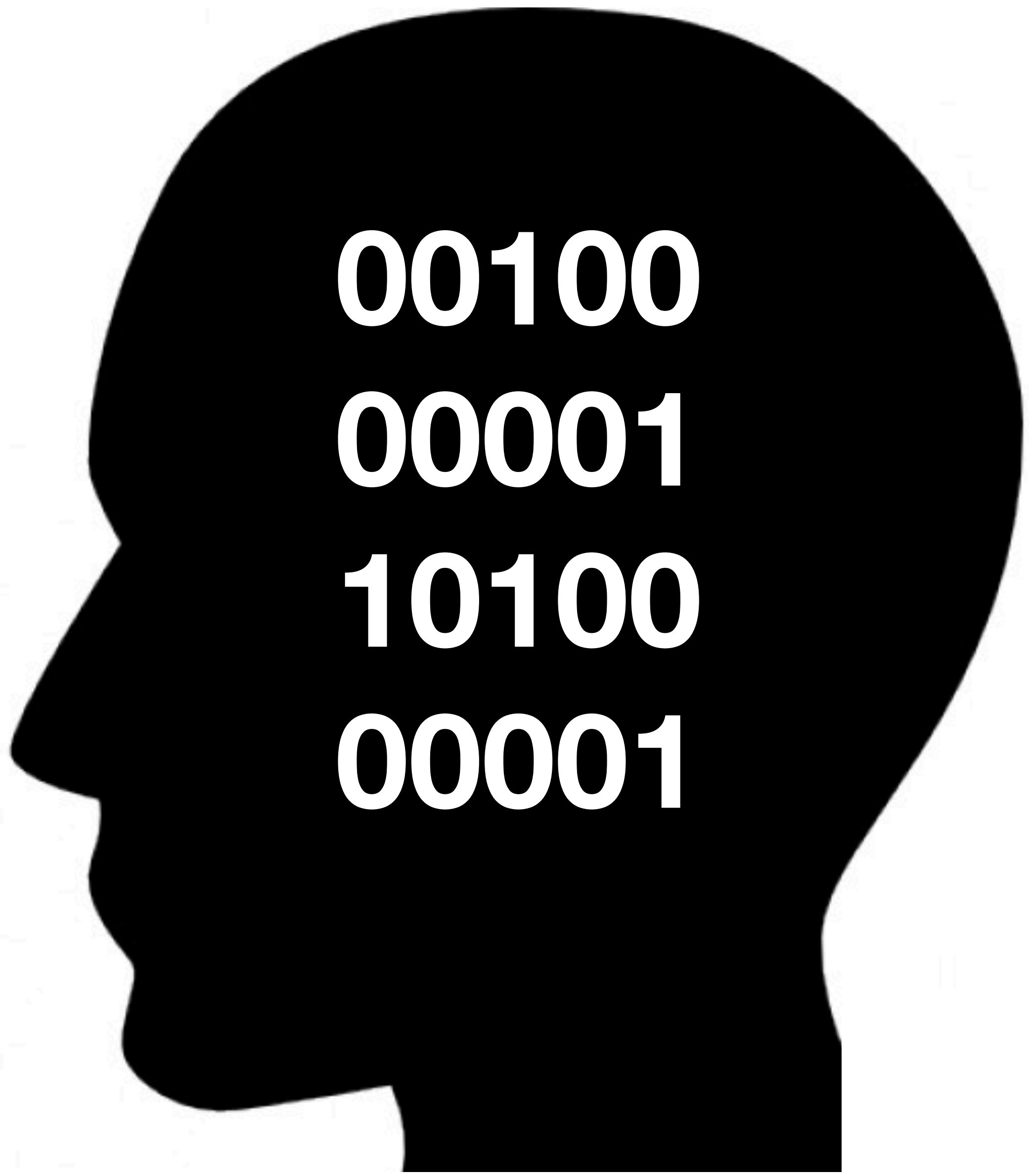


COG260: Data, Computation, and The Mind

Spatial Cognition

Announcements

OH for this upcoming Friday is cancelled.

A make-up doubled OH will be offered on the upcoming Tuesday 10am-12pm.

A two-day extension to lab 3 (details later) has been provided.

Question about slide availability before each class.

Lab 1: Number estimation

Complex or overly articulated hypothesis, not fully justified or motivated

Defined accuracy as {(the number of correct answers) / (total=47)}x100, and if the number of dots is 40, the accuracy will be under 30%.

Hypothesis: The percent error in estimation accuracy will range from X to Y when the target value is greater than 10 .... and will increase as the target value increases.

Hypothesis : As the number of dots in the clusters increases, the magnitudes are percieved similarly and the error terms start to gradually stay confined to a small range.

Open-ended hypothesis, difficult to be falsified

If there are more than X number of dots on the screen, then the accuracy of participants' answers will decrease.....

A good hypothesis

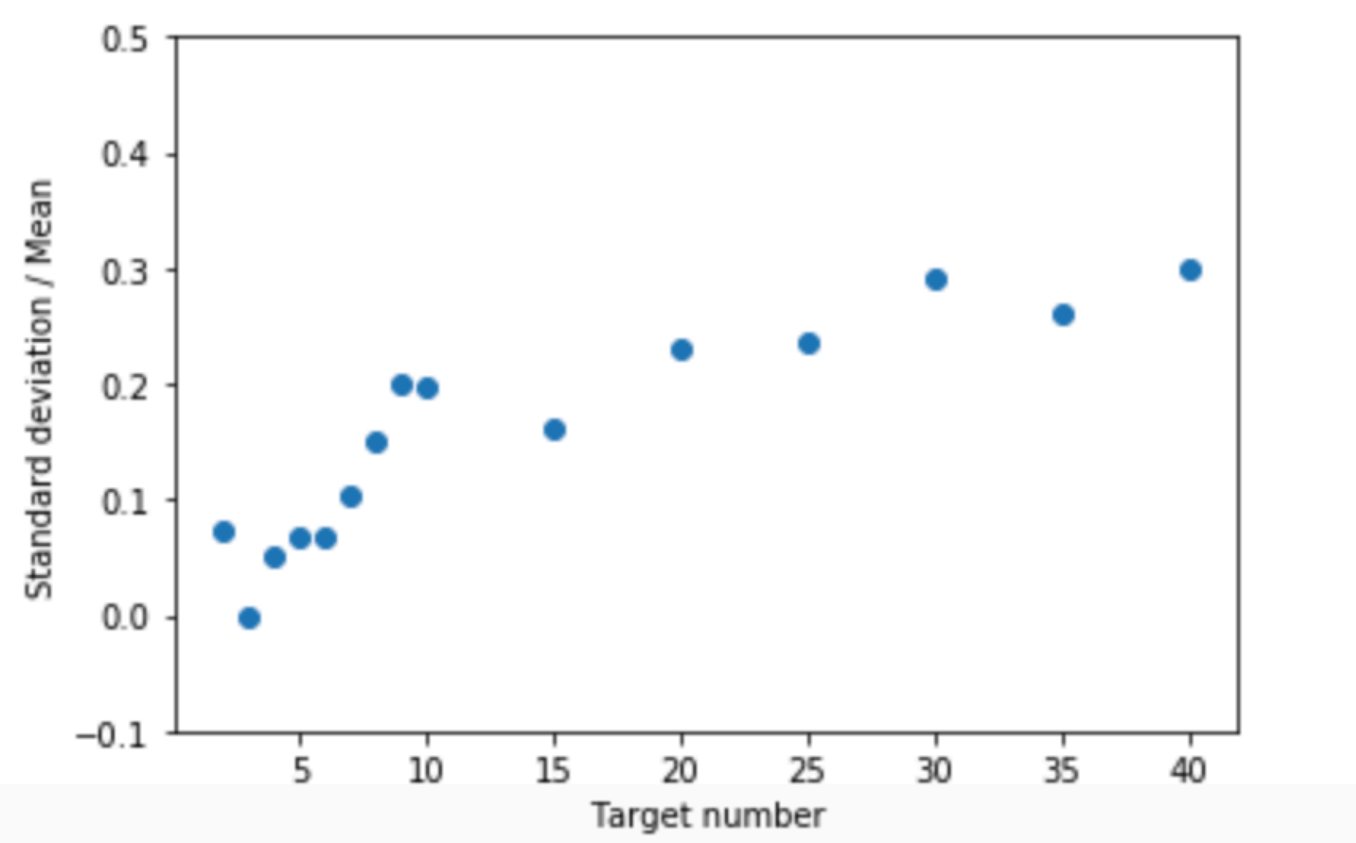
We hypothesize that a strong correlation exists between the number of target items and the mean numerical distance of our estimates from the ground truth number of items.

Lab 2: Weber fraction

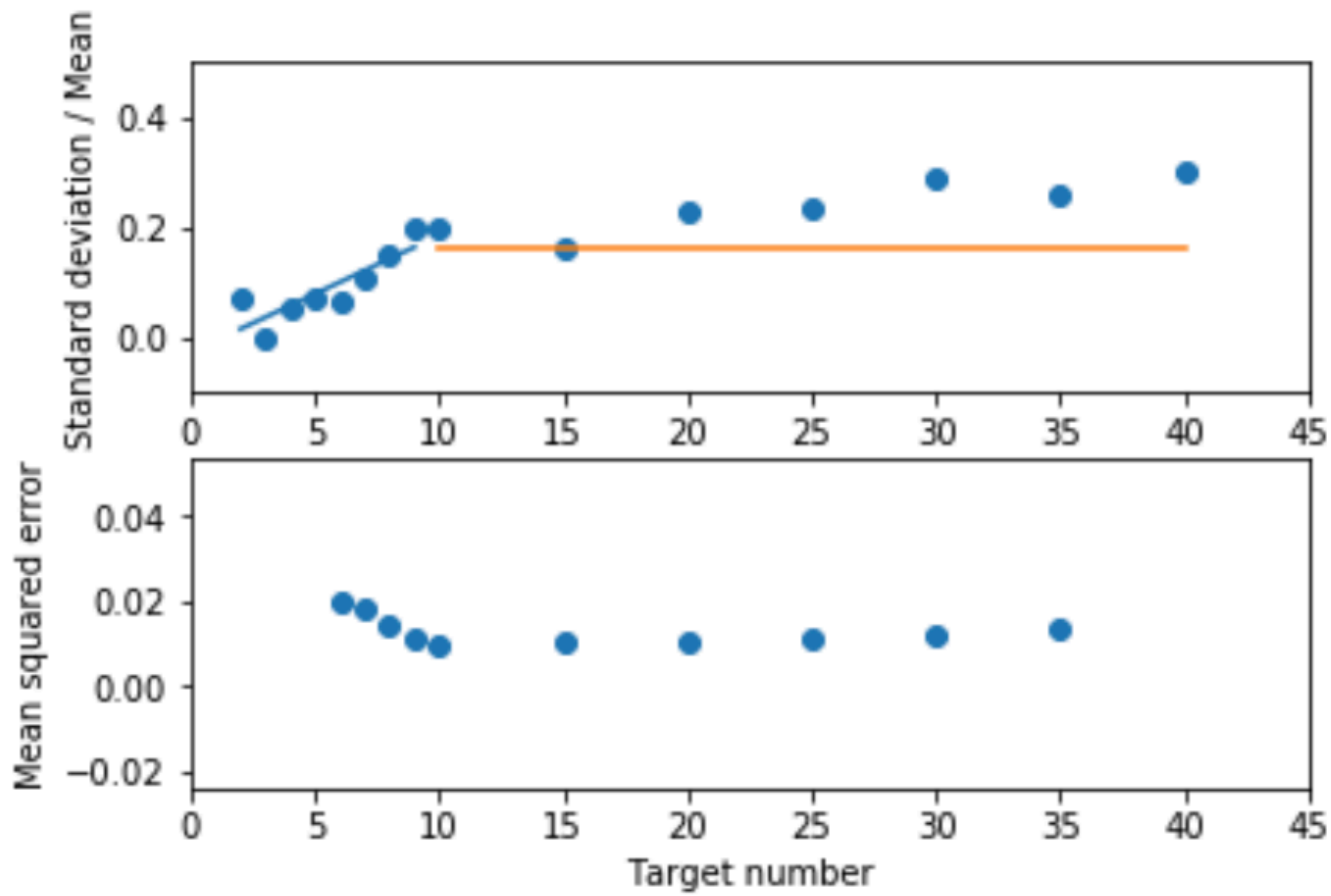
```
# Compute coefficient of variation: do not use "for" loop
cv = np.divide(sd,mn)

plt.figure()

# Plot coefficients of variation vs targets
plt.scatter(targets,cv)
plt.xlabel('Standard deviation / Mean')
plt.ylabel('Target number')
plt.ylim([-.1,.5])
plt.show()
```



Lab 2: Weber fraction




```
Estimated Weber fraction:
0.247011189166
optimal threshold:
10
```

Accept solutions in the range :
Threshold target = 8,9,10,15,20
Or thres = 7,8,9,10,11

Outline

- Spatial cognition
- Lab 3

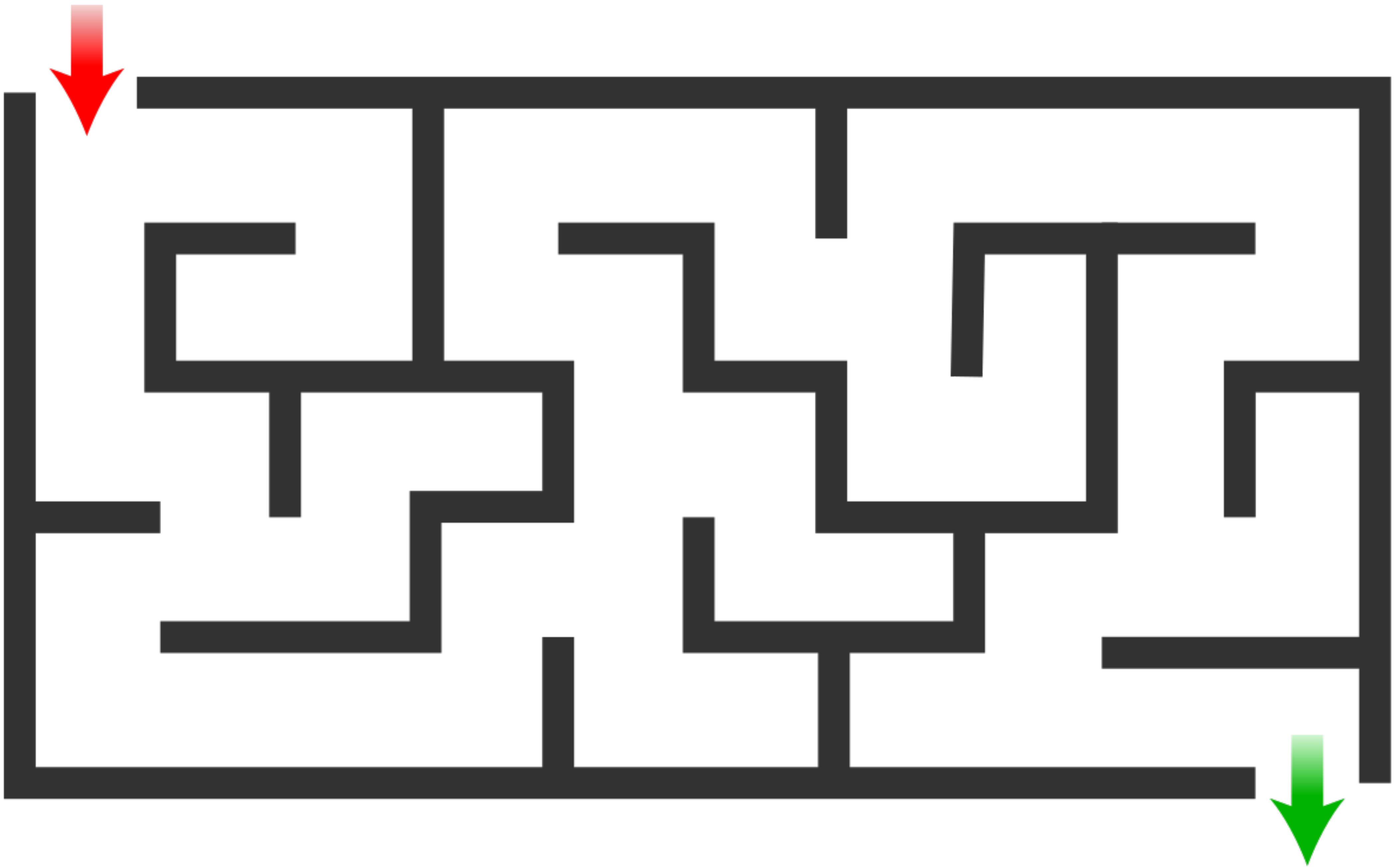
Spatial cognition

- Three fundamental aspects:
  - Spatial navigation
  - Spatial orientation
  - Spatial relation

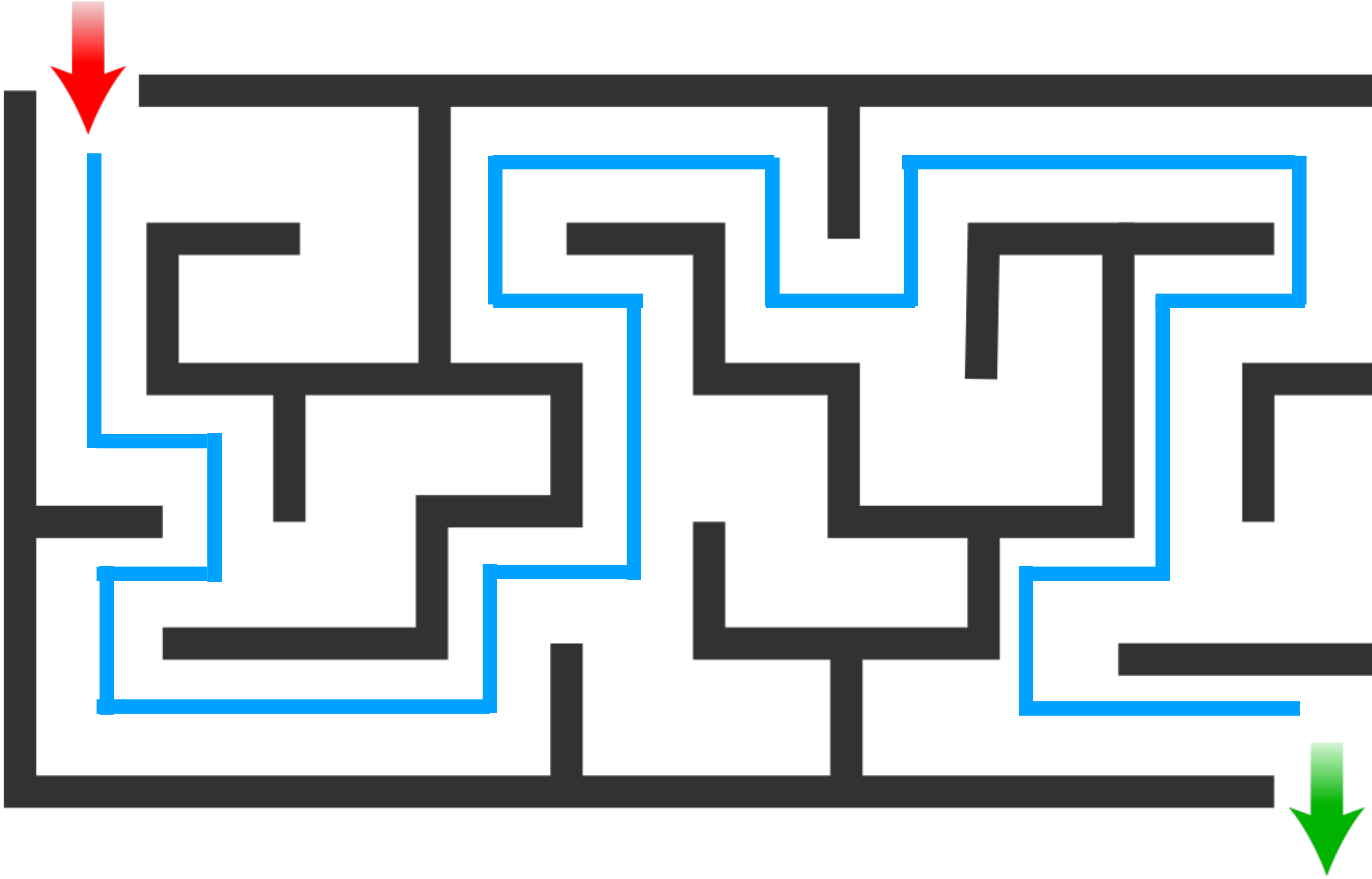
Spatial cognition

- Three fundamental aspects:
  - Spatial navigation: How to get from A to B
  - Spatial orientation
  - Spatial relation

Spatial navigation



Spatial navigation



Tolman's criticism on behaviorism

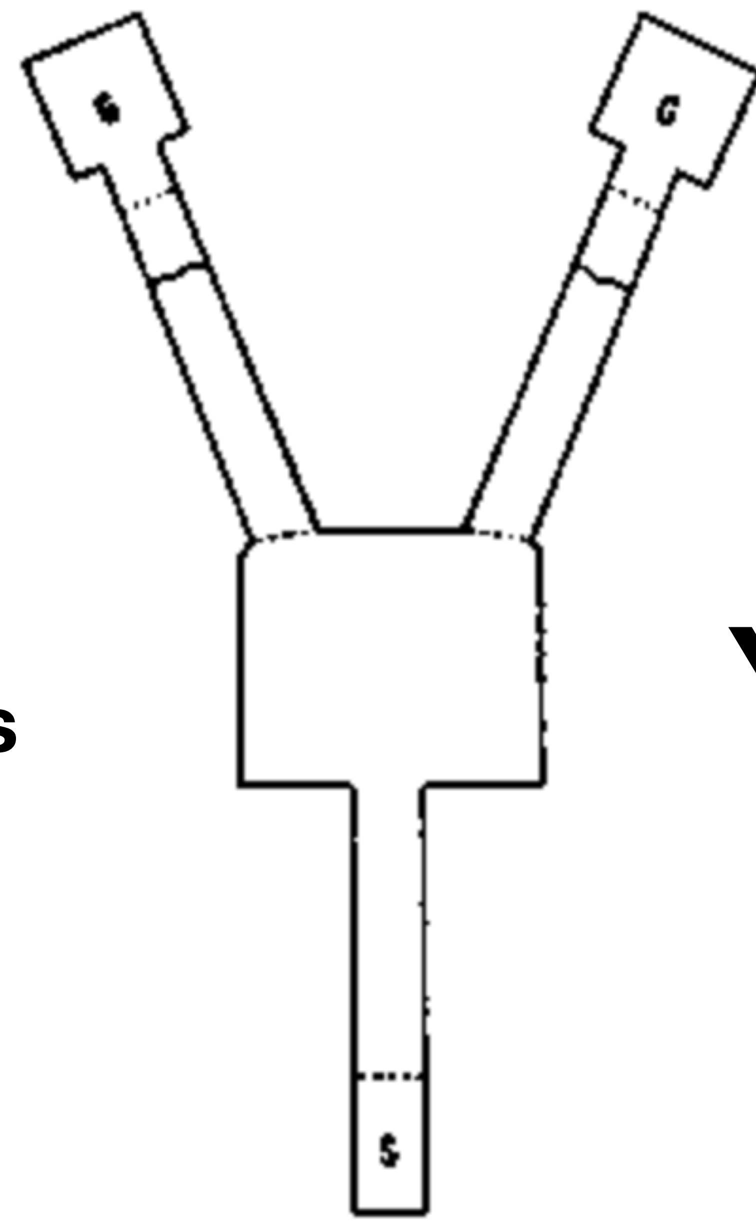
"there is a school of animal psychologists which believes that the maze behavior of rats is a matter of mere simple stimulus-response connections. Learning, according to them, consists in the strengthening of some of these connections and in the weakening of others. According to this 'stimulus-response' school the rat in progressing down the maze is helplessly responding to a succession of external stimuli-sights, sounds, smells, pressures, etc. impinging upon his external sense organs-plus internal stimuli coming from the viscera and from the skeletal muscles."

