Vision in Man and Machine

Part 10
Philosophical Questions

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Neuroscience vision research and computer vision

- What is the interrelation of brain science and computer science ?
- Building models
- Analysis by synthesis
- Can we use computer vision to identify brain functions ?

Philosophical views on truth in science (Lipton 2004)

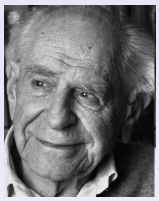
(The Medawar Lecture 2004, Phil. Trans. Royal Soc. B)

- Scientific Realism
  - Provide increasingly accurate and comprehensive descriptions of unobservable reality independent of the scientific theories
  - Theories claim truth over all observable and unobservable phenomena
- Instrumentalism
  - Provide increasingly accurate descriptions, but claim relevance only over the observable entities
  - "Empirically adequate" theories
- Projectivism
  - There is no absolute reality independent from the process of investigating and describing it
  - The scientific process is a human-centered construction rather than nature-centered

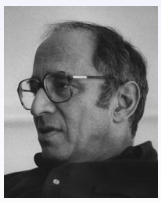
→ *Problem of unobservability is crucial for brain-function*

Important philosophers of science

- Karl Popper
  - Scientific theories must be falsifiable
  - The goal of science is truth → Realism
  - Falsification is necessary to decide between competing theories



- Thomas Kuhn
  - Scientific practice is made of "exemplars" and perceived similarity relations
  - Scientfic progress through paradigm shifts
  - Projectivist view point



The Pessimistic Induction (Laudan 1984)

- All past scientific theories have turned out to be wrong
- Thus, also all current theories will follow the same fate

→ Scientific realism has to be refuted

The miracle argument (Putnam 1978)

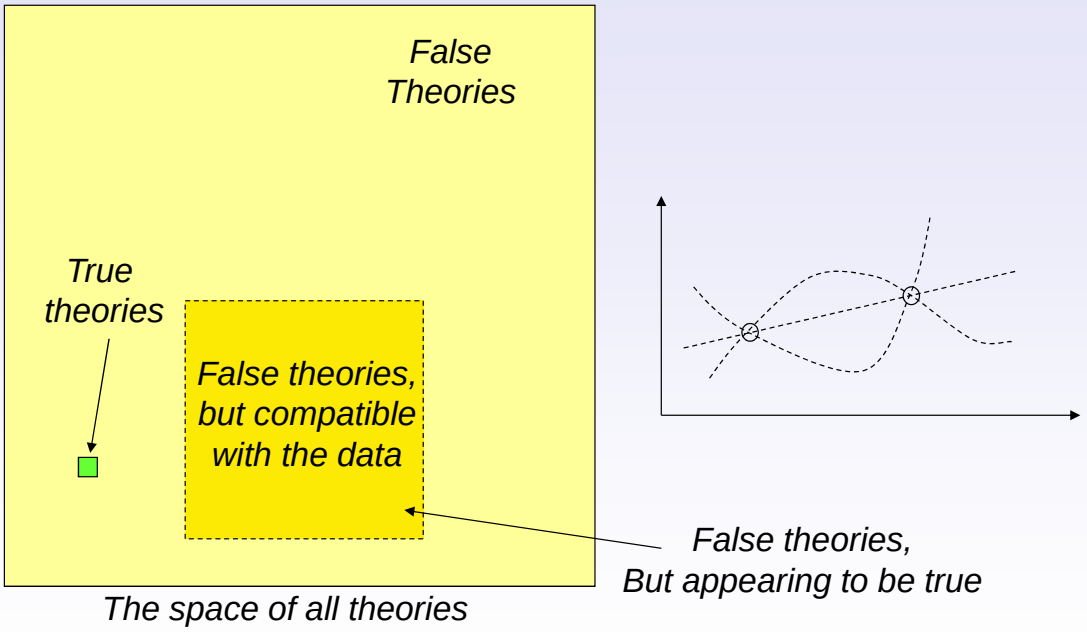
- Imagine yourself in a dense jungle

- You find a map in your pocket

- While walking through the jungle, you note that the map correctly describes every area you explore
- Should you expect that the map is correct in general, even if you have explored only a small fraction of it ?

→ If you have a successful theory explaining all available data, it is most likely true

But: The statistics of truth



→*Theories compatible with all data are most probably false*

Rene Descartes Dioptrics (1637)

- Building up a perceptual world using two sticks
- For a sighted person in the dark this is difficult
- For a blind man this is like "seeing with their hands"
- Normal vision is analogous in exploring the outside with rays of light

Molyneux's problem

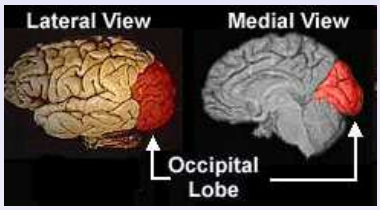
"If a blind man could suddenly see,
could he tell between a globe and a cube ?"

