Visual Concept-Metaconcept Learner

Learning Visual Concepts and Relational Metaconcepts with a linguistic interface

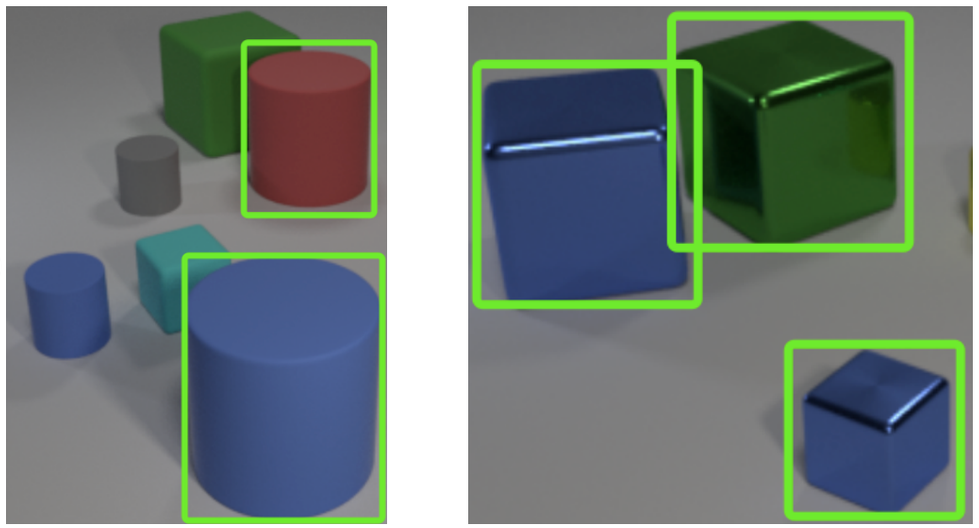
Concepts and Metaconcepts

Concepts

Concept: **Cylinder**

Concept: **Cube / Box**

CLEVR
(Johnson et al. 2017)



Concept: **Laridae**

Concept: **Ivory Gull**

Concept: **Black Tern**

CUB
(Wah et al. 2011)

Metaconcepts

Metaconcept:

"Cube" is a **synonym** of "Box".

Concepts "cube" and "sphere" are of the **same kind**.

Metaconcept:

"Laridae" is a **hypernym** of "Ivory Gull".

Categorization at Various Levels

Metaconcepts

Visual Concepts

Objects

Same-kind

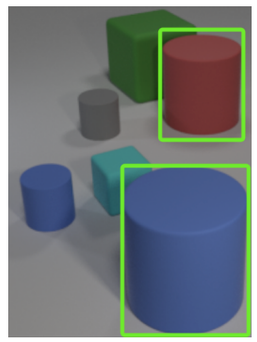
Synonym

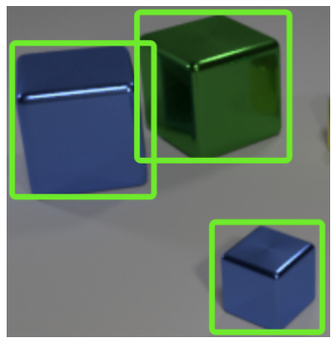
Cube

Cylinder

Box

Yellow





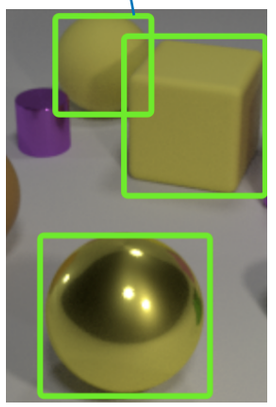


Image source: Johnson et al. 2017

Application from a Bottom-up point of view: Concepts Help Metaconcepts Generalize

