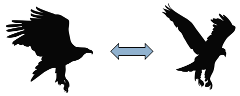
Representation of shape and space when objects undergo transformations

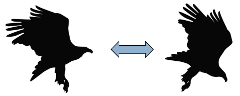
Filipp Schmidt, Patrick Spröte, & Roland W. Fleming
Department of Psychology, Justus-Liebig-University Giessen, Germany

Introduction

- Shape is the most important visual feature for object recognition.
- However, object shape is subject to manifold transformations, from simple rigid changes like rotation or translation to complex non-rigid transformations like twisting, bending or biological growth.
- These transformations may be grouped into two broad classes:
  - Transformations of the physical objects themselves (due to movements and changes of objects).



  - Transformations of the object images on the retina (due to movements of the observer's eyes, head, and body).



- Perception of stable objects in space and time (*object constancy*; Cassirer, 1944).
- Idea about the type of transformation that has given an object its present form (*causal history*; Leyton, 1989).

Research Questions

- We measure the effects of two rigid transformations (scaling, rotation) on representations of shape and space to test for object constancy, causal history, and transformation of space.
- Specifically, we ask to what extent…
  - …participants can infer (causal history) and follow the transformation that produced one shape from the other (accuracy).
  - …different levels of transformation influence this accuracy.
  - …contour information (surprisal) influences this accuracy.
  - …transformations extend to the space around shapes (egocentric vs. object-based reference frame).

Funding sources

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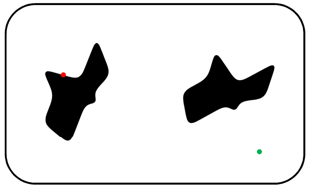
- http://www.allpsych.uni-giessen.de/sfb/

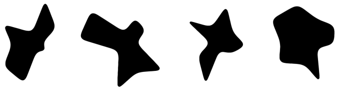
Stimuli and Procedure

- We use the *dot matching task* (Phillips, Todd, Koenderink, & Kappers, 1997) that asks participants to identify corresponding dots between two objects.
- Example display:



Participants use the cursor to move the green dot to the position that they perceive as corresponding to the position of the red dot (no time constraints).

- Stimuli (Cohen & Singh, 2007; 9.0 to 10.6°):



Experiment 1

- Testing shape contours
  - n = 14 • 10 equi-spaced dots • 12 levels of transformation • **constrained to shape contours**

rotation	scaling	combined
20°	0.6	20°/0.6
40°	0.8	20°/1.4
80°	1.2	160°/0.6
160°	1.4	160°/1.4

- Dependent variable: Euclidean distance as a percentage of shape perimeter

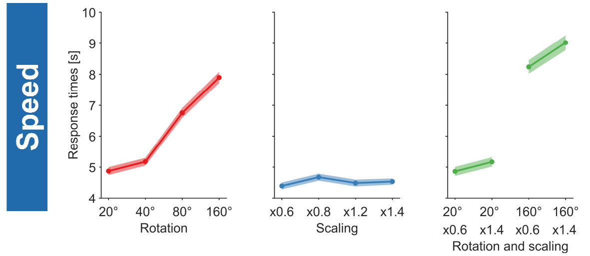
Experiment 2

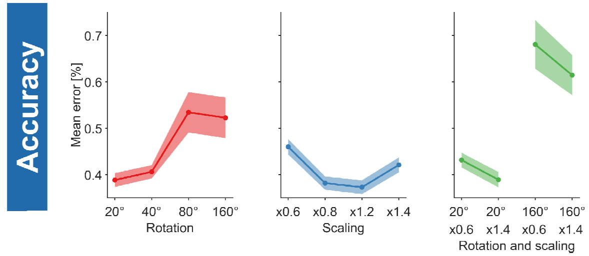
- Testing shape and space
  - n = 14 • 24 dots • three levels of transformation • **various positions inside and outside of each shape** ('compare left to right side of screen')

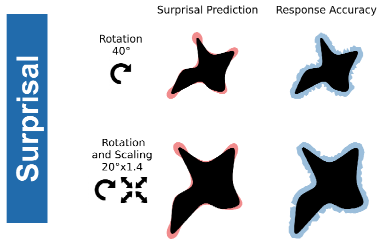
rotation	scaling	combined
80°	0.6	80°/0.6

- Dependent variable: Euclidean distance

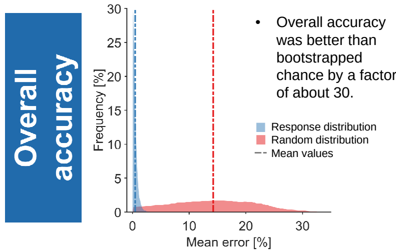
Experiment 1 – Results for Shape Contours





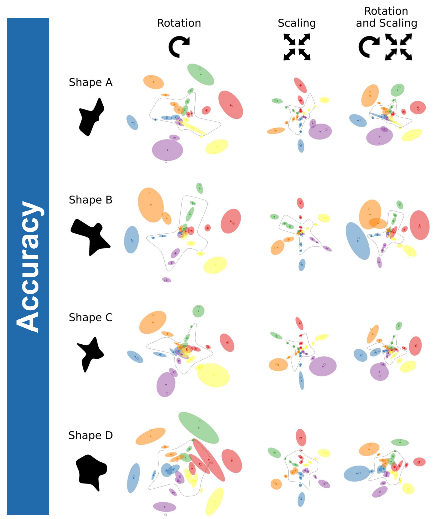


- Correlation between surprisal and response accuracy was significant but relatively low (0.2 to 0.3 depending on shape and transformation).
- Correlation was stronger for unsigned surprisal (Attneave, 1954) compared to signed surprisal (Singh & Feldman, 2000).
- The optimal integration window size was between 5% to 20% of the shape perimeter (examples on the left used a size of 10%).

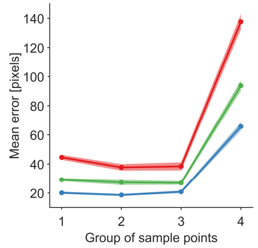


- Overall accuracy was better than bootstrapped chance by a factor of about 30.

Experiment 2 – Results for Shape and Space

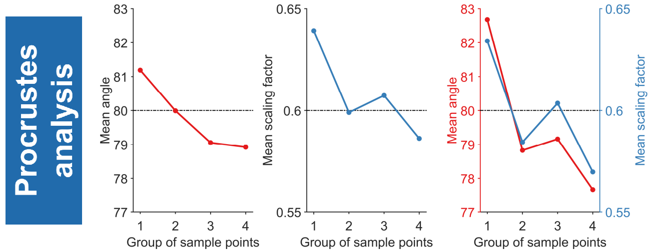


- Responses close to true locations of transformed dots – no switches (object-centered frame of reference) .
- Correlation of response accuracy with surprisal not feasible because dots were not on the contour.



Speed

- Response times were slowest for rotation (m = 8.74s), fastest for scaling, (m = 6.08s), and in-between for both combined (m = 8.01s).



Conclusions

- Shape representations are remarkably robust against rigid transformations. Still, they are modulated by the (1) type and level of transformation (Moran & Leiser, 2002), (2) contour saliency, (3) and the distance to the contour (Phillips et al., 1997).
- Space representation is transformed in line with the shape, so participants infer causal history and establish object-centered reference frames.
- The experiments are a starting point for investigations into more complex transformations resulting from changes of the physical objects themselves.

Filipp.Schmidt@psychol.uni-giessen.de