Tolman (1948)

Tolman's experiment

food

water



Ground plan of the apparatus

Fig. 7

Rats were trained
to run down both paths

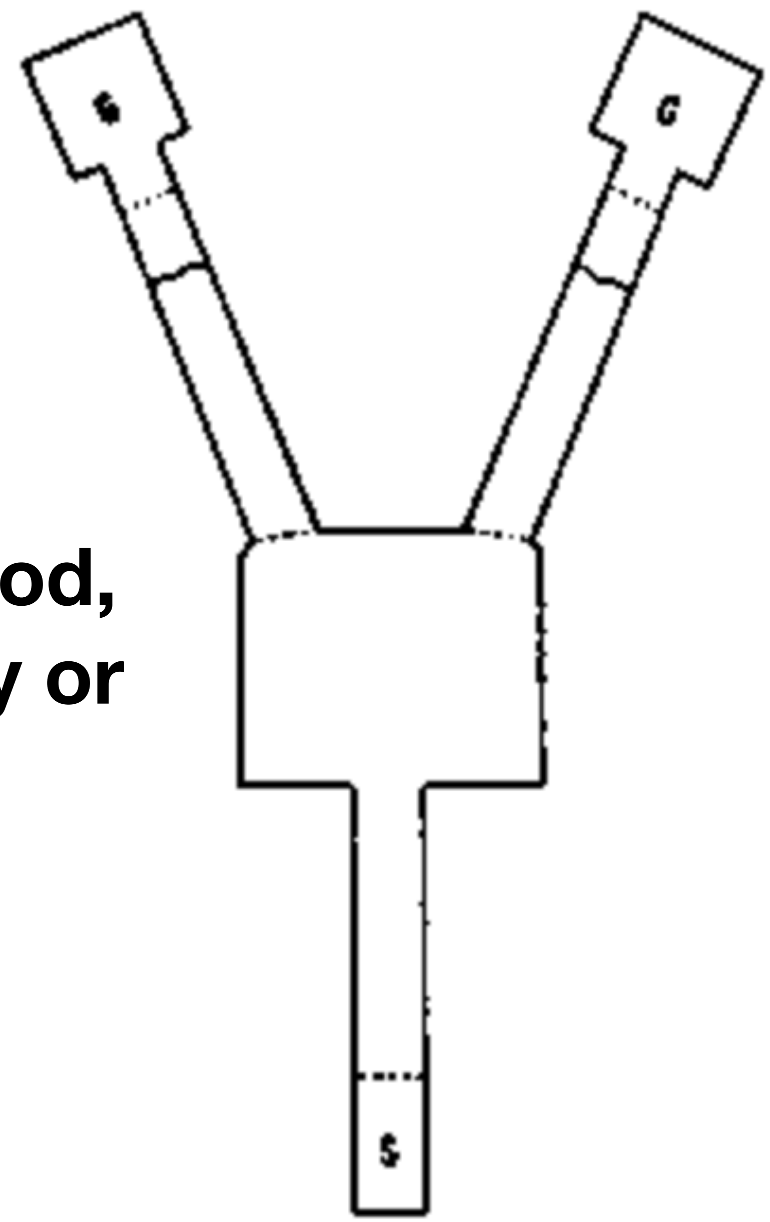
Y-maze

Tolman (1948)

Tolman’s experiment

no food

no water



Ground plan of the apparatus

FIG. 7

During the testing period, rats were either hungry or thirsty

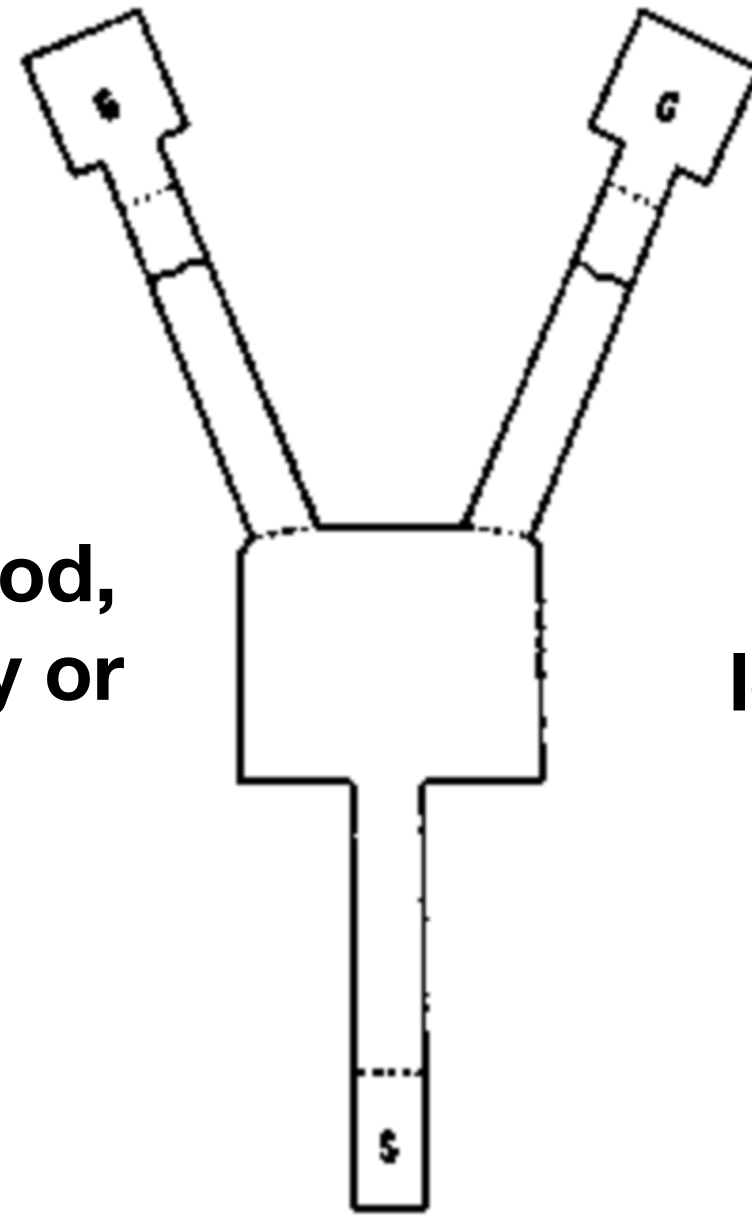
Tolman (1948)

Discuss: where should the rat go according to behaviorism?

Tolman's experiment

no food

no water



Ground plan of the apparatus

Fig. 7

Tolman (1948)

During the testing period, rats were either hungry or thirsty

Behaviorism predicts:

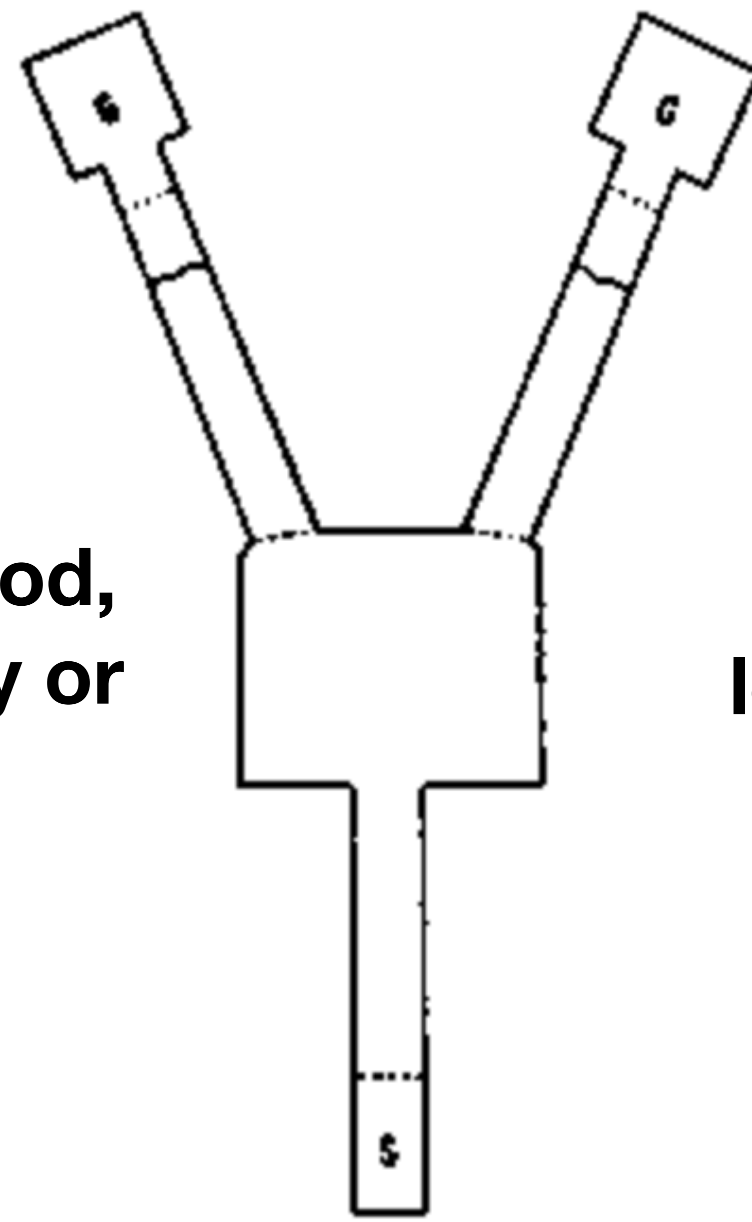
left **right**

Tolman’s experiment

no food

no water

During the testing period, rats were either hungry or thirsty



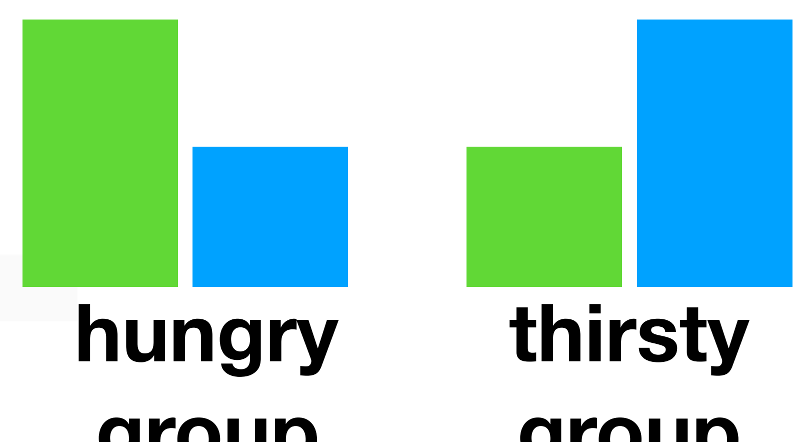
Ground plan of the apparatus

Fig. 7

Tolman (1948)

Behaviorism predicts:

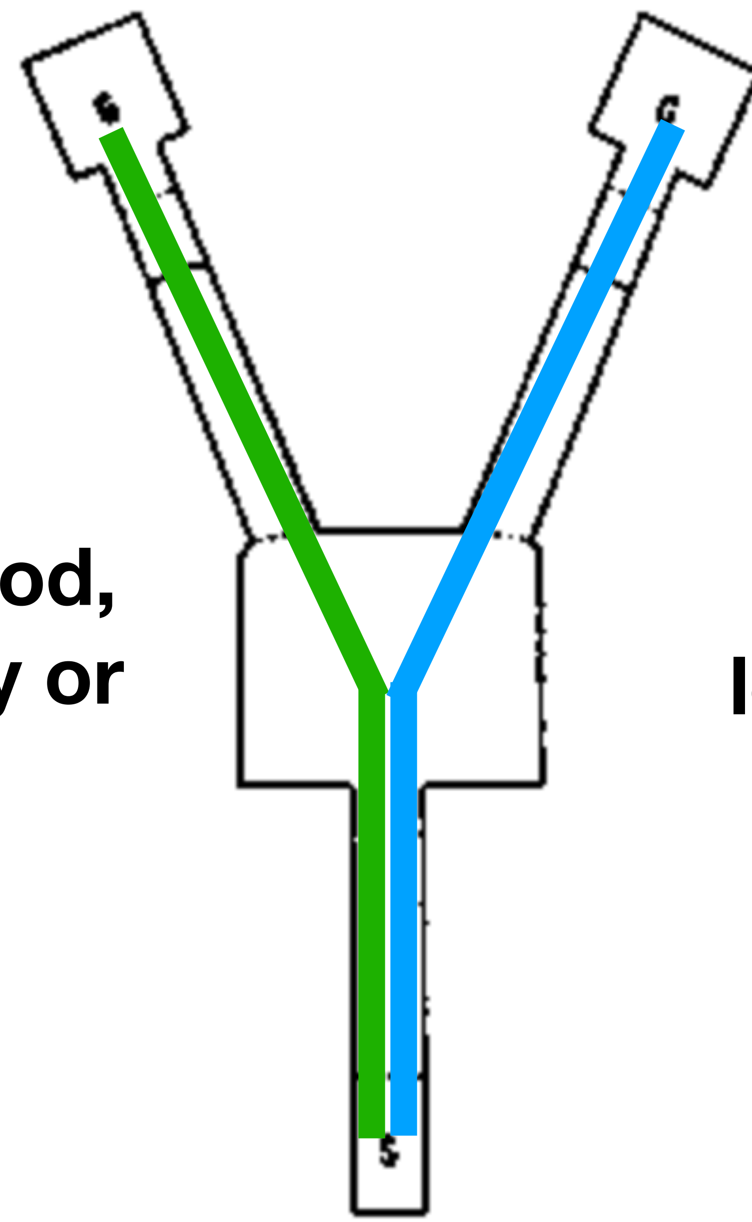
Actual findings:



Cognitive maps

no food

no water



Ground plan of the apparatus

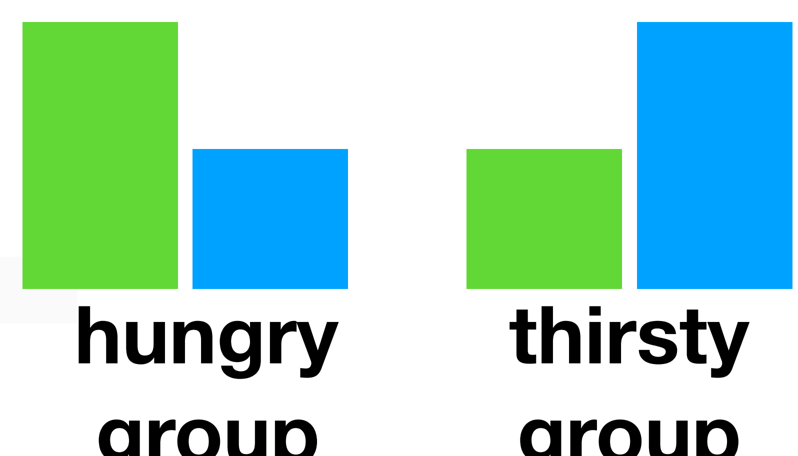
FIG. 7

Tolman (1948)

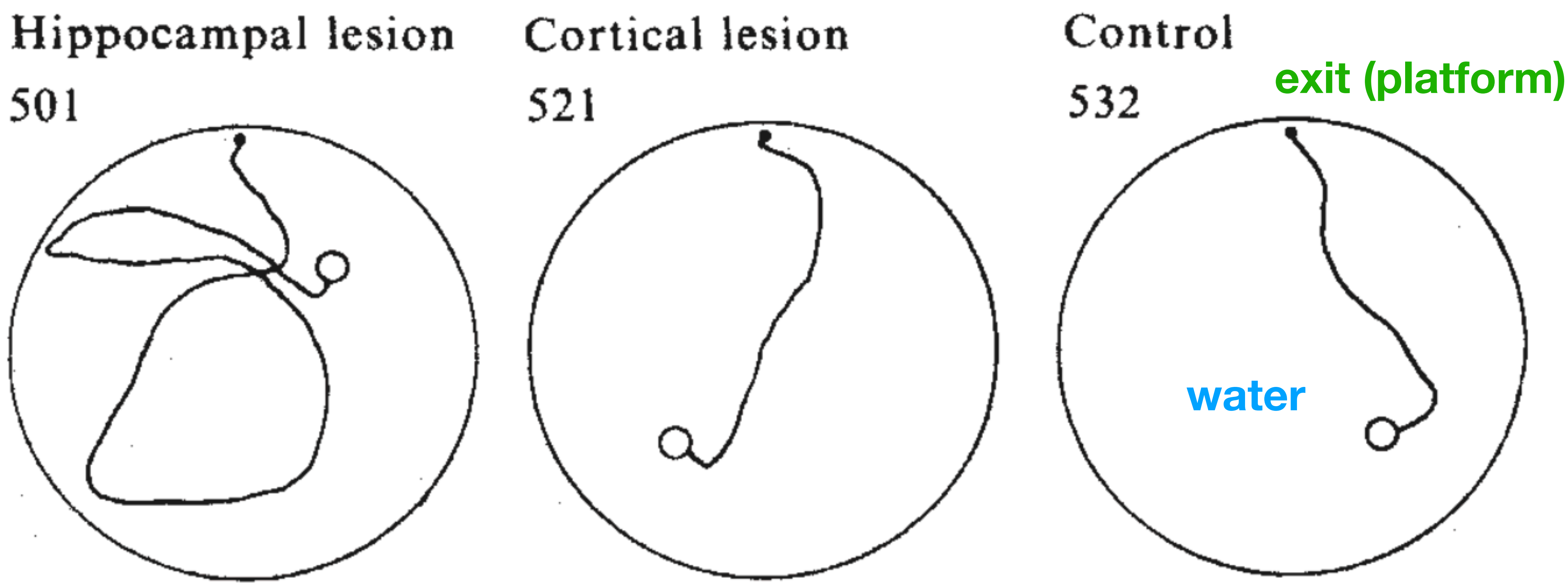
During the testing period, rats were either hungry or thirsty

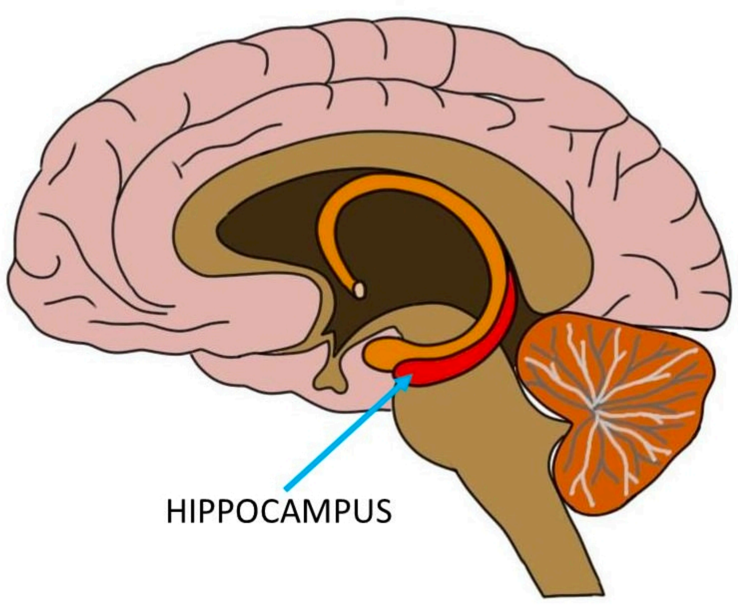
Behaviorism predicts:

Actual findings:



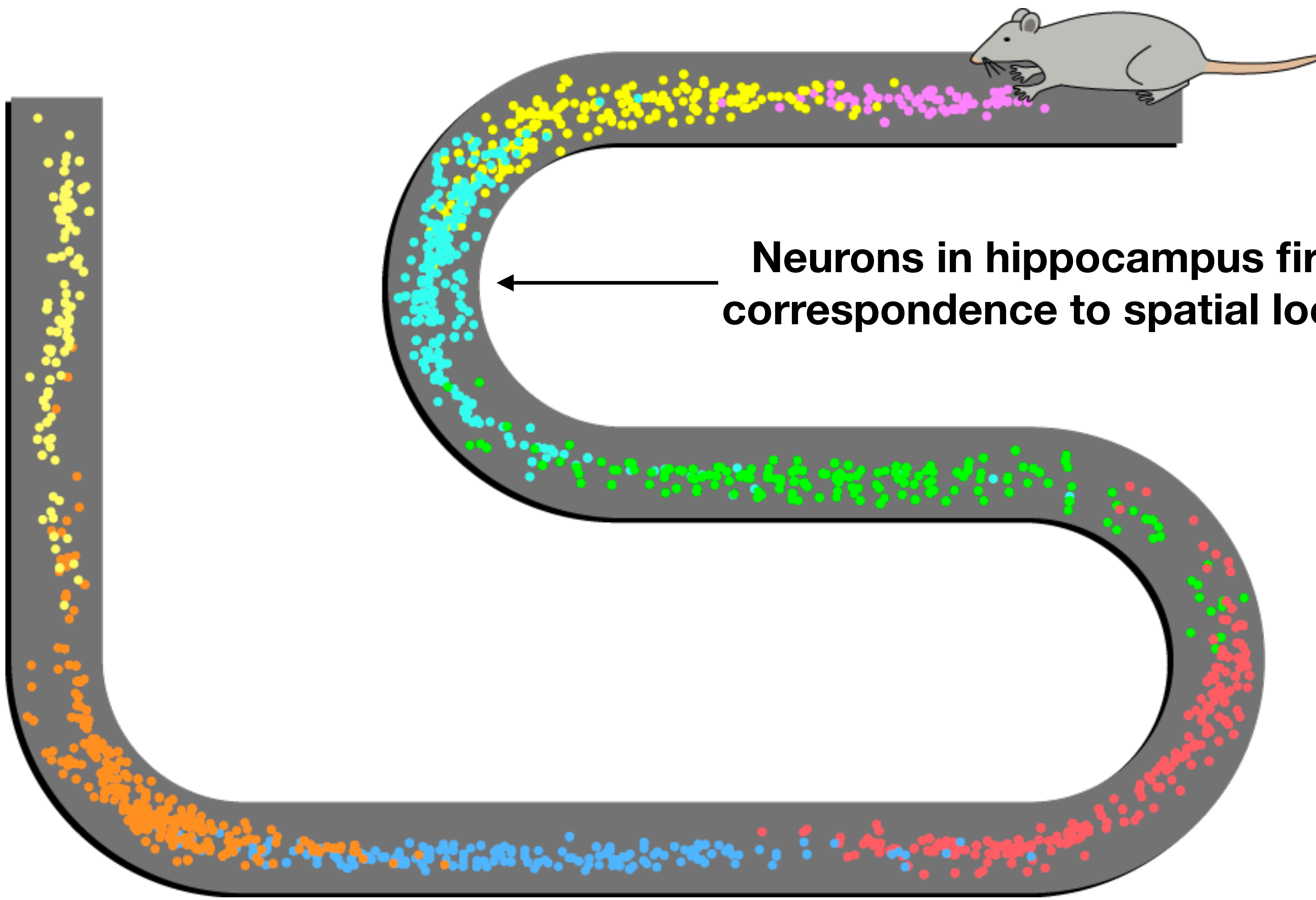
Hippocampus: Cognitive maps in the brain





Morris et al. (1982)