Metaconcepts

Visual Concepts

Objects

Training session: jointly learning concepts and metaconcepts

Synonym

Cube

Box

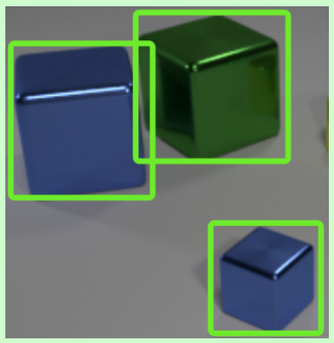
Sphere

Ball

Q: Is "box" a synonym of "cube"?
A: Yes

Q: Is there any box in the image?
A: Yes

Q: Is there any cube in the image?
A: Yes



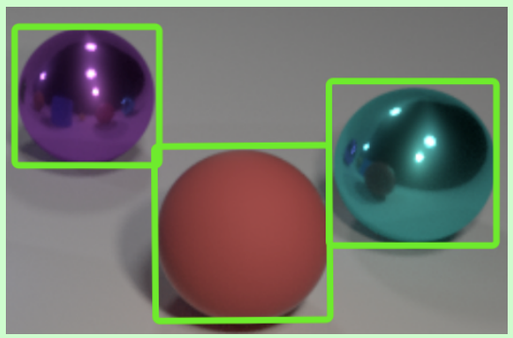


Image source: Johnson et al. 2017

Application from a Bottom-up point of view: Concepts Help Metaconcepts Generalize

Metaconcepts

Visual Concepts

Objects

Test session:
Generalize to unseen pairs

Synonym

Q: Is “ball” a synonym of “sphere”?
A: Yes

Cube

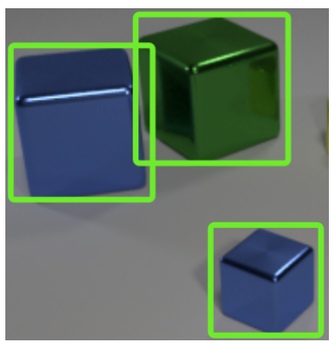
Box

Sphere

Ball

Q: Is “box” a synonym of “cube”?
A: Yes

Q: Is there any box in the image?
A: Yes



Q: Is there any cube in the image?
A: Yes

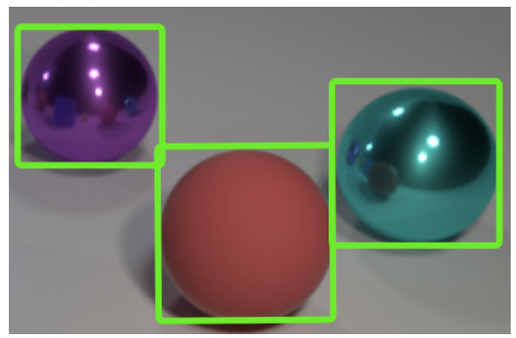


Image source: Johnson et al. 2017

Application from a Top-Down point of view: Metaconcepts Help Learning Concepts

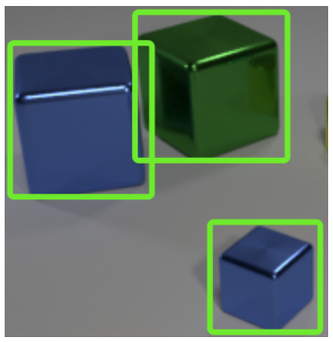
(I) Metaconcept “synonym” supports zero-shot learning of novel concepts

