Available online at www.sciencedirect.com

SCIENCE DIRECT®

Cognitive Psychology 51 (2005) 285–333

Cognitive Psychology

www.elsevier.com/locate/cogpsych

Acquiring new spatial intuitions: Learning to reason about rotations ☆

John R. Pani *, Julia H. Chariker, Thomas E. Dawson, Nathan Johnson

Department of Psychological and Brain Sciences, University of Louisville, Louisville, KY 40292, USA

Accepted 12 June 2005
Available online 13 September 2005

Abstract

There are certain simple rotations of objects that most people cannot reason about accurately. Reliable gaps in the understanding of a fundamental physical domain raise the question of how learning to reason in that domain might proceed. Using virtual reality techniques, this project investigated the nature of learning to reason across the domain of simple rotations. Learning consisted of the acquisition of spatial intuitions: there was encoding of useful spatiotemporal information in specific problem types and a gradual accumulation of this understanding across the domain. This pattern of learning through the accumulation of intuitions is especially interesting for rotational motion, in which an elegant domain-wide kinematics is available to support insightful learning. Individual ability to reason about rotations correlated highly with mastery motivation, skill in fluid reasoning, and skill in reasoning about spatial transformations. Thus, general cognitive advantages aided the understanding of individual rotations without guaranteeing immediate generalization across the domain.

☆ The first and second authors were supported by a grant from the National Library of Medicine, National Institutes of Health, during preparation of this manuscript (Grant 1 R01 LM008323-01A1; Histological Reasoning: Visual Cognition in Microanatomy). The second, third, and fourth authors received support from the Grawemeyer Awards during conduct of this research. We thank Carolyn Mervis for advice and training in the use of psychometric tests.
* Corresponding author.
E-mail address: jrpani@louisville.edu (J.R. Pani).
URL: http://www.louisville.edu/~jrpani01/ (J.R. Pani).

0010-0285/$ - see front matter
doi:10.1016/j.cogpsych.2005.06.002

Keywords: Learning; Visual cognition; Reasoning; Mental models; Qualitative reasoning; Perceptual organization; Spatial organization; Mental rotation; Virtual reality

1. Introduction

Rotational motion is fundamental in mathematics and physical science, common among ecological motions, and a mainstay of engineering. The ability to predict the outcome of a rotation is a prototypic instance of physical reasoning. Thus, people can reason about the rotations of a great variety of objects, the spatial properties of rotation are simple and elegant, and formal systems for describing rotation reduce it to a few fundamental principles. Indeed, it has sometimes seemed that the ability to think about rotations is a systematic internalization of constraints on the physical world (e.g., Cooper & Shepard, 1973; Shepard, 2001; Shepard & Metzler, 1971).

These characteristics of cognition with regard to rotation make it especially interesting that there are elementary instances of rotational motion that most people are very poor at reasoning about (e.g., Just & Carpenter, 1985; Massironi & Luccio, 1989; Pani, 1989, 1993, 1997; Pani & Dupree, 1994; Parsons, 1987, 1995). Such constraints on spatial knowledge are most apparent when experimental tasks are not confined to the classical paradigm of mental rotation (i.e., when the test of knowledge is not a discrimination of an object and its mirror reversal; see Pani, 1993; Parsons, 1995). For example, suppose an individual is shown a physical assembly like that illustrated in Fig. 1 and is asked to indicate which direction the dish would be facing after a rotation around the long shaft (e.g., 180°). For the case at the left (Fig. 1A), the person would respond fairly quickly and the answer likely would be

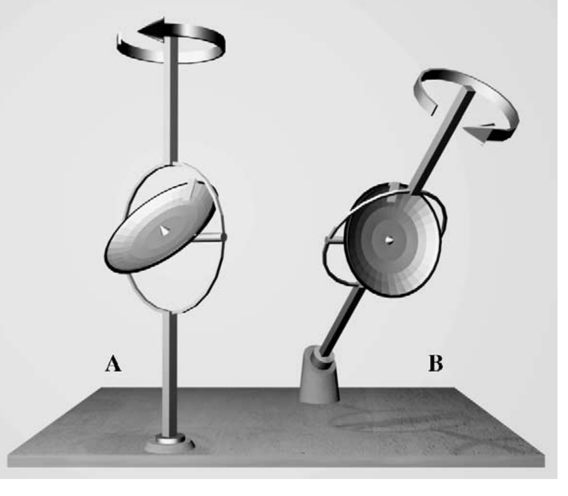

Fig. 1. Two configurations in which the main shaft can be an axis of rotation for the dish assembly.