?

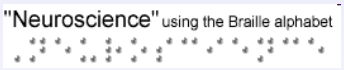
John Locke
"Essay concerning human understanding" (1690)

What does the visual cortex do in blind people ?

- Primary visual cortex in blind people is activated by
  - Sound
  - Touch



- Evidence: fMRI studies for Braille reading



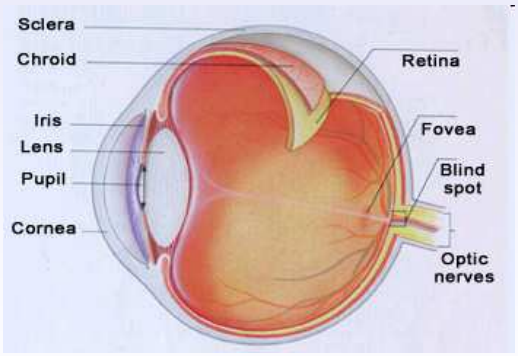
- Level of activity depends on onset of blindness

Critical periods for visual development

- Critical period: Phase in brain development that requires particular sensory stimulation for development of normal perceptual competence
- Examples: Cat visual cortex
  - Closing one eye during the first 3 months after birth disturbs the pattern of stimulus preferences in early visual cortex (Hubel & Wiesel)
  - No such effect for adult cats
- Examples primates
  - Dark-reared primates have great difficulty to recover functional vision
- Humans
  - Stereo vision depends on proper eye alignment during first year
  - But this can actually be compensated for by long training

Recovery from Congenital Blindness

- Causes of congenital blindness considered here:
  - Opaqueness of the cornea
  - Opaqueness of the lens (cataract)
- Can be treated by
  - Lens removal (earliest reports of 1020 in Arabia)
  - Lens replacement
  - Corneal transplantation
- In industrialized countries typical treatment within first 6 months after birth
  → Operations at later age are extremely rare



Literature on visual recovery after congenital blindness

- Marius von Senden. "*Raum- und Gestaltauffassung bei operierten Blindgeborenen* (1932)
  - Analysis of 66 known cases of recovery from blindness after operation
  - Highly influential to Donald Hebb's work "The organisation of behavoir" (1949)
- R. Gregory & J. Wallace. "Recovery from Early Blindness. A Case Study." (1963)
  - Detailed analysis of the case S.B.
- Y. Ostrovsky, A. Andalman, & P. Sinha. Vision following extended congenital blindness. (2006)
  - Project Prakash: Support for eye surgery in poor families in India

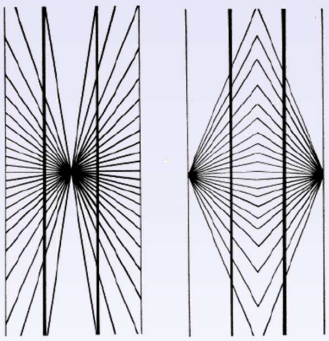
The case S.B.

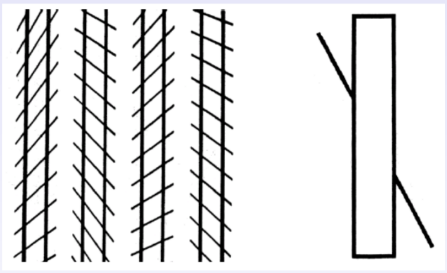
- S.B. developed strong cataract at age of 10 months
- After that S.B. lived practically as a blind person
  - Long periods of wearing bandages around the head
- At the age of 52 he received corneal transplants on both eyes
- His visual recovery was investigated by Richard Gregory and coworkers
- S.B.'s character: Intelligent, co-operative, curious, and honest

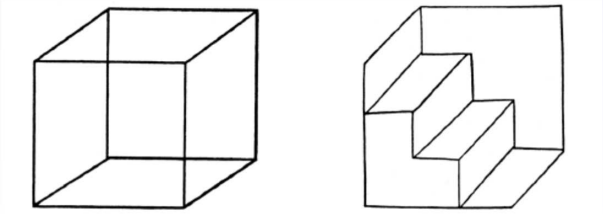
First visual experiences

- Impression of the surgeon's face after bandage removal:
  - "A Blur", only identifiable by voice
- Separation of lorries and cars
  - "Different sounds"
- Perceived scale distortions
  - Looking down a window
  - "Buses are much too high"
- Few 'surprises'
  - "Quarter moon"
- Fascination for reflections, mirrors

