Not all Gestalts are equal: The encoding of parts and wholes in the visual cortical hierarchy

Johan Wagemans
Laboratory of Experimental Psychology
Department of Brain & Cognition
University of Leuven, Belgium

AIP XXI Congresso di Psicologia Sperimentale
Rovereto, September 10, 2015
Some examples
Visual hierarchy

• features

• parts

• wholes, e.g.
  – objects
  – faces
  – bodies
  – scenes
Cortical hierarchy: Mainstream view

- based on single-unit recordings (Hubel & Wiesel)
  - tuning properties of different types of cells in different areas of the brain
  - functional specialization
  - hierarchical organization
- confirmed in human fMRI (modules, maps)
- standard view in several approaches
Gestalt theory: Berlin school

- Max Wertheimer (1880-1943)
- Kurt Koffka (1886-1941)
- Wolfgang Köhler (1887-1967)
Alternative views possible

- Gestalt theory: Berlin school
  - wholes are more than the sum of the parts
  - wholes are different from the sum of the parts
  - 2-sided dependency
  - wholes come first
    (e.g., global precedence effect)
Alternative views possible

- more recent views
Alternative views possible

- more recent views

- interesting characteristics from viewpoint of Gestalt theory
  - wholes come first
  - highly interactive
  - highly dynamic
The problem

• How to understand the relationships between parts and wholes in visual experience

• How to understand the encoding of parts and wholes in the hierarchy of visual cortex

• How to understand the relationships between cortical encoding and visual experience
My proposal

• Not all Gestalts are equal.

• There are different types of “Gestalts” with their own relationships between parts and wholes, both in visual experience and in their neural encoding.

• Some Gestalts seem to be encoded in low-level areas based on feedback from higher-order regions.
My proposal

• There are different types of “Gestalts” with their own relationships between parts and wholes, both in visual experience and in their neural encoding.

• Some Gestalts seem to be encoded in lower-level areas based on feedback from higher-level areas.

• Other Gestalts seem to be encoded in higher-level areas, while the parts are encoded in lower-level areas:
  – without suppression of the parts
  – with suppression of the parts
Preservative versus eliminative Gestalts

1. “preservative Gestalts”
   – functional “wholes” arise spontaneously and “parts” become less functional
   – but the encoding of these “wholes” at higher levels of the cortical hierarchy does not suppress the encoding of the “parts”

2. “eliminative Gestalts”
   – “wholes” dominate and “parts” disappear from experience
   – “wholes” emerge in higher areas of the brain and encoding of “parts” is then suppressed
Preservative Gestalts

- excellent example: configural-superiority effect
- Pomerantz et al. key papers:
- neural basis?
Kubilius et al. (2011)


- behavioral results

- fMRI decoding results
Behavioral results

parts + corner → whole

Accuracy and response time graphs showing the effect of parts and whole images on performance across different testing runs.
Scanning protocol

**Experimental runs**
- 150 ms parts cond.
- 1850 ms
- 150 ms whole cond.
- 1850 ms

**Localizer runs**
- 300 ms
- 500 ms
- 16 sec objects block
- 300 ms
- 500 ms
- 16 sec scrambled objects block

**Meridian mapping runs**
- 16 s
- 16 s
- ...
fMRI results: Retinotopic mapping
MVPA: decoding

- **fMRI data voxel responses**
  - **condition 1**
    - run 1
    - run 2
  - **condition 2**
    - run 1
    - run 2

- **split in half**

- **half 1**
  - learn a rule to differentiate between the two conditions

- **half 2**
  - test how well the rule does on unseen patterns (reported as % correct)
fMRI results: decoding
fMRI results: decoding

SVM classification performance

<table>
<thead>
<tr>
<th></th>
<th>V1</th>
<th>V2</th>
<th>V3</th>
<th>LO</th>
<th>pFs</th>
</tr>
</thead>
<tbody>
<tr>
<td>parts -&gt; parts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>whole -&gt; whole</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>parts -&gt; whole</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>whole -&gt; parts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

percent correct classification

0.4 0.5 0.6 0.7 0.8
Discussion

• behavioral configural-superiority effect

• neural configural-superiority effect:
  – better coding of “wholes” than “parts” in higher shape-selective regions
  – better coding of “parts” than “wholes” in lower-level retinotopic regions

