on perceiving revolving events have often made use of stimuli reduced to revolving configurations of point lights. In some studies, observers viewed point lights attached to unseen wheels in otherwise dark rooms (Duncker, 1929/1938; Johansson, 1950, 1973; Rubin, 1927; Wallach, 1965). Other researchers have presented point-light stimuli on video or computer monitors (Green, 1961; Proffitt & Cutting, 1979, 1980a, 1980b; Proffitt, Cutting, & Stier, 1979; Restle, 1979; Cutting & Proffitt, Note 1, Note 2). The use of such reduced

stimuli allows for an exact description of the distal event; unfortunately, measures of the observers' perceptions have fallen far short of this degree of precision.

JUDGMENTAL RESPONSES OF PERCEIVED ROTATIONS

In most studies of perceived rotation, observers were asked simply to verbally report what they saw when presented a stimulus event (Duncker, 1929/1938; Johansson, 1950, 1973; Restle, 1979; Rubin, 1927; Wallach, 1965). Although this phenomenological approach created the field of motion perception and set the trends of theoretical speculations, it suffers from a disproportionate ability to describe the physical stimulus compared with the response measure to which such a description must be related. This asymmetry of exactness in description between the physical stimulus and the response measure is especially pronounced in recent studies. Percepts are given complex vector descriptions, with only the observers' unquantified verbal descriptions offered as evidence for their validity.

Subjective scaling is considered an improvement over unquantified verbal reports. In studies on the kinetic depth effect, Green (1961) presented displays of revolving point lights to observers and asked them to rate the perceived rigidity of the rotating configurations on a 5-point scale. A frequently used technique in our studies required observers to rate on a 7-point scale the "wheel-likeness," "hopping," or "wobbling" motions of a variety of events (Proffitt & Cutting, 1979, 1980b; Proffitt et al., 1979). This procedure required observers to make scaled judgments about the motions of numerous stimulus configurations. Since the perceived common motion of a configuration describes the motion path of the perceived configural center, the center's perceived location could be inferred from the scaling design. In a recent study using a multidimen-

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sional scaling design, observers were required to rate on a 7-point scale how similar pairs of stimulus events appeared (Cutting & Proffitt, Note 1). This procedure has the advantage that it does not suggest to the observer the dimension upon which judgments are to be made (Kruskal & Wish, 1978).

The basic shortcomings of scaling methodologies result from their correlational designs. One or more physical dimensions of interest in the stimulus event must be made to vary across the set of stimuli presented to observers for rating, and the analyses seek to determine how the ratings vary in concordance with these dimensional variations. To counter objections to correlational designs, we employed a paired-comparison methodology (Proffitt & Cutting, 1980a, Note 2). Stimuli were presented in pairs, and observers were asked to state which member of the pair appeared to "be most wheel-like," "hop the most," or "wobble the most." A final methodology required observers to draw the motion path of rolling configurations.

Although the quantifiable response measures discussed above are improvements over simple phenomenological reports, there continues to exist a great disparity between the precision with which we can measure physical stimuli and our observer response measures. The revolving X-Y plotter was developed to reduce this discrepancy in the study of rotational motions. The apparatus allows an observer to directly effect the motion parameters of a revolving stimulus as the event is viewed. No verbal judgments are required, since the observer can directly effect changes in the stimulus event that can be measured with an exactness equaling the description of the stimulus configuration.

DIRECT OBSERVER CONTROL OF MOTION PARAMETERS: THE REVOLVING X-Y PLOTTER

The apparatus consists of two systems. The first is the revolving X-Y plotter, which allows an observer to effect the location of a stimulus mounted on a revolving disk. The second system consists of video components for the presentation of the event to the observer.

Figure 1 depicts a front view of the disk on the revolving X-Y plotter, and Figure 2 shows a side view of the entire apparatus. The disk itself has a radius of 76.2 cm and is driven by a motor at a constant speed of 60 rpm. Two pulley systems are mounted on the disk's back. The belt on each pulley system makes a loop that crosses over or twists once so that the positions of the belt on opposite sides of each pulley system move in the same direction. Consider the outer pulley system in Figure 1. As the belt wraps around the top two double pulleys, it twists, thus sending the belt from the top pulley on one side to the bottom pulley on the other, and vice versa. In this manner, the extreme left and right portions of the belt move up and down together. A rod is attached at the extreme opposite sides of the belt on

S Limit Switch
M Motor Driven Pulley
T Tension Pulley
D Double Pulley

Figure 1. A front view of the disk on the revolving X-Y plotter. The pulley systems move two rods in directions at right angles to each other, and at the point of their intersection rides a glide. Stimuli can be mounted over this glide and positioned anywhere within the pulley systems as the disk revolves.

