UCL

Perceptual Processing Deficits Associated with Schizophrenia

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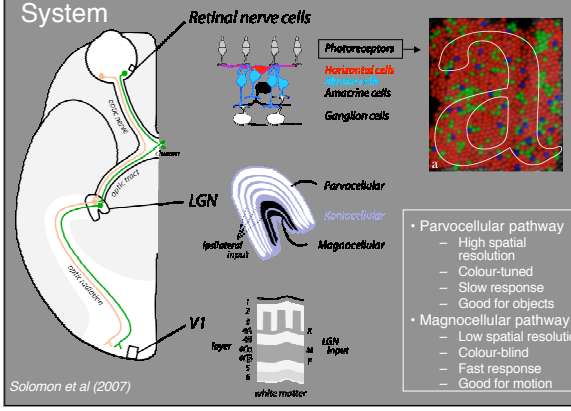
Overview

- Background: Structure of the human visual system
- Key functional concepts
  - Gain control
  - Integration
- Processing deficits for visual attributes
  - Contrast
  - Form
  - Motion
- Relevance to other perceptual systems
  - Eye movements and auditory perception

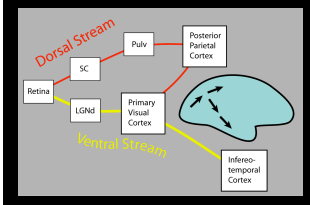
Background I: Architecture of the Early Visual System



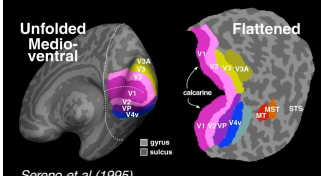
- Parvocellular pathway
  - High spatial resolution
  - Colour-tuned
  - Slow response
  - Good for objects
- Magnocellular pathway
  - Low spatial resolution
  - Colour-blind
  - Fast response
  - Good for motion

Solomon et al (2007)

Background II: Cortical visual processing streams

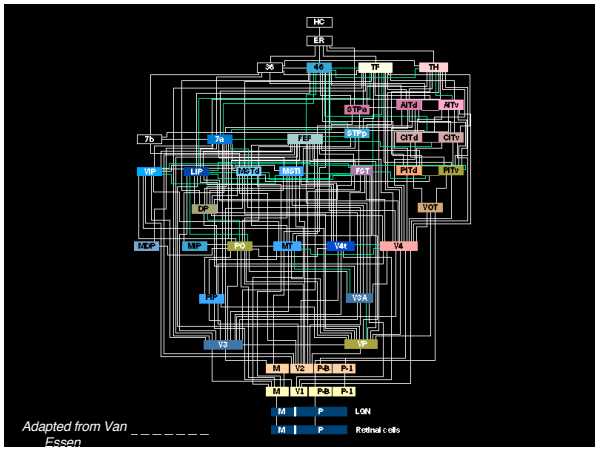


- Dorsal ("where")
  - Eye movements (SC)
  - Action guidance
  - Attentional modulation (LIP)
  - Motion perception (MT)
  - Visual/somatosensory integration
- Ventral ("what")
  - Object recognition
  - Linked to long term memory



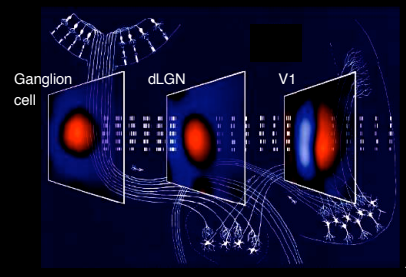
- Dorsal areas
  - V1: Motion
  - V3: Global motion(?)
  - MT/MST Global motion, eye movements
- Ventral areas
  - V1: Orientation/size
  - V2: Contour/form
  - V4: Shape
  - IT: Objects/faces

Sereno et al (1995)



Adapted from Van _ _ _ _ _ _ _ Essen

Background III: Receptive fields



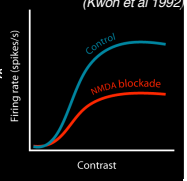
After Reid (2006)

- Receptive fields (RFs)
  - When visual stimuli fall in a region of space known as the *receptive field*, they induce neurons to fire
  - Neurons signal change
  - Sensitivity/complexity is refined from one visual area to next
  - RFs increase in size as one passes along the visual hierarchy

