Notes from Frances Wang's lecture on Multi-Dimensional Comprehension

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Abstract

Frances Wang is an Assistant Professor in the Psychology Department. Her main interest is determining if humans can meaningfully conceptualize four-dimensinoal objects or space. To this end, she has been running experiments testing people's abilities to comprehend shapes by seeing only thier lower dimension cross sections or projections.

1 Purpose

- to understand people's intuition of 4D
- Can people psychologically/intuitively understand 4D?
- Research Question: Can people learn the sturcture of a 4D object? If yes, how and when. If not, what are the cognitive limitations?

2 Problems with learning 4D

- A 4D object cannot be presented entirely in 3D. Only one part at a time can be presented.
- to percieve 4D we need the ability to:
  - assemble pieces to form a whole (general ability)
  - imagine 4D space (special ability)

  Our visual system is able to take the 2D images from the retina of each eye and assemble it into a meaningful 3D image. For this reason, there is little doubt that humans lack the first ability; it is the second that is most concerning.

Before studying 4D directly, it makes sense to start with a more managable plan: study analogous tasks in lower dimensinos. This will yield information about the nature of people's "mental assesmbly" process as well as the effectiveness of various presentation techniques.

3 Presentation Techniques

- projection (e.g. human vision - 3D world $\rightarrow$ 2D retina)
  - parallel vs. perspective projection
  - rotate object vs. rotate observer (over time interval)

    Object rotation vs. observer rotation are graphically very similar paradigms, but psychologically, they are completely different. A simple experiment shows this nicely. Subjects look through a hole at a complex item which is centered in a cylindrical room with uniformly textured background. One group then walks to another viewing hold at an angle of $70°$ with respect to the initial view while another group is told (and shown by spinning an example object) that the object in the room has been turned by an angle of $70°$. Thus, both views are identical for both groups. The independent variable is whether a new object is substituted for the original between views, and the dependent variable is whether the subject can properly identify the object as "same" or "new" on the second view. Subjects did significantly better at the task when they physically walked around the room to the next viewing hole compared to the object within being rotated equivelently.

- slicing
  - rotation vs. translation
  - object vs. gap movement
  - thin vs. thick gap

4 Experiments

Experiment 1. 1D $\rightarrow$ 2D Slicing
Target: randomly shaped quadrilinials
Task: study the object, then draw it

Conditions: see variables for "slicing" above

See Figure 1

Experiment 2. 1D $\rightarrow$ 2D Projection
Target: randomly shaped quadrilinials
Task: study the object, then draw it

Conditions: only object rotation vs. screen rotation

See Figure 2

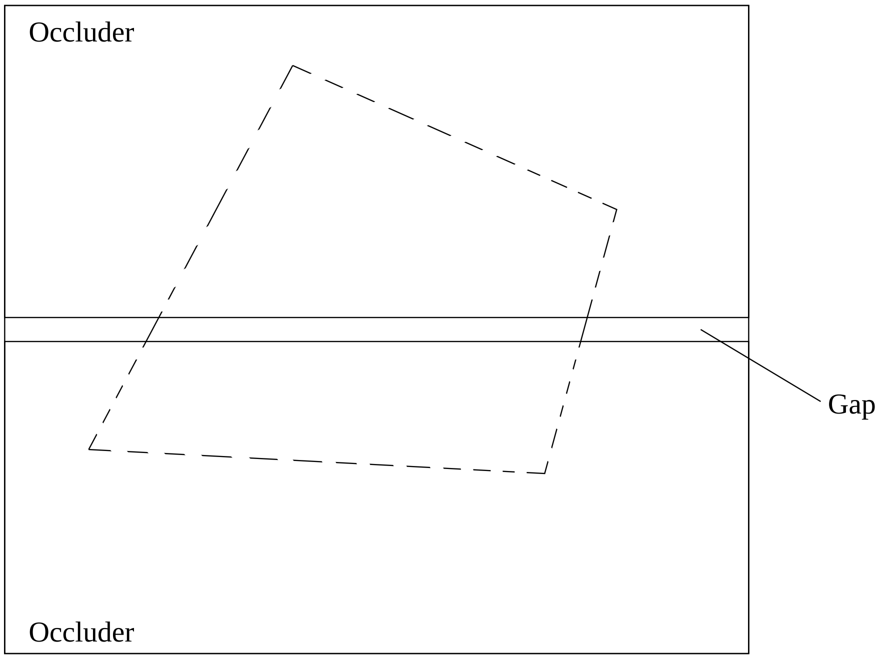

Figure 1: Portions of the shape behind occluders are not seen. They are shown as dotted lines for the sake of clarity

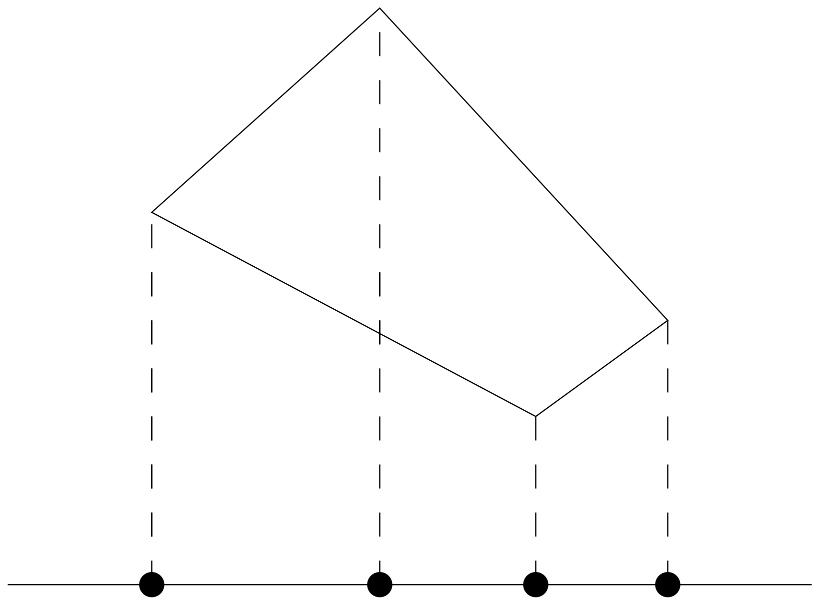

Figure 2: Vertices of the 2D figure are projected onto 1D space. As rotation occurs, the “dots” will move back and forth. Subjects are to draw the original 2D shape after a short time of study

Experiment 3. 2D $\rightarrow$ 3D Projection
Target: Solids generated by connecting 4 randomly chosen points on a shpere
Task: study the object, then draw it or judge distances between points

Conditions:

- thin vs. thick slice
- slice vs. object movement
- object rotation vs. tranlsation
- object vs. viewer rotation (for projection only)

Experiment 4. 3D $\rightarrow$ 4D Projection
Target: 4D solids generated by connecting 5 randomly chosen points on a 4D shpere
Task: study the object, then judge distances between points (cannot possible draw shapes)

Conditions:

- section thickness? No, a section with any thickness would have to be a 4D object. Brightness could be used to represent the 4th dimension giving an analog to section thickness.
- object movement only - section movement would involve moving a 3D "slicer" through 4-space
- object rotation vs. translation for slicing
- object rotation only for projection