Simple Gestalts: Emergent Features in Two-line Space

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Anna I. Stupina
James R. Pomerantz
Rice University
Houston, TX, USA
Simple Gestalts: Emergent Features in Two-line Stimulus Space
James R. Pomerantz & Anna I. Stupina, Rice University

The speed with which a line segment of one orientation can be found in a field of segments with other orientations can change dramatically when a second, identical context line is added to each of the originals to form two-line configurations (such as T, L, //, - -, ||, or V.) We systematically sampled a portion of the infinite space of all possible configurations of two-line segments falling in plane to determine what emergent features (EFs) they possess. I.e., what novel and salient features emerge from two-line configurations that are not possessed by either line segment alone but that are responsible for making the configurations discriminable. The results suggest that salient EFs from two lines include parallelism, connectivity, and intersections. These results add to a growing list of EFs - Gestalts - that are more salient to the visual system than are the components from which they are constructed.

Main points to cover:
The signal is the same over the whole surface
Consider making simple pairs, animating the addition of context
Consider showing 8-dimensional space (x,y coordinates of 2 endpoints, 2 segments
Underscore the complexity of even 3-line configurations; with just 2, multiple regression is still needed.
Flow of Talk:

Introduction: The Gestalt problem
Converging Operations:
  Seven signatures of grouping
  Configural Superiority Effects
  Exploration of 2-line space
Conclusions
Max Wertheimer, 1912
Apparent Motion
Apparent Motion
Apparent Motion
Our Basic Question = The *Gestalt* Question

Various ways to express the question:

- When do parts configure into unitary stimuli?
- How does the “whole differ from the sum of its parts”?
- What does it mean to say that two parts, A and B, form a group?
Core Concept: Gestalt as Non-Additivity

Whole ≠ Sum of Parts

A + B = A+B?
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Converging Operations: Seven Signatures of Grouping

1. Failure (absence) of selective attention as measured by Garner Interference
2. Successful divided attention
3. Redundancy losses
4. False pop out
5. Configural superiority effects
6. Search slopes, flat and negative
7. Search asymmetries
Converging Operations: Seven Signatures of Grouping

1. Failure (absence) of selective attention as measured by Garner Interference
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6. Search slopes, flat and negative
7. Search asymmetries
Configural Superiority Effects

Target: A A A A

Context: C C C C

Composite: AC AC AC BC
Dilution of Dissimilarity
Masking

\[
\begin{array}{cc}
A & A \\
A & B \\
\end{array}
+ \begin{array}{cc}
C & C \\
C & C \\
\end{array}
= \begin{array}{cc}
\hat{A} & \hat{A} \\
\hat{A} & B \\
\end{array}
\]
Increased processing load, distraction

Target  +  Context  =  Composite

A  A  |  C  C  |  AC  AC
A  B  |  C  C  |  AC  BC
DISCRIMINATION: POSITIVE vs NEGATIVE DIAGONAL

\[
\begin{array}{ccc}
\bar{RT} = 1884 & + & \bar{RT} = 749 \\
\bar{RT} = 1884 & + & \bar{RT} = 2020
\end{array}
\]
Two Veteran Configural Superiority Effects Revealing Emergent Features

Configural Superiority Effects - Arrow vs. Triangle

|  /  /  |  /  /  |
|  /  |  /  |
|  /  |  /  |

RT = 1884 msec

Context

| L  L  | L  L  |
| L  | L  |
| L  | L  |

Configural Superiority Effects - Parenthesis Pairs

| ( ) ( ) | ( ) ( ) |
| ( ) | ( ) |
| ( ) | ( ) |

RT = 2400 msec

Context

| { } { } | { } { } |
| { } | { } |
| { } | { } |

RT = 749 msec

| { } { } | { } { } |
| { } | { } |
| { } | { } |

RT = 1450 msec
Important Control: Configural Inferiority Effects

B. F. Skinner: you don’t really understand an effect until you can make it go away.
Extensions: Recently discovered CSEs
Extensions: Arrow-triangle stimulus space, created by moving the L context around.
Arrow-triangle stimulus space
Mapping Emergent Feature Space
Problem: What’s the Effective EF?