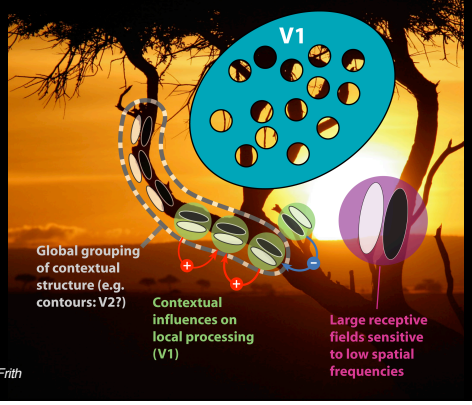
Background IV: Contextual effects

- Neurons do not operate in isolation (e.g. suppression)
- **Gain control**
  - Neurons have limited dynamic range
  - Various ways to be influenced by neighbours to keep signaling useful change ("salience")
  - Effected by: intracellular, direct connectivity (excitation/inhibition), feedback.
  - NMDA has central role
- **Integration/binding** (Gestalt perception)
  - Cells in later visual areas get bigger and more complex by *integrating* small (local) features in bigger (global) features (e.g. form, motion…)
  - Effected by: direct connectivity (excitation/inhibition, sychronization), feedback.
- Attentional effects not considered here

(Kwon et al 1992)

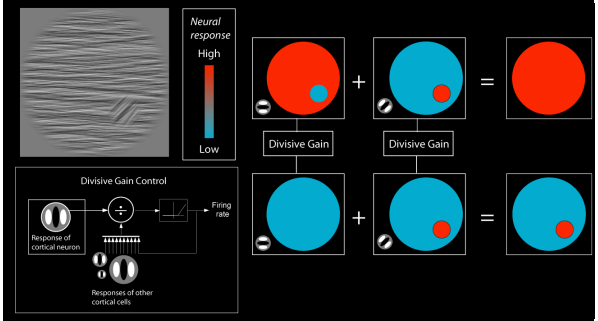


Example: Orientation integration



Dakin & Frith (2005)

Example: Gain control & orientation pop-out



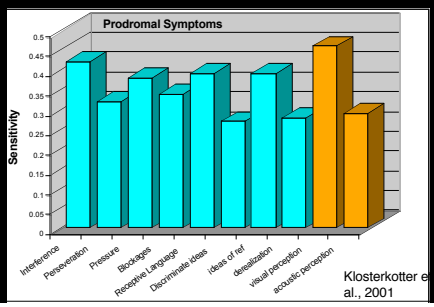
- Gain control & integration underpin *salience*
- Vision = cascaded gain-control/integration system, deriving increasingly complex types of salience

Visual deficits in schizophrenia

- Many patients report visual deficits early in the disease

"Everything is in bits. You put the picture up bit by bit into your head. It's like a photograph that's torn in bits and put together again."

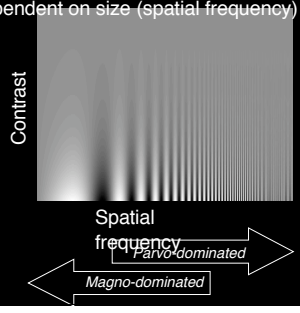
-McGhie and -Chapman, 1961



Klosterkotter et al., 2001

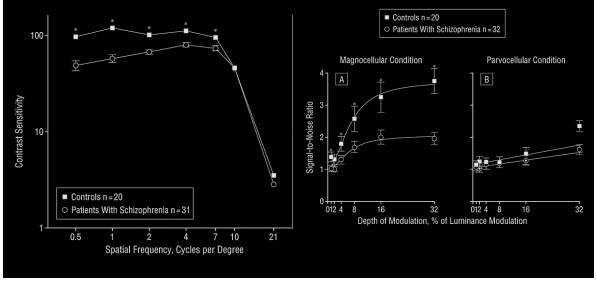
Visual processing of **Contrast**

- Fundamental visual property with standard measures
- Subject to gain control & integration
- Dependent on size (spatial frequency)



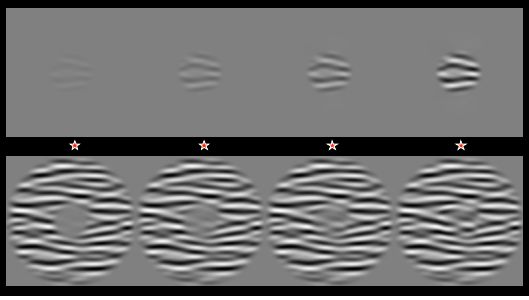
Contrast sensitivity

- Deficits in SZ
  - Psychophysics indicates generalised deficit (Slaghuis, 1998) or M-specific deficit (Butler et al, 2005)
  - ERP indicates dorsal/M-deficit (Butler et al, 1997)

