Introduction to an ongoing study:

"Seeking evidence for the independent functioning of the two visual-perceptual systems“

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Presentation at the Sixth Meeting of the
Advisory Council of the
Max Wertheimer Minerva Center
for Cognitive Processes and Human Performance

February 13th, 2006

Outline of the talk:

- A bit of personal history – how I became interested in the two perceptual/visual systems.
- An introduction to the two systems.
- The aims and methods of the current study.

Personal history:

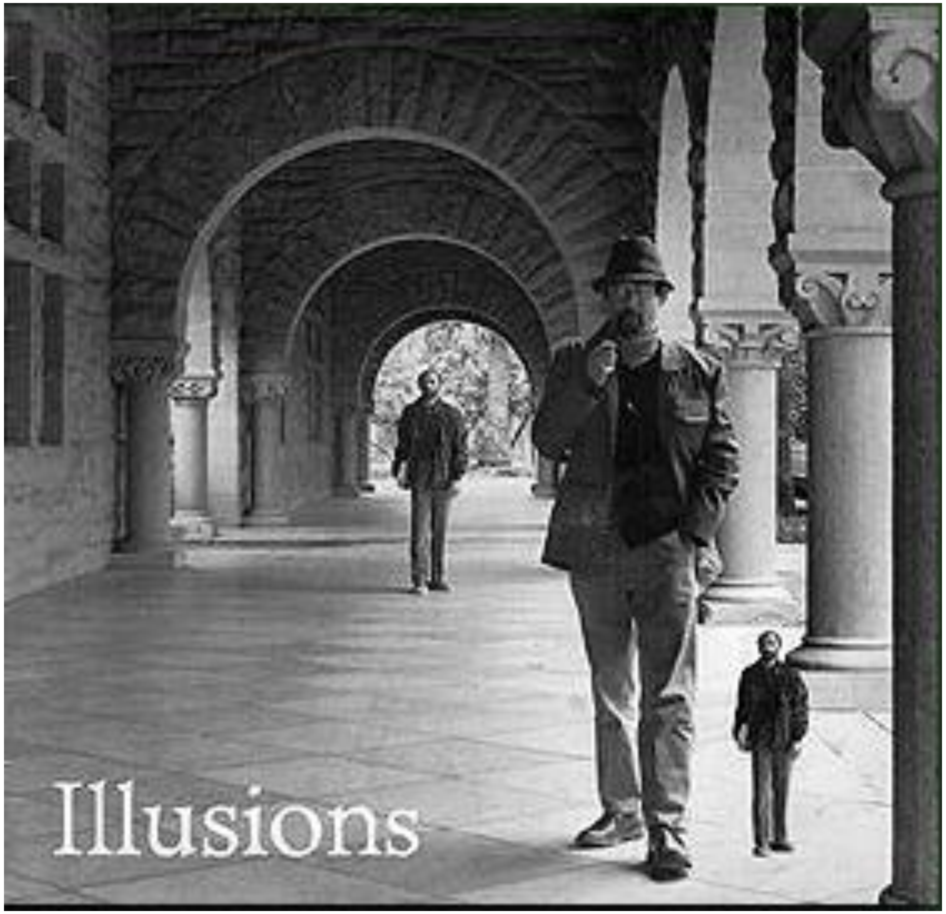
Continuous interest in **Space Perception**:

How do we achieve veridical perception of 3-D space from two 2-D images on our retinas?

Example: **Size Perception**

Objects are not perceived as becoming smaller as we move away from them.

Size Constancy


Illusions

How is size constancy achieved?

Two theoretical approaches:

Classical: Constructivist

Ecological: Gibsonian

Constructivist Theory = a “taking into account” theory.

An Indirect theory – “Unconscious inference”

Size constancy achieved by the taking into account of the object’s distance.

Ecological Theory = A Direct theory

Size constancy is achieved by the direct pickup of information from the visual stimulus.

No inferences are called for.

Which theory is correct?

I ran a study in an attempt to find out

Norman, J. (1980). Direct and indirect perception of size. *Perception and Psychophysics*, *28*(4), 306-314.

My results were complex:

“To sum up, it is being suggested that both direct and indirect perception occur, that they do not define a dichotomy but a continuum, and that the location of a perceptual act on that continuum is determined by some interaction of the difficulty of the perceptual discrimination required and the richness of the stimulus conditions….. The challenge facing the perceptual theorist is not to choose between the two theories, but to incorporate the two approaches into a common framework with the aim of delineating the conditions under which direct and indirect processes emerge.” (Norman, 1983).

How can both theoretical approaches be valid?

I searched for an answer for many years, and finally found it in a revised version of the **two visual systems** concept.

My ideas appeared as a target article in the *Behavioral and Brain Science*:

Norman, J. (2002). Two visual systems and two theories of perception: An attempt to reconcile the constructivist and ecological approaches. *Behavioral and Brain Sciences, 25(1),* 73-144.

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- **An introduction to the two systems**.

- The aims and methods of the current study**.**

Two Visual Systems

Ungerleider, L. G., & Mishkin, M. (1982). Two cortical visual systems. In D. J. Ingle, M. A. Goodale, & R. J. W. Mansfield (Eds.), *Analysis of Visual Behavior* (pp. 549-586). Cambridge, MA: MIT Press.