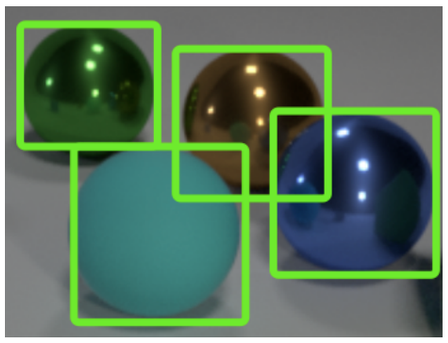
Cube

Box

Ball

Sphere





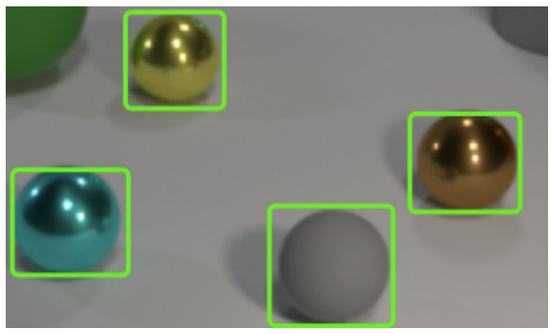


Image source: Johnson et al. 2017

Application from a Top-Down point of view: Metaconcepts Help Learning Concepts

(I) Metaconcept "synonym" supports zero-shot learning of novel concepts

Visual concept learning

Cube

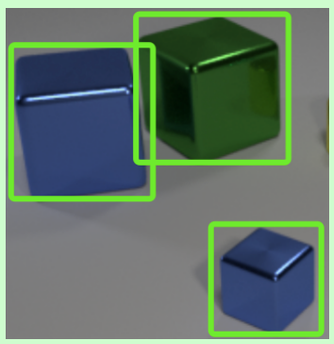
Box

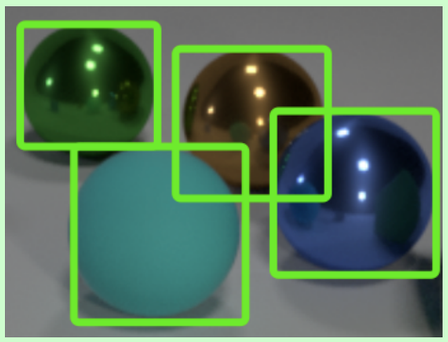
Sphere

Ball

Q: Is there any box in the image?
A: Yes

Q: Is there any cube in the image?
A: Yes





Q: Is there any sphere in the image?
A: Yes

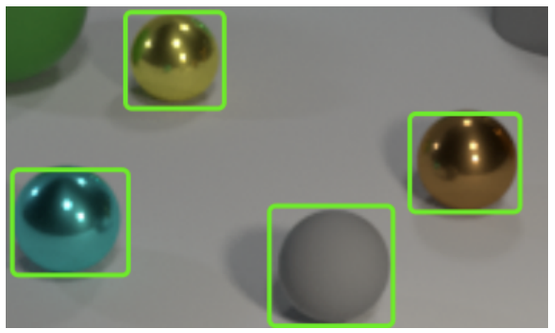


Image source: Johnson et al. 2017

Application from a Top-Down point of view: Metaconcepts Help Learning Concepts

Metaconcept learning

Synonym

Cube

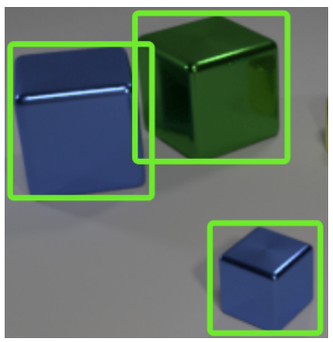
Box

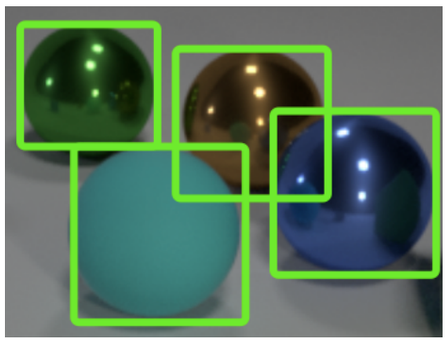
Q: Is “box” a synonym of “cube”?
A: Yes

(I) Metaconcept “synonym” supports zero-shot learning of novel concepts

