A ‘puzzle picture’
Dallenbach (1951)
an absolute depth judgment with respect to fixation, while fine stereopsis requires the judgment of relative depth, i.e., comparing depth across space; (2) the particular coarse stereopsis task used requires the monkey to discriminate a signal in noise, while the fine task does not; (3) the range of disparities is quite different. Chowdhury and DeAngelis (2008) replicate the finding that monkeys initially trained on coarse stereopsis show impaired coarse depth discrimination when muscimol is injected into MT. Remarkably, the same animals, after a second round of training on fine stereopsis, are unimpaired at either fine or coarse depth discrimination by similar injections. Moreover, recordings in MT show that neuronal responses are not altered by learning the fine stereopsis task. Given the differences between the tasks and the large number of visual areas containing disparity-sensitive neurons, one might not be surprised to find different areas involved in the two tasks. But it is quite unexpected that merely learning one task would change the contribution of areas previously involved in the other. Chowdhury and DeAngelis conclude that the change in outcome reflects a change in neural decoding—decision centers that decode signals to render judgments of depth, finding MT signals unreliable for the fine stereopsis task, switch their inputs to select some better source of disparity information. Candidates include ventral stream areas V4 or IT, where relative disparity signals have been reported (Orban, 2008) and which contain far more neurons (Figure 1). When challenged afresh with the coarse depth task, these same decision centers may now find that their new sources of information can solve the coarse task as well as the old ones. MT is no longer critical. Perhaps in other monkeys MT would never have a role in stereopsis at all. Chowdhury and DeAngelis' monkeys were trained simultaneously or previously to discriminate motion, which engages MT. Faced with a qualitatively similar random dot stimulus, it might make sense for the cortex to try to solve the new problem of stereopsis with existing decoding strategies. But if the animals were initially trained on a different task—say, a texture discrimination—MT might never be engaged at all. It would also be interesting to see the outcome if monkeys were trained on depth tasks that were less different and could be interleaved in the same sessions, for example noise-limited depth judgments using similar absolute or relative disparity

Figure 1. A Scaled Representation of the Cortical Visual Areas of the Macaque

Each colored rectangle represents a visual area, for the most part following the names and definitions used by Felleman and Van Essen (1991). The gray bands connecting the areas represent the connections between them. Areas above the equator of the figure (reds, browns) belong to the dorsal stream. Areas below the equator (blues, greens) belong to the ventral stream. Following Lennie (1998), each area is drawn with a size proportional to its cortical surface area, and the lines connecting the areas each have a thickness proportional to the estimated number of fibers in the connection. The estimate is derived by assuming that each area has a number of output fibers proportional to its surface area and that these fibers are divided among the target areas in proportion to their surface areas. The connection strengths represented are therefore not derived from quantitative anatomy and furthermore represent only feedforward pathways, though most or all of the pathways shown are bidirectional. The original version of this figure was prepared in 1998 by John Maunsell.
Vision in jumping spiders

(Wayne Maddison)

(Bair & Olshausen, 1991)
One-day old jumping spider
(filmed in the Bower lab, Caltech)
Orientation by Jumping Spiders During the Pursuit of Prey

(D.E. Hill, 1979)
Navigation
(Tarsitano & Jackson 1997)
Head-direction cells in ellipsoid body of Drosophila (Seelig & Jayaraman 2015)

Ellipsoid body activity (calcium imaging)

Decoded vs. actual head dir.

Accumulated PVA (rad)

Accumulated ball rotation (rad)