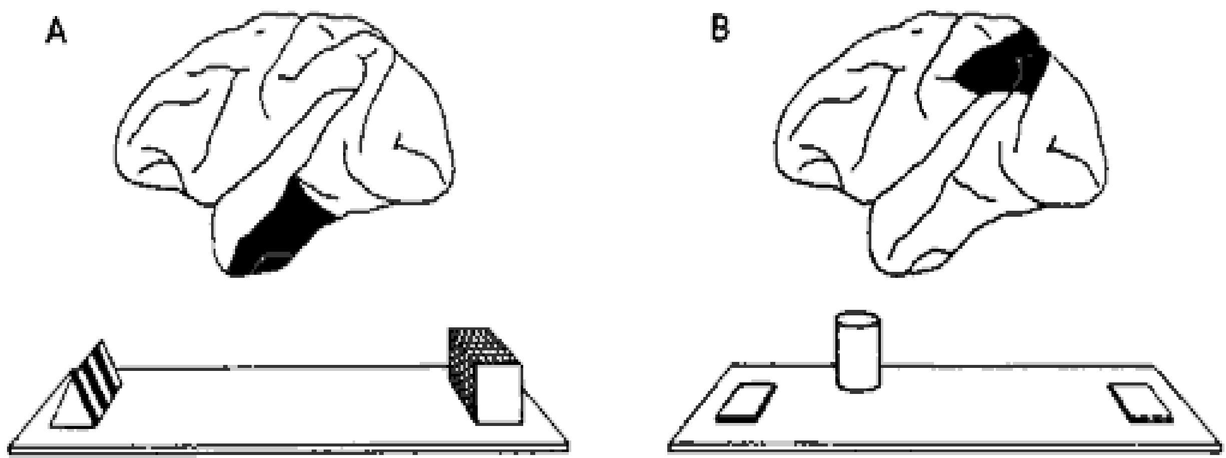
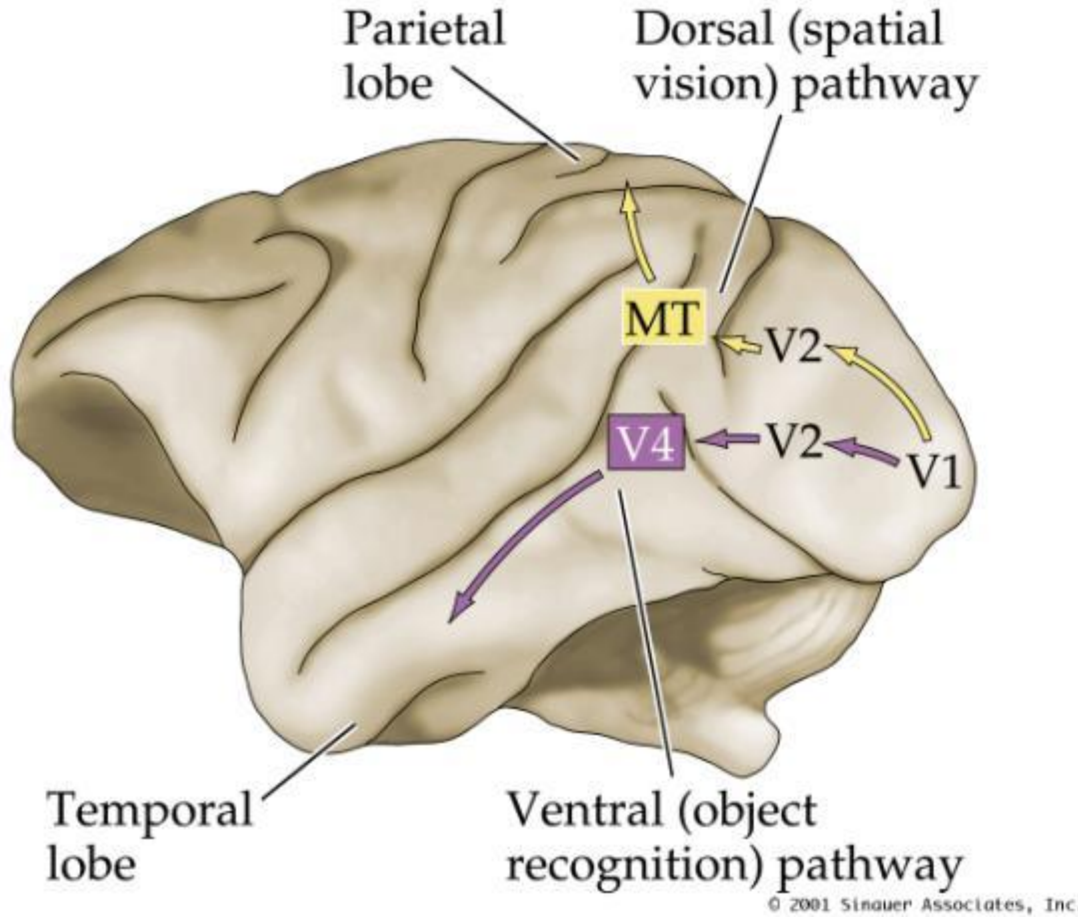


Fig. 2 *Behavioral tasks sensitive to cortical visual lesions in monkeys.* **(A)** *Object discrimination. Bilateral removal of area TE in inferior temporal cortex produces severe impairment on object discrimination. A simple version of such a discrimination is a one-trial object-recognition task based on the principle of non-matching to sample, in which monkeys are first familiarized with one object of a pair in a central location (familiarization trial not shown) and are then rewarded in the choice test for selecting the unfamiliar object.* **(B)** *Landmark discrimination. Bilateral removal of posterior parietal cortex produces severe impairment on landmark discrimination. On this task, monkeys are rewarded for choosing the covered foodwell closer to a tall cylinder, the 'landmark', which is positioned randomly from trial to trial closer to the left cover or closer to the right cover, the two covers being otherwise identical.*

Dorsal and ventral streams



Ungerleider & Mishkin and many others suggested that:

The **ventral stream** answers the question **“what”**, i.e., identification of what we see.

The **dorsal stream** answers the question **“where”**, knowledge of the spatial location of the object.

The what-where distinction was very popular until ….

A somewhat different approach to Two Visual Systems:

Not "what" and "where", but "what" and "how". Neuropsychological studies by Goodale and Milner.

Goodale, M. A., & Milner, A. D. (1992). Separate visual pathways for perception and action. *Trends in Neurosciences*, *15*(1), 20-25.

Goodale, M. A., Milner, A. D., Jakobson, L. S., & Carey, D. P. (1991). A neurological dissociation between perceiving objects and grasping them. *Nature*, *349*(6305), 154-156.

Milner, A. D., & Goodale, M. A. (1995). *The visual brain in action.* Oxford, England UK: Oxford University Press.

Goodale, M. A., & Milner, A. D. (2004). *Sight unseen: An exploration of Conscious and Unconscious Vision.* Oxford: Oxford University Press.

Goodale and Milner agreed that the ventral stream's central task was identifying the elements of the viewer's visual environment.

BUT, they suggested that the dorsal stream's central task is to utilize visual input for the control of action (motor activities).