Place cells in hippocampus



Neurons in hippocampus fired in correspondence to spatial locations

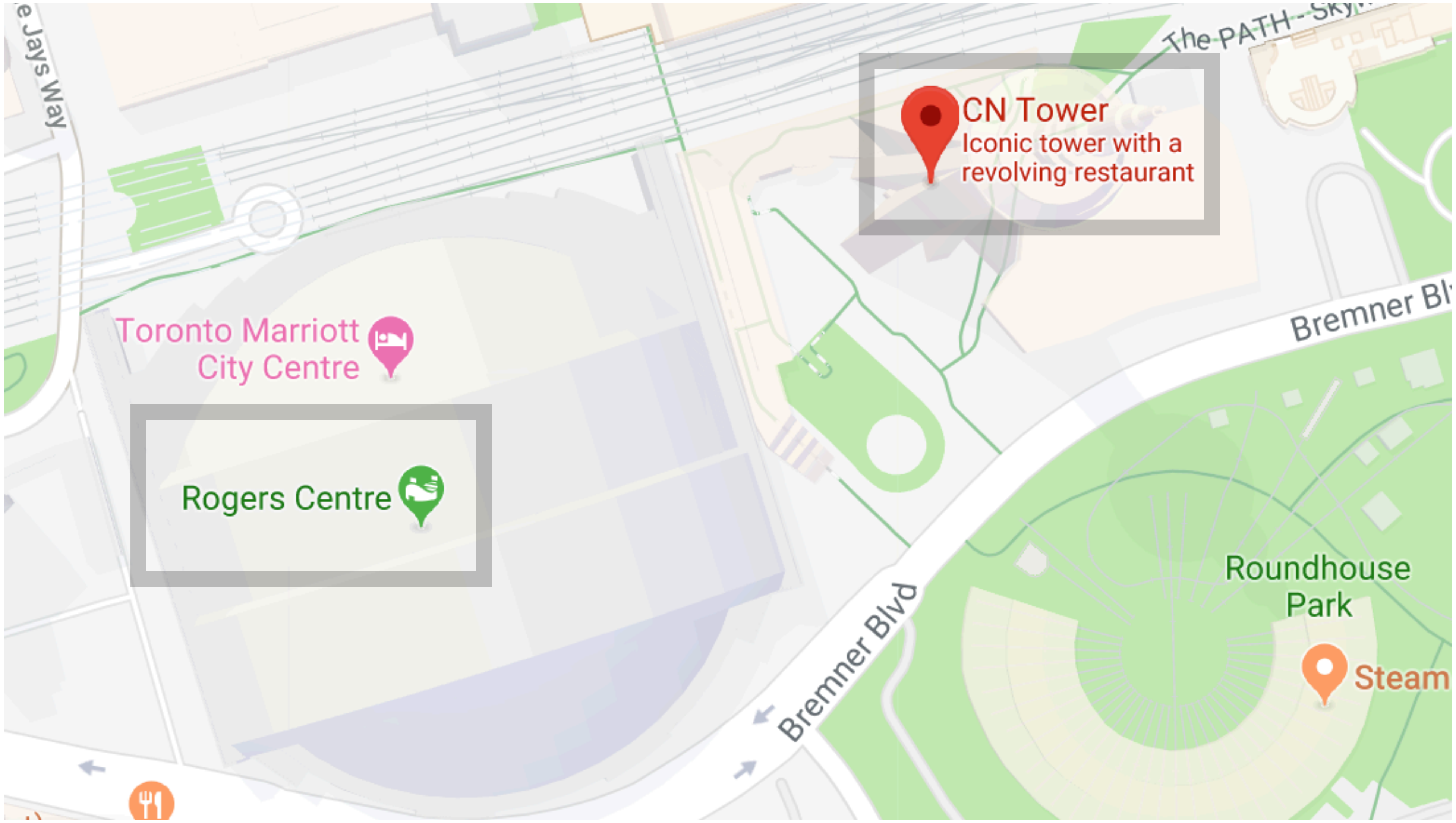
Wikipedia

Spatial cognition

- Three fundamental aspects:
  - Spatial navigation: How to get from A to B
  - Spatial orientation: How A is located with respect to B
  - Spatial relation

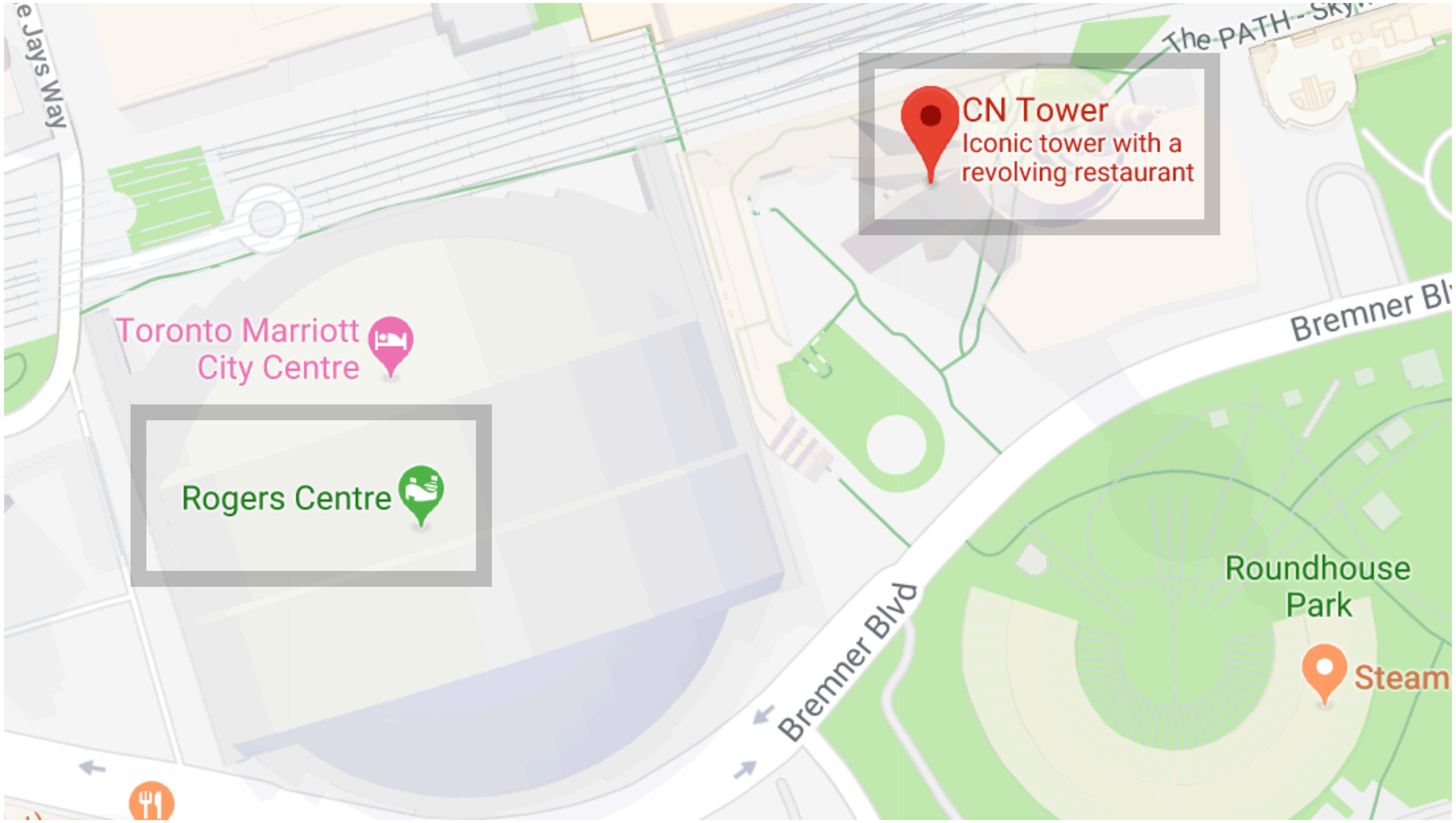
Spatial orientation

Where is CN Tower relative to Rogers Centre?



Spatial orientation

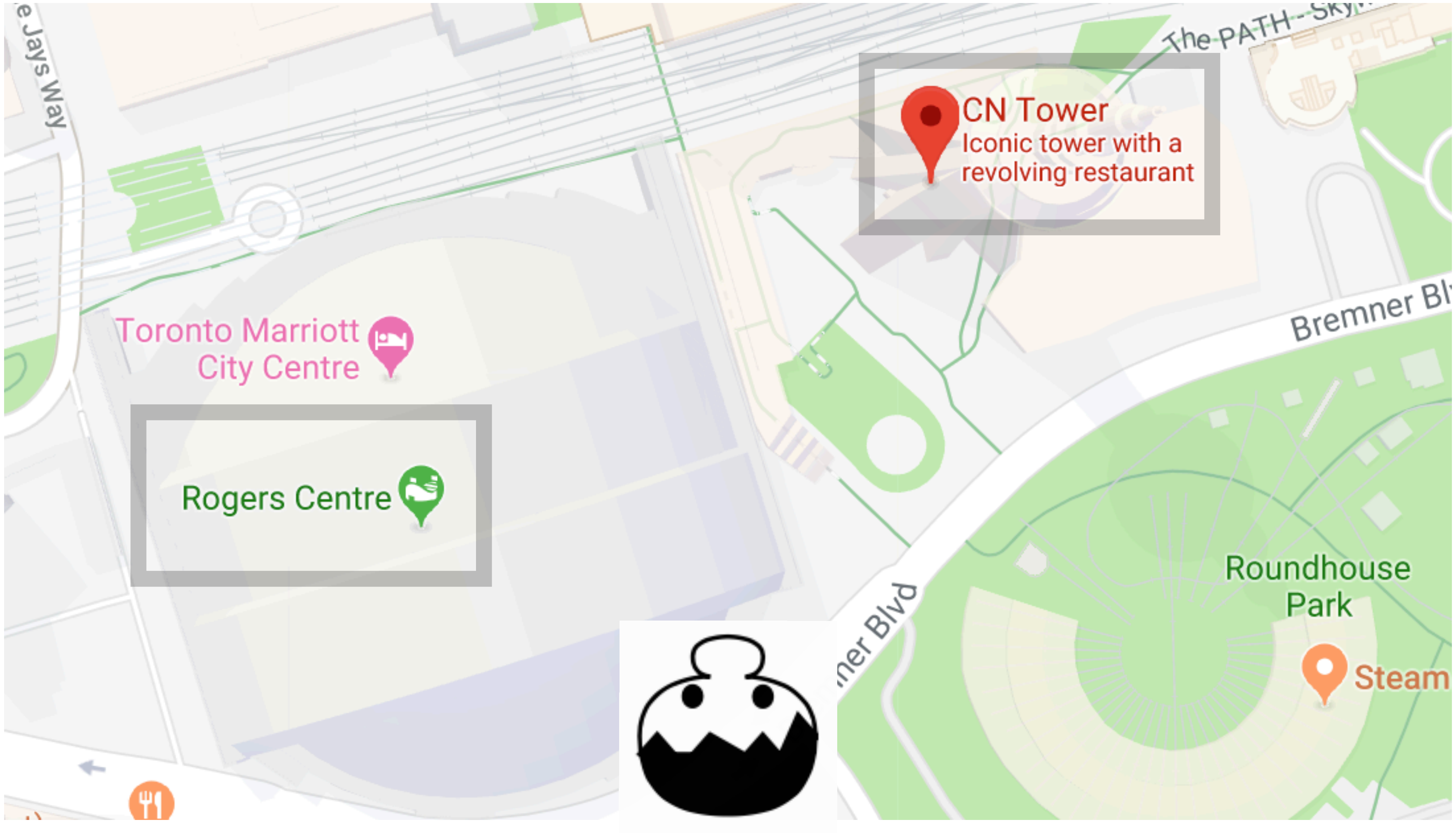
Absolute frame: CN Tower is to the NE of Rogers Centre.



Spatial orientation

Absolute frame: CN Tower is to the NE of Rogers Centre.

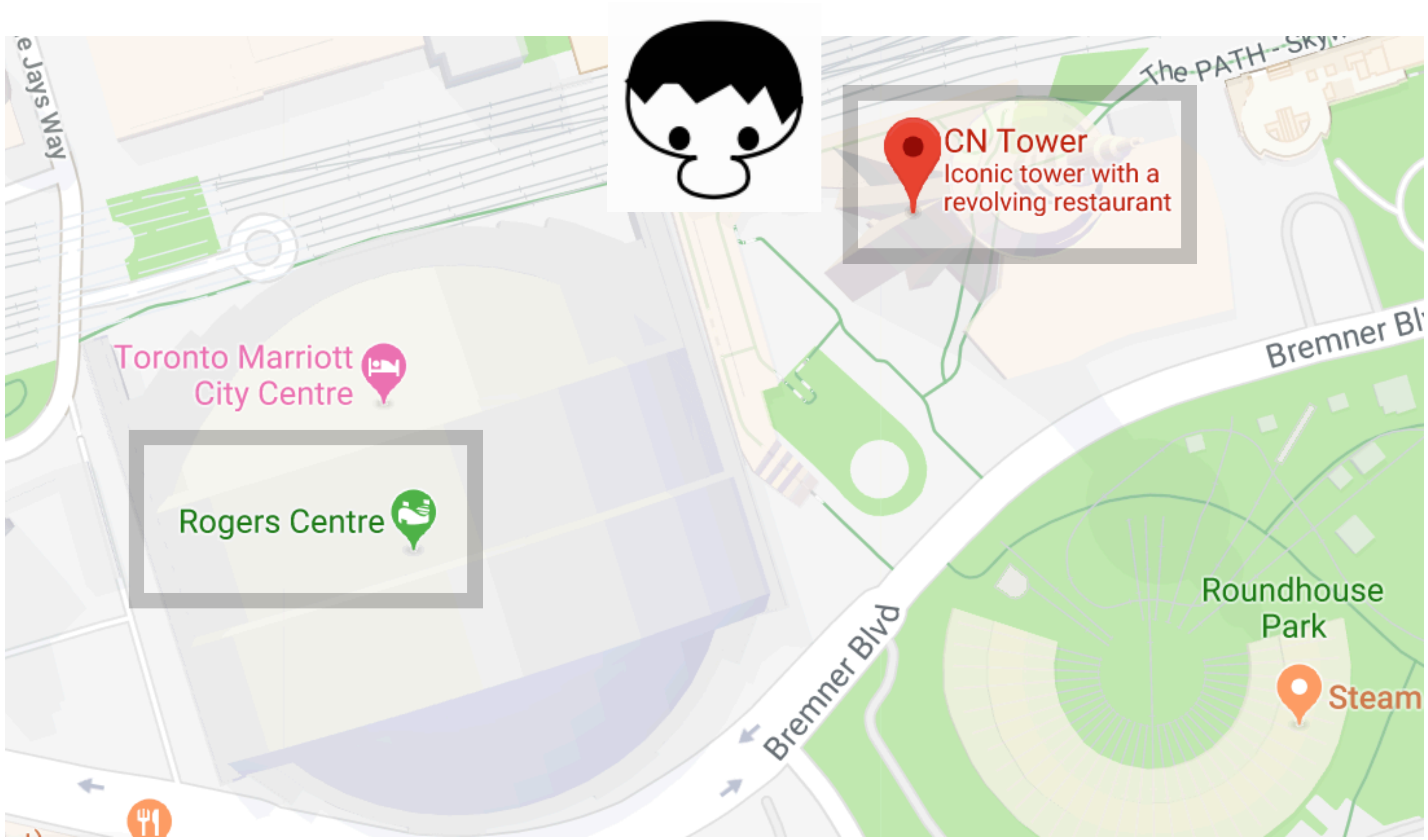
Relative frame: CN Tower is to the right of Rogers Centre.



Spatial orientation

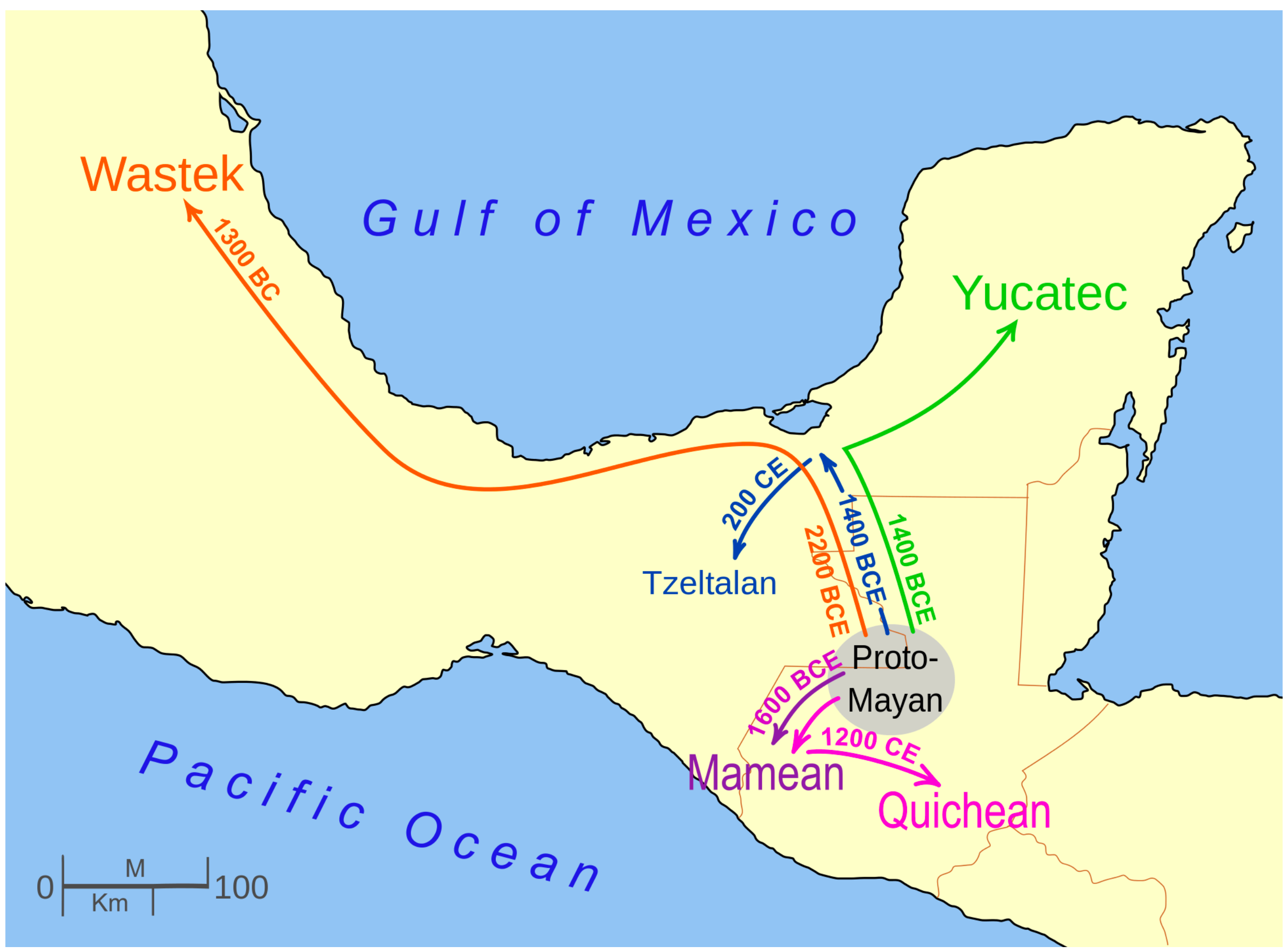
Absolute frame: CN Tower is to the NE of Rogers Centre.

Relative frame: CN Tower is to the left of Rogers Centre.



Cultural differences in spatial frames of reference

Tzeltal speakers: Absolute frame



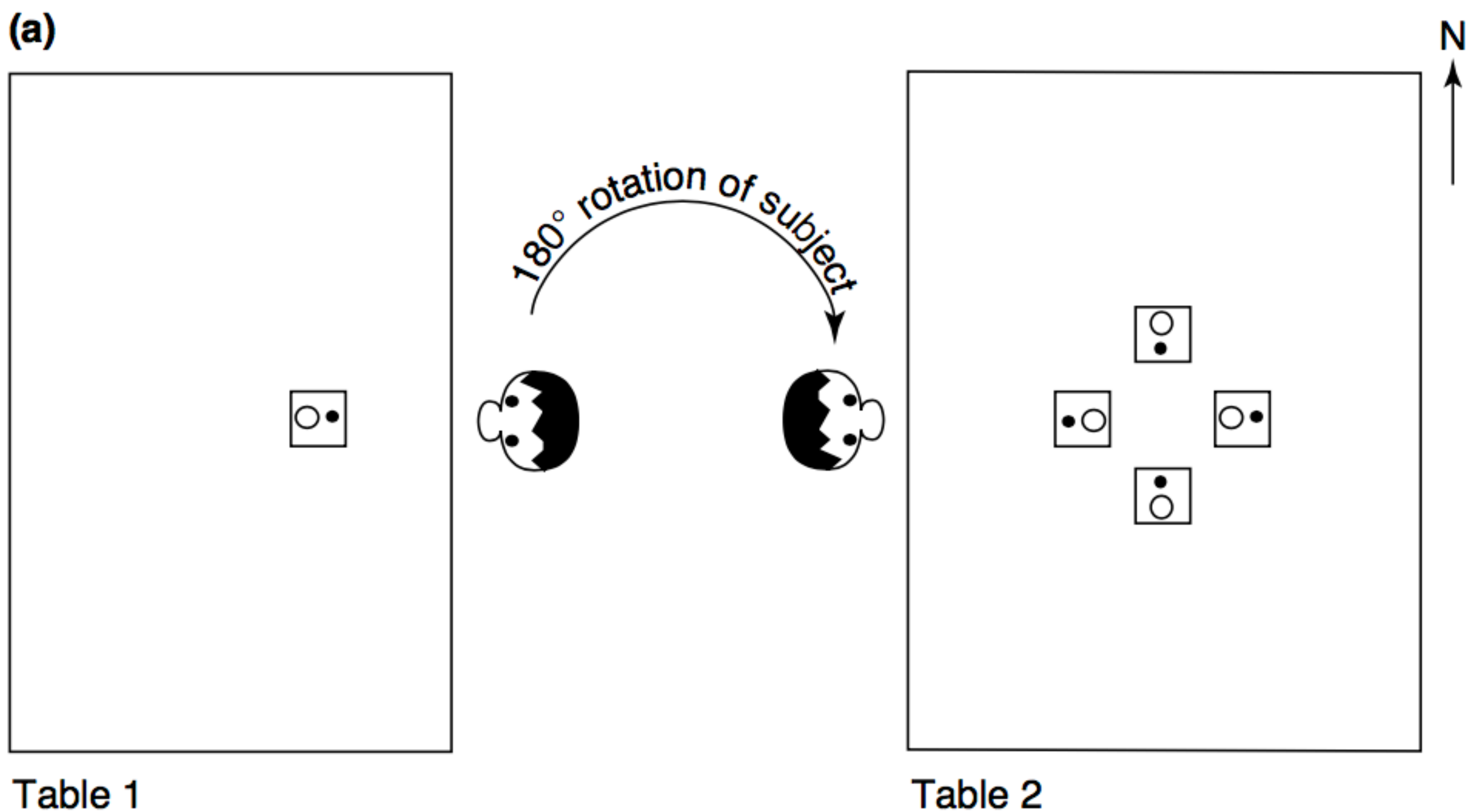
Dutch speakers: Relative frame

Cultural differences in spatial frames of reference

Tzeltal speakers: Absolute frame **Dutch speakers: Relative frame**

Relative: The fork is to the left of the spoon
Absolute: The fork is to the north of the spoon
Intrinsic: The fork is at the nose of the spoon

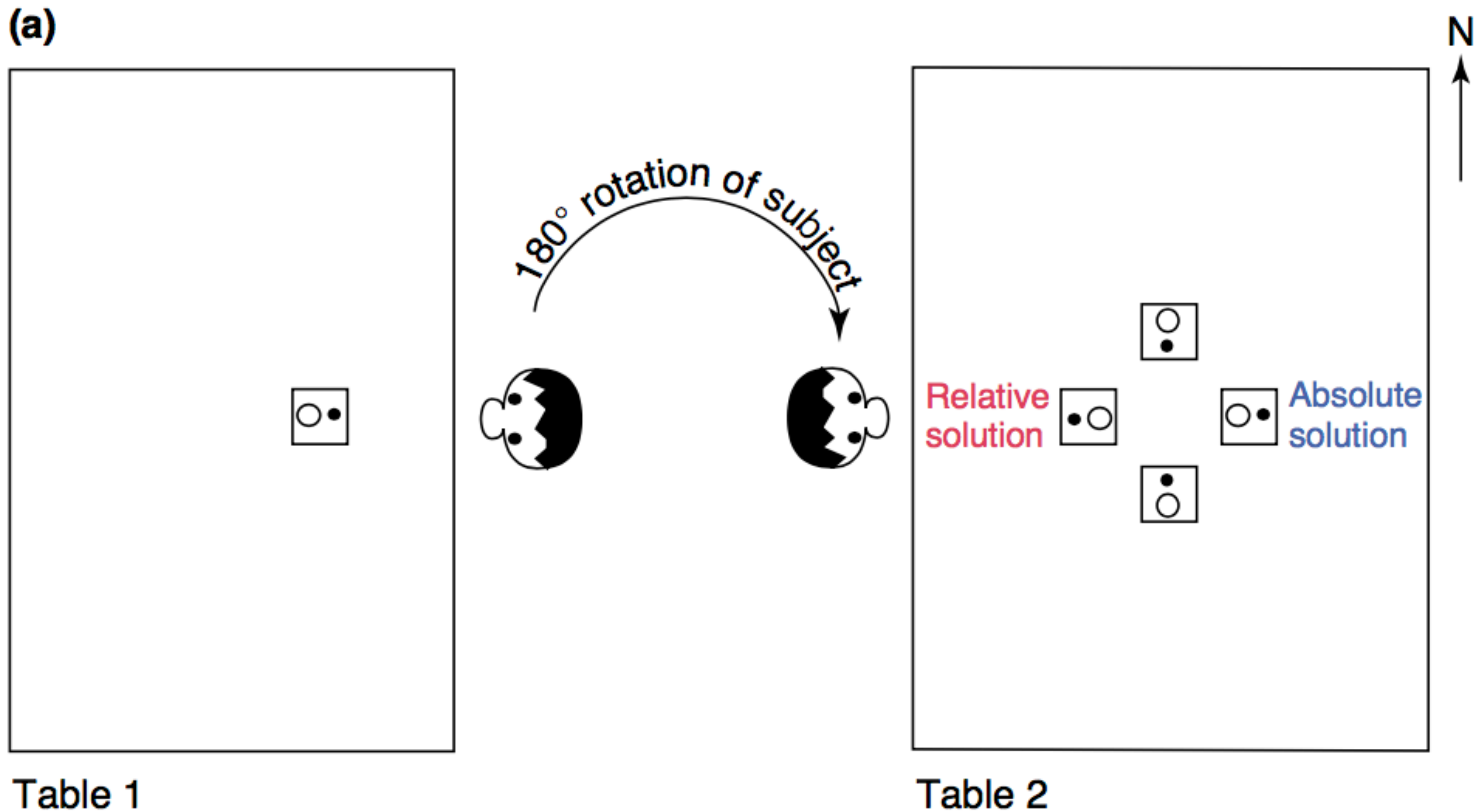
Which is the matching pattern?



