Title
The Structure of Integral Dimensions

Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 28(28)

ISSN
1069-7977

Authors
Goldstone, Robert L.
Jones, Matt

Publication Date
2006

Peer reviewed

The Structure of Integral Dimensions

Matt Jones (mattj@psy.utexas.edu)
Department of Psychology, University of Texas
1 University Station A8000, Austin, TX 78712 USA

Robert L. Goldstone (rgoldsto@indiana.edu)
Psychology and Cognitive Science, Indiana University
1101 E. Tenth Street, Bloomington, IN 47405 USA

A robust body of research has shown that some perceptual dimensions, such as those composing color, are perceived in an integral fashion. Variation along one dimension interferes with processing of another, and people cannot selectively attend to one dimension without effort (Garner, 1974). The fused nature of integral dimensions suggests they may be better thought of as composing a single perceptual dimension with multiple physical degrees of freedom. The question is how to model such dimensions.

A perceptual dimension with a single degree of freedom, such as the length of a line, has a natural ordering that allows it to be identified with the real numbers. In modeling a stimulus space defined by multiple, separable dimensions, it is common to use Cartesian space (e.g., the Cartesian plane). This product-space representation is justified by the analyzable nature of the stimuli. However, this approach does not clearly apply to integral dimensions, because they are not trivially decomposable. Therefore, although Cartesian space is commonly used to model integral perceptual spaces just as it is with separable spaces, the rich geometric structure implied by this representation may not be psychologically meaningful.

One strong hypothesis is that integral spaces have no more structure than that of a topological manifold. Past findings taken to indicate stable geometrical structure may depend on the set of stimuli present in the task rather than indicating pre-existing geometry. The present experiments tested this idea using the dimension differentiation paradigm of Goldstone and Steyvers (2001). In that study, subjects were trained to classify stimuli from a two-dimensional integral space into two categories. They were then transferred to a different category structure using the same stimuli. Performance on the second task was better if the category boundaries for the two tasks differed by 90 degrees than by 45 degrees. Goldstone and Steyvers concluded that, in learning the first task, subjects learned to differentiate the relevant dimension from the complementary dimension. When the learned complementary dimension became the diagnostic dimension in the second task (i.e., in the 90-degree condition), learning was facilitated.

According to geometrical models of integral dimensions, the complementary dimension is defined as being orthogonal to the diagnostic dimension. According to the topological model, orthogonality is meaningless; instead, the complementary dimension is statistically uncorrelated with the diagnostic dimension under the distribution of stimuli present in the task. These competing explanations are indistinguishable in Goldstone and Steyvers' (2001) study because stimuli were arranged in a circle (in objective coordinates).

To de-confound geometrical and statistical relationships among dimensions, we used an elliptical stimulus arrangement as illustrated in Figure 1. Two experiments built on this basic design, one using colors varying in brightness and saturation and another using morphed faces. In both experiments, transfer performance averaged 6% greater when the transfer bound was orthogonal, rather than uncorrelated, to the training bound (both *p*s $< .05$). These results support the geometrical model of integral dimensions and suggest that integral spaces have an inherent geometry despite their unanalyzable nature.

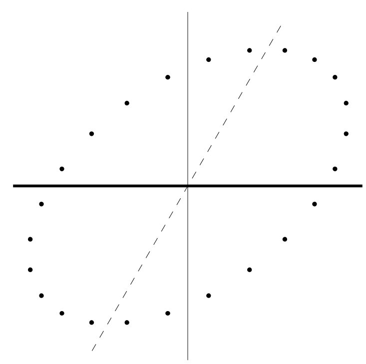

Figure 1. Key aspects of experimental design. Dots represent stimuli. The horizontal line represents the category bound in the training task. The geometrical hypothesis predicts subjects will show greatest transfer to the vertical bound. The topological hypothesis predicts transfer will be greatest for the dashed bound.

Acknowledgments

This work was supported by NIH NRSA F32-MH068965 to MJ and Department of Education IES grant R305H050116 and NSF REC grant 0527920 to RLG.

References

Garner (1974). *The Processing of Information and Structure*. Oxford, England: Lawrence Erlbaum.

Goldstone, R. L., & Steyvers, M. (2001). The sensitization and differentiation of dimensions during category learning. *Journal of Experimental Psychology: General*, *130*(1), 116-139.