Time (s)
How to build a model of world from sensory data?
Bayesian inference

\[ P(H|D) = \frac{P(D|H) P(H)}{P(D)} \]
Perception as inference

\[ P(I|H) \times P(H) \propto P(H|I) \]
Area V1
Macaque visual cortex

Lewis & Van Essen (2000)
Visual areas

inflated

flattened
Chowdhury and DeAngelis (2008) replicate the finding that monkeys initially trained on coarse stereopsis show impaired coarse depth discrimination when muscimol is injected into MT. Remarkably, the same animals, after a second round of training on fine stereopsis, are unimpaired at either fine or coarse depth discrimination by similar injections. Moreover, recordings in MT show that neuronal responses are not altered by learning the fine stereopsis task. Given the differences between the tasks and the large number of visual areas containing disparity-sensitive neurons, one might not be surprised to find different areas involved in the two tasks. But it is quite unexpected that merely learning one task would change the contribution of areas previously involved in the other. Chowdhury and DeAngelis conclude that the change in outcome reflects a change in neural decoding—decision centers that decode signals to render judgments of depth, finding MT signals unreliable for the fine stereopsis task, switch their inputs to select some better source of disparity information. Candidates include ventral stream areas V4 or IT, where relative disparity signals have been reported (Orban, 2008) and which contain far more neurons (Figure 1). When challenged afresh with the coarse depth task, these same decision centers may now find that their new sources of information can solve the coarse task as well as the old ones. MT is no longer critical. Perhaps in other monkeys MT would never have a role in stereopsis at all. Chowdhury and DeAngelis' monkeys were trained simultaneously or previously to discriminate motion, which engages MT. Faced with a qualitatively similar random dot stimulus, it might make sense for the cortex to try to solve the new problem of stereopsis with existing decoding strategies. But if the animals were initially trained on a different task—say, a texture discrimination—MT might never be engaged at all. It would also be interesting to see the outcome if monkeys were trained on depth tasks that were less different and could be interleaved in the same sessions, for example noise-limited depth judgments using similar absolute or relative disparity.
Lateralization of the visual pathways
V1 is highly overcomplete

Temporal reconstruction of the image also has to face the problem that the image is often moving continuously, but is only represented by impulses at discrete moments in time. In these days he often has to deal with visual images derived from cinema screens and television sets that represent scenes sampled at quite long intervals, and we know that the homunculus also has to face the problem that the image is often moving continuously, but is only represented by impulses at discrete moments in time.

Recent psychophysical work has improved our understanding of these problems. At one time it was thought that image motion aided resolution (Narash; SI. Talbot 1942), but this was hard to believe because of the blurring effect of the eye's long LGN afferents.

![Diagram](image.png)

**FIGURE 8.** A tracing of the outlines of the granule cells of area 17 in layers IVb and IVc of monkey cortex, where the incoming geniculate fibres terminate (from fig. 3c of Hubel & Wiesel 1972). The dots at the top indicate the calculated separation of the sample points coming in from the retina, allowing two impulses per cycle of the highest spatial frequency resolved. The misaligned vernier at right has a displacement corresponding to one sixtieth of the sample separation, or 0.5 mm for 60 cycle/deg optimum acuity. The 'grain' in the cortex appears to be much finer than in the retina. That he does a good job at interpreting them even when the sample rate is only 16 s−1, as in amateur movies. One only has to watch a kitten playing, a cat hunting, or a bird alighting at dusk among the branches of a tree, to appreciate the importance and difficulty of the visual appreciation of motion. Considering this overwhelming importance it is surprising to find how slow are the receptors and how long is the latency for the message in the optic nerve, and even more surprising to find how well the system works in spite of this slowness.

Barlow (1981)
1 mm² of cortex contains 100,000 neurons and receives input from \(~14 \times 14\) ‘pixels’ in retina
Single-unit electrophysiology
Extracellular microelectrode recordings can be used to measure action potentials.
Mapping of simple cell receptive field
VI - topographic representation
Cortical magnification

courtesy of Arash Fazl
Foveal oversampling in LGN and Cortex (Connolly & Van Essen, 1984)

“...despite the fact that the estimated total number of LGN cells is similar to the total number of retinal ganglion cells, their ratio must vary from many LGN cells per retinal ganglion cell for the fovea to fewer than one LGN cell per retinal ganglion cell in the periphery.”
Cortex:LGN cell ratio ranges from 1000:1 in fovea to 100:1 in periphery (Connolly & Van Essen, 1984)
Primary visual cortex slice (Nissl stain)

Cortical layers
Connections of cortical layers in V1
Ocular dominance columns
(Horton)
1 mm² of cortex analyzes ca. 14 x 14 array of retinal sample nodes and contains 100,000 neurons.