KU LEUVEN

The role of object shape in tool-selective parietal areas

Karla Matić & Stefania Bracci
Laboratory of Biological Psychology, KU Leuven, Belgium
karla.matic@student.kuleuven.be

Rationale and design

Within a few milliseconds we can recognize – with extraordinary precision – the scenes and objects around us. Converging evidence suggests that this cognitive capability is supported by areas within visual cortex specifically devoted to process certain object categories such as faces, bodies or scenes. The representational content of these category-selective areas is often studied in terms of their semantic and visual properties. However, it has been proposed that perception of objects triggers the neural representation of an additional object feature, namely its potential for movement; this feature is often explored by studying the visual perception of man-made tools.

Perception of man-made tools activates a network of areas within the ventral and dorsal visual pathway, and representations within these tool-selective areas are believed to reflect the semantic and functional aspects of tools rather than their visual properties. However, previous studies did not specifically control for object shape properties, leaving the question of the exact role of shape in tool-selective areas unanswered.

The dorsal pathway, which spreads from occipital cortex over the parietal areas, has shown strong activation to tools in areas of intraparietal sulcus (IPS) and superior parietal lobule; since the parietal areas are functionally mostly related to movements, it has been proposed that the action-related features – or "toolness" – of manipulable man-made tools is processed through the dorsal pathway. However, an ongoing debate questions the extent to which parietal activations to pictures of tools represent the functional feature of an object or can be explained by specific visual features common to most man-made tools (i.e., an elongated shape).

The present study investigates the role of object shape in representations encoded within the tool-selective areas of the human parietal cortex. Using a set of stimuli matched by shape, and comprised of diverse manipulable objects, non-manipulable objects, and tools (Figure 1) we performed a functional MRI (Figure 2) and behavioural study of judgements of representational similarity (Figure 3 and 4). We identified a region of interest in intraparietal sulcus (IPS; Figure 5), and will proceed with the representational similarity analysis (Figure 6).

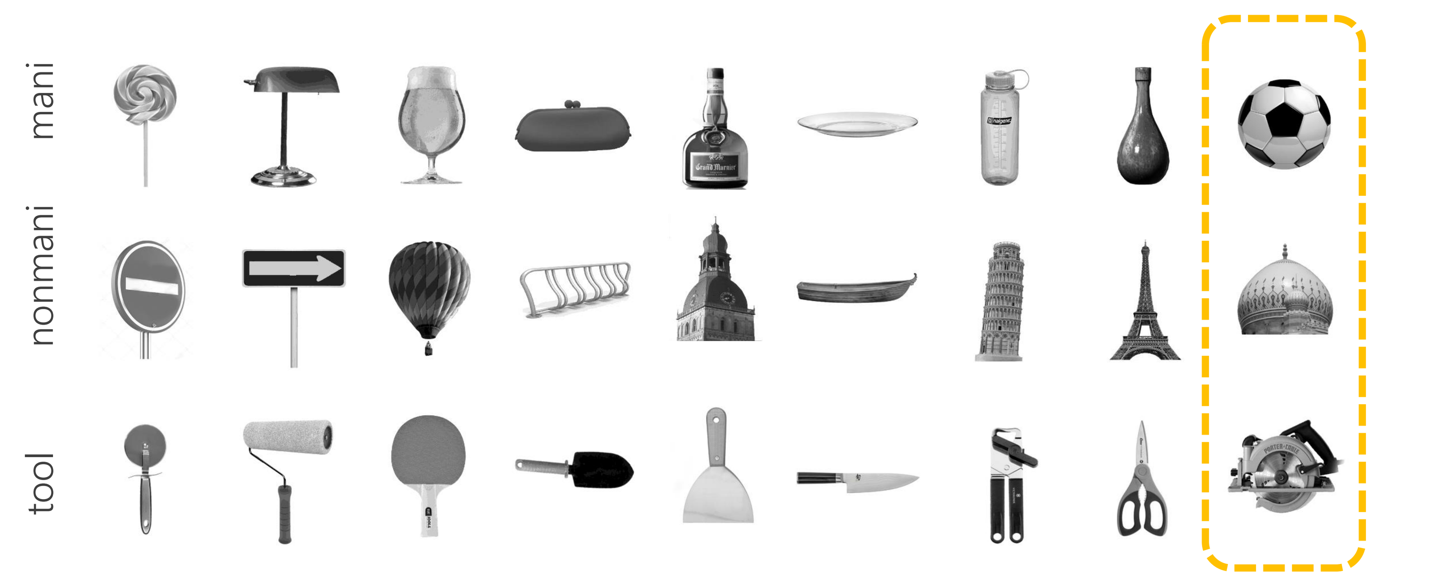
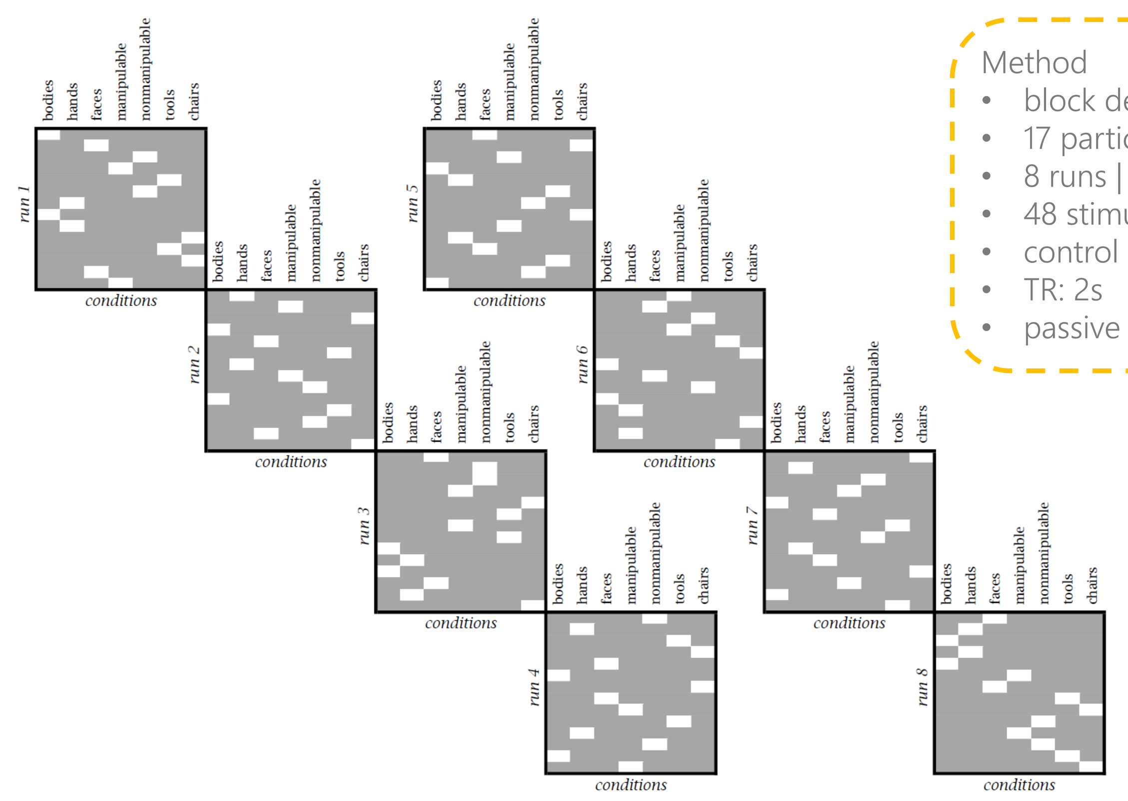


