

# **Perception Viewed as an Inverse Problem**

## **Psychophysical Experiments**

# **Inverse problems and human perception**

- **Locality of constraints**
- **Perceptual constancy**
- **Dynamic nature of stimuli**

# Locality of Constraints

- **Human perceptual system does not have priors for all possible stimuli and environments. Instead, it has priors only for some abstract features of the environment.**
- **Priors are not used in the case of features that are reliably represented in the proximal stimulus.**
- **Local priors allow the observer to solve the inverse problem in the case of many stimuli, including those that the observer has never perceived before (e.g. unfamiliar smooth curve).**

# Perceptual Constancy

- **Perceptual constancy refers to the fact that the percept of a distal stimulus is constant despite changes in the proximal stimulus. The proximal stimulus may change because of changes in the viewing conditions.**
- **Perceptual constancy is often used as a measure of veridicality of perception.**
- **In the case of viewing a familiar object, the inverse problem can be solved by using the family of familiar objects, only. This recognition problem is almost always well-posed.**

# Perceptual Constancy (cont.)

- **Memory of stimuli can be used not only to recognize familiar objects, but also to reconstruct unfamiliar objects that are similar to one or more familiar ones, by constraining the solution of the inverse problem.**
- **Memory may involve only some aspects of the distal stimuli. This may be used as a constraint by comparing the memory representation to the ‘projection’ of the distal stimulus to the subspace, which is represented in the memory.**

# Dynamic nature of the stimuli

- **The proximal stimulus  $Y$  is a function of time. To assure the stability in time of the solution one should impose constraint that  $\|X(t+1)-X(t)\|$  is small.**
- **Such a constraint leads to a stable percept in each presentation, even though the percept may be unstable across presentations. Stability of the percept in a given presentation has been used in the past to support claims that the percept is not an underconstrained problem.**

# Methodology of Experiments

- **Criteria for classification of experiments:**
  - ◆ **Does the perceptual system attempt to solve an inverse problem?**
  - ◆ **Can effective *a priori* constraints be applied to a given stimulus?**

## ***(Cont.)***

- **There are three types of experiments, depending on which of these two criteria are satisfied:**
  1. ***inverse psychophysics*** (both criteria are satisfied);
  2. ***Under-constrained inverse psychophysics*** (first, but not the second criterion, is satisfied);
  3. ***forward psychophysics*** (neither criterion is satisfied).

# Inverse Psychophysics

- **The distal stimuli are complex and structured**
- **The distal stimulus is richer than the proximal stimulus**
- **The percept resembles the distal rather than the proximal stimulus**

# **Underconstrained Inverse Psychophysics**

- **The perceptual system tries to solve the inverse problem, but effective constraints cannot be applied.**
- **The percept is unreliable and non-veridical.**

# Forward Psychophysics

- **When the stimulus is too impoverished, the perceptual system will not attempt to solve the inverse problem.**
- **The percept is a mere coding of the proximal stimulus.**
- **The distinction between inverse and forward psychophysics, parallels Thomas Reid's (1864) distinction between perception and sensation.**

# The Structure Degradation Procedure

- The main question in the framework of inverse problems is the nature of *a priori* constraints.
- Begin with stimuli that represent inverse psychophysics. Test the subject's ability to discriminate or identify the stimuli.
- Next, construct versions of the stimuli with “degraded” structure, i.e. structure in which some constraints can no longer be applied.
- If the observer's performance (e.g.  $d'$ ) is strongly affected by this manipulation, we can conclude that the constraints under consideration are incorporated by the perceptual system.

# Experiment on Shape Constancy

- **Do subjects discriminate 3D shapes reliably when the shapes are structured?**
- **What is the nature of constraints?**
- **Are they all equally important?**
- **Does removing all constraints lead to chance performance?**

# Shape Identification

- **Run 20 practice trials for ‘polyhedron’, ‘vertices’ and ‘polygonal line, exp. 1’ conditions.**
- **On each trial two presentations of a rotating 3D stimulus motion are shown. The stimulus shown on the second presentation is the same or different from that in the first presentation. “Same” means identical shape, but not necessarily identical size or orientation.**

# Shape Identification

- Run 100 trials for ‘polyhedron’, ‘planar asymmetric’, ‘non-planar, asymmetric’, ‘three quadrilaterals’, ‘polygonal line, Exp. 1’ and ‘vertices’.
- Plot a bar graph with  $d'$  values.
- Results show (probably) that performance is good when all constraints from Chan et al.’s paper can be applied. Performance drops when some (or all) constraints cannot be applied.

# References

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- Reid, T. (1764/1997) *An Inquiry into the Human Mind on the Principles of Common Sense*. University Park, PA: Penn State Univ. Press (D.R.Brookes, Ed.).