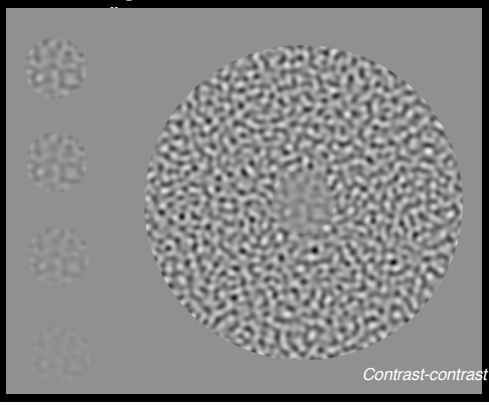


Contrast: Sensitivity & gain control

- Contrast is subject to (e.g. centre-surround) gain control & integration
- Induces changes in sensitivity and appearance

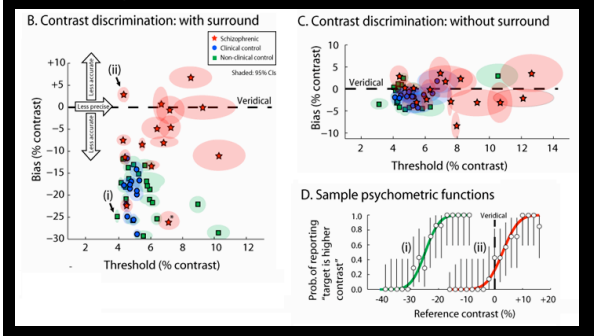


Contrast gain control & “Contrast-



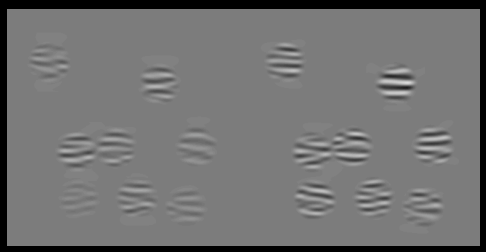
Contrast-contrast

Abnormalities in contrast gain control in chronic schizophrenia



Dakin, Carlin & Hemsley

Contrast perception: Integration

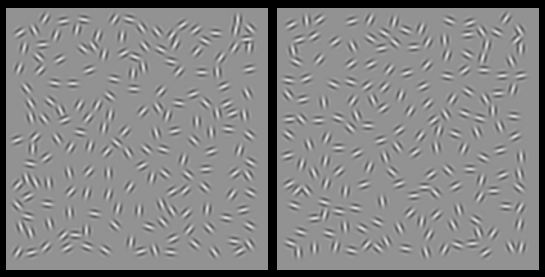


- Pooling across space?

Visual Processing of **Form/Gestalt**

- Integration/binding
  - Emphasised by several theories of schizophrenia
- Less influence of global on local (Place & Gilmore, 1980; Rief, 1991)
- Deficits associated with SZ
  - Silverstein et al (2000) report poor contour integration in SZ
  - Simpler Gestalt tasks unaffected (Chey & Holzman, 1997) but role of top-down cannot be ruled out (John & Hemsley, 1992)
  - May be attributable to long-range disruption in synchronization of neural activity (e.g. reduced phase synchrony in β band; Uhlhaas et al 2006, lower frequency phase-locking (Spencer et al, 2003,2004) +- correlated with hallucination; γ–band findings are equivolcal)

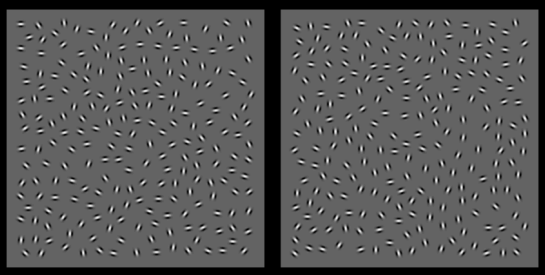
"Path" paradigm



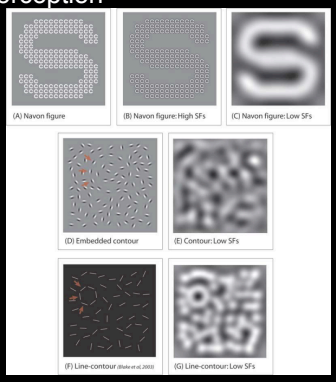
Task: "which image contains an extended contour?"