Ball

Sphere





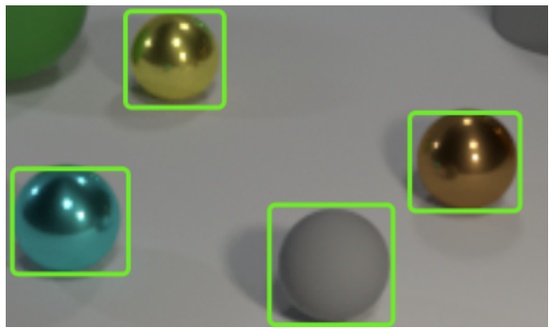


Image source: Johnson et al. 2017

Application from a Top-Down point of view: Metaconcepts Help Learning Concepts

Novel concept inference

Synonym

(I) Metaconcept "synonym" supports zero-shot learning of novel concepts

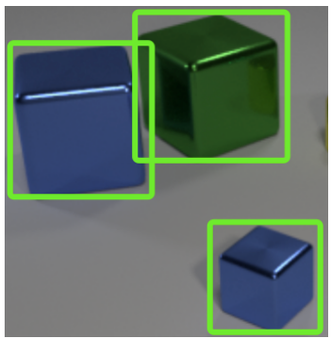
Cube

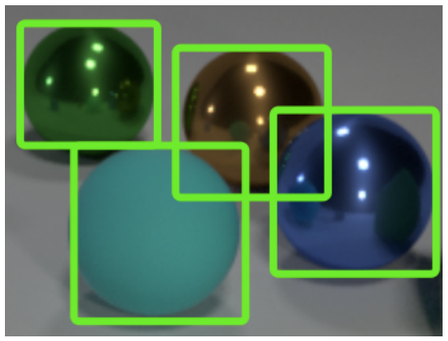
Box

Q: Is "ball" a synonym of "sphere"?
A: Yes

Ball

Sphere





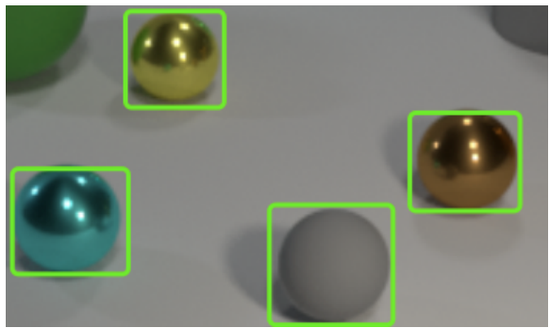


Image source: Johnson et al. 2017

Application from a Top-Down point of view: Metaconcepts Help Learning Concepts

(I) Metaconcept "synonym" supports zero-shot learning of novel concepts

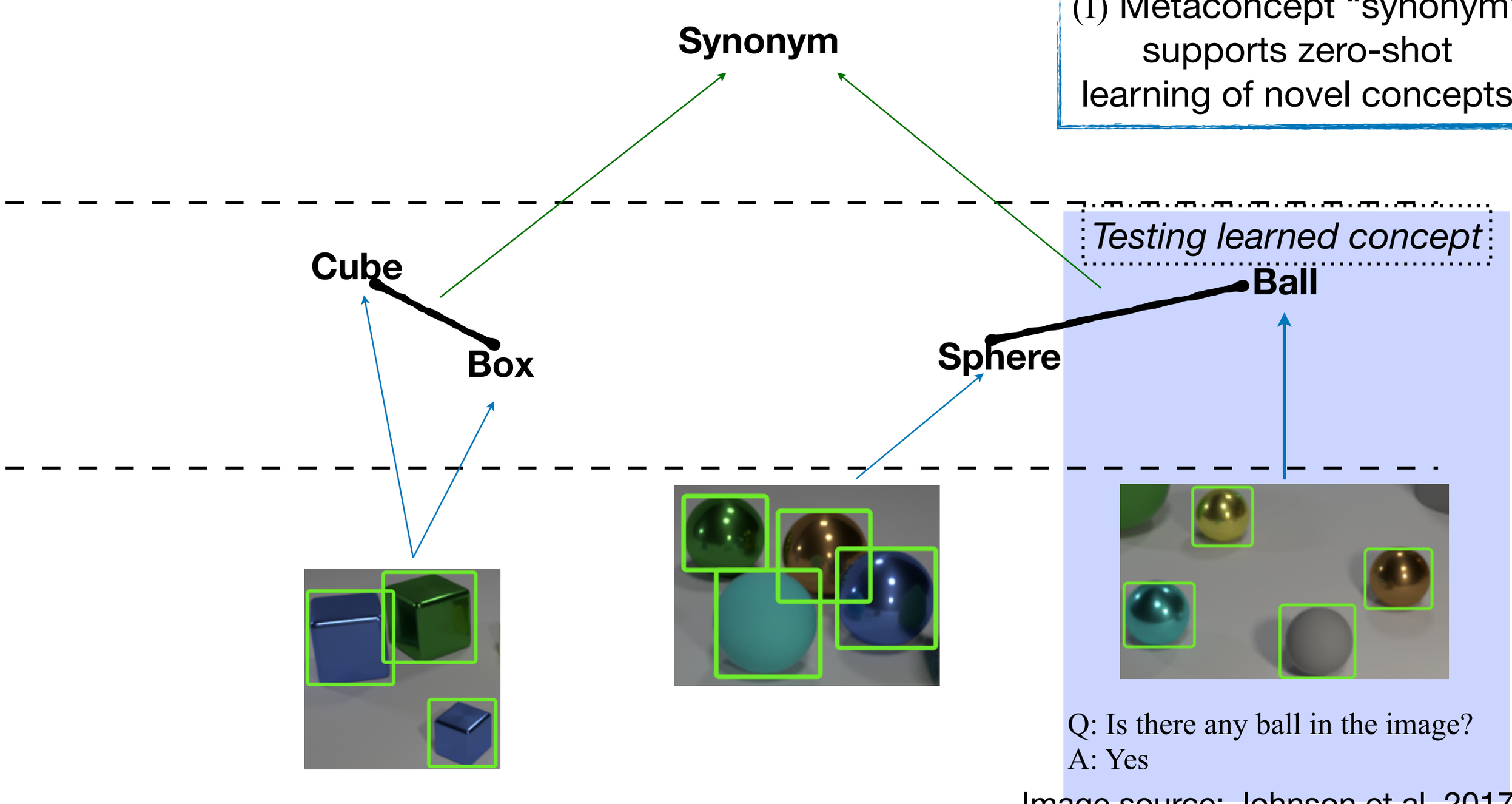


Image source: Johnson et al. 2017

Application from a Top-Down point of view: Metaconcepts Help Learning Concepts

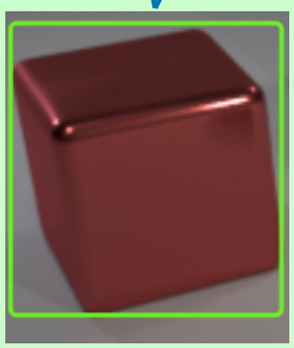
(II) Metaconcept "same-kind" supports learning from biased data

Same kind