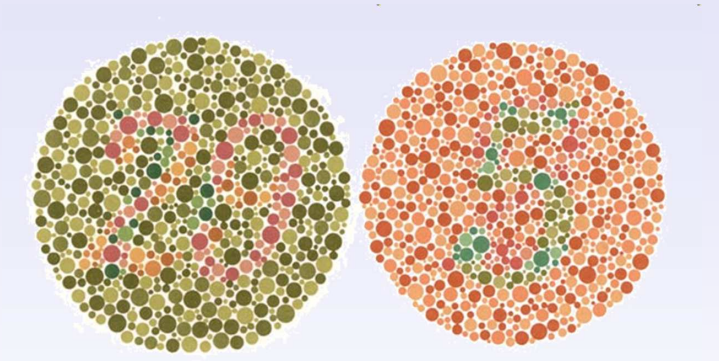
Perceptual Tests







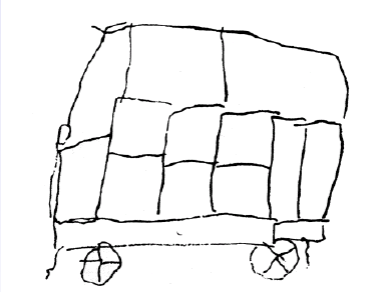
Perceptual Tests



Ishihara color vision test

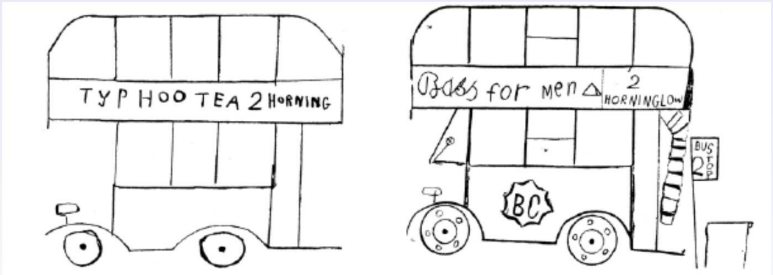
Normal performance

Drawings



(a)

Fig. 10. Drawing of a Bus (48 days after the first operation).



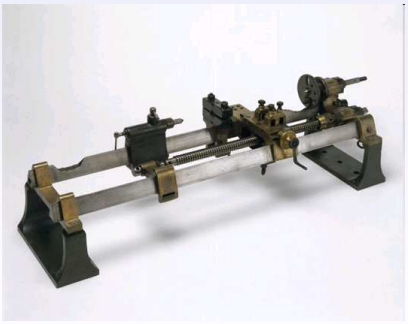
(a) (b)

Fig. 14. Drawings of a Bus. (a) 6 months later; (b) one year later.

Sight and touch

- Reading capitals

- Visit to the science museum, London
  - "Now that I've felt I can see"