Field, Hayes & Hess (1993). Kovács & Julesz (1993) & Moulder

Gain-control likely plays a role in contour integration

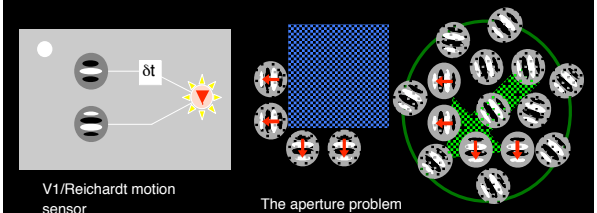


Potential pitfalls in form perception



Attribute 3: **Motion**

A hierarchical view: motion is signaled by direction selective cells in V1 then pooled by MT neurons with larger receptive fields. Why?



V1/Reichardt motion sensor

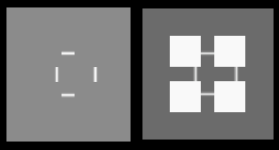
The aperture problem

MT collector unit

MT: Large receptive fields (integration) and antagonistic center-surround (gain control)

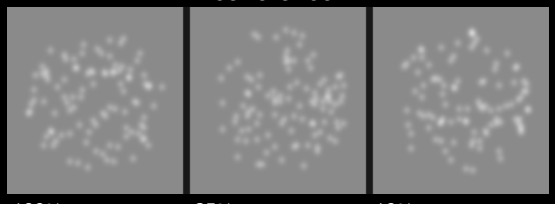
Varieties of global motion integration

Integration can have a profound influence on perception



(Lorenceau et al)

Assessing motion integration: Motion coherence



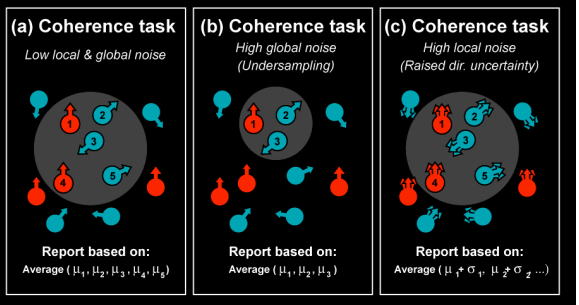
100% *25%* *10%*

Report "up or down?"

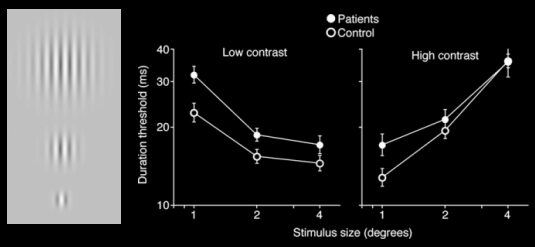
(Newsome et al)

- People with SZ are poor at motion integration (Chen & Nakayama, 1980; Wells & Leventhal, 1984; Rief, 1991)

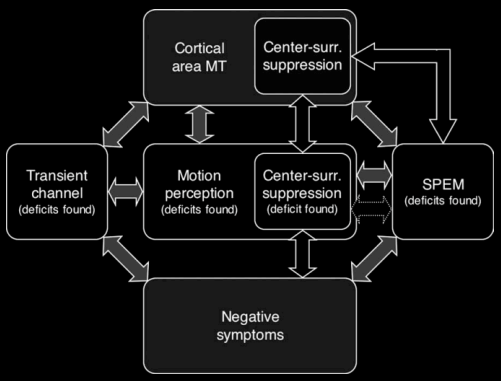
Motion coherence: local or global motion



Deficits in gain control for motion processing associated with schizophrenia (Tadin et al, 2006)



- 4/16 patients showed no surround suppression
- Poorest performance with severe negative symptoms



Summary

✓/ × Consistent/inconsistent with SZ deficit

	Contrast	Form	Motion
Sensitivity (local)	✓	✓	✓
Gain control (Appearance)	✓	✓	?
Gain control (Sensitivity)	✓	?	✓
Integration (global)	?	✓	✓
Mag. v. Par.	✓	?	✓
Image-able	✓	✓	✓
Superior perf.	✓	?	✓

Practicalities

- Testing is straightforward (cards/computers)
- Behavioural tests can elicit superior performance ruling out attentional/top-down effects
- Underlying neural circuitry is increasingly clear e.g. gain control
- Imaging visual areas is straightforward (large areas located on the cortical surface)
- Drug models (e.g. ketamine) and animal models (macaque) are established

Conclusions

- Consistent deficits in low-level/bottom-up visual processing are observed in schizophrenia
- Gain control & integration are a common thread running through various deficits (including figure-ground and eye-movement control). Candidate constructs?
- Magno deficit is also clear; may provide physiological substrate for gain control
- Such bottom-up phenomena may explain effects previously attributed to top-down factors