Majid et al. (2004)

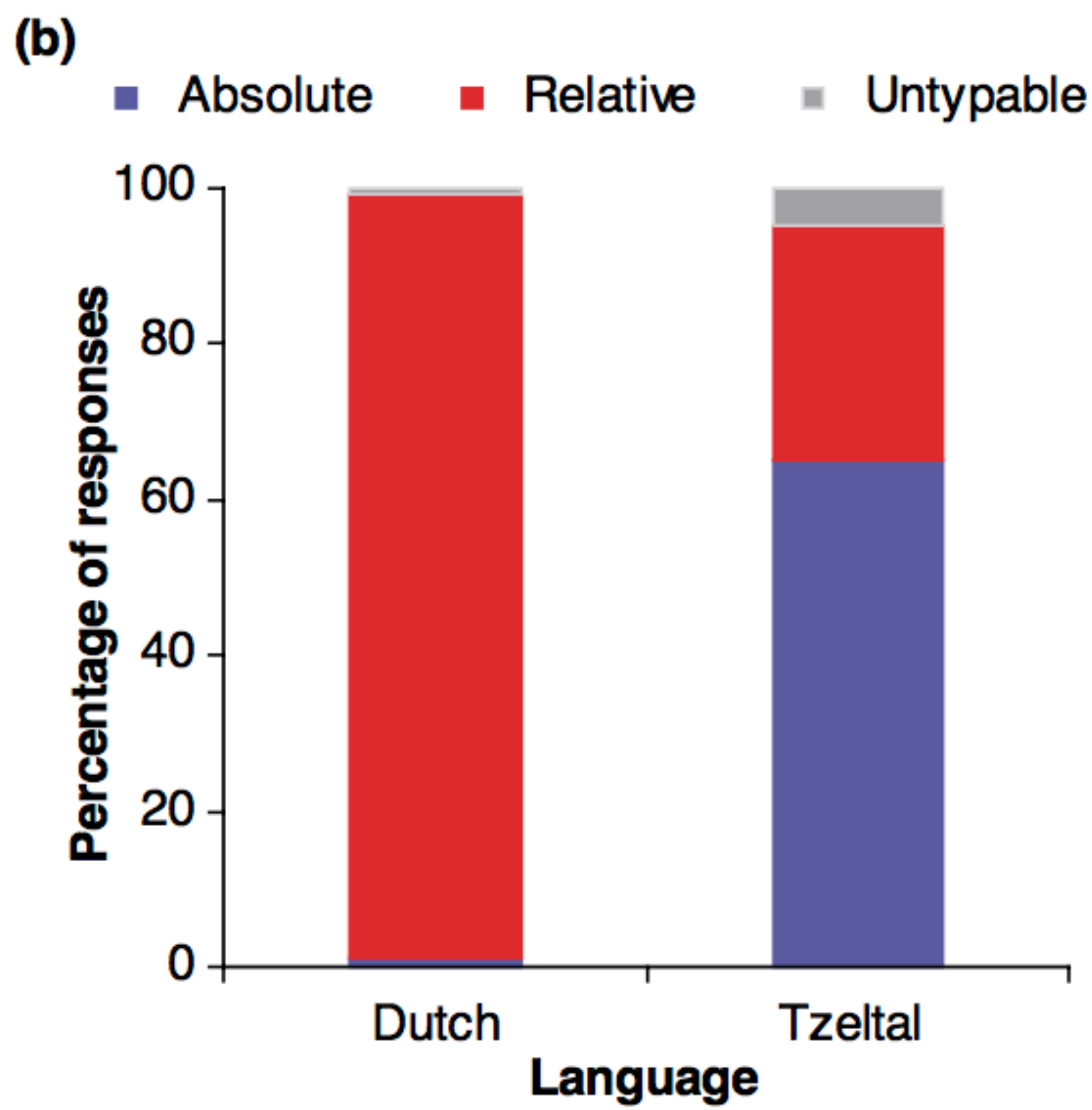
Discuss: which pattern(s) do you think that absolute and relative frame speakers would choose, respectively? Or would they choose the same pattern? If so which?

Language and spatial orientation judgments



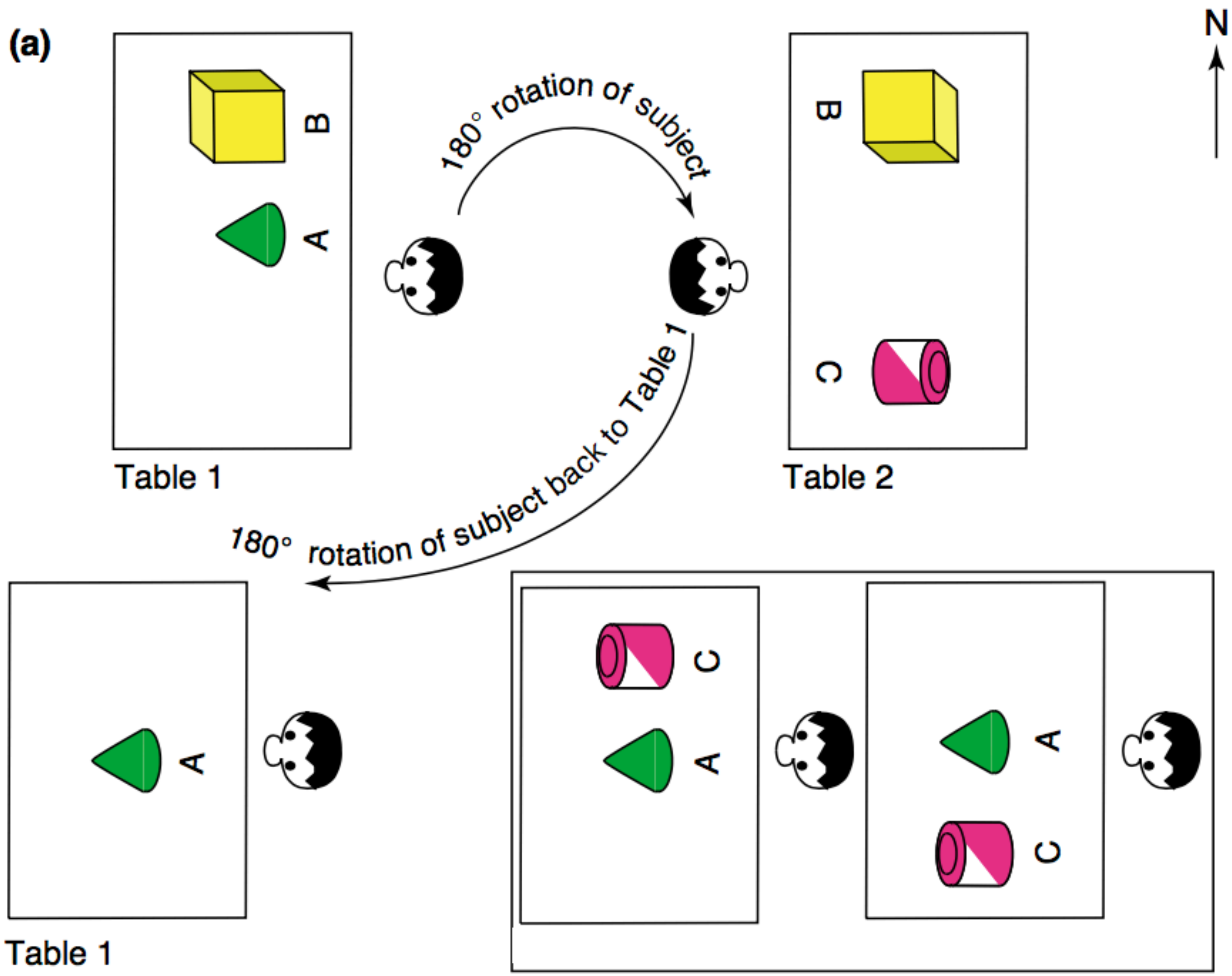
Majid et al. (2004)

Language and spatial orientation judgments



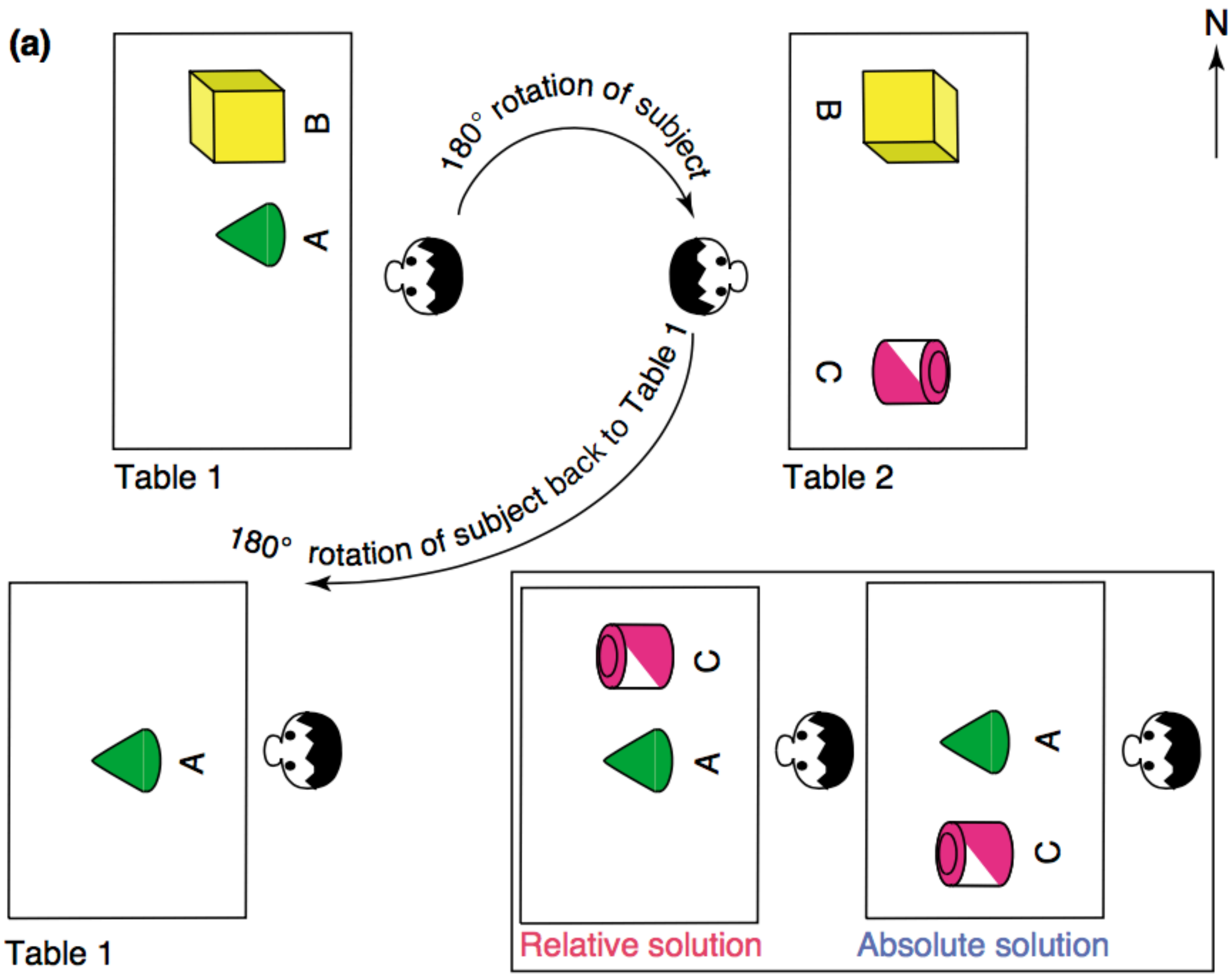
Majid et al. (2004)

Which is the matching object C?



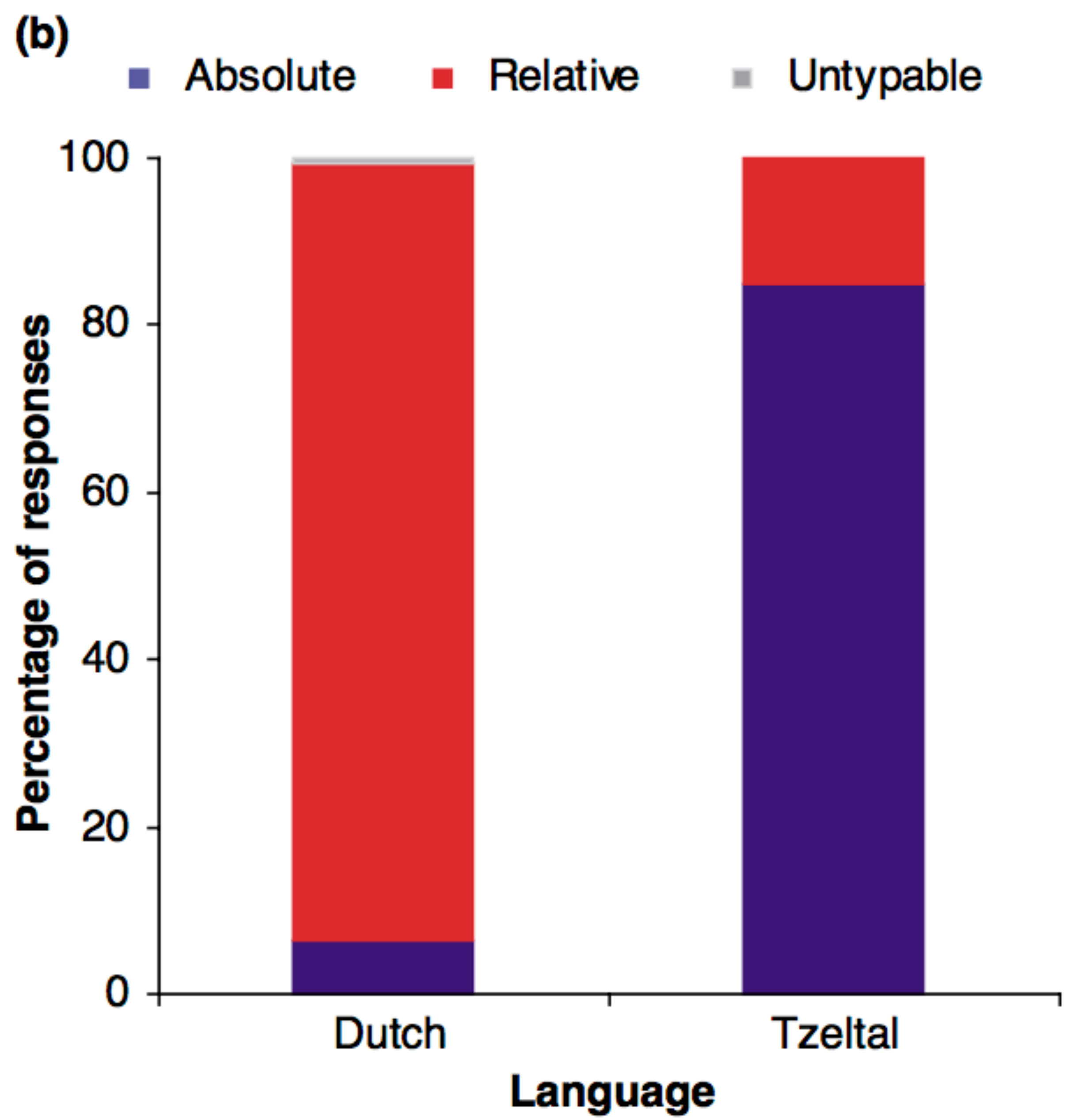
Majid et al. (2004)

Language and spatial orientation judgments



Majid et al. (2004)

Language and spatial orientation judgments

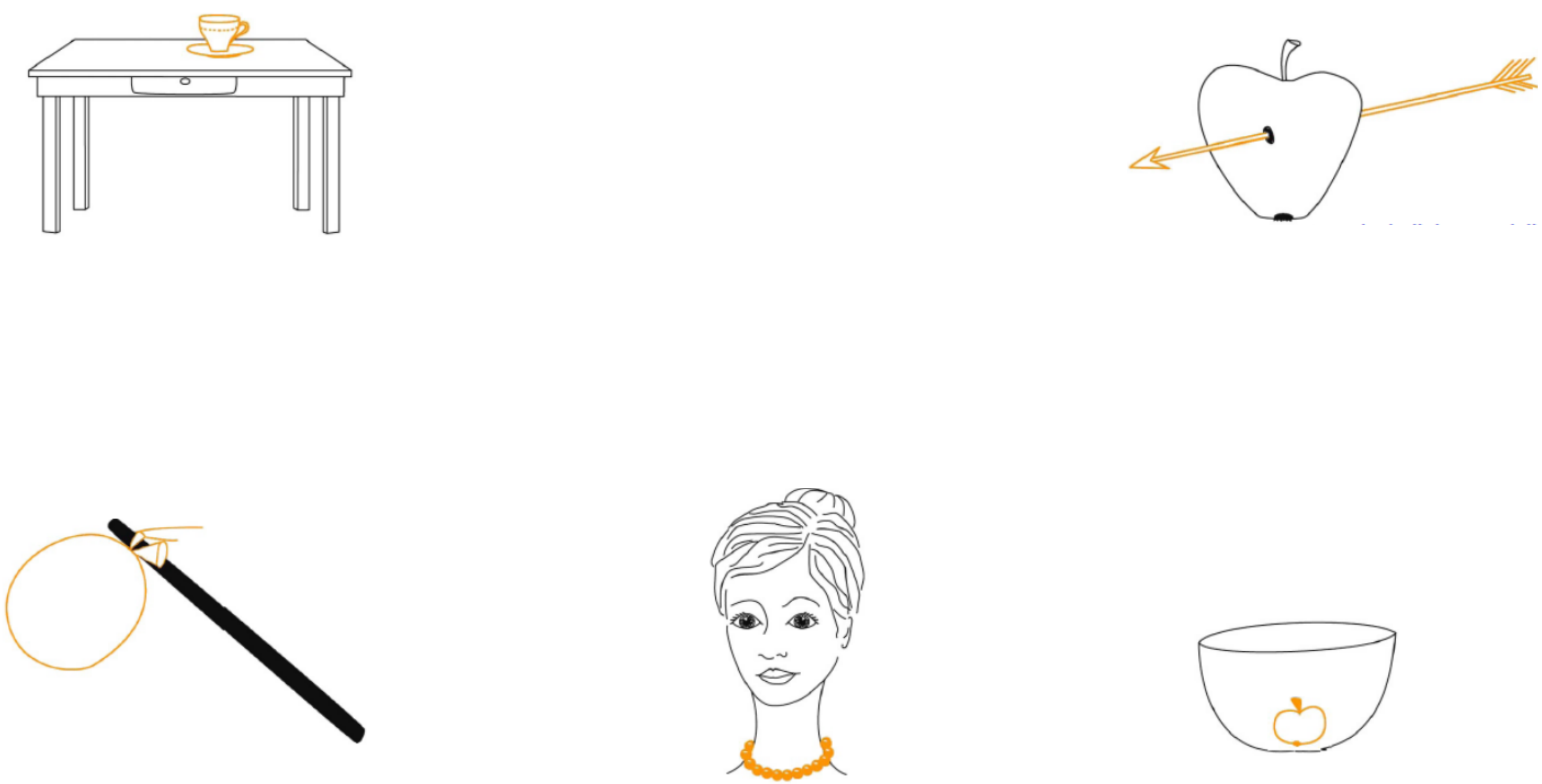


Majid et al. (2004)

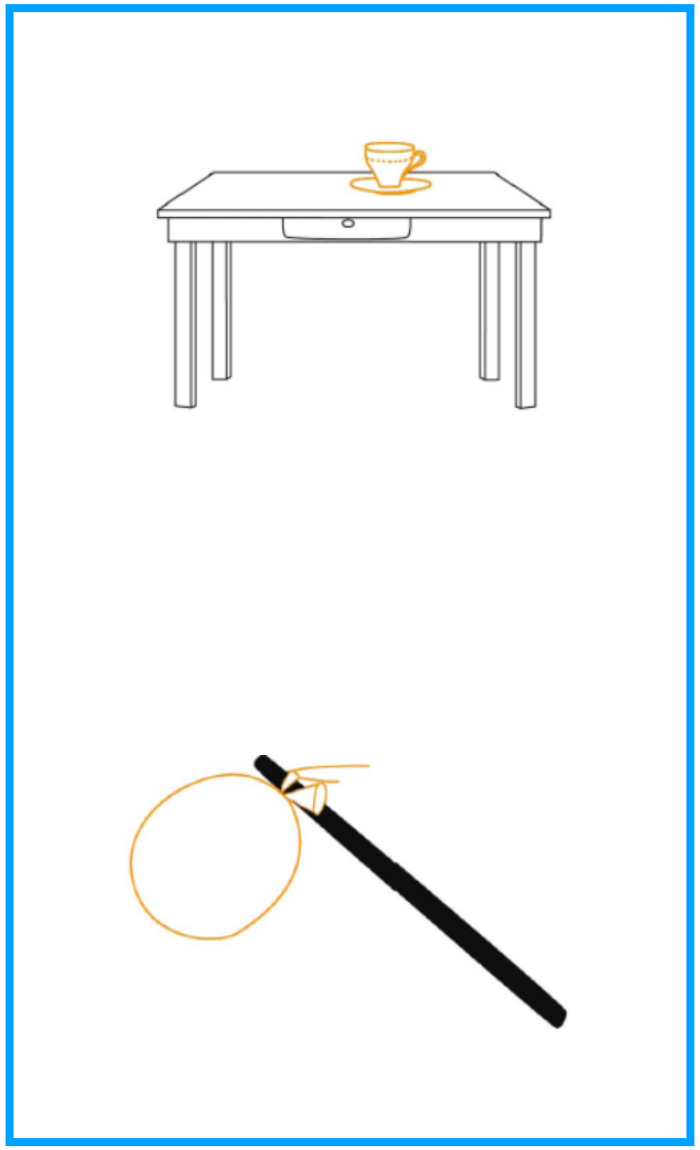
Spatial cognition

- Three fundamental aspects:
  - Spatial navigation: How to get from A to B
  - Spatial orientation: How A is located with respect to B
  - Spatial relation: How A is located to B (in proximity)