What makes a triangle so discriminable from an arrow?
- Endpoints
- Intersections
- Closure?

Need principled approach; these stimuli are too complex
Same Problem: What’s the Effective EF?

What EF(s) make pairs of curves so discriminable?

- Symmetry
- Parallelism
- Closure?

Again, these stimuli are too complex.
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Simplify the Stimuli, Part 1: Dots arranged in n-dot space

Portillo (2006)
Exploring 2-dot stimulus space
Configural Superiority: Proximity

Target

Context

Composite

RT = 1460
Error = 29%

RT = 1022
Error = 6%

CSE = 438 ms, F (1,21) = 73.5, p<.0001
   = 23%, F (1,21) = 63.4, p<.0001
Configural Superiority: Orientation

Target

Context

Composite

RT = 1460
Error = 29%

CSE = 427 ms, F (1,21) = 1416.1, p<.0001
= 21%, F (1,21) = 63.1, p<.0001

RT = 1033
Error = 8%
Exploring 3-dot stimulus space
Configural Superiority: Symmetry

Target

\[
\begin{array}{cccc}
\bullet & \bullet & \cdot & \cdot \\
\cdot & \cdot & \bullet & \bullet \\
\cdot & \cdot & \cdot & \cdot \\
\cdot & \cdot & \cdot & \cdot \\
\end{array}
\]

\[\text{RT} = 1574, \quad \text{Error} = 43\%\]

Context

\[
\begin{array}{cccc}
\cdot & \cdot & \cdot & \cdot \\
\cdot & \cdot & \cdot & \cdot \\
\cdot & \cdot & \cdot & \cdot \\
\cdot & \cdot & \cdot & \cdot \\
\end{array}
\]

\[\text{RT} = 1451, \quad \text{Error} = 15\%\]

Composite

\[
\begin{array}{cccc}
\cdot & \cdot & \cdot & \cdot \\
\cdot & \cdot & \cdot & \cdot \\
\cdot & \cdot & \cdot & \cdot \\
\cdot & \cdot & \cdot & \cdot \\
\end{array}
\]

\[\text{CSE} = 123 \text{ ms}, \quad F(1,21) = 10.4, \quad p<.0005 \quad \text{(All nonlinear)}
\]

\[= 28\%, \quad F(1,21) = 92.45, \quad p<.0001\]
Configural Superiority: **Linearity**

**Target**

```
  +  +  +  +
  +  +  +  +
  +  +  +  +
  +  +  +  +
```

RT = 1479  
Error = 34%

**Context**

```
  +  +  +  +
  +  +  +  +
  +  +  +  +
  +  +  +  +
```

RT = 878  
Error = 2%

**Composite**

```
  +  +  +  +
  +  +  +  +
  +  +  +  +
  +  +  +  +
```

CSE = 601 ms, F (1,21) = 142, p<.0001  
(All symmetric)

= 32%, F(1,21) = 120, p<.0001
Simplify the Stimuli, Part 2: Lines arranged in n-line space

- Length/prox
- Orientation
- Color, Size
- Terminators
- Collinearity
- Symmetry
- Parallelism
- Intersections
- Closure
- Zigzag (IP)
- Intersections
- Inside/outside
Start with a single line segment
Add a second line segment. Do they group?
Do they group more strongly in this case?
Lots of Emergent Features
Arise with Just 2 Line Segments
< These lack emergent features, thus don't appear to group well

< These possess emergent features, thus appear to form strong groups
Emergent Features are properties of wholes that:

1. Are not possessed by any individual part

2. Are processed as or more quickly than are the properties of the parts

Parallelism

Connectivity

Symmetry

Intersections

Collinearity
Preview of Anna Stupina’s exploration of two-line space
RT Data map
Prediction Map

List 2B Prediction Data
Difference Map: Data - predictions
Data map  Prediction map  Difference map  $r > .73$
The Odd Quadrant Task

Indicate the odd one out by pressing it on the touch screen.
Emergent Features

Base + Context = Composite

No Intersection difference
Parallelism difference, etc.

Intersection difference
Parallelism difference, etc.
Emergent Features of Interest with Two-line Configurations:

- # of Terminators
- Collinearity
- Symmetry
- Parallelism
- Co-Termination
- Intersections
- Connectivity
- Pixel Mass/Luminous flux
Terminators

- Coded from 0 – 1 based on # of terminators in odd quadrant, vs. # in other three quadrants

<table>
<thead>
<tr>
<th># of Terminators in Odd Quad</th>
<th>4</th>
<th>3</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0</td>
<td>0.5</td>
<td>0.25</td>
</tr>
<tr>
<td>3</td>
<td>0.75</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>0.75</td>
<td>0</td>
</tr>
</tbody>
</table>

- Terminator Difference (1)
- No Terminator Difference (0)
- Less Terminators in Odd Quad (.25)
Collinearity

- 2 segments in line, others not = 0.5
- 2 segments not in line, others are = 1

Collinearity Difference (.5)  No Collinearity Difference (0)  No Collinearity in Odd Quad (1)
Symmetry

- Odd quad symmetric, others not = 0.5
- Odd quad not symmetric, others are = 1
- Axial symmetry only

Symmetry Difference (.5)  No Symmetry Difference (0)  No Symmetry in Odd Quad (1)
Parallelism

- Odd Quad **not** parallel, others are $= 1$
- Odd Quad parallel, others not $= 0.5$

Parallelism Absence in Odd Quad (1)
No Parallelism (0)
Parallelism Presence in Odd Quad (.5)
Co-Termination

- Horizontal/Vertical
  - Co-T in OQ: 0, .2, .4, .6, .8, 1
  - Co-T in others: 0, .1, .3, .5, .7, .9

- Positive/Negative Diagonals
  - Co-T in OQ: 0, 1/7, 2/7, 3/7, 4/7, 5/7, 6/7, 1
  - Co-T in others: 0, .1, .2, .3, .4, .5, .6, .7
Emergent Feature: Intersections

Intersections present in OQ, absent in others = 1
Intersections absent in OQ, present in others = 0.5

Intersection present in odd quadrant (1)
No intersection difference (0)
Intersection absent (.5)
Connectivity

- Connected in OQ, not in others = 1
- Not connected in OQ, connected in others = 0.5
Pixel Mass (luminous flux)

- More pixels in OQ = 1
- Less pixels in OQ = 0.5
Generating the Stimulus Space

Base

Context

Composite

A  A
A  B

C  C
C  C

AC  AC
AC  BC
Sampling of Two-line Space
Prediction Maps

For each display count the number of EF differences between its odd quadrant and its other 3 quads

The more EF differences, the better the predicted performance – easier discrimination
Setup of Experiment

- 3 Lists, based on differing combinations of stimuli and contexts

Target Displays:

Contexts:

List 1A
List 1B
List 2A
List 2B
List 3A
List 3B
Find V in Hs with added Vs (List 1A)

RT Data Map

RT Prediction Map
Difference Map: Fit – List 1A

- $R = -0.788$
  - Terminators (-0.627)
  - Parallelism (-0.621)
  - Intersections (-0.718)
  - Co-Termination (-0.611)

RT map – Prediction map = Difference map
Find Hs in Vs with added Vs (List 1B)
Difference Map: Fit – List 1B

- $R = -0.765$
  - Intersections (-0.562)
  - Co-Termination (-0.611)
  - Parallelism (-0.530)
Find V in Hs with added Hs (List 2A)

RT Data Map

RT Prediction Map
Difference Map: Fit – List 2A

- $R = -0.859$
  - Co-Termination (-0.645)
  - Terminators (-0.602)
  - Intersections (-0.616)
Find H in Vs with added Hs (List 2B)
Difference Map: Fit – List 2B

- $R = -0.884$
  - Terminators (-0.647)
  - Parallelism (-0.656)
  - Intersections (-0.782)
  - Co-Termination (-0.676)
Find V in Hs with added Ds (List 3A)

RT Data Map

RT Prediction Map
Difference Map: Fit – List 3A

- $R = -0.656$
  - Terminators (-0.598)
  - Intersections (-0.468)
  - Pixel Mass (-0.448)
Find H in Vs with added Ds (List 3B)
Difference Map: Fit – List 3B

- $R = -0.660$
  - Terminators (-0.613)
  - Pixel Mass (-0.481)
  - Intersections (-0.356)
## Correlating individual EFs with RTs

<table>
<thead>
<tr>
<th>EF/List</th>
<th>1A</th>
<th>1B</th>
<th>2A</th>
<th>2B</th>
<th>3A</th>
<th>3B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminators</td>
<td>-.627</td>
<td>-.492</td>
<td>-.602</td>
<td>-.647</td>
<td>-.598</td>
<td>-.613</td>
</tr>
<tr>
<td>Collinearity</td>
<td>-.053&lt;sub&gt;ns&lt;/sub&gt;</td>
<td>-.033&lt;sub&gt;ns&lt;/sub&gt;</td>
<td>-.065&lt;sub&gt;ns&lt;/sub&gt;</td>
<td>-.029&lt;sub&gt;ns&lt;/sub&gt;</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Symmetry</td>
<td>-.269</td>
<td>-.211</td>
<td>-.139&lt;sub&gt;ns&lt;/sub&gt;</td>
<td>-.307</td>
<td>-.283</td>
<td>-.348</td>
</tr>
<tr>
<td>Parallelism</td>
<td>-.621</td>
<td>-.530</td>
<td>-.552</td>
<td>-.656</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Intersections</td>
<td>-.718</td>
<td>-.562</td>
<td>-.616</td>
<td>-.782</td>
<td>-.468</td>
<td>-.356</td>
</tr>
<tr>
<td>CoTermination</td>
<td>-.542</td>
<td>-.611</td>
<td>-.645</td>
<td>-.676</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Connectivity</td>
<td>-.609</td>
<td>-.486</td>
<td>-.533</td>
<td>-.652</td>
<td>-.468</td>
<td>-.356</td>
</tr>
<tr>
<td>Pixel Mass</td>
<td>-.526</td>
<td>-.466</td>
<td>-.542</td>
<td>-.565</td>
<td>-.448</td>
<td>-.481</td>
</tr>
<tr>
<td>Overall R</td>
<td>.788</td>
<td>.765</td>
<td>.859</td>
<td>.844</td>
<td>.656</td>
<td>.660</td>
</tr>
</tbody>
</table>

All correlations p<.01 unless otherwise noted
Future Direction:
Expanded sampling of 2-line space

- 12 Stimuli, 4 Contexts = 48 possible stimulus spaces
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- Conclusions
Conclusions

We all want to know how we perceive complex scenes and objects. We’d love to know how faces are perceived. Sadly, we don’t yet know how we tell arrows from triangles! But...

- Two-line configurations possess simple but rich Gestalts.
- They generate the same effects seen with complex stimuli.
- Discriminating a horizontal from a vertical line depends on the orientation and position of a second, irrelevant context line.
- Discrimination ease arises from emergent features: intersections and parallelism, terminators and connectivity.
- Saying two lines group means only that together, they produce salient emergent features.
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Thank You!

- Mary Portillo
- Shaiyan Keshvari
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- Diane Chen
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- Erin Sparck
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