• general conclusions:
  – at least some Gestalts emerge only at higher stages of visual information processing
  – feedforward processing may be sufficient to produce some Gestalts
Two examples of eliminative Gestalts

- **Motion silencing**

- **Bistable diamond**
Suchow & Alvarez (2011)


- “Best Illusion of the Year 2011”
Demonstration
Demonstration
More demonstrations
Methods

• **Stimuli:**
  – 100 dots
  – first stationary, then rotating back and forth for 30°
  – 2 phases alternating every 3 s

• **Task:**
  – observers had to adjust the rate of change during the stationary phase to match the apparent rate of change in the moving phase
  – rate of change ("silencing factor") between 0.1 (static perceived as changing slower) and 10 (static perceived as changing faster)
Results
• Suchow & Alvarez:
  – local mechanisms with small receptive fields
  – because a fast-moving object spends little time at any one location, a local detector is afforded only a brief window in which to assess the changing object

• alternative interpretation:
  – objecthood
  – when a good “whole” is formed, the details of the “parts” are fundamentally less accessible to conscious perception
Our study


- motivation: to test this alternative interpretation with biological motion
Why biological motion?

• a prototypical case of a complex hierarchical stimulus (Johansson, 1973; Cutting & Proffitt, 1982)
  – multiple elements, each with their own spatio-temporal trajectories
  – organized quickly and efficiently in a hierarchical configuration, in which the motion of the local elements are coded relative to a more global structural description

• the perceptual Gestalt is constructed automatically by the visual system (Thornton & Vuong, 2004)

• the construction of the perceptual whole implies a more efficient representation of the relationships between the parts (Tadin et al., 2002)

• inversion allows control over low-level motion trajectories (Sumi, 1984; Pavlova & Sokolov, 2000)
Demonstrations
Demonstrations
Demonstrations
Methods

• Stimuli:
  – motion captured point-light treadmill walkers (Vanrie & Verfaillie, 2004)
  – 70 colored dots ("confetti walker")
  – upright, inverted, phase-scrambled

• Task: adjust rate of change in the test figure until it matches the rate of change in the comparison figure

• Direct comparison of dynamic and static
  – comparison figure: scrambled
  – test figures: upright or inverted
Results

inversion effect

level difference

condition

static
dynamic

upright
inverted
Discussion

- on top of the effect of static vs moving, there is a clear effect of configurality ("goodness" of the whole percept)

- cost of objecthood: the more strongly the parts are integrated into the perception of a whole object, the less accessible the changing features of the parts are (e.g., also embedded figures)
Eliminative Gestalts

- excellent example: bistable diamond

- Murray et al. key papers:
Nice features

- perceptual bi-stability:
  - “parts” seen to move vertically
  - “whole” seen to move horizontally

- switching relatively slow, perceptual states rather clear

- stable individual differences

- studied rather extensively at psychophysical level, e.g.
• present bistable diamonds

• ask observers to indicate perception of “parts” (line segments) or “whole” (diamond)

• record BOLD responses (fMRI) in different areas and relate these to the reported percepts
Murray et al.: Results
Murray et al.: Results
• convincing demonstration of inverse activity patterns in V1 and LOC

• interpretation?
  – perception of “parts” suppressed by perception of “whole”
  – predictive coding framework: “explaining away”
Discussion

• however
  – in a recent follow-up study, we have shown that the reduction of activity in V1 is global, not retinotopically specific

The encoding of parts, wholes and their relationships constitutes a serious challenge to the visual system.

The visual system appears to have developed flexible mechanisms with different characteristics:

- Sometimes wholes are encoded in low-level areas (feedback?)
- Sometimes wholes are encoded in high-level areas, while parts are preserved in low-level areas
- Sometimes wholes are encoded in high-level areas, while parts are suppressed in low-level areas

Hence, not all Gestalts are equal.

Further research is needed to establish the specific properties of these cases (computational reasons, boundary conditions, etc.).
Thank You

johan.wagemans@psy.kuleuven.be

www.gestaltrevision.be