Much of their experimental work was on a single neurological patient, known as DF.

Patient DF. Suffers from Visual Form Agnosia.

Cannot report on anything she sees (not conscious).
BUT she can perform visually guided motor actions.

Patient D.F.: a case history of visual form agnosia **129**

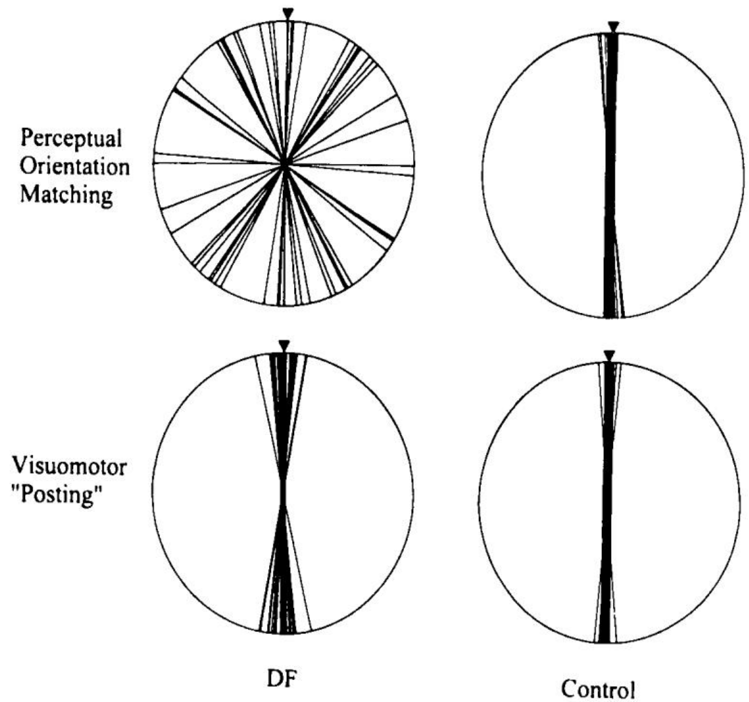
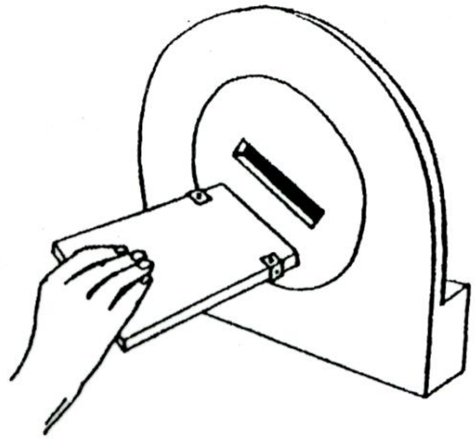
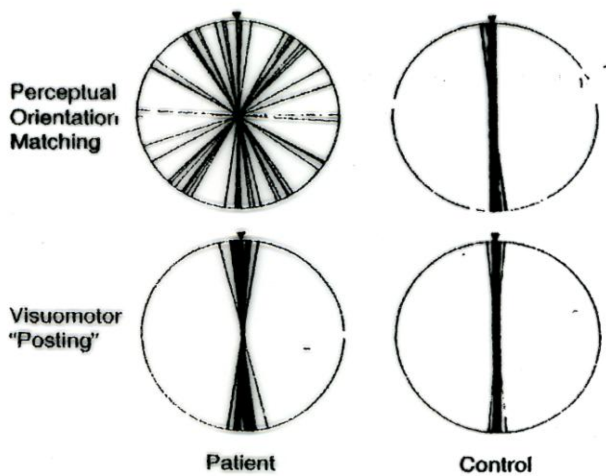


Fig. 5.3 Polar plots illustrating the orientation of a hand-held card in two tasks of orientation discrimination, for D.F. and an age-matched control subject. On the perceptual matching task, subjects were required to match the orientation of the card with that of a slot placed in different orientations in front of them. On the posting task, they were required to reach out and insert the card into the slot. The correct orientation has been normalized to the vertical. Adapted from Goodale *et al.* (1991).




Perceptual
Orientation
Matching
Visuomotor
"Posting"
Patient
Control

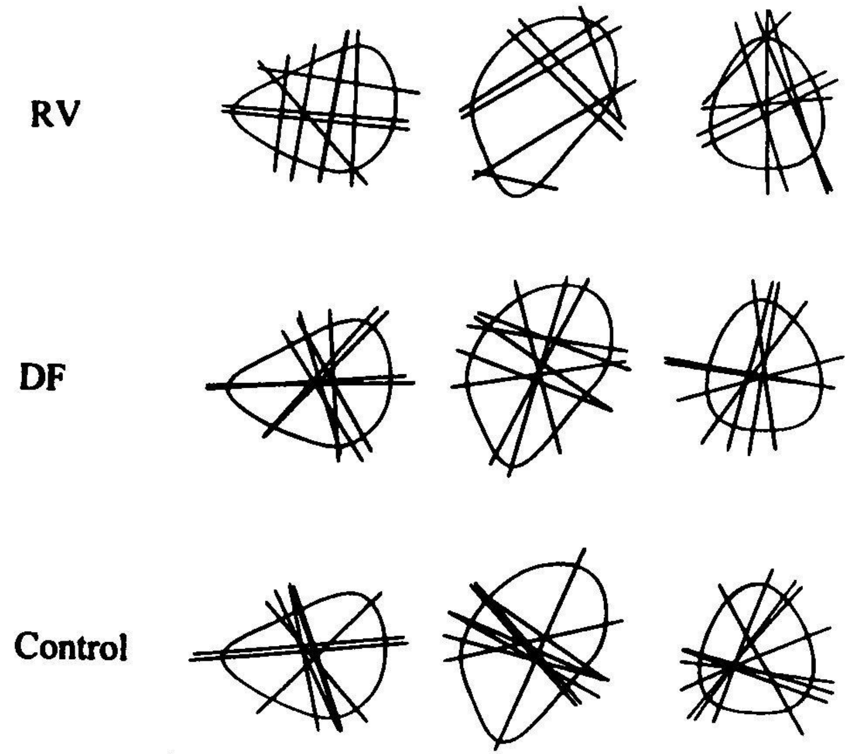


Fig. 5.7 The 'grasp lines' (joining points where the index finger and the thumb first made contact with the shape) selected by the patient D.F. (visual form agnosia), the patient R.V. (optic ataxia), and a control subject, when picking up three different shapes. The four different orientations in which each shape was presented have been rotated so that they are aligned. The grasp lines selected by D.F. and the control subject are virtually identical and pass approximately through the centre of mass of the shape. Moreover, both D.F. and the control subject tended to choose stable grasp points on the object boundary. Their performance contrasts with that of R.V., the patient with dorsal stream damage, who was discussed in Chapter 4.