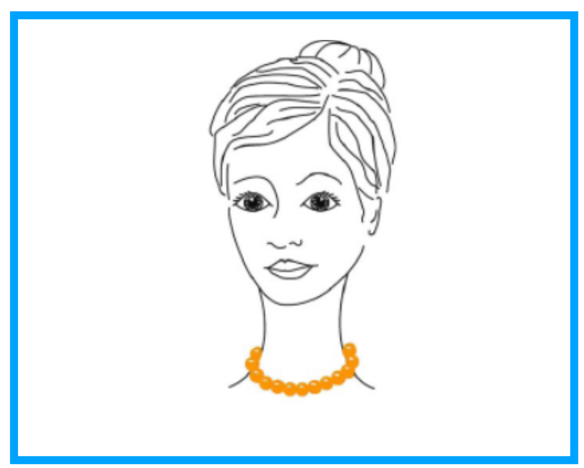
Spatial relations



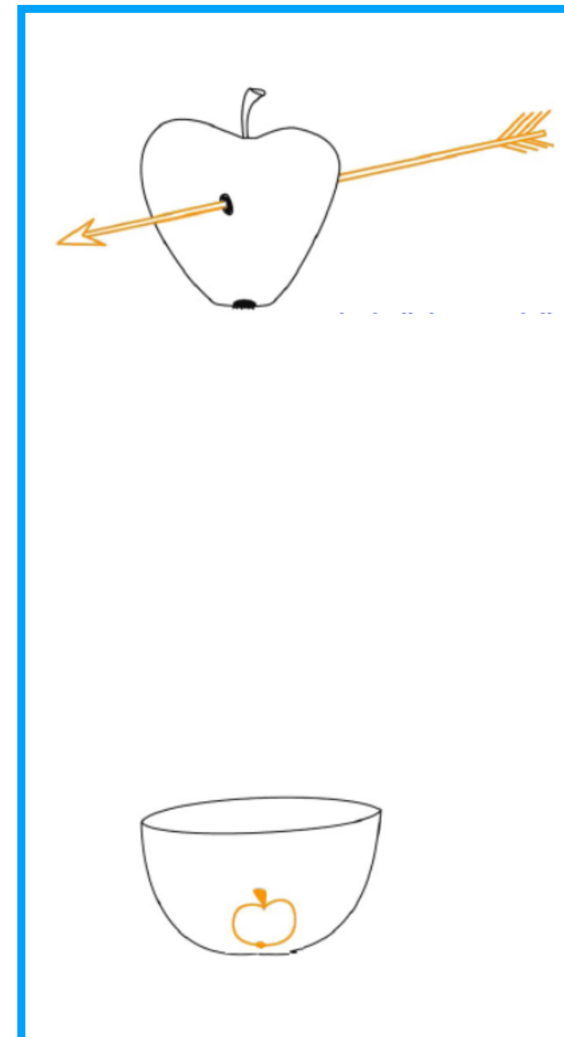
Spatial relations



English ON

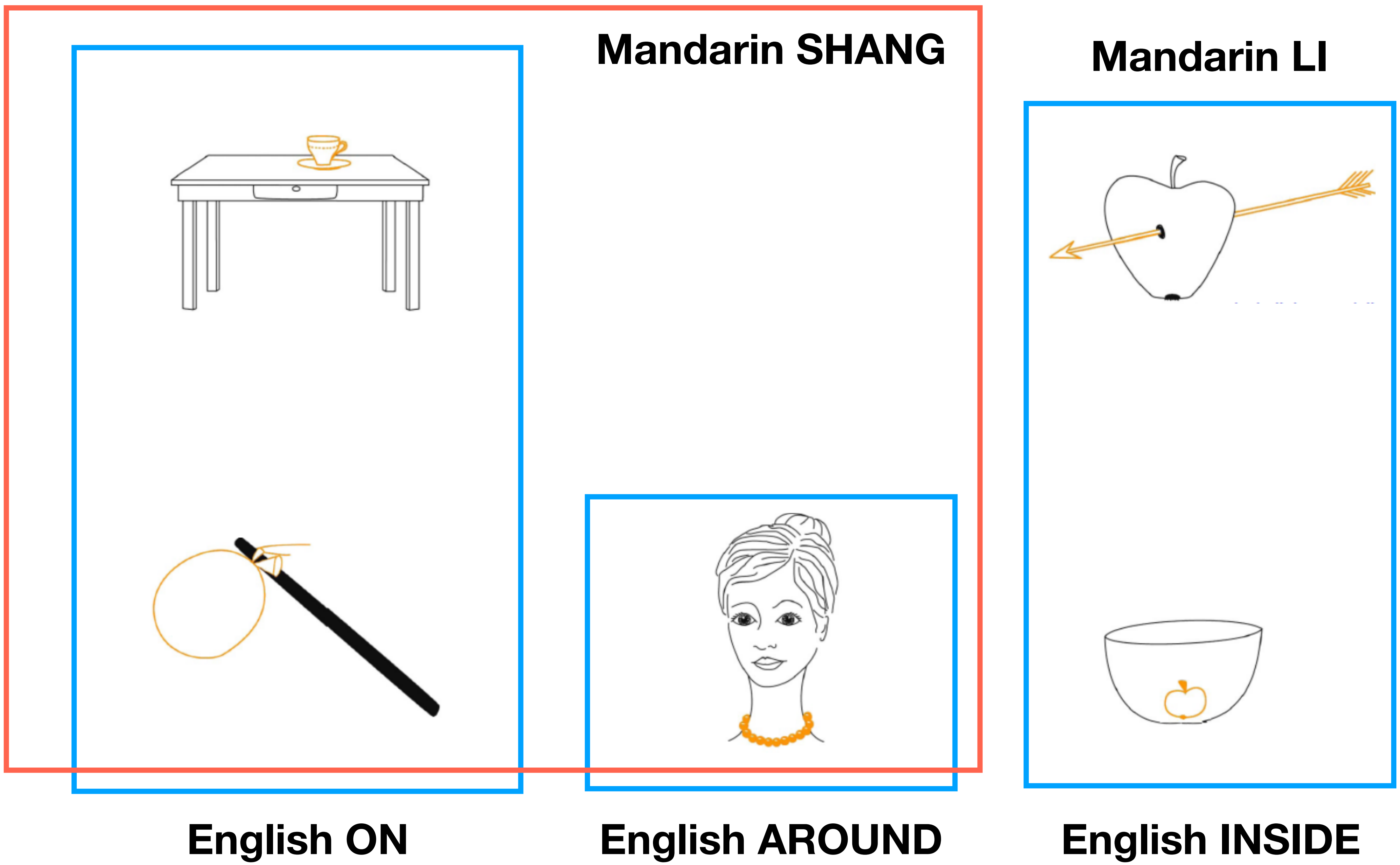


English AROUND

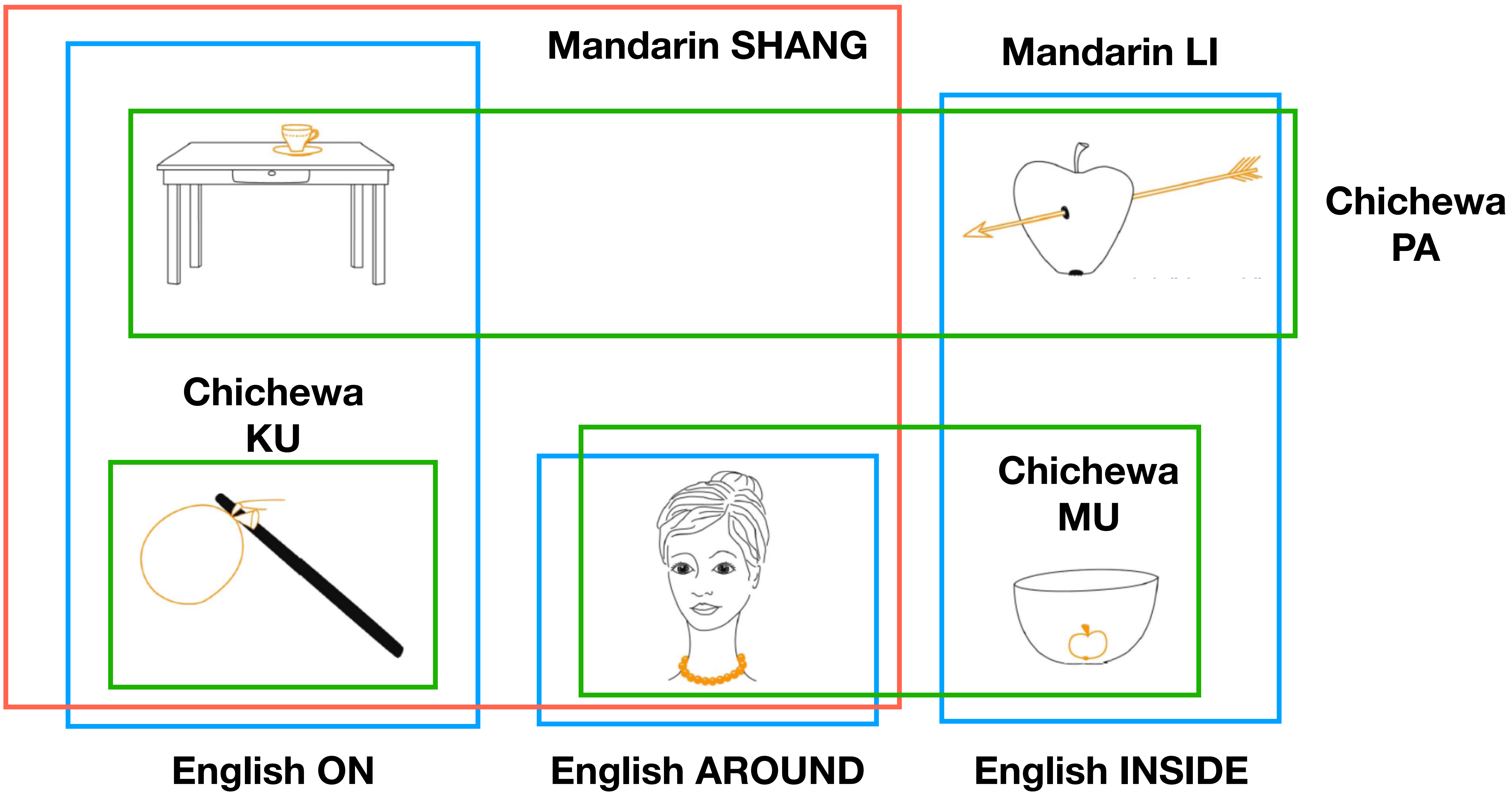


English INSIDE

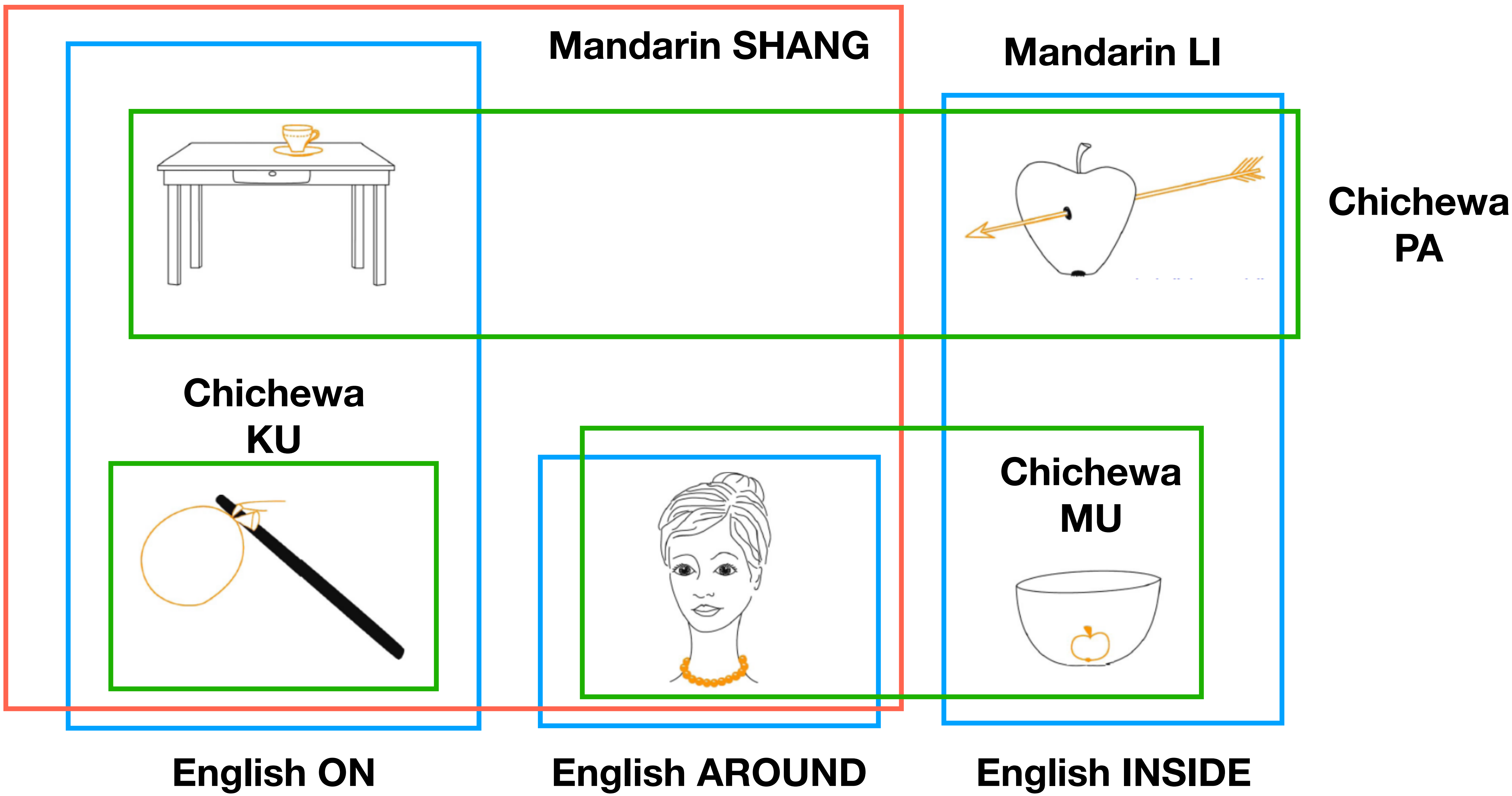
Spatial relations

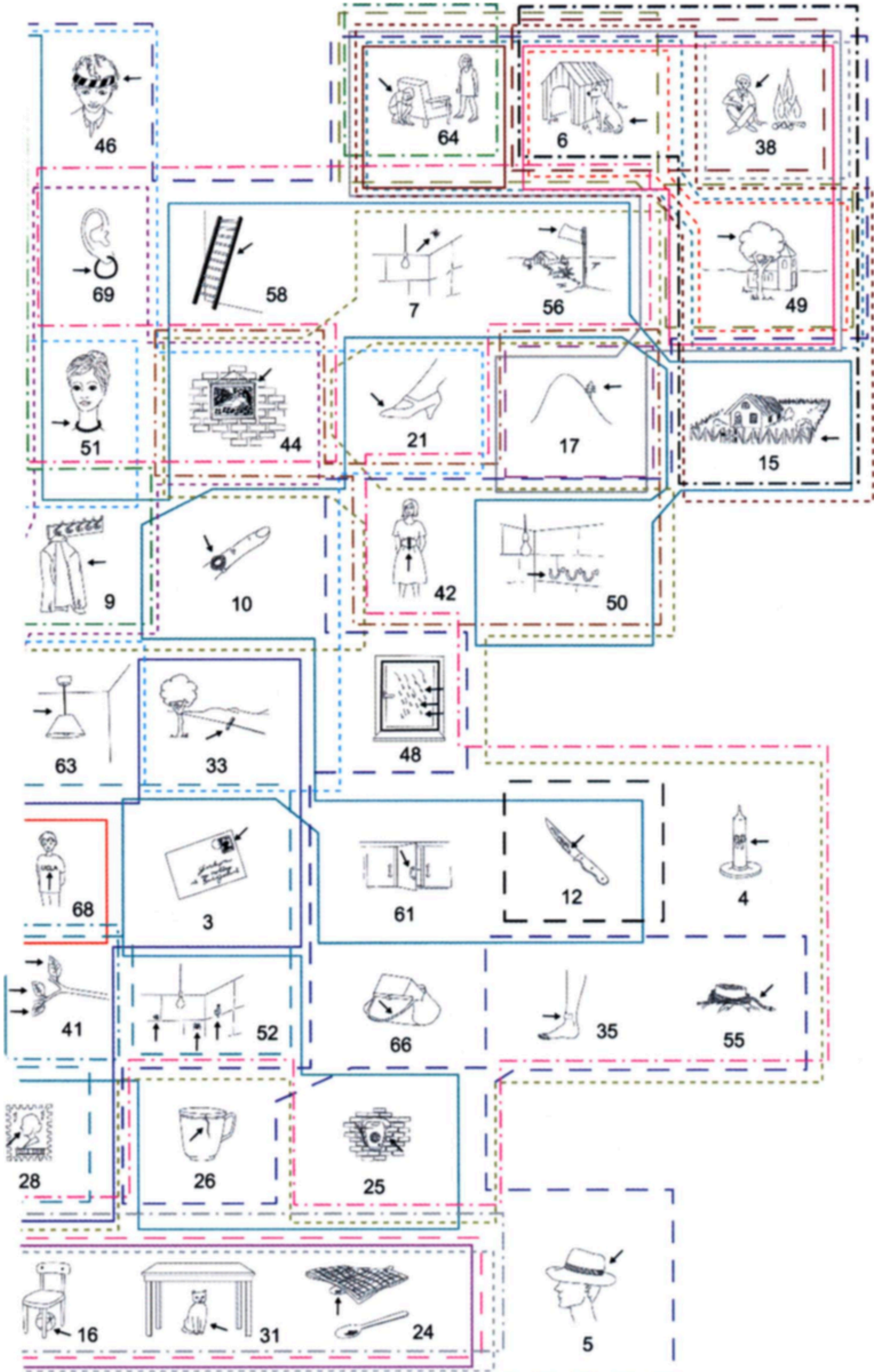


Spatial relations



Is there a universal or shared representation of spatial categories?





Test for universals

Naming experiment in 9 languages from *non-industrialized societies

Multiple speakers per language

Levinson et al. (2003)

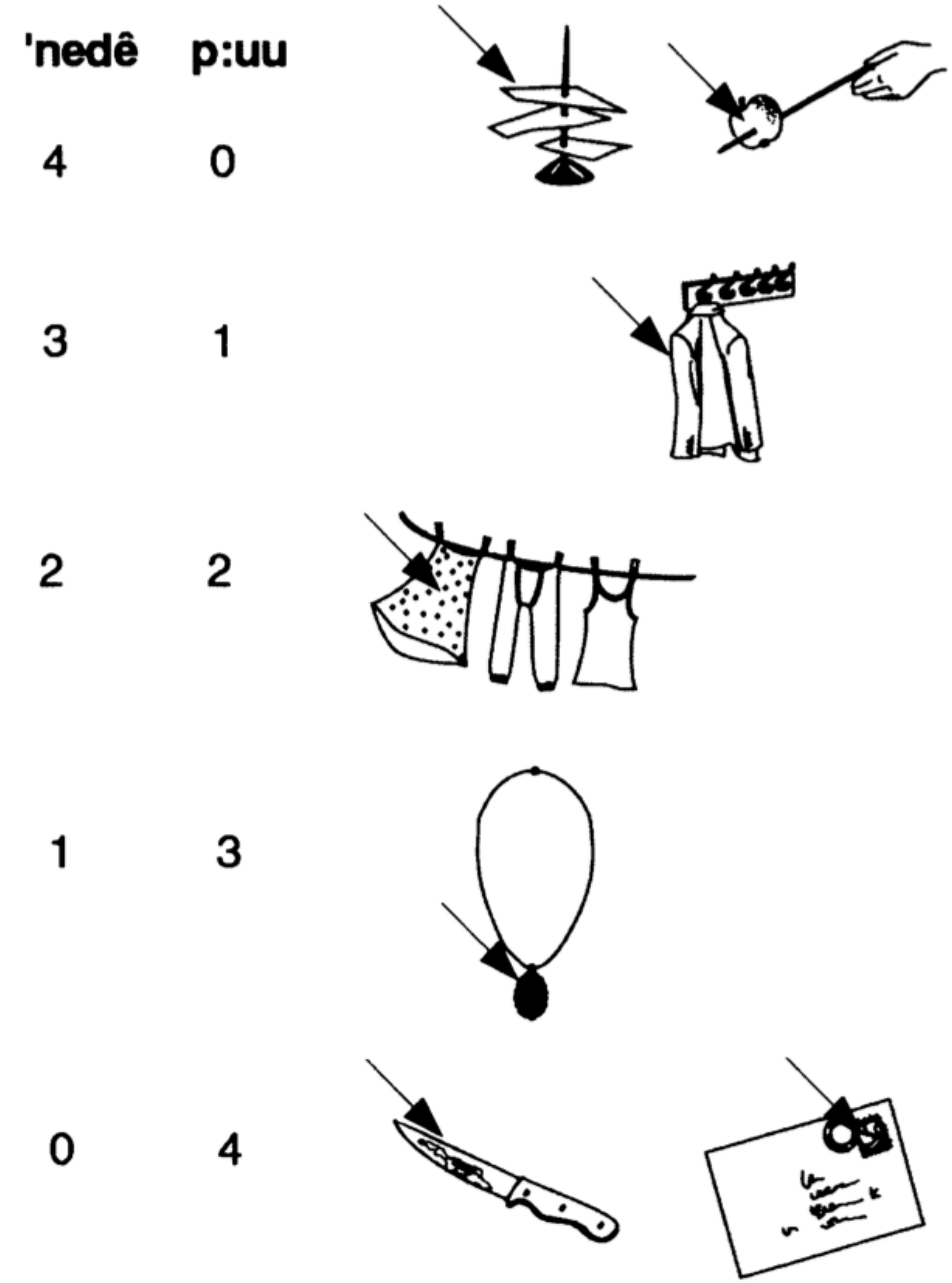
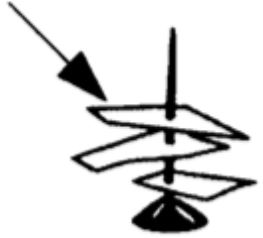


FIGURE 3. Choices between adpositions (Yélî Dnye); 4 consultants, 7 scenes.