If there is visual bias in training data, we may learn a corrupted visual concept

Red

Cube



Q: Is there any cube in the image?
A: Yes

(Visual bias: All cubes in the training split are gray, blue, brown, or yellow)

Image source: Johnson et al. 2017

Application from a Top-Down point of view: Metaconcepts Help Learning Concepts

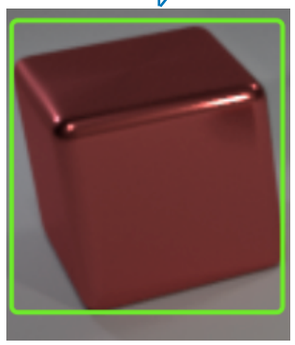
(II) Metaconcept "same-kind" supports learning from biased data

Same kind

Red

Cube

(Wrongly classify "cube" concept based on the hue of the object)



Q: Is there any cube in the image?
A: No

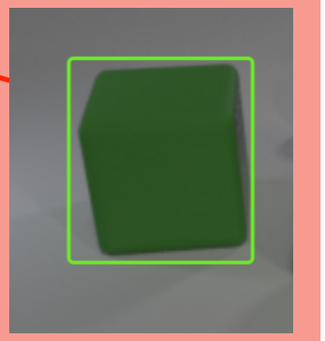


Image source: Johnson et al. 2017

Application from a Top-Down point of view: Metaconcepts Help Learning Concepts

(II) Metaconcept "same-kind" supports learning from biased data

Same kind

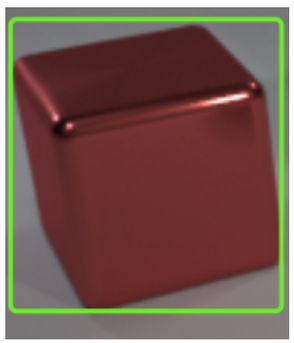
Learning Visual Concepts

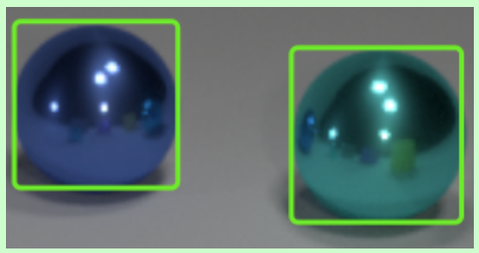
Red

Cube

Sphere

Cylinder