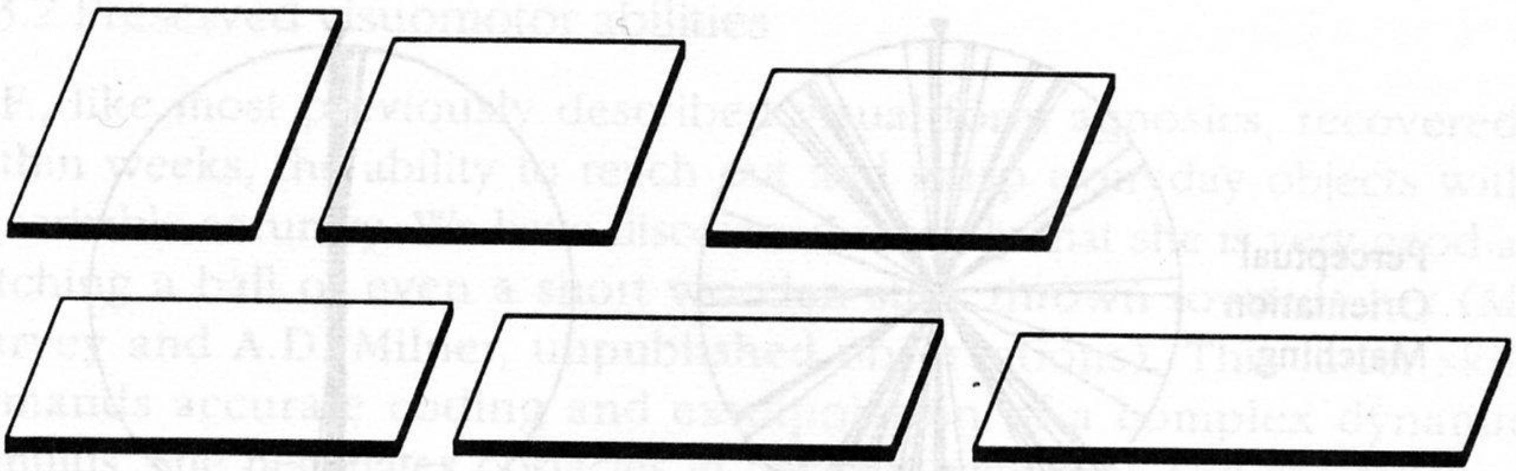


Fig. 5.4 Diagram illustrating the range of a typical set of 'Efron rectangles', in this case in the form of solid plaques. These shapes all have the same surface area but differ in the ratio of their length and width. Different studies (for example, Efron 1969; Warrington, 1985*a*, *b*; Goodale *et al.* 1991; Milner *et al.* 1991) have used different ranges of length-width ratios, but the principle is the same.

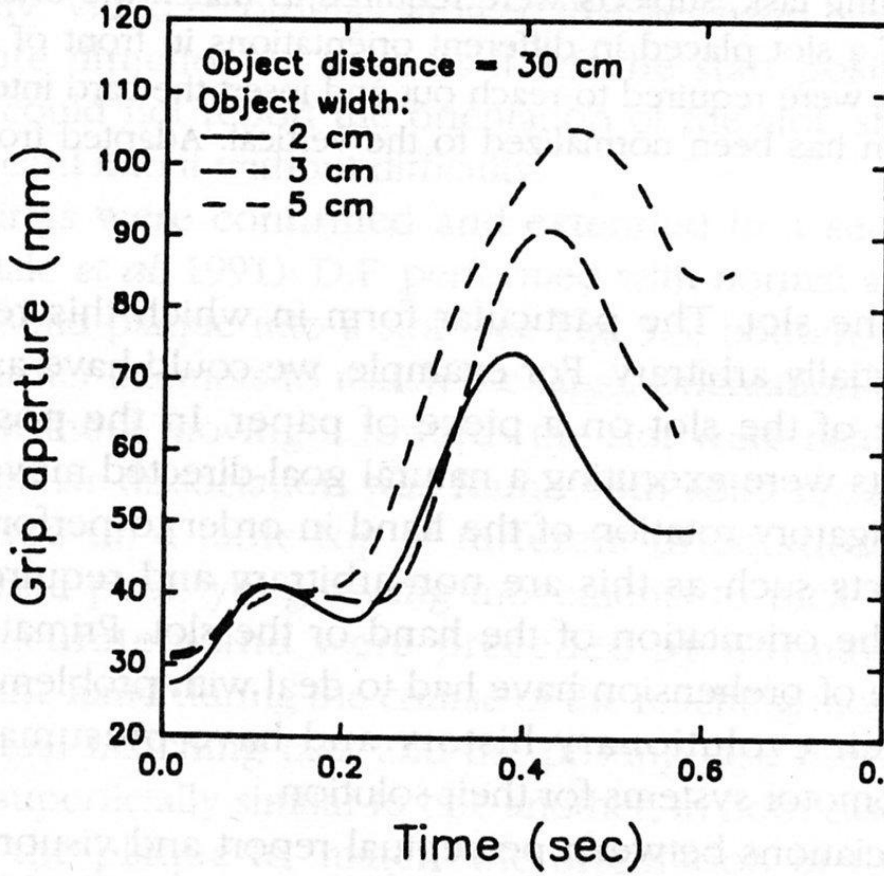


Fig. 5.5 The relationship between the forefinger–thumb grip aperture and object size, for a normal subject reaching out and grasping a small block of three different sizes placed 30 cm away.