Levinson et al. (2003)

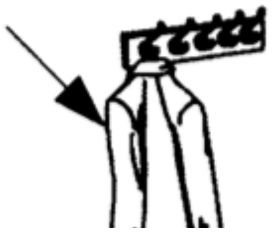







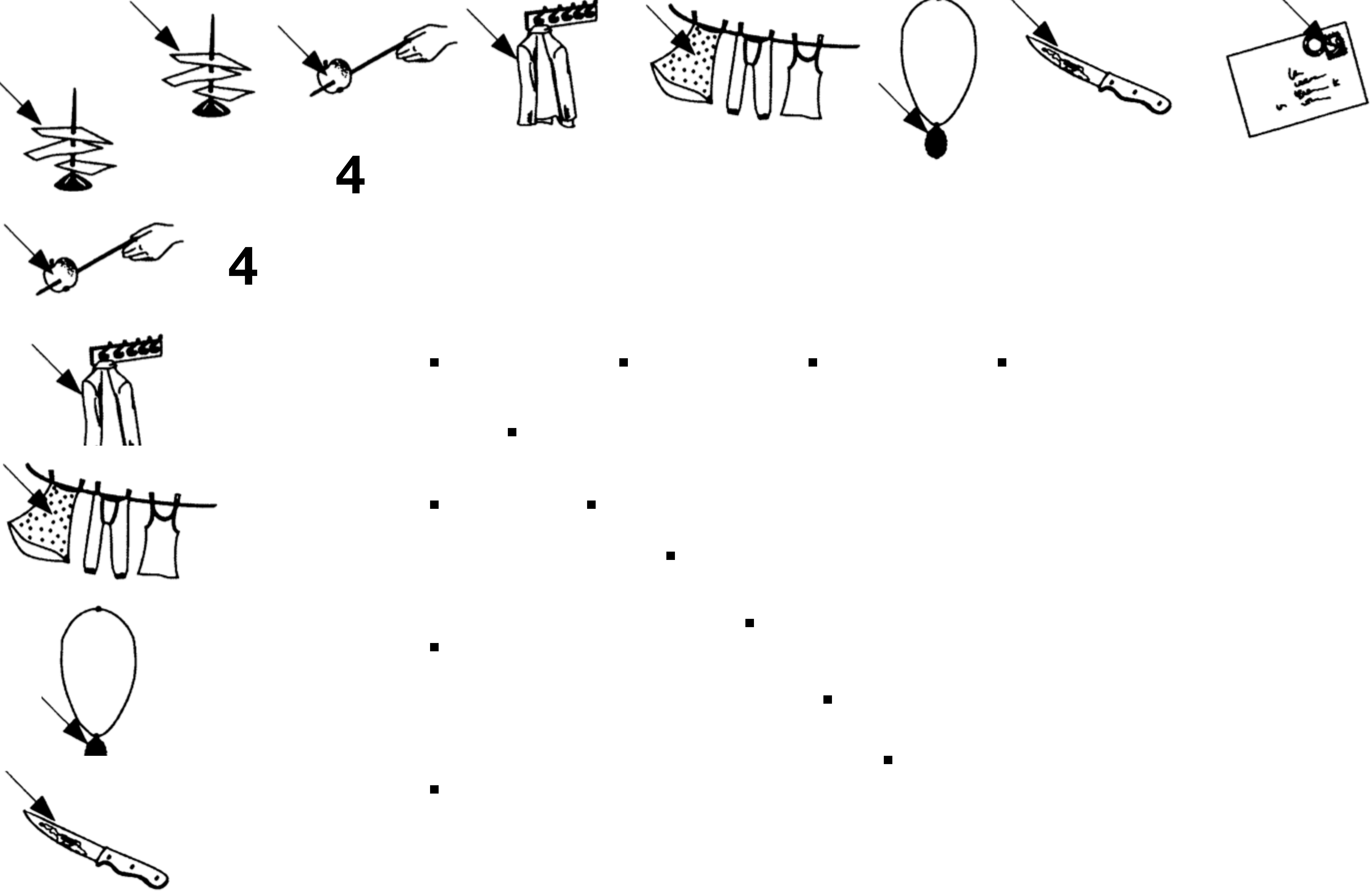
4

4



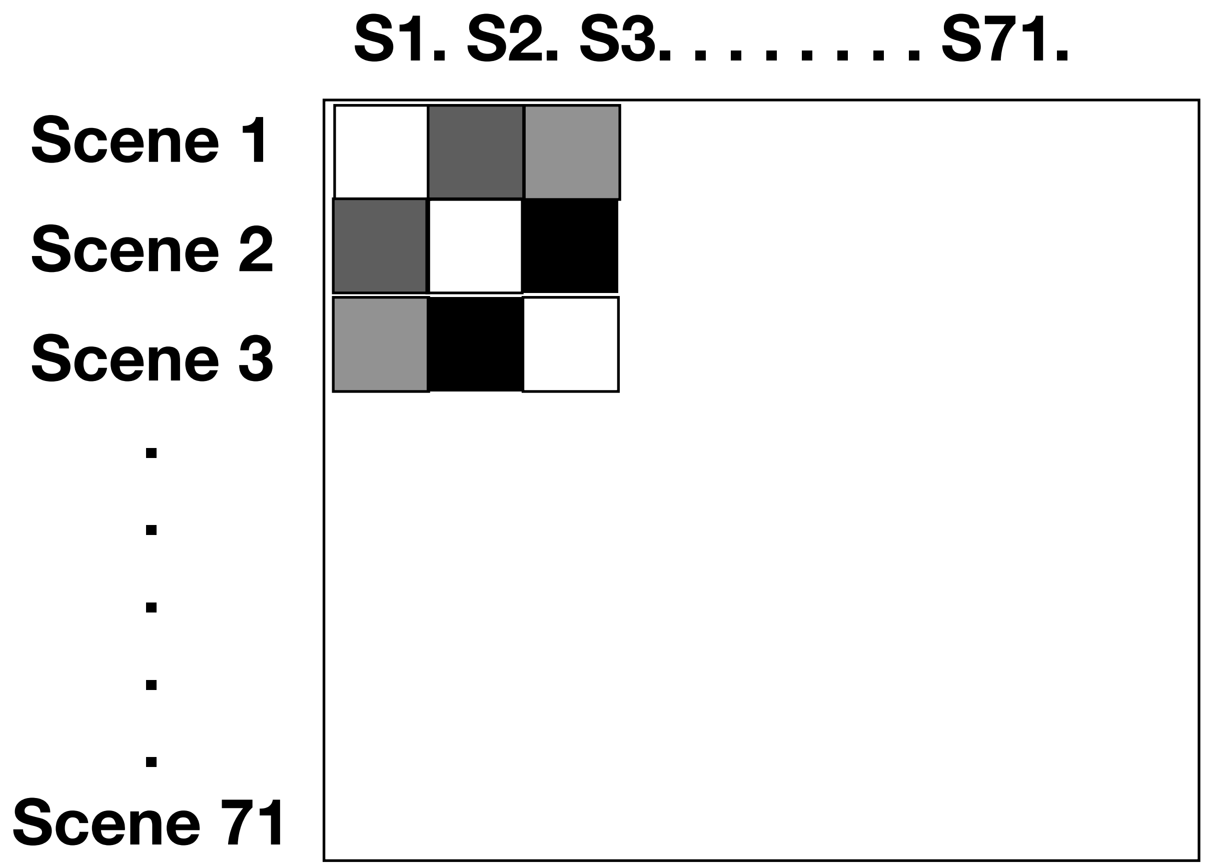


Levinson et al. (2003)



Levinson et al. (2003)

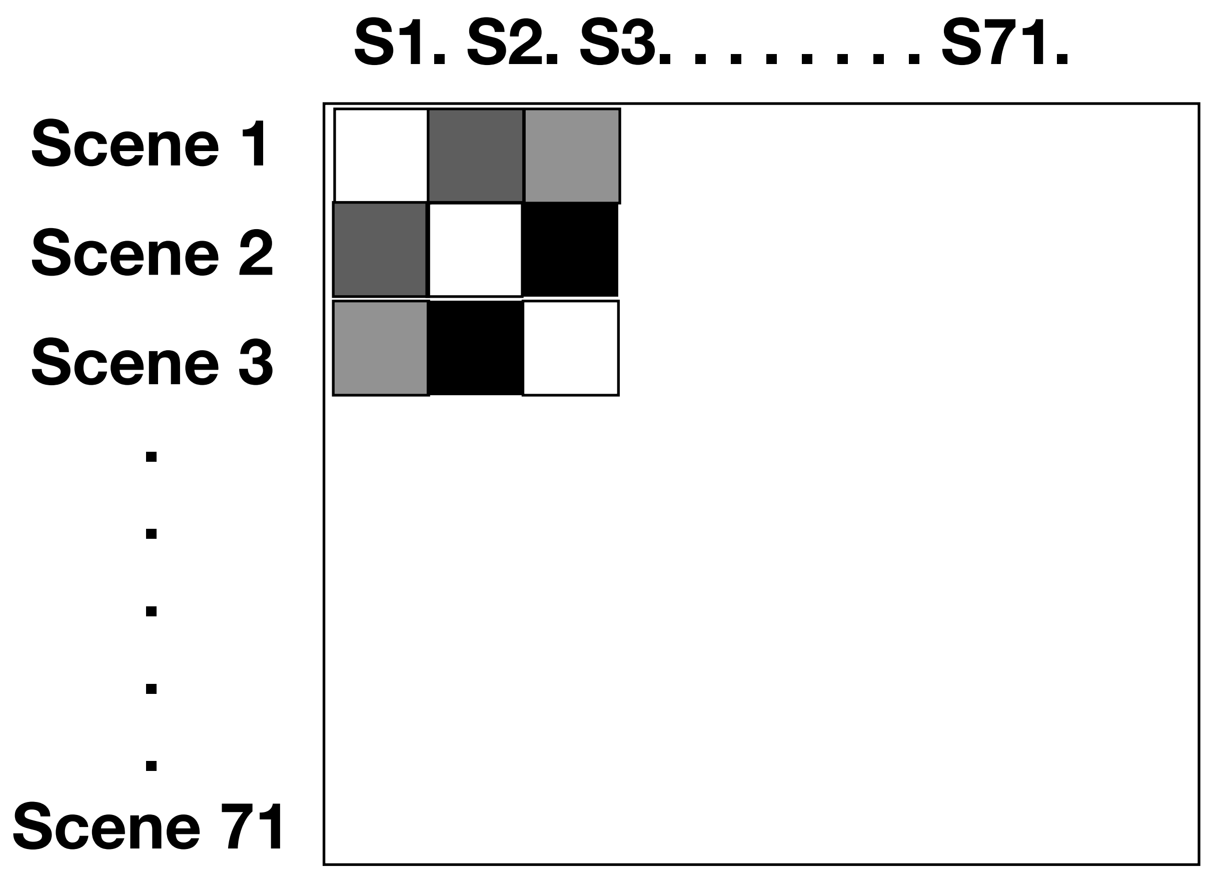
Similarity matrix



Speakers from 1 language

Levinson et al. (2003)

Similarity matrix



Speakers from 1 language

x 9

Levinson et al. (2003)

Discuss: how would you test for "universality" given the cross-linguistic data?

Multi-dimensional scaling

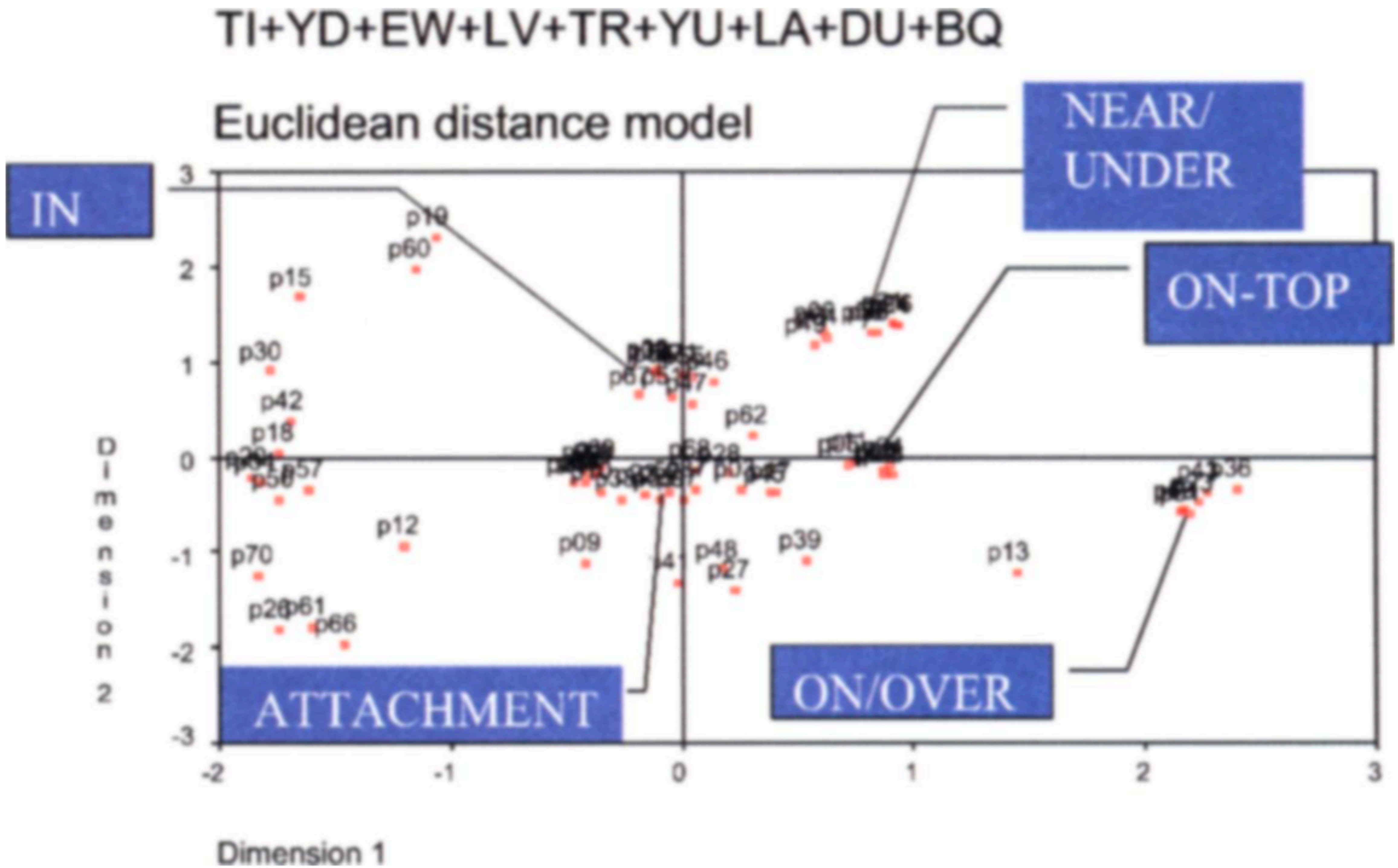
$$S = \left\{ \frac{\sum_{i,j} (d_{ij} - \hat{d}_{ij})^2}{\sum_{i,j} d_{ij}^2} \right\}^{1/2}$$

$$d_{ij} = \left\{ \sum_{k=1}^{K} (x_{ik} - x_{jk})^2 \right\}^{1/2}$$

Euclidean distance

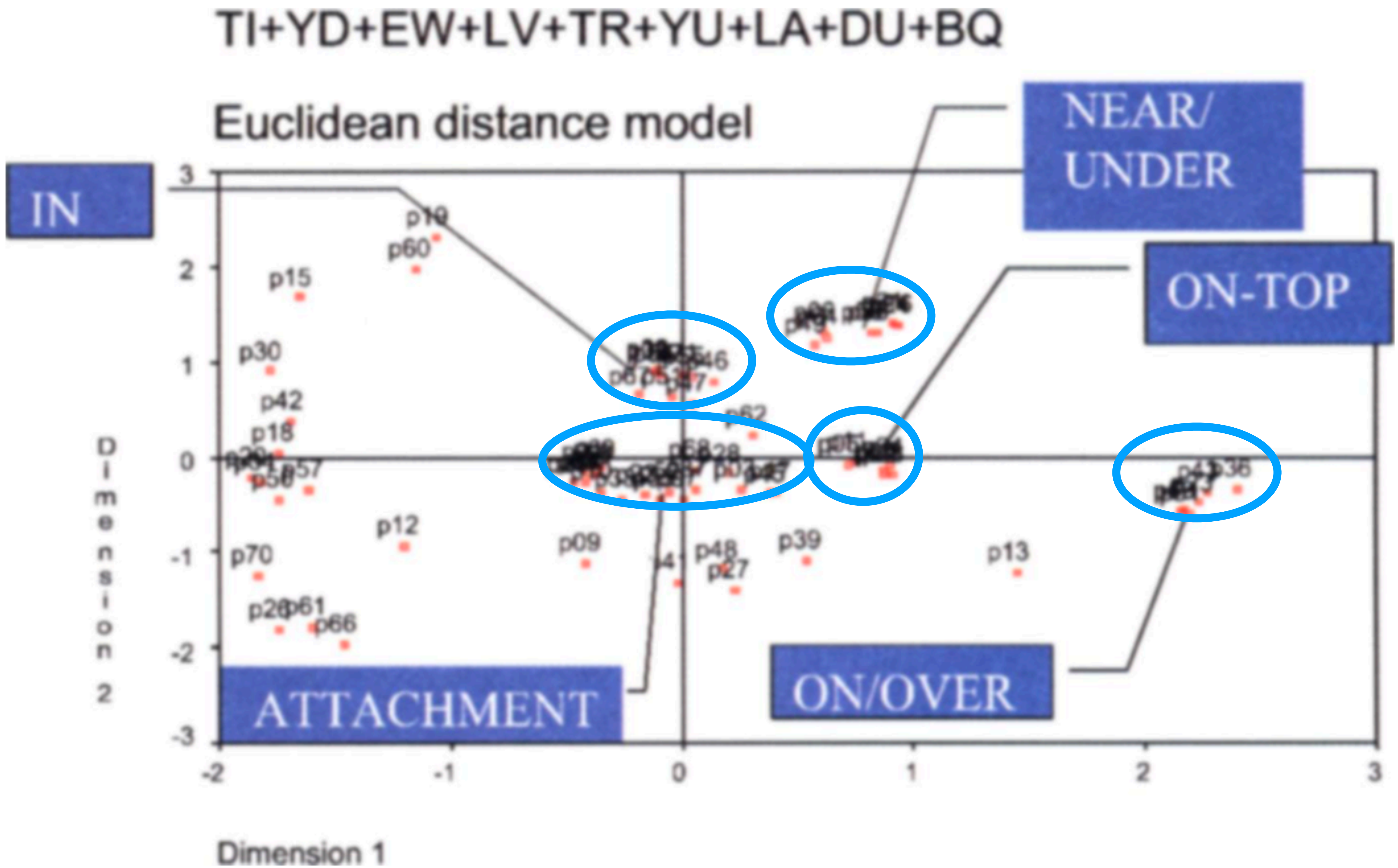
e.g., Shepard (1979)

Mapping from 71D to 2D



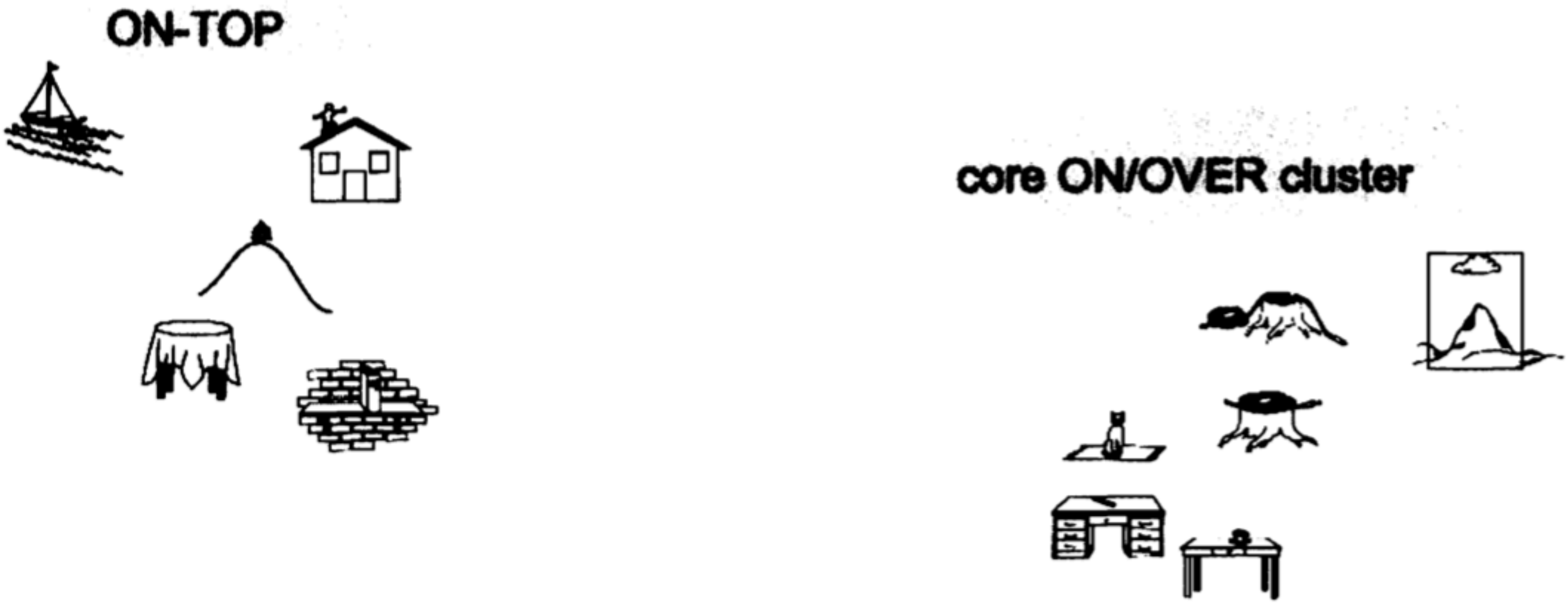
Levinson et al. (2003)

Universal tendencies



Levinson et al. (2003)

Universal tendencies



Levinson et al. (2003)

Universal tendencies

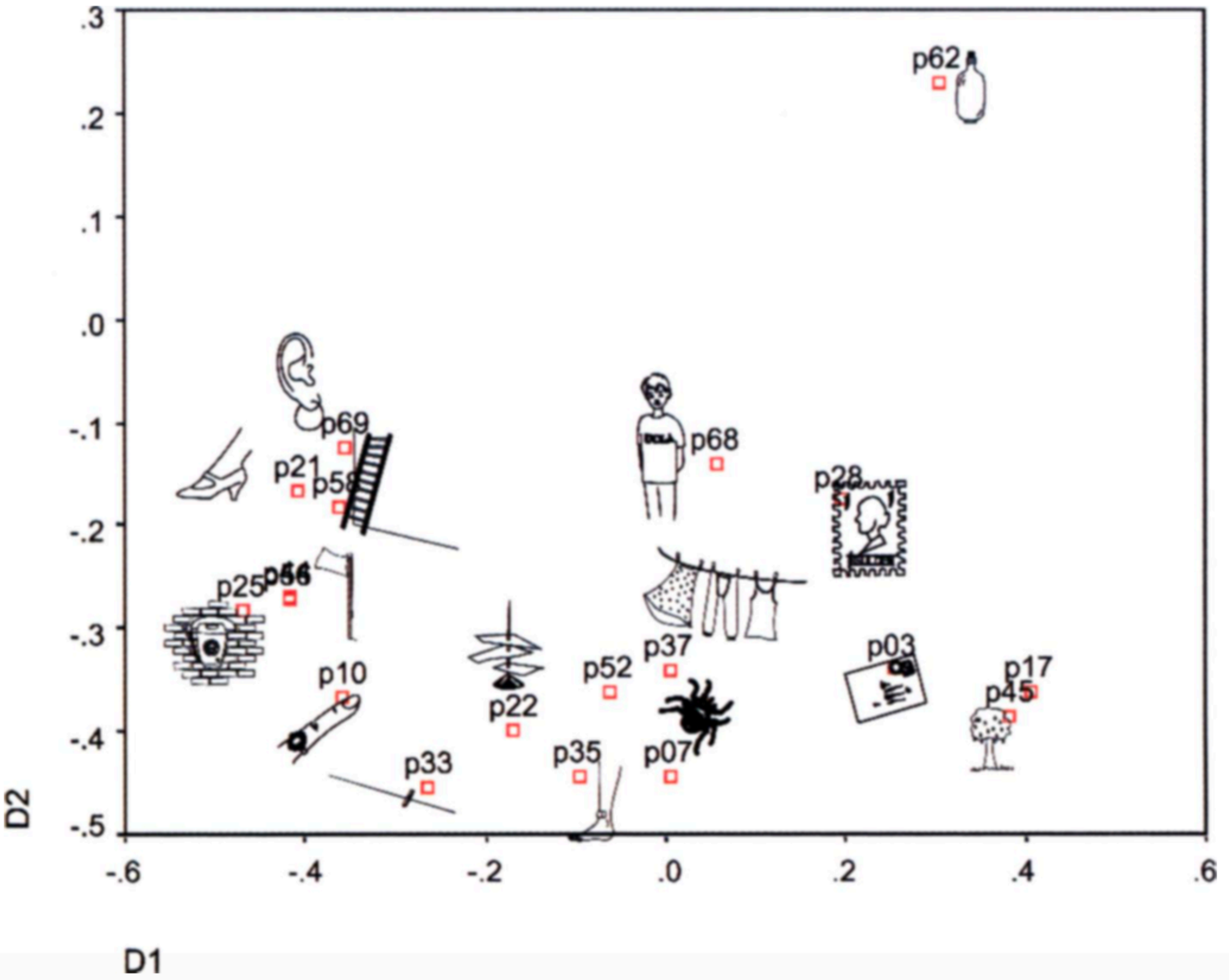


FIGURE 11. Blowup of ATTACHMENT area.

Levinson et al. (2003)

Summary

- The discovery of cognitive maps in spatial navigation provides strong evidence against behaviorism.
- Judgments of spatial orientation may be influenced by frames of reference, e.g., through language.
- Cultural variation in spatial relational categories may not be incompatible with the notion of universality or a culturally shared representation.

Readings

Required reading:

- Levinson, S., Meira, S., and The Language and Cognition Group. (2003). 'Natural concepts' in the spatial topological domain-adpositional meanings in crosslinguistic perspective: An exercise in semantic typology. *Language*, 79(3), 485–516.

Technical reference:

- Chapter 8 in *Stats*.

Linear regression (Lab 3)

Readings

Optional readings:

– Tolman, E. C. (1948). Cognitive maps in rats and men. *Psychological Review*, 55(4), 189–208.

– Morris, R. G. M., Garrud, P., Rawlins, J. A., and O'Keefe, J. (1982). Place navigation impaired in rats with hippocampal lesions. *Nature*, 297(5868), 681–683.