Figure 2. A side view of the revolving X-Y plotter with the disk positioned at a vertical slant.

each pulley system. For the outer pulley system, this rod moves up and down as the belt moves, and for the inner system, the rod moves left and right. At the intersection of the two rods is a small Teflon glide through which both rods slide. Thus, the glide moves with this point of intersection and can be made to move to any location on the disk within the pulley systems. A pointer is mounted to the underside of the glide, and the disk is scored with a .5-cm grid, the origin of which is at the disk's center of rotation. The location of the glide can, therefore, be determined quickly by the position of the pointer on the grid. Attached to the top of the glide is a small disk upon which stimuli can be mounted. The disk, rods, and stimulus mounting disk are anodized, giving them a flat black color that prevents any part of the apparatus from being seen on the video monitor that is used to display the stimulus. Limit switches are placed near the pulleys to prevent the rods' being pulled through the pulleys. The disk and its drive motor are balanced and supported by a stand that allows the disk to be slanted from a vertical position as shown in Figure 1, through 15-deg increments to a horizontal position.

Figure 3. A wiring diagram for the system controlling the motors that drive the pulley systems. The motors, M1 and M2, are mounted on the back of the disk of the revolving X-Y plotter, and the control switches, S2-S5, are located on a panel before the observer who views a video presentation of the revolving stimulus.

As the revolving X-Y plotter spins, the glide and stimulus can be moved to any location within the range of the pulley system by utilizing four buttons on a control panel. Figure 3 is a wiring diagram for this control system. Each motor of the pulley systems is controlled by a pair of buttons on the control panel. These buttons engage the pulley motors in either a clockwise or counterclockwise torque. Electrical current is transferred from the control switches to the motors via a set of power pick-up rings on the main motor shaft behind the disk.

Stimuli are presented to observers on a video monitor. A typical stimulus configuration, be it a solid shape or some arrangement of points, is fashioned out of stiff cardboard, covered with light-reflective tape, and attached to the stimulus mounting disk on the revolving X-Y plotter. A low-illumination surveillance video camera (Dage 650 SN equipped with a Vidicon sensing device and low-illumination internal bias lights) is focused on the center of rotation of the revolving X-Y plotter, and bright lights are directed at the face of the disk. The video picture is presented to an observer on a 700-line video monitor with a 31-cm CRT (Panasonic WV-5400). Monitor brightness is turned to minimum and the contrast is adjusted to near maximum, causing only the luminous stimulus to be seen on an otherwise blackened screen. As the stimulus revolves on the monitor's screen, the observer can change its coordinates with respect to the unseen origin of rotation by pressing the control buttons. A record of the observer's adjustments can be videotaped on a video-cassette recorder (Sony SLO-320).

In a typical experimental situation, the observer views a stimulus configuration revolving on the screen at some location away from the unseen center of rotation of the motion generating disk. The observer is instructed to change the motion of the stimulus so that it appears to spin about its center without moving as a whole around the screen. Previous research has demonstrated that a configuration revolving about any point other than its perceptual center appears to have two motion components: a spinning motion around the perceptual center and the rotation of this abstract center point (Proffitt & Cutting, 1979). The instructions require the observer to locate the perceived center of the configuration at the origin or center of the motion generating disk. The observer is asked to perform this task a number of times for each stimulus. The location within the configuration that coincides with the disk's center is recorded each time. The mean location of these points is the perceived center of the stimulus.

Numerous experiments can be performed using this experimental apparatus. The effects of slant on perceived configural centers can be studied, as the disk can be slanted away from the video camera at 15-deg intervals from a vertical to a horizontal position. Solid forms can be attached to the mounting disk, as well as wire configurations that appear as luminous edges.

Studies on the kinetic depth effect can readily be conducted by setting the slant of the disk at or near its horizontal position. Additional motion components can be added to the stimulus event by moving the camera as the disk revolves. Translating the camera laterally in phase with the disk's rotation, for example, produces the wheel-generated motion phenomenon. All of these studies allow the observer to directly affect some of the motion parameters of the stimulus event that he or she is observing. The response measures of these adjustments can be made with an accuracy equaling the description of the stimulus configuration.

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