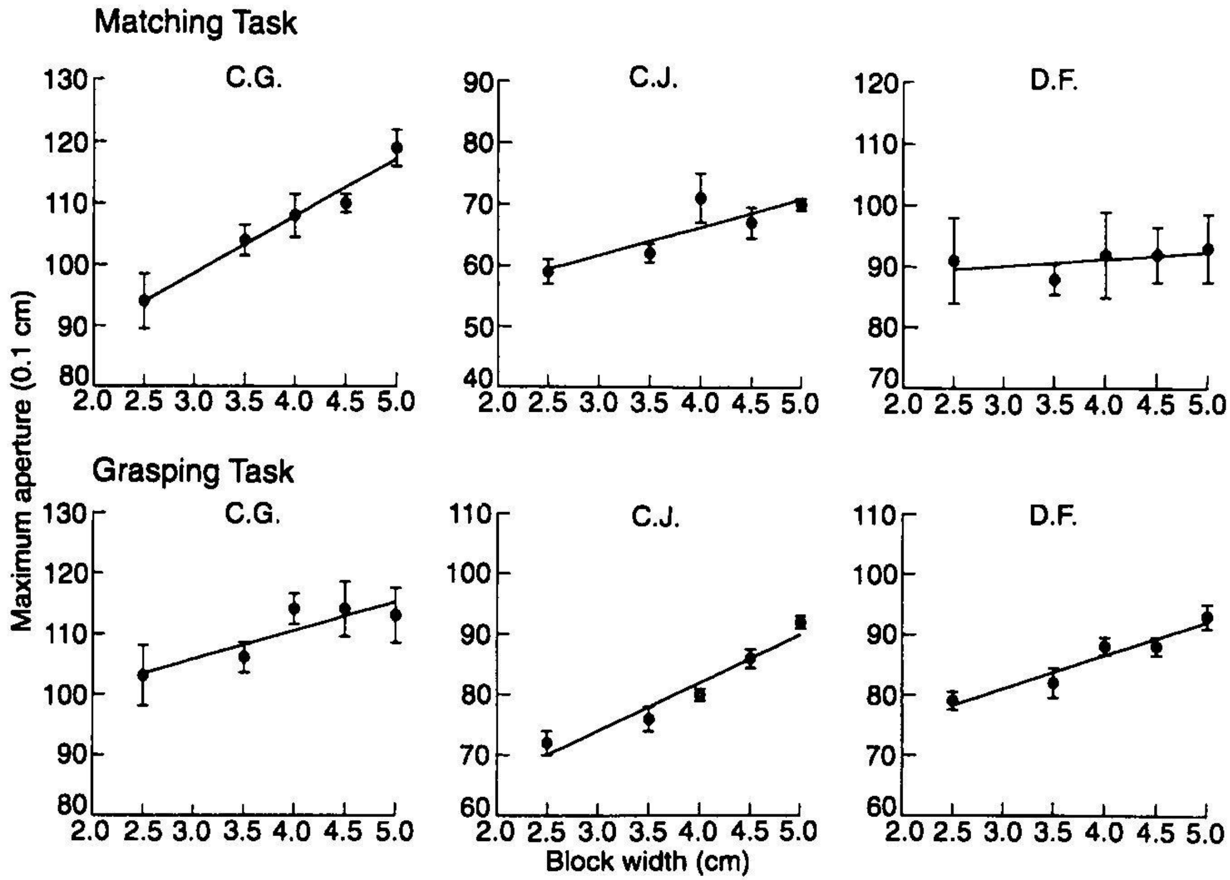
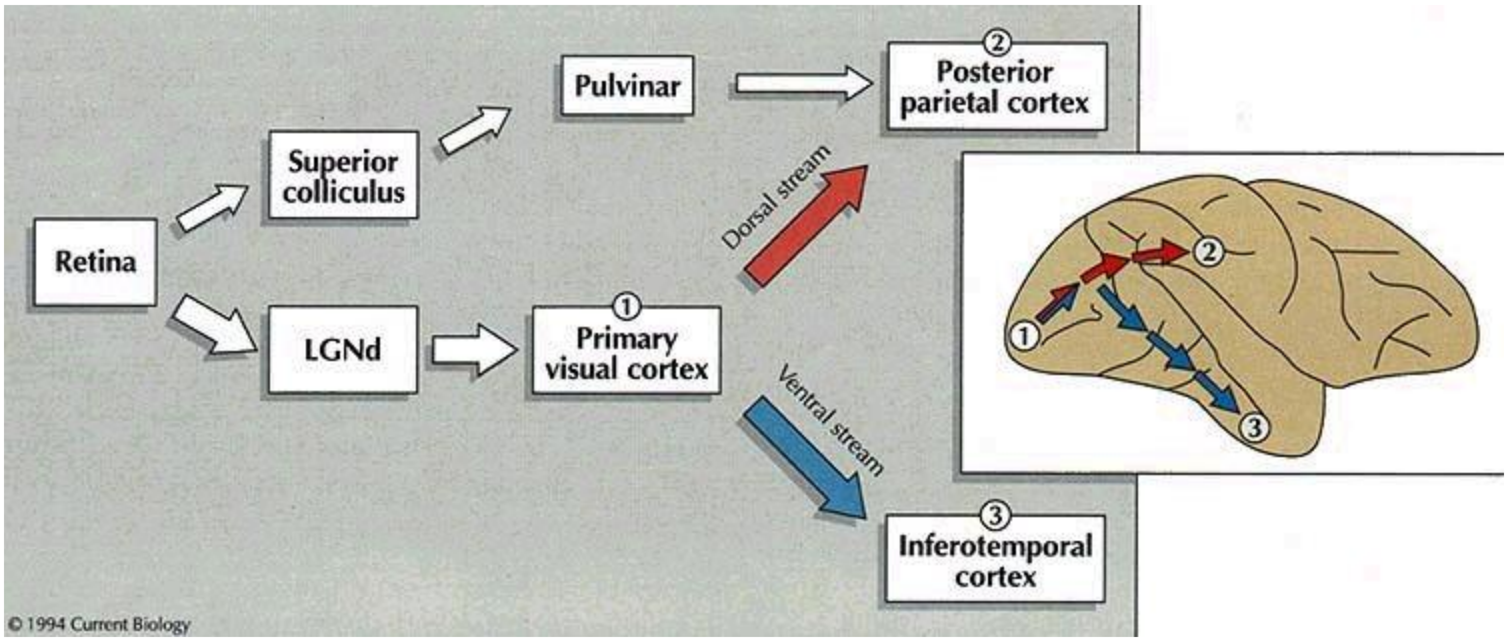


Fig. 5.6 The relationship between object width and thumb–index finger aperture on a matching task and a grasping task for the patient D.F. and two age-matched control subjects (C.G. and C.J.). When D.F. was required to indicate how wide the block was by opening her finger and thumb, her matches were unrelated to the object width and showed considerable trial to trial variability (upper right graph). When she reached to pick up the block, however, the size of her anticipatory grasp was well-correlated with the width of the block (lower right graph). Adapted from Goodale *et al.* (1991).