– Landau, B. and Jackendoff, R. (1993). "What" and "where" in spatial language and spatial cognition. *Behavioral and Brain Sciences*, 16(2), 217–238.

– Majid, A., Bowerman, M., Kita, S., Haun, D. B., and Levinson, S. C. (2004). Can language restructure cognition? The case for space. *Trends in Cognitive Sciences*, 8(3), 108–114.

Recommended book:

– Newcombe, N. S., and Huttenlocher, J. (2003). *Making space: The development of spatial representation and reasoning*. MIT Press.

Question of the day

- How can a fixed, small set of spatial prepositions (e.g., ON, IN, ABOVE, BELOW) express a diverse, large set of spatial scenarios?

Question of the day

- How can a fixed, small set of spatial prepositions (e.g., ON, IN, ABOVE, BELOW) express a diverse, large set of spatial scenarios?

Spider ON wall

Cup ON table

Door knob ON door

Hat ON head

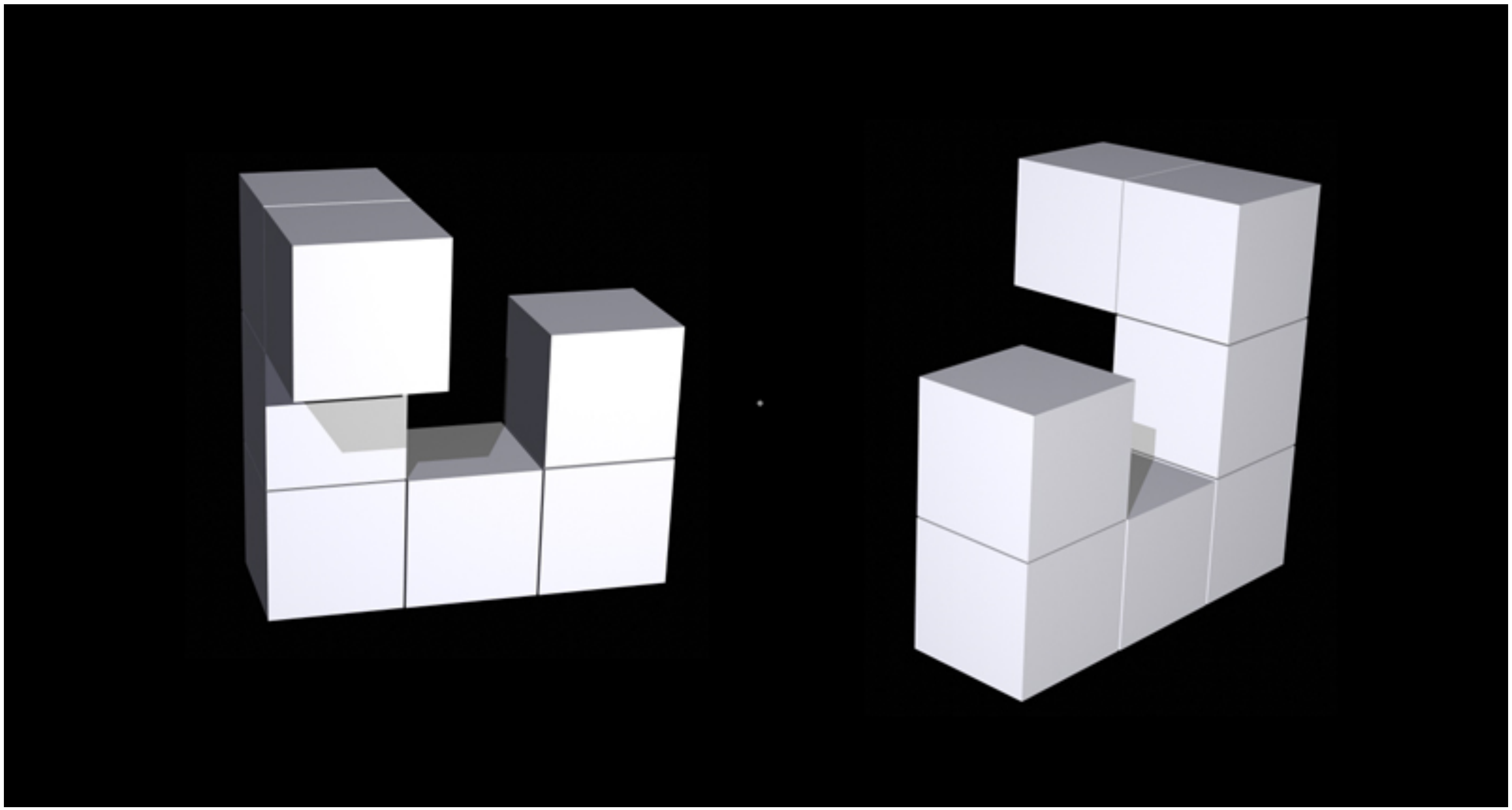
Building ON fire

https://visualgenome.org/

5-minute break

Lab 3: Mental rotation

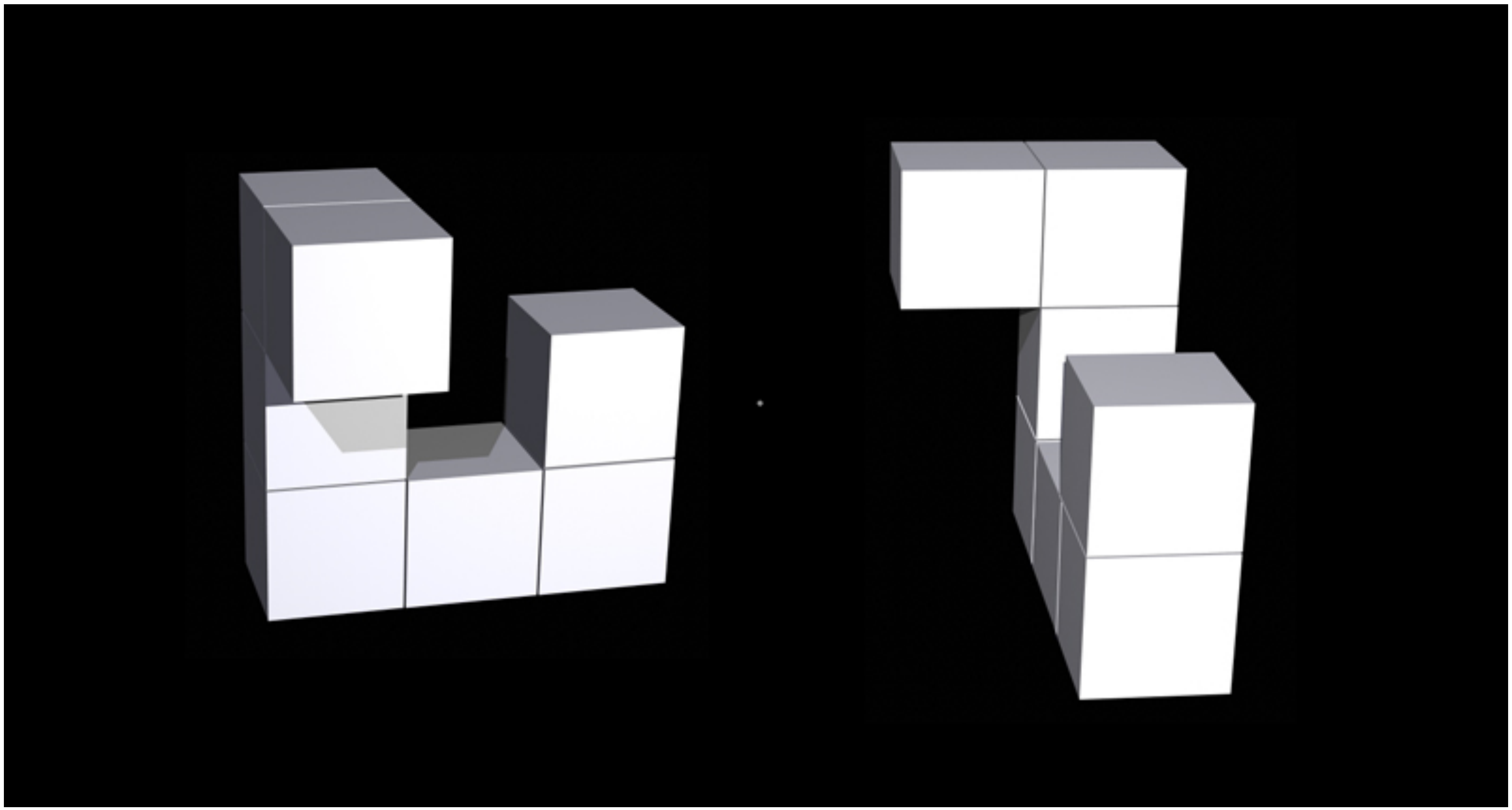
Rotation = 150 degrees



cf. Shepard & Metzler (1971)

Lab 3: Mental rotation

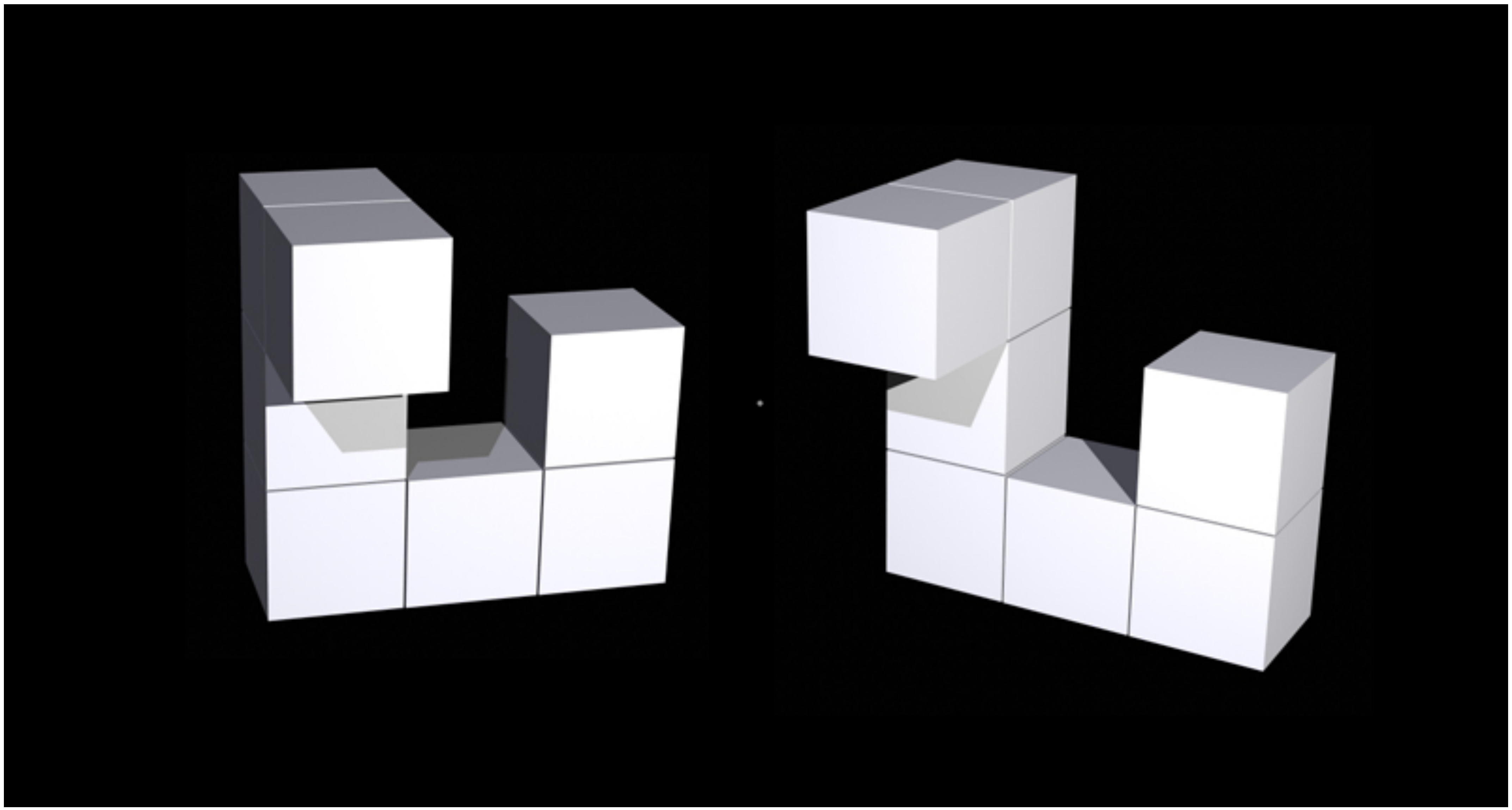
Rotation = 100 degrees



cf. Shepard & Metzler (1971)

Lab 3: Mental rotation

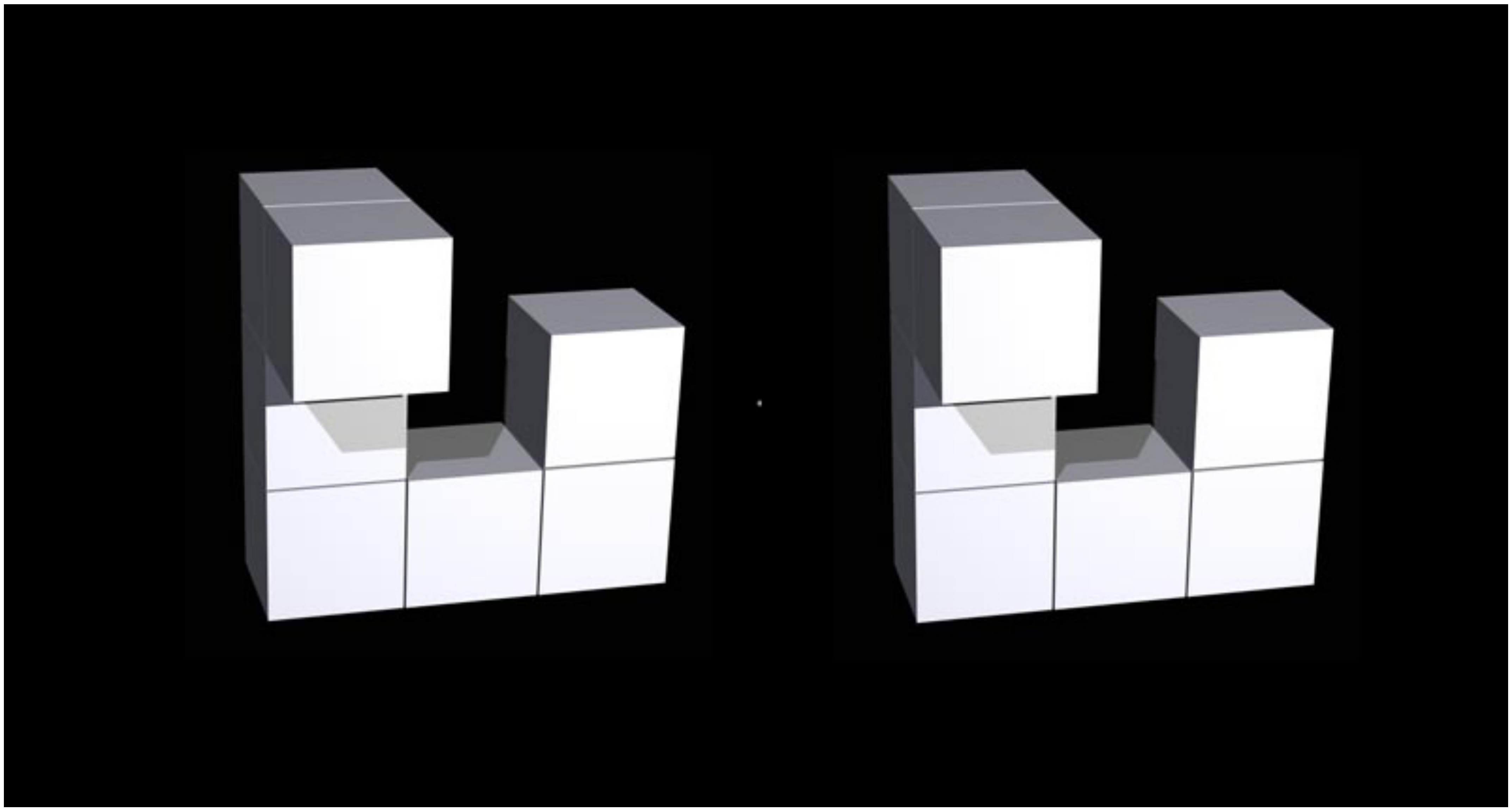
Rotation = 50 degrees



cf. Shepard & Metzler (1971)

Lab 3: Mental rotation

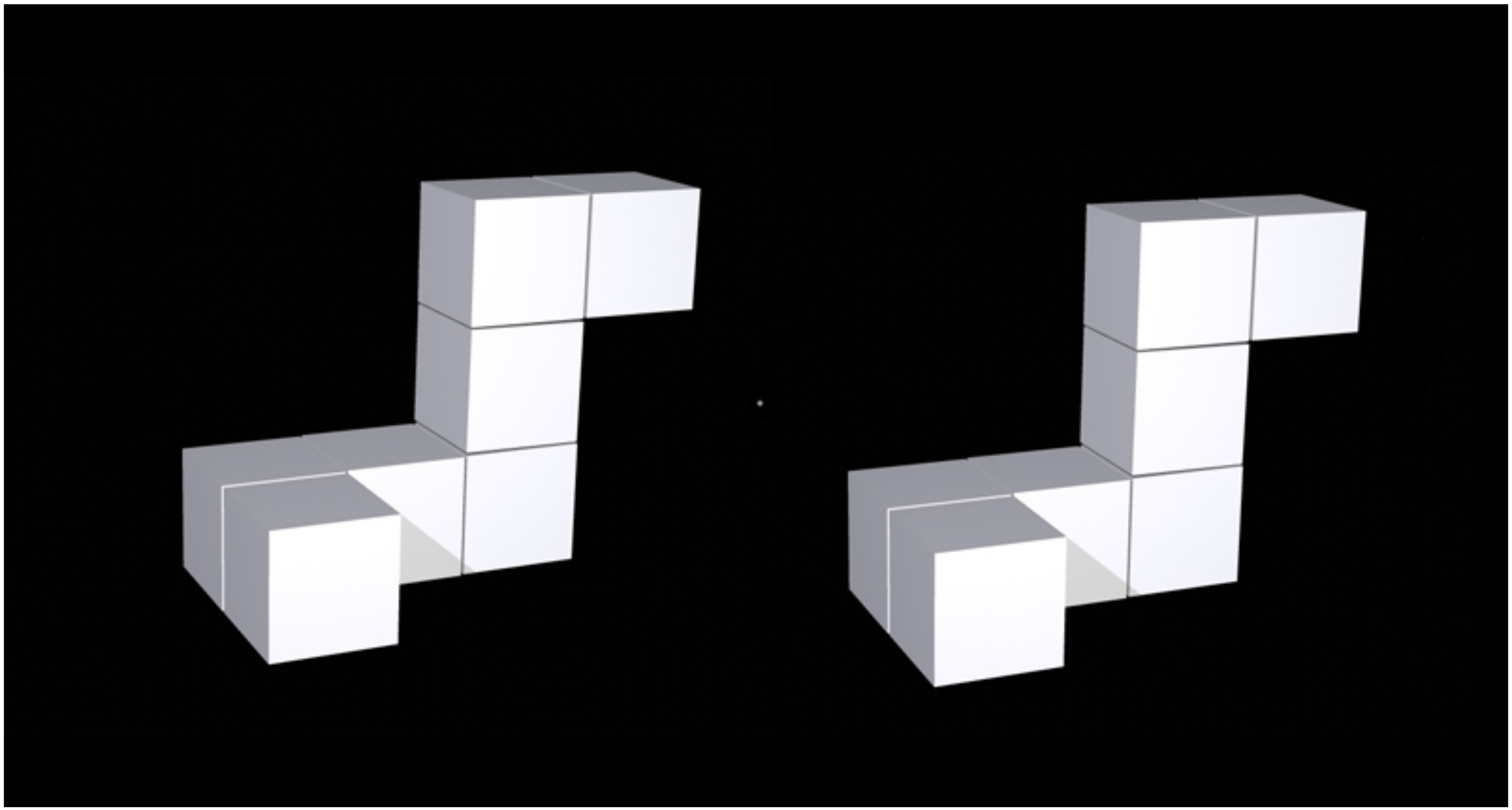
Rotation = 0 degree



cf. Shepard & Metzler (1971)

Lab 3: Mental rotation

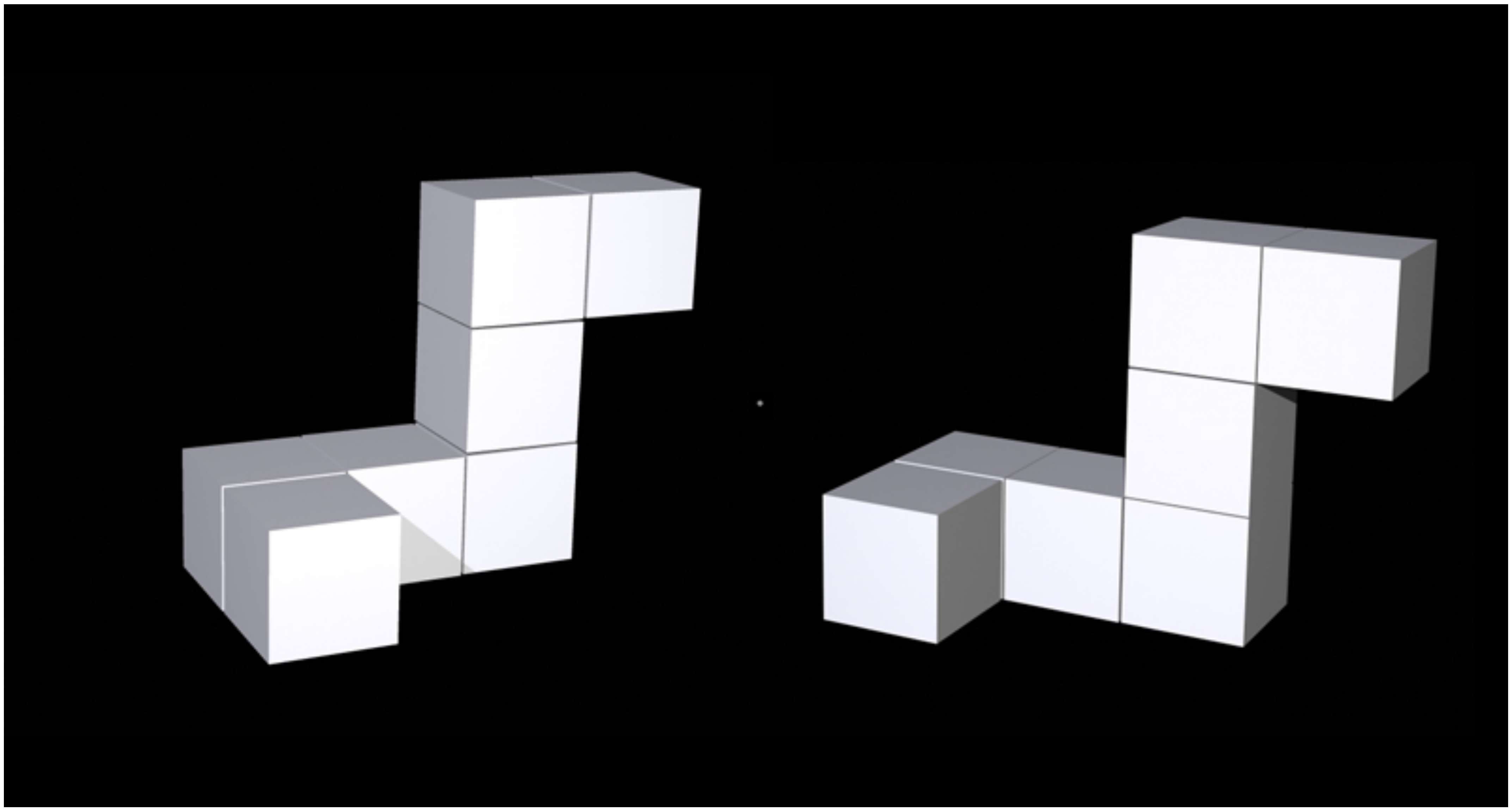
Rotation = 0 degree



cf. Shepard & Metzler (1971)