Figure 1. An example set of stimuli used for categories of tools, manipulable objects, and non-maninpulable objects, matched by shape.



Method
- block design fMRI study
- 17 participants
- 8 runs | 2 blocks per run
- 48 stimuli per condition
- control condition: chairs
- TR: 2s
- passive viewing

Figure 2. Illustration of the randomised stimuli presentation in block-design functional MRI study.

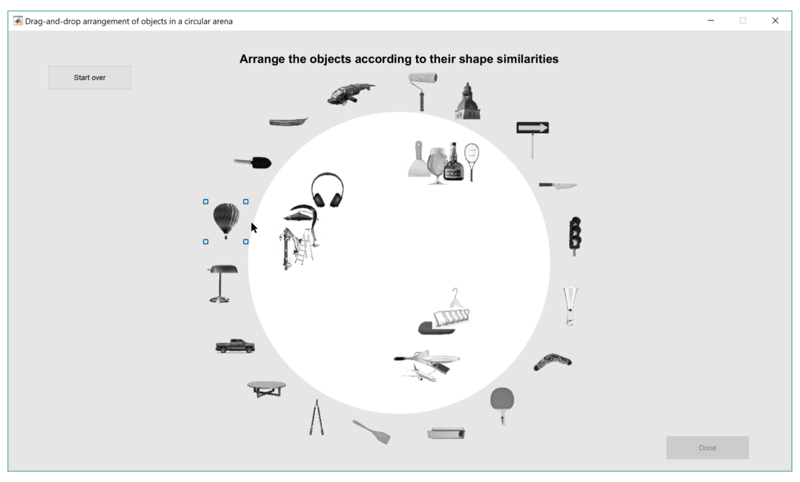


Figure 3. Behavioural task of similarity judgements.