Retina
Superior colliculus
Pulvinar
LGNd
Primary visual cortex
1
Posterior parietal cortex
2
Inferotemporal cortex
3
Dorsal stream
Ventral stream
1
2
3
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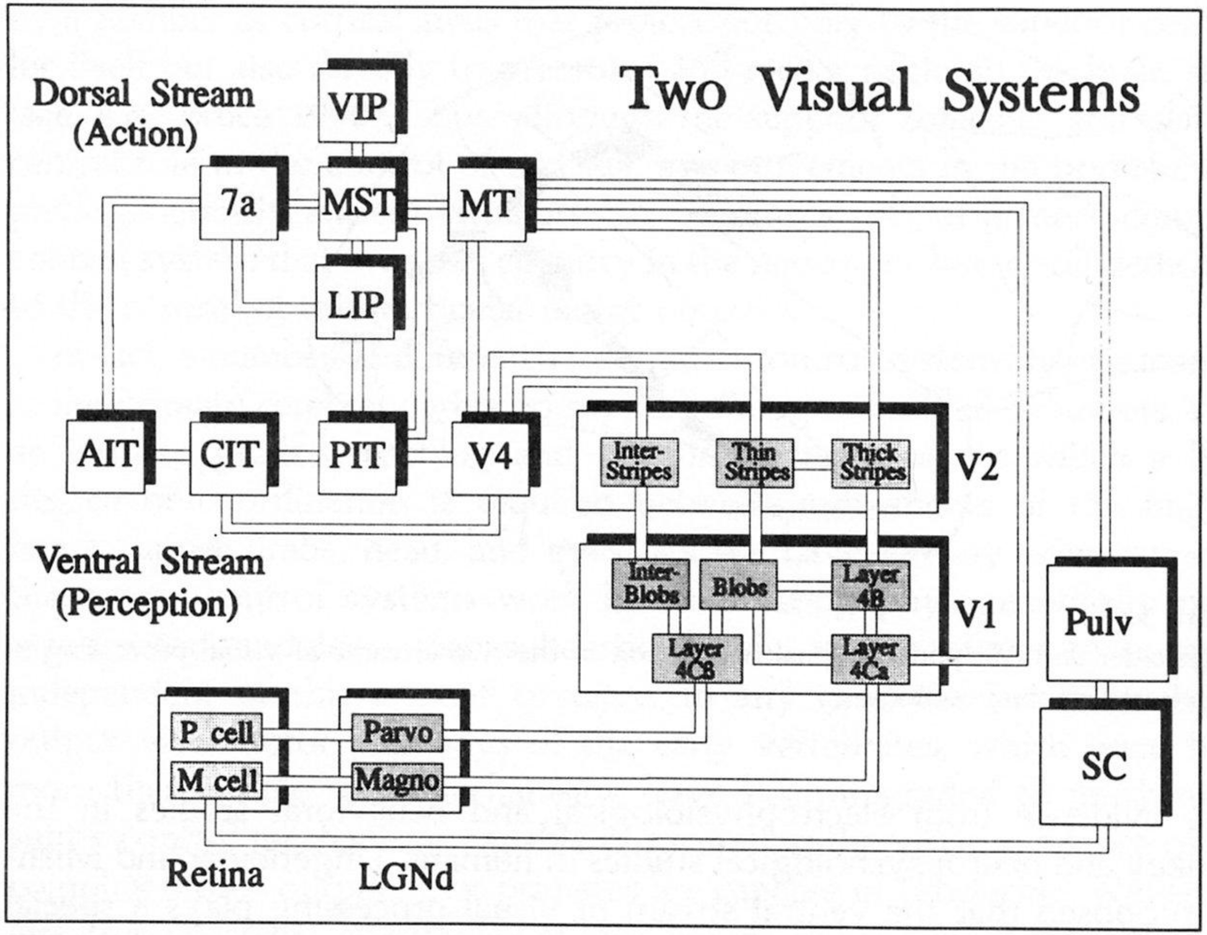
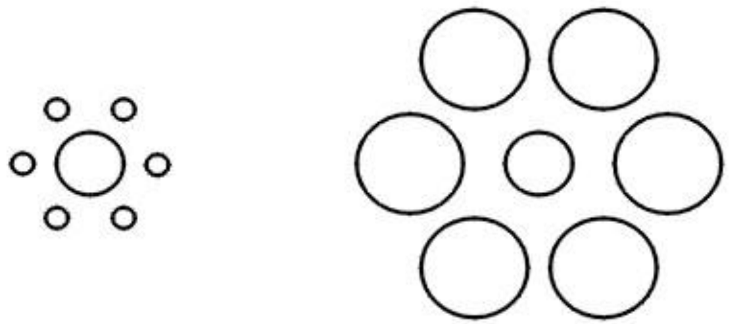
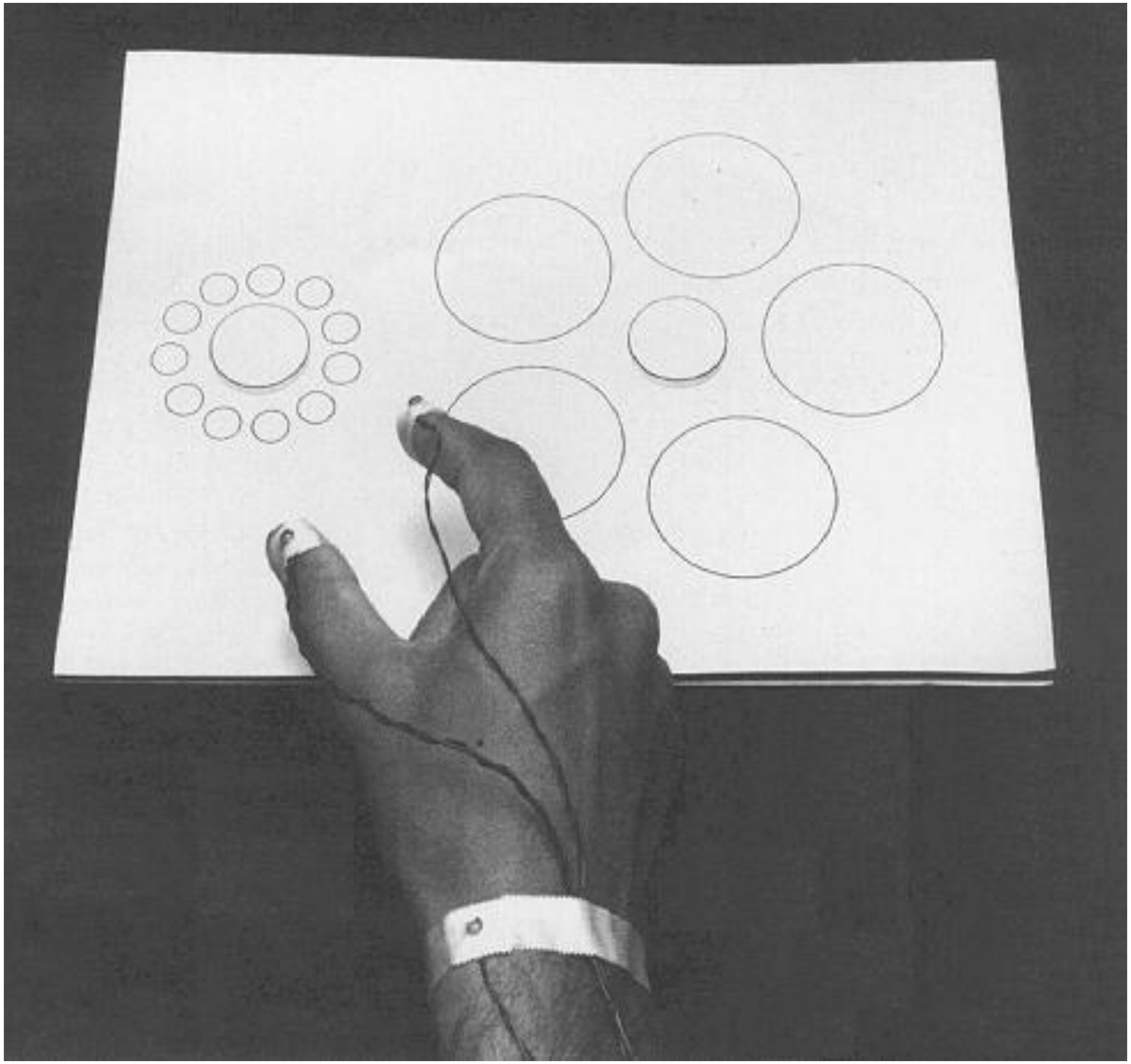