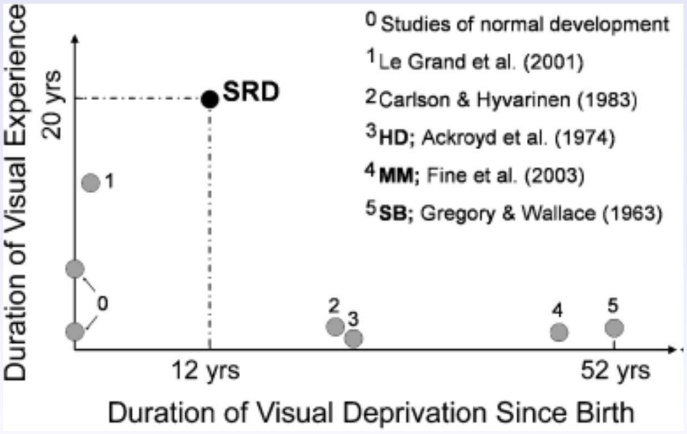


Maudeslay screw cutting machine

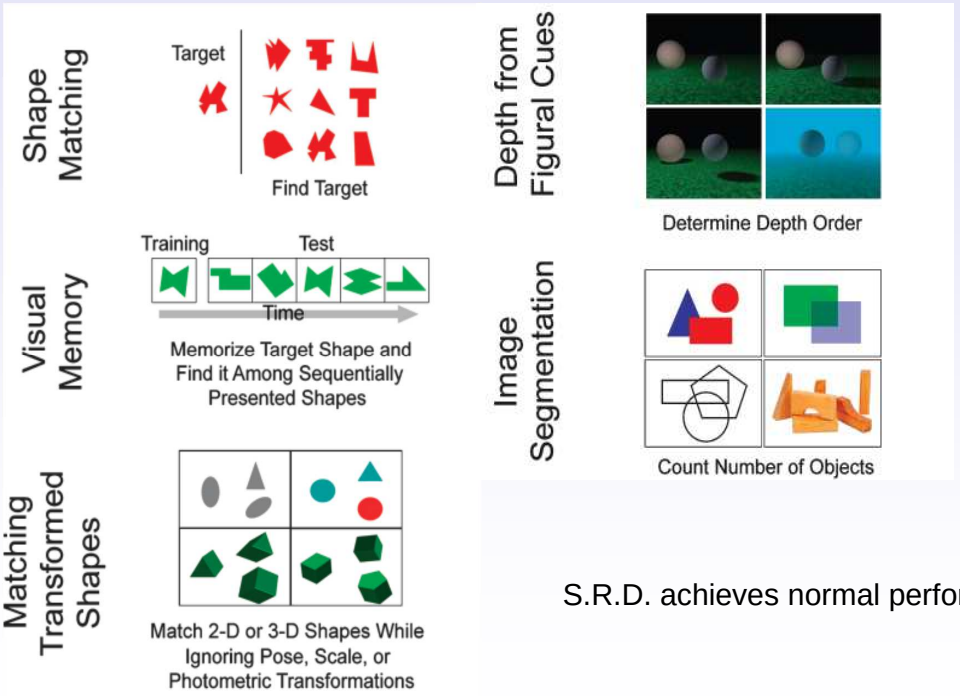
Summary S.B.'s case

- Outstanding finding: Direct transfer from touch to vision
- Visual performance gain was saturating quickly after 1 year
  - Still reporting progress in seeing more details
  - Object appearance change when walking around them
- S.B. was very depressed about this
  - Feeling that he had lost more than he gained

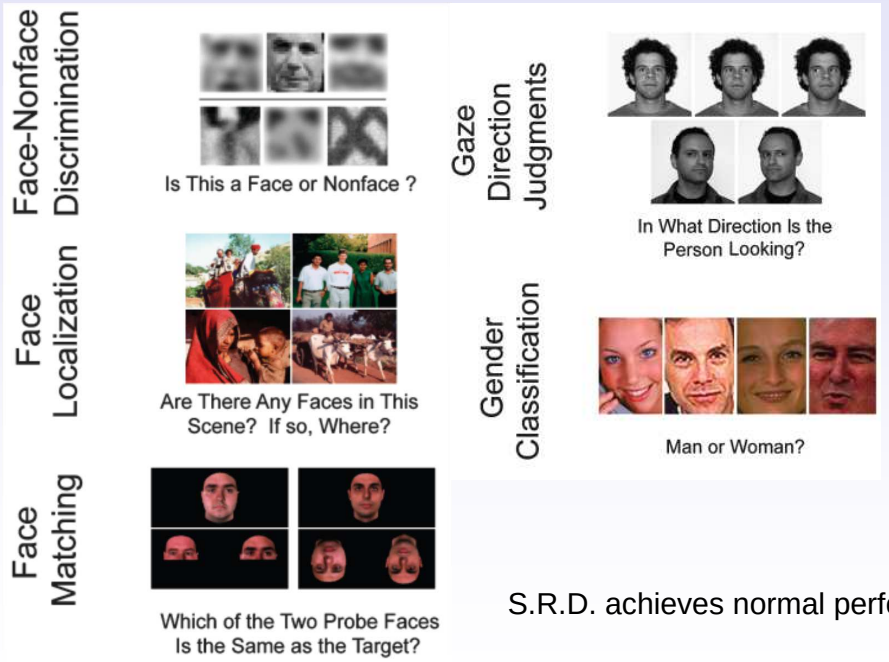
Overview of reported cases



Perceptual testing of S.R.D.



S.R.D. achieves normal performance



S.R.D. achieves normal performance

Summary

- Recovery of visual abilities is possible after congenital blindness
- Gainable performance depends on age
- Critical periods exist, but do not make later adaptation and learning impossible

Summary and conclusion

- Visual perception
  - Active process → Construction of the visual world
- Human visual pathways
  - Hierarchical processing of features
- Sensory coding
  - Sparse coding and feature representations
- Feature representations
  - Perceptual learning
  - Selectivity-stability dilemma
- Object recognition models
  - Hierarchical feature detection and pooling architectures
- Gestalt
  - Perceptual organization of the visual input
- Online learning
  - Building integrated visual learning architectures using biologically motivated models

Literature

- Stephen Palmer "Vision Science", MIT Press
  - Chapter 1
  - Chapter 2 page 45 until end of 2.1.2, section 2.2.3
  - Chapter 4 pages 145-175, 188-192
- R. Goldstone. Perceptual Learning. Annu. Rev. Psychol. (1998). 49:585-612
- T. Palmeri & I. Gauthier. Visual Object Understanding. Nature Reviews Neuroscience. (2004) 5:1-13
- K. Tanaka. Columns for Complex Visual Object Features in the Inferotemporal Cortex: Clustering of Cells with Similar but Slightly Different Stimulus Selectivities. Cerebral Cortex (2003) 13:90–99