Lab 3: Mental rotation

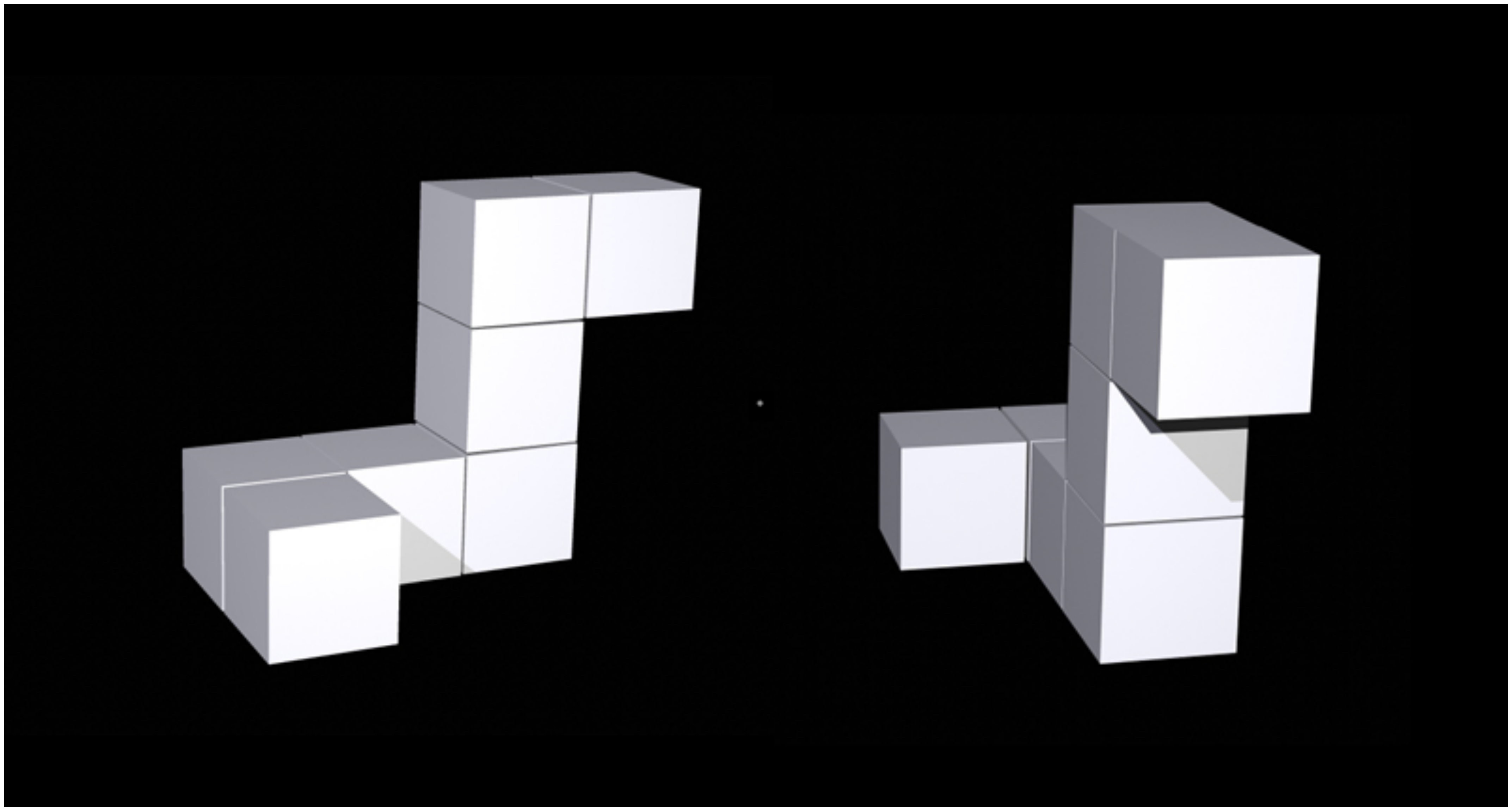
Rotation = 50 degrees



cf. Shepard & Metzler (1971)

Lab 3: Mental rotation

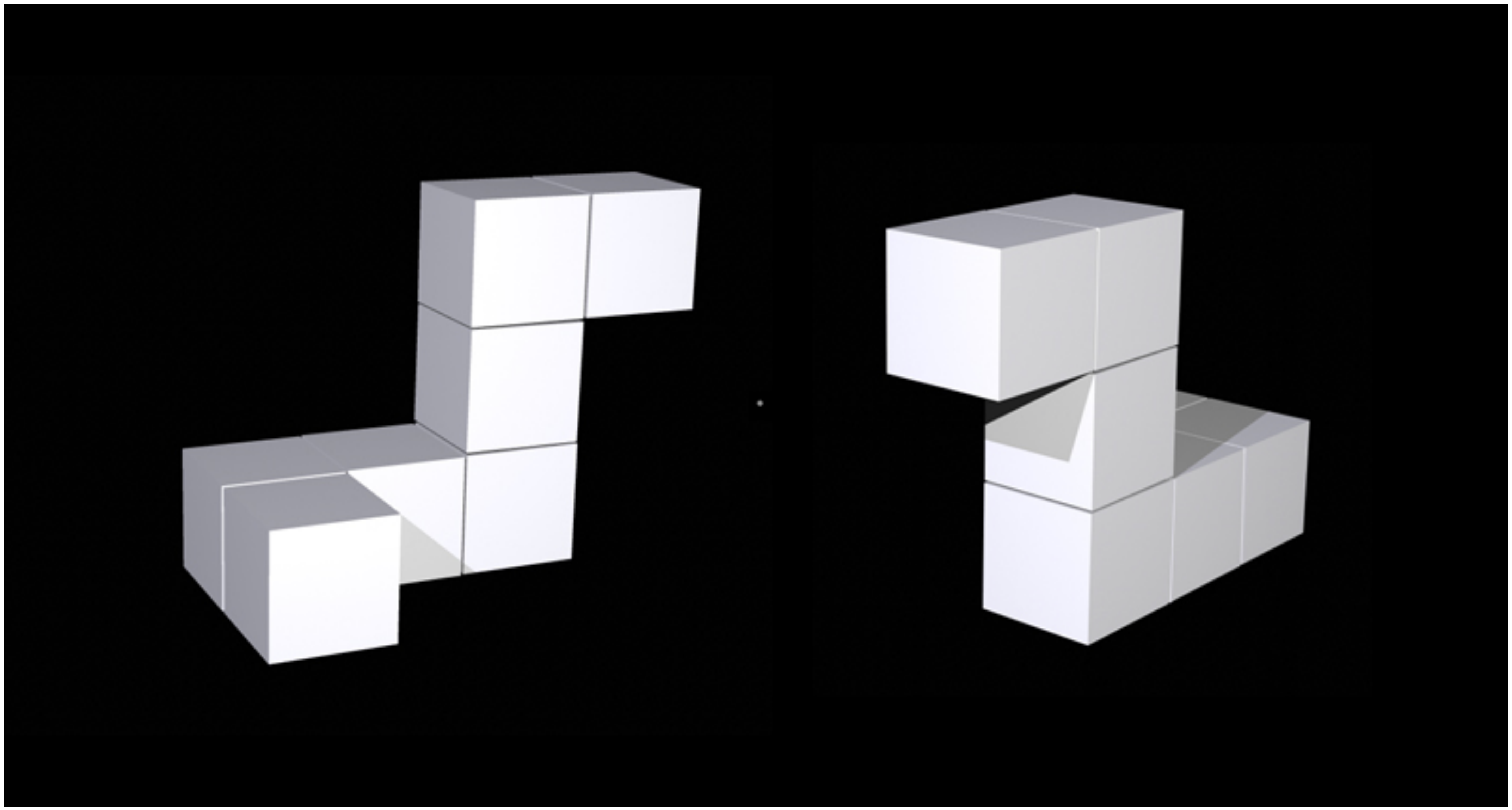
Rotation = 100 degrees



cf. Shepard & Metzler (1971)

Lab 3: Mental rotation

Rotation = 150 degrees



cf. Shepard & Metzler (1971)

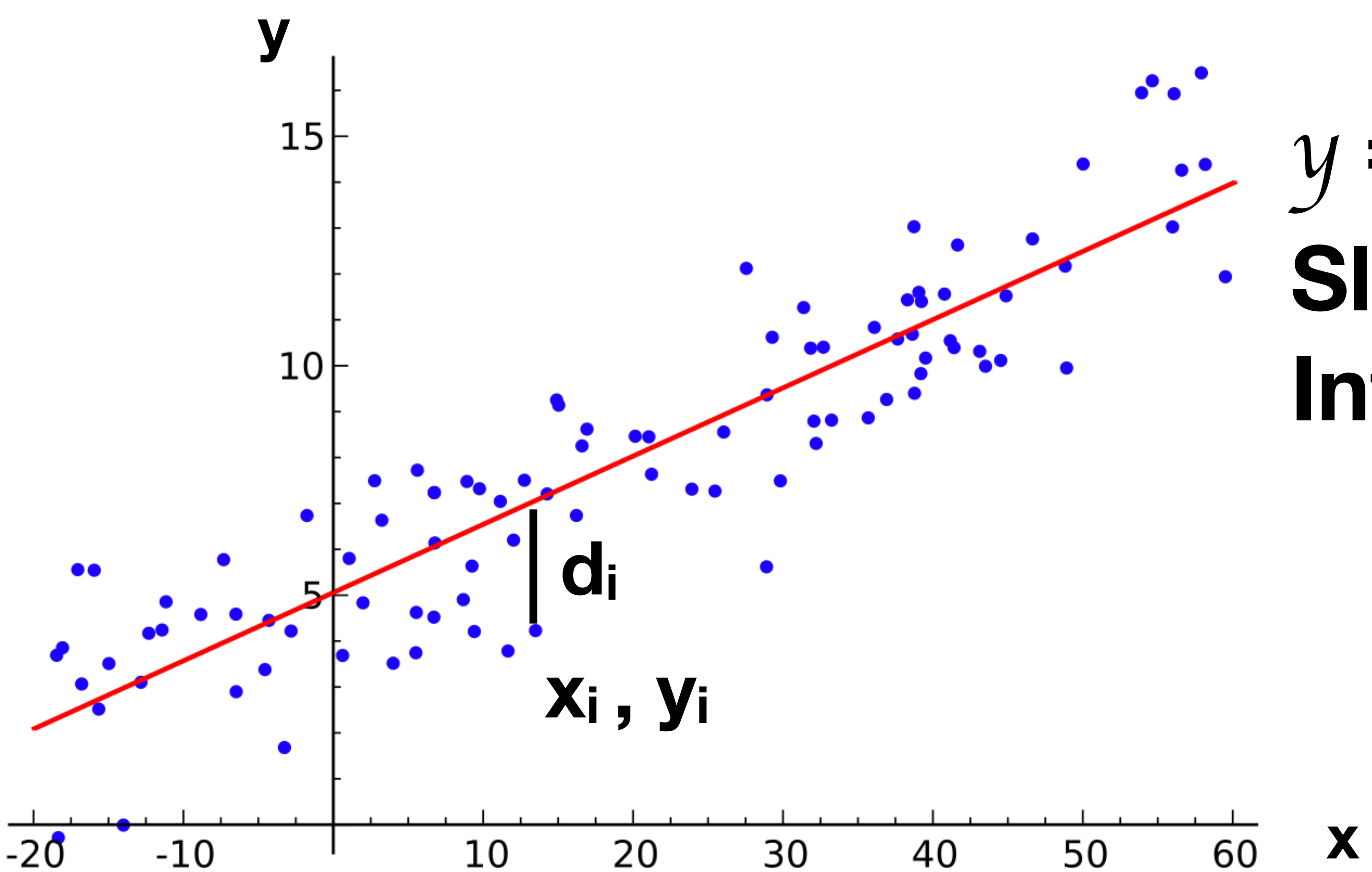
Lab 3: Mental rotation

- Response time was recorded for
  - each angle (0, 50, 100, 150);
  - each object (48 in total);
  - each subject (54 in total).
- For this analysis, we are going to analyze
  - *reaction time* vs *angle*

Lab 3: Mental rotation

- Hypothesis: reaction time increases near-linearly as angle increases
- We will test this in each subject individually and across all subjects

Line fitting (linear regression)

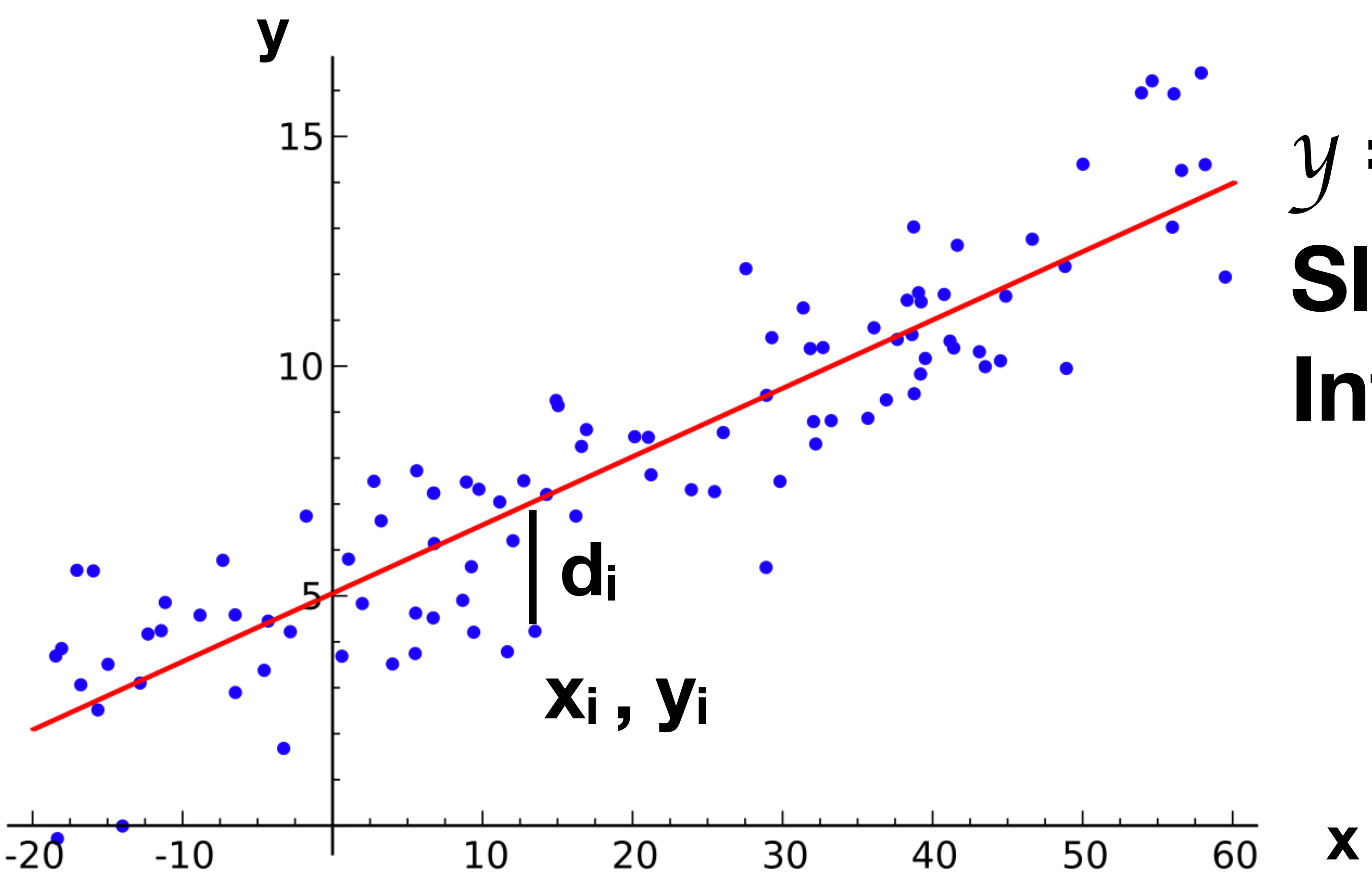


y = ax+b

Slope = a

Intercept = b

Line fitting (linear regression)



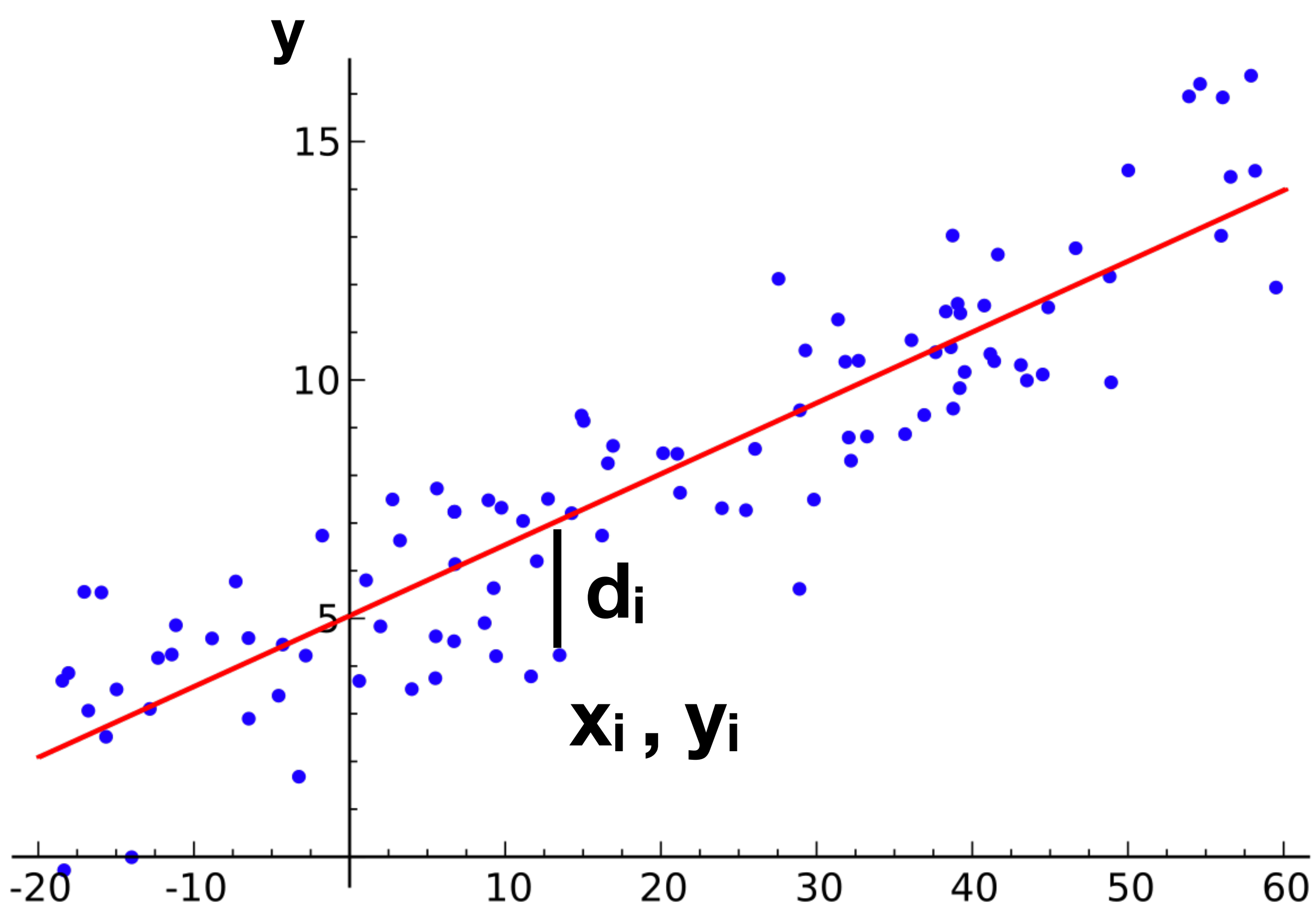
$\mathcal{y}$ = ax+b

Slope = a

Intercept = b

$$\min \quad \sum_i d_i^2 = \sum_i (y_i - \mathcal{y}_i)^2 = \sum_i (y_i - ax_i - b)^2$$

Line fitting (linear regression)



$\textit{y}$ = ax+b

Slope = a

Intercept = b

$$\min \quad \sum_i d_i^2 = \sum_i (y_i - \textit{y}_i)^2 = \sum_i (y_i - a x_i - b)^2$$

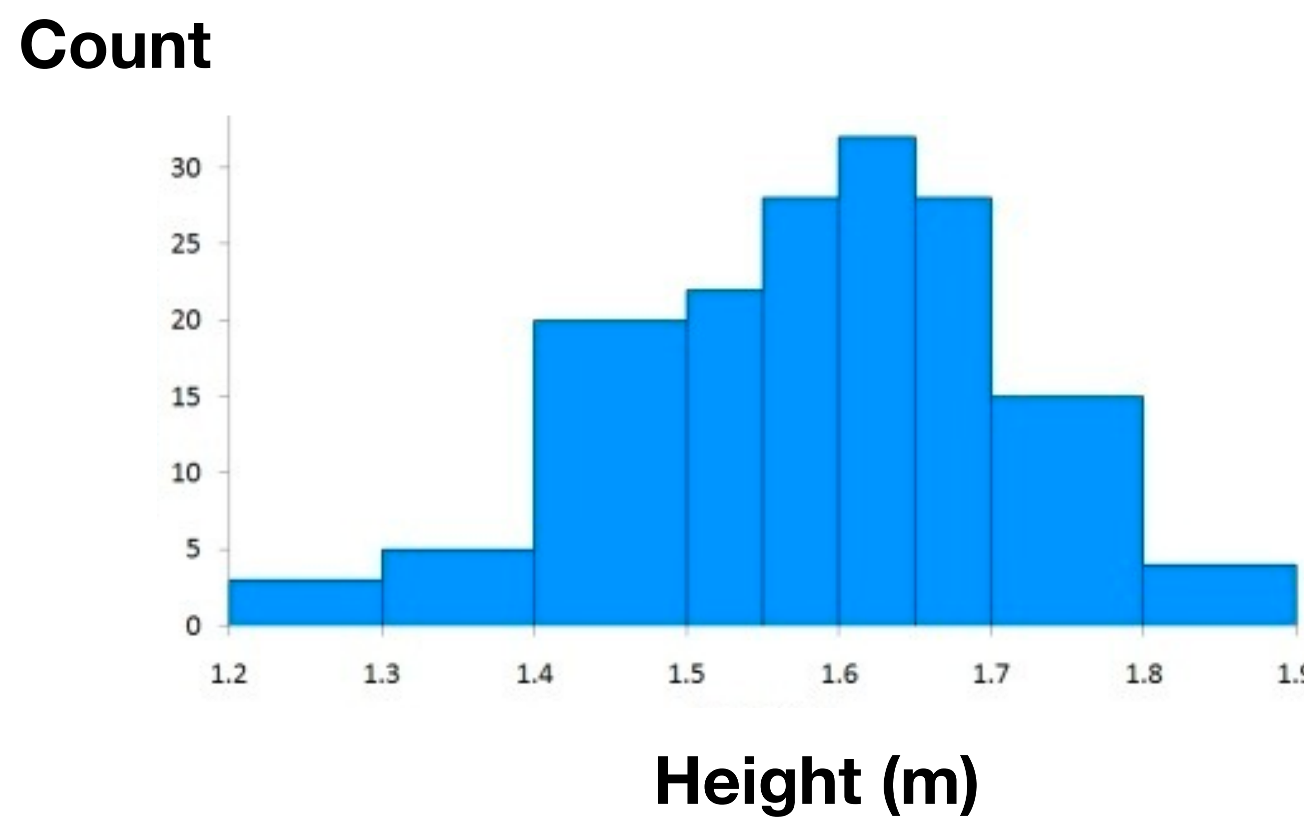
$$\Rightarrow a = \frac{\sum x_i (y_i - m(y))}{\sum x_i (x_i - m(x))}$$

Lab 3: Mental rotation

- Some functions that might help your analysis:

1. Line fit
   linefit = np.polyfit(x,y,1)

2. Plotting functions:
   plt.scatter(x,y)
   plt.errorbar(x,y,yerr=Std Dev)
   plt.hist(x,bins=n)



3. Treatment of NaN values in Numpy:
   np.isfinite(x): retrieve indices of finite values in x
   np.nanmean(x): take average of non-empty values in x
   np.nanstd(x): take standard deviation of non-empty values in x