Figure 5.7
Schematic diagram of Goodale and Milner's conception of the two streams of visual processing in the primate cerebral cortex. LGNd: lateral geniculate nucleus, pars dorsalis; SC: superior colliculus; Pulv: pulvinar; PIT: posterior inferotemporal cortex; CIT: central inferotemporal cortex; AIT: anterior inferotemporal cortex; MT: middle temporal area; MST: medial superior temporal area; LIP: lateral intraparietal sulcus; VIP: ventral intraparietal sulcus. For a discussion of the functions of these areas, see Milner and Goodale (1995).



Aglioti, S., DeSouza, J., & Goodale, M. (1995). Size-contrast illusions deceive the eye but not the hand. *Current Biology*, *5*(6), 679-685.



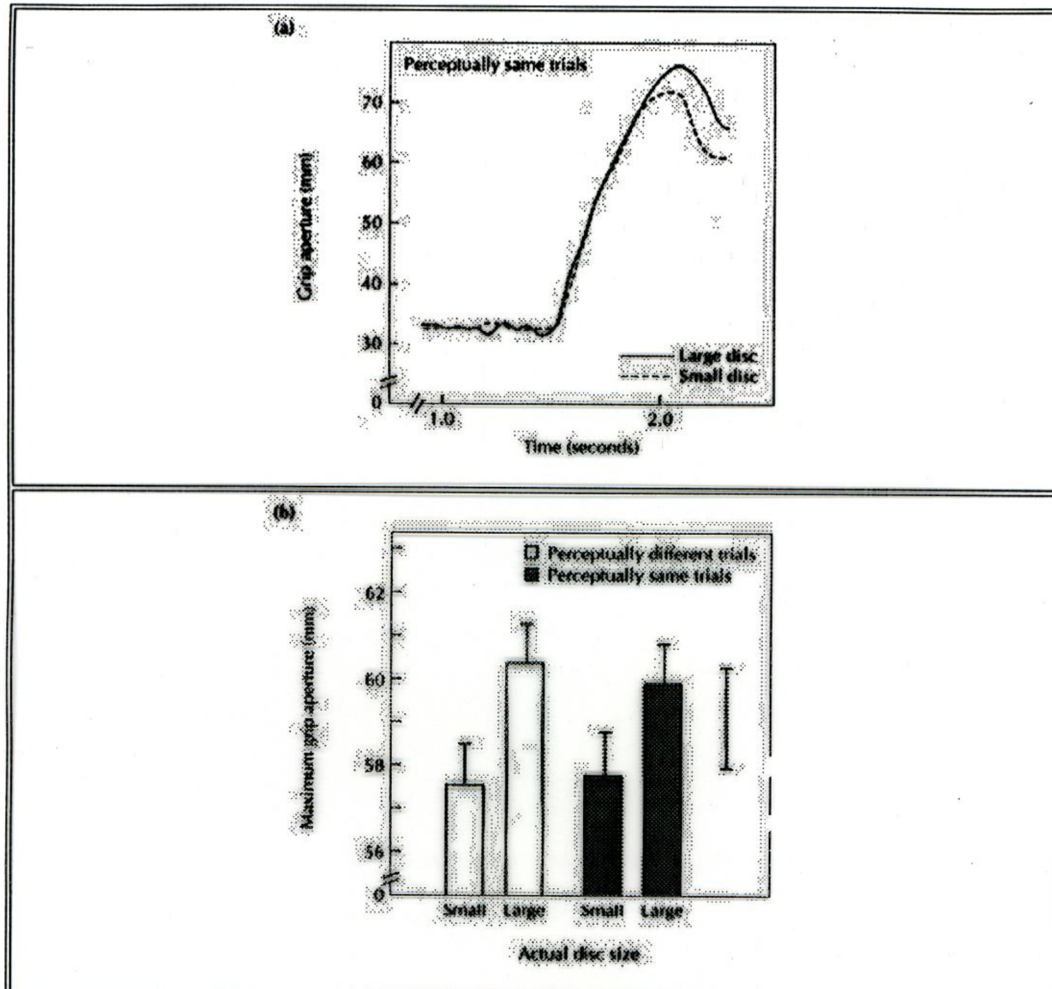


Fig. 4. Graphs illustrating grip aperture under different testing conditions. **(a)** Representative grip-aperture profiles for one subject picking up a large disc and a small disc on separate trials in which he judged the two discs to be identical in size (even though, of course, the two discs were physically quite different). In both cases, the disc was located on the left hand side of the display. **(b)** The mean maximum grip aperture for the 14 subjects in different testing conditions. The grey bars indicate the maximum aperture on trials in which the two discs were judged to be perceptually the same, even though they were physically different in size. The open bars indicate the mean maximum aperture on trials in which the two discs were judged to be perceptually different, even though they were physically the same size (either two large discs or two small discs). The line to the extreme right of the graph indicates the average difference in disc size that was required to achieve perceptual equivalence in the pre-test. The difference between the maximum grip aperture achieved for large discs was significantly greater than the maximum grip aperture achieved for small discs, independent of whether or not the subject believed the discs were the same or different sizes ($p < 0.001$). No other comparisons were significant. Error bars indicate the standard error of the mean.

The dual-process approach to visual perception:

Visual (space?) perception consists of the functioning of two systems:

	Ventral System	Dorsal System
Anatomical Location:	Temporal Lobe (inferior)	Parietal Lobe (posterior)
Main Functions:	Recognition, Identification	Visually guided behavior
Sensitivity:	High SFs (fine details)	High TFs (motion)
	Lower contrast sensitivity	Higher contrast sensitivity

(more ..)

	Ventral System	Dorsal System
Memory:	Memory-based (representations)	Only very short-term
Speed:	Slower	Faster
Awareness:	Usually	Rarely (via ventral?)
Frame of reference:	Egocentric	Allocentric (exocentric)
Visual input:	Foveal or parafoveal	Better attuned to periphery

Above differences do not prevent the two systems from functioning synergistically in normal subjects (e.g., picking up a hammer).

In my BBS article I reviewed the two theoretical approaches, constructivist and ecological, and also reviewed research on the two visual systems. Then I mustered all the evidence I could gather to show that the two theoretical approaches could be reconciled by assuming that the ecological theory paralleled the dorsal system and the constructivist theory the ventral system.

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"Seeking evidence for the independent functioning of the two perceptual systems“

Main aim:

Determining the extent to which the two systems can function independently.

Can the two systems function concurrently with very little interference between them?

Can we utilize the dorsal system to perform one function while a second function is performed by the ventral system?

Since the dorsal system requires little or no awareness, does this imply that more cognitive capacity can be devoted to ventral system tasks carried out simultaneously?

In other words: do the two systems compete for the same cognitive resources?

Very little experimental work has been carried out in this vein, but everyday experience indicates that we can carry out two tasks simultaneously, when one is dorsal and one ventral:

E.g., walking down a path while reading a book, or driving a car while listening to a radio drama.

How does one experimentally examine these questions?

Basic experimental method:

Dual-Task Paradigm

Participants are required to try and perform two tasks at the same time:

A steering task and an identification task.

Identification is always ventral.

Steering can be carried out either by relying on dorsal system information, or on ventral system information.

Experiment utilizes a very large display, an SGI Reality Center screen – 2.66 X 1.18 m.

Participants sit very near the screen, 1 m, yielding a display that is 105 degrees wide.

Identification task – relatively small pictures appear in the middle of the screen, changing very quickly (every 90 s). 2000 different pictures are used; half of animals and half of inanimate objects. The participants have to quickly determine “animal or inanimate” and press the appropriate button (left hand).

Steering task – The participants' task is to keep the "space ship" on course, or "straight ahead". The computer program changes the course very often. A "flight" lasts 5 minutes.

Course information comes in two modes:

Digital – Small display in the center of the screen. "0" signifies being on course, negative numbers being off course to the left and positive numbers being off course to the right.

Optical Flow – A "star field" or "cloud of dots" flows towards the participant. When that flow field is symmetrical (left-right) the ship is on course. If the ship is off course the flow field is seen to swing to the right or to the left.

Between-subjects design – three groups of subjects.

All perform the identification task, but differ on the steering information they receive:

1) Dots only – steer with the flow field display (no digital information).

2) Numbers only – steer with the digital display (no optical flow).

3) Both – can steer with either or both types of course information.

Rationale:

Steering with optic flow – a dorsal system task.

Steering with numbers – a ventral system task.

General hypothesis:

Performance on the identification task (ventral) will be better when steering by flow (dorsal) than when steering by numbers (ventral). In other words, it will be easier when the two tasks are split between the two systems.

Further experiments will examine the following questions:

- Do two dorsal tasks interfere with each other?
- How does limiting the optic flow to different parts of the visual field affect performance?
- How does stereoscopic presentation of the flow affect performance?
- Does optic flow made up of elements differing in size, shape, and color affect performance?

Results?

Will be presented at:

The Seventh Meeting of the Advisory Council of the Max Wertheimer Minerva Center for Cognitive Processes and Human Performance