Shape scission:
causal segmentation of shape

Filipp Schmidt, Flip Phillips, & Roland W. Fleming
Shape scission
Shape scission

Crumpled!
Shape scission

Crumpled!

Crushed!
Shape scission

Crumpled!

Crushed!

Squeezed!
• Evidence that observers can infer the causal history of objects (Chen & Scholl, 2016; Leyton, 1989; Op de Beeck, Torfs, & Wagemans, 2008; Pinna, 2010; Pittenger & Todd, 1983; Spröte & Fleming, 2013, 2016; Spröte, Schmidt, & Fleming, 2016)
Shape scission

- We suggest that we do this by separating shape into causal layers (*shape scission*)
Shape scission

Inspired by Adelson (2000)
Shape scission

Original shape

Observed shape

Transformation
To what extent can we separate shape into causal layers?
64 Stimuli

- 8 base shapes
64 Stimuli

- 8 base shapes
64 Stimuli

- 8 base shapes
64 Stimuli

- 8 base shapes

[Images of blue shapes generated by Blender]
64 Stimuli

- 8 transformations
64 Stimuli

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![Blender Logo](https://example.com/blender_logo.png)
“Name or describe the change or process that happened to the object.”
Stimulus validation

- Responses (n = 16)

<table>
<thead>
<tr>
<th>Response Type</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melted</td>
<td>100%</td>
</tr>
<tr>
<td>Cut</td>
<td>94%</td>
</tr>
<tr>
<td>Grown</td>
<td>88%</td>
</tr>
<tr>
<td>Dried</td>
<td>81%</td>
</tr>
<tr>
<td>Inflated</td>
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</tr>
<tr>
<td>Stretched</td>
<td>57%</td>
</tr>
<tr>
<td>Twisted/Pulled/Strangulated</td>
<td>44%</td>
</tr>
</tbody>
</table>
Stimulus validation

- Responses (n = 16)

<table>
<thead>
<tr>
<th>Stimulus</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>melted</td>
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</tr>
<tr>
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Stimulus validation

- **Responses (n = 16)**

<table>
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## Stimulus validation

- **Responses (n = 16)**

<table>
<thead>
<tr>
<th>Response</th>
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**Indented/pushed in**
Stimulus validation

- Responses (n = 16)

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Showered melted/runny
Stimulus validation

• Responses (n = 16)

<table>
<thead>
<tr>
<th>Stimulus</th>
<th>Percentage</th>
<th>Image</th>
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<tbody>
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<td><img src="image" alt="Indented Image" /></td>
</tr>
<tr>
<td>melted</td>
<td>100%</td>
<td><img src="image" alt="Melted Image" /></td>
</tr>
<tr>
<td>cut</td>
<td>94%</td>
<td><img src="image" alt="Cut Image" /></td>
</tr>
<tr>
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### Stimulus validation

- **Responses (n = 16)**

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**Images:**

- **Grown/bulged out**
- **Pierced/pressed in with rod**
- **Grown over/colonized**

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**Pulled out**
Stimulus validation

- Responses ($n = 16$)

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<tr>
<td>inflated</td>
<td>69%</td>
</tr>
<tr>
<td>strained</td>
<td></td>
</tr>
<tr>
<td>pulled</td>
<td></td>
</tr>
<tr>
<td>heated/melted</td>
<td></td>
</tr>
<tr>
<td>kneaded</td>
<td></td>
</tr>
<tr>
<td>inflated</td>
<td></td>
</tr>
<tr>
<td>squashed</td>
<td></td>
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## Stimulus validation

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- cooled down
- filed off/carved
- pierced from inside
- stretched
- spikes
- kneaded
### Responses (n = 16)

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Experiment 1: Shape scission

• Classification experiment \((n = 15)\)

"Group objects according to what happened to them"
Experiment 1: Shape scission

- Classification experiment ($n = 15$)

„Group objects according to what happened to them“
Experiment 1: Shape scission

• Classification experiment ($n = 15$)

„Group objects according to what happened to them“

„Group objects according to the shape they had before something happened to them“
Experiment 1: Shape scission

Transformation prediction

Perceived as within same group
Experiment 1: Shape scission

Transformation prediction

Perceived as within same group
Experiment 1: Shape scission
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Transformation prediction

Perceived as within same group
Experiment 1: Shape scission
Experiment 1: Shape scission

Transformation instruction: $R^2 = 0.99$

Shape instruction: $R^2 = 0.99$

Perceived as within same group
Experiment 1: Shape scission

- Observers can identify “transformations” across objects and “objects” across transformations
Experiment 1: Shape scission

- Observers can identify “transformations” across objects and “objects” across transformations

- Can they infer other characteristics of transformations on top of this causal separation?
Experiment 2: Location

- Painting experiment
Experiment 2: Location

• Painting experiment
Experiment 2: Location

- Painting experiment
Experiment 2: Location

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Experiment 2: Location

- Painting experiment
Experiment 2: Location

• Painting experiment
Experiment 2: Location

- Responses

painting (n = 14)
Experiment 2: Location

- Responses

painting (n = 14)
Experiment 2: Location

- Responses

painting (n = 14) 3D mesh transformed shape
Experiment 2: Location

- Responses

painting (n = 14)  

3D mesh difference
Experiment 2: Location

- Responses

painting (n = 14)  prediction from difference
Experiment 2: Location

- Responses

painting (n = 14)  
prediction from difference
Experiment 2: Location

$r = 0.62$ (across all)
Experiment 3: Magnitude

5 levels of deformation (examples)
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5 levels of deformation (examples)
Experiment 3: Magnitude

Not deformed

Strongly deformed
Experiment 3: Magnitude

• Analysis
Experiment 3: Magnitude

- Analysis
Experiment 3: Magnitude

- Analysis

deformation
Experiment 3: Magnitude

- Mesh measures
  - **magnitude of deformation**: average distance of each deformed vertex from non-deformed vertex location (per stimulus)
Experiment 3: Magnitude

- **Mesh measures**
  - **magnitude of deformation**: average distance of each deformed vertex from non-deformed vertex location (per stimulus)
  - **area of deformation**: average area of deformed faces (per stimulus)
Experiment 3: Magnitude

- Mesh measures

$r = 0.16$
Experiment 3: Magnitude

- Multiple linear regression
  - Explained variance: $R^2 = 0.50$
  - Regression weights
    - Magnitude of deformation: 0.47
    - Area of deformation: 0.45

![Bar chart showing regression weights for magnitude and area with $R^2 = 0.50$.]
Experiment 3: Magnitude

• Analysis: magnitude of deformation per transformation

- Perceived deformation vs. magnitude of deformation for different transformations:
  - Grown: $R^2 = 0.78$
  - Twisted: $R^2 = 0.36$
  - Cut: $R^2 = 0.55$
  - Dried: $R^2 = 0.53$
  - Indented: $R^2 = 0.61$
  - Inflated: $R^2 = 0.63$
  - Melted: $R^2 = 0.59$
  - Stretched: $R^2 = 0.74$
Experiment 3: Magnitude

- Analysis: area of deformation per transformation

![Graphs showing the relationship between area of deformation and perceived deformation for different transformations. Each graph has a corresponding $R^2$ value indicating the goodness of fit.](image-url)
Experiment 3: Magnitude

- Multiple linear regression per transformation
  - Average explained variance: $R^2 = 0.66$
Experiment 3: Magnitude

- Multiple linear regression per transformation

- Average explained variance: $R^2 = 0.66$

- Inflated: $R^2 = 0.64$
- Indented: $R^2 = 0.61$
- Dried: $R^2 = 0.53$
- Cut: $R^2 = 0.55$
- Stretched: $R^2 = 0.75$
- Twisted: $R^2 = 0.56$
- Melted: $R^2 = 0.76$
- Grown: $R^2 = 0.87$
Conclusion

• We can identify “transformations” across objects and “objects” across transformations, by separating observed features by their causal origin (*shape scission*)
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• This allows us to make inferences about...
  o …what other members of the same class might look like (classification)
Conclusion

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• This allows us to make inferences about...
  o …what other members of the same class might look like (classification)
  o …how objects have been altered by forces in their past (meaning, location, and magnitude of transformations)
Conclusion

• We can identify “transformations” across objects and “objects” across transformations, by separating observed features by their causal origin (*shape scission*)

• This allows us to make inferences about...
  o …what other members of the same class might look like (classification)
  o …how objects have been altered by forces in their past (meaning, location, and magnitude of transformations)

• Shape features to build these inferences are chosen depending on transformation
Conclusion

• Main challenges
  o Identify perceptual information used to separate causal layers
Conclusion

• Main challenges
  
  o Identify perceptual information used to separate causal layers
  o Identify neural representation of this information
Conclusion

• Main challenges
  o Identify perceptual information used to separate causal layers
  o Identify neural representation of this information
  o Define computations that extract properties of the layers
Thank you for your attention!

…and thanks to my colleagues from Gießen
MDS transformation classification

MDS transformations

grown
-twisted
cut
dried
intended
inflated
melted
stretched
MDS shape classification
Experiment 3: Magnitude

- Mesh measures

\[ R^2 = 0.29 \]

\[ R^2 = 0.28 \]
In the limits...

We should not think about recovering causal history as an all or nothing process, but as a process that can take place on different levels of abstraction and resolution.

Depending on the specific stimulus and task, the inferences presumably span both perceptual and cognitive abilities.

At one extreme, detecting crumpled, dents or cracks in objects is presumably primarily a perceptual process.

At the other extreme, inferring the culprit of a crime from a bloody dagger and some crumbs of mud on the floor is clearly a taxing cognitive task.

Many other causal history inferences fall somewhere between these two extremes, presumably enabling different levels of detail in the inference about the sequence of events that led to the observed state of the object.

Spröte & Fleming (2006)