GUIDELINE FOR PARTICIPANTS:
1. Object manipulability/graspability
   Consider the following statements:
   - *This object is easy to pick up;*
   - *This object is designed specifically for being easily graspable by one or both hands."*
2. Body extension
   Consider the following statements:
   - *This object is like a physical extension of my hand or arm; after using it for a while it almost feels to become part of my body;*
   - *When I use this object, my hand/arm movements are directly controlling this object to physically act on another object or surface.*
3. Visual similarity
   - Arrange the objects according to their shape similarity (regardless of object orientation).

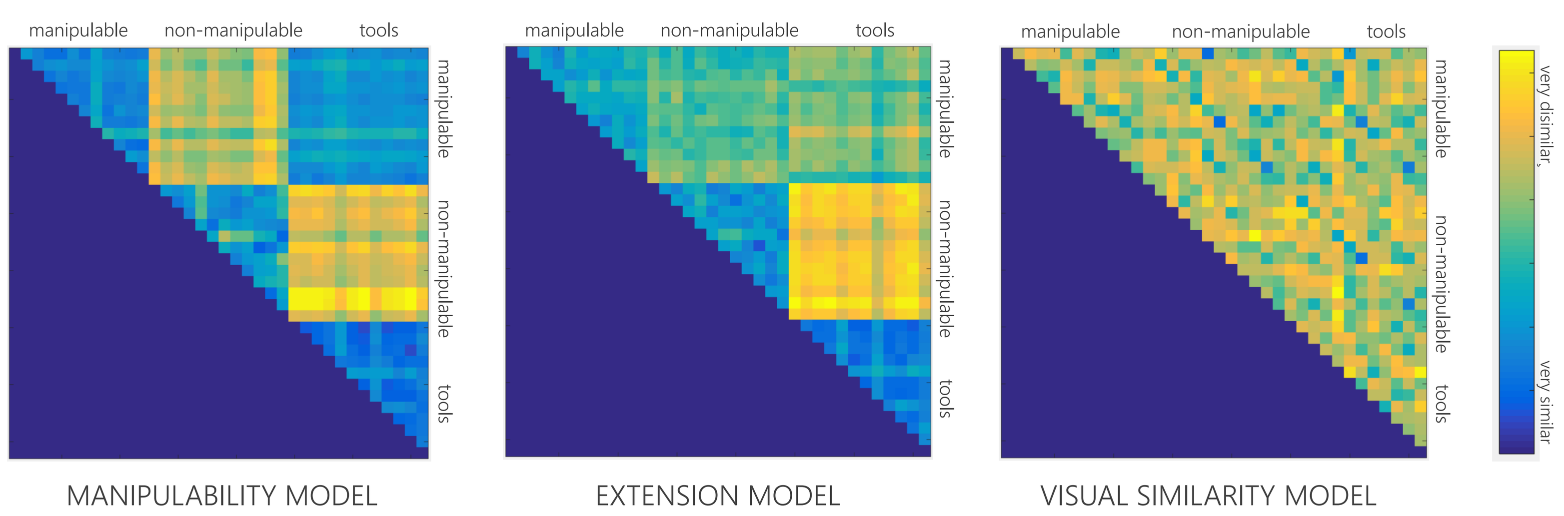


Figure 4 . Representation disimilarity matrices of behavioural models of representation of three categories of objects (manipulable, non-manipulable, tools).

Representational similarity analysis

- **representational similarity analysis (RSA)** = experimental and data-analytical framework which allows us to relate the measures of neural activity to behavioural judgements
- **goal:** understand which aspects of physical or psychological representations are coded in neural representational space --> how are different dimensions of man-made tools (e.g., shape and potential for action) encoded in parietal regions
- models are expressed by computing **representational dissimilarity matrices (RDMs)**
- each cell of RDM contains a number reflecting the dissimilarity between the patterns of neural activity or behavioural judgements associated with the three object categories;
  - MANIPULABILITY MODEL = a model in which no distinction is made between tools and other graspable objects
  - EXTENSION MODEL = a model in which objects that can be considered an extension of our hands when we manipulate them (e.g., a knife) are represented differently than other manipulable objects
  - VISUAL MODEL = a model in which objects that share similar visual properties (i.e. shape) are represented similarly

Multi-voxel pattern analysis

- analysis of multivariate patterns of brain activation elicited for different stimuli categories --> representations of categories are believed to be reflected in differences between patterns of voxel activation
- **approach**: the theoretical models (based on behavioural similarity judgements) are fitted to neural data of one region of interest (ROI) --> correlation is computed between the predicted model (e.g., Figure 3) and the neural MVPA matrix
- **bottleneck of the present study**: unexpectedly weak activations in parietal areas (IPS)

Predictions of neural data

1) If the functional neural data is better explained by the **extension model**, where tools are distinct from manipulable objects, we can conclude that tool-selective response in IPS cannot be explained solely by object visual properties (e.g., elongation).

2) If the functional neural data is better explained by the **manipulability model**, where tools and manipulable objects are similarly represented, we can conclude that previously reported tool selectivity in IPS might be related to tool-specific visual properties (e.g., elongation), and not tool action properties.

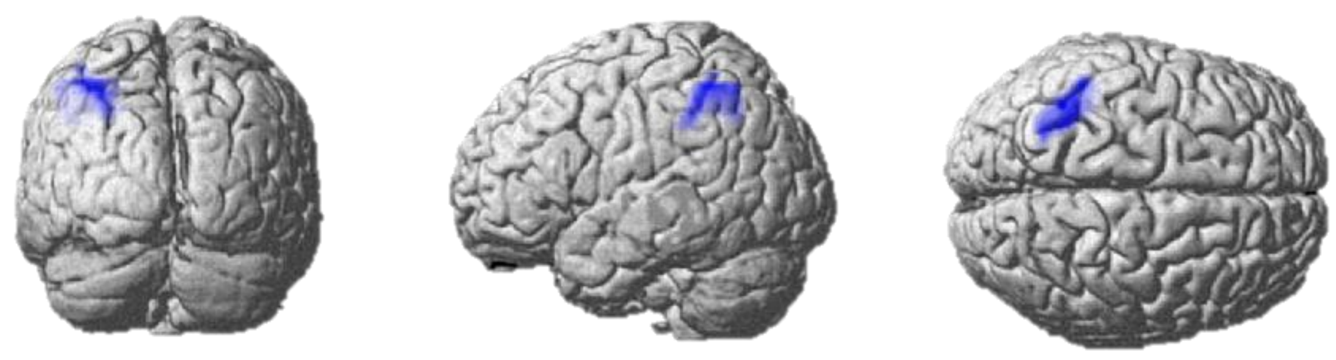


Figure 5. Anatomicaly localised region of interest in left intraparietal sulcus (IPS).

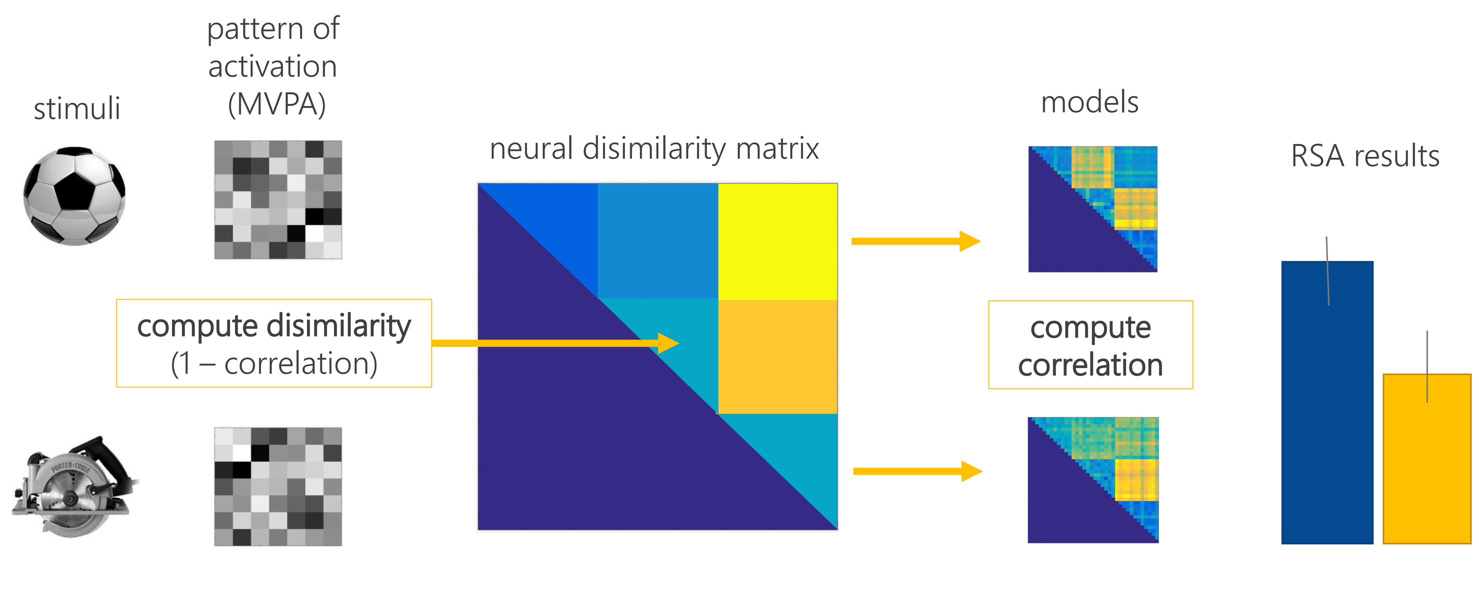


Figure 6. The complete process of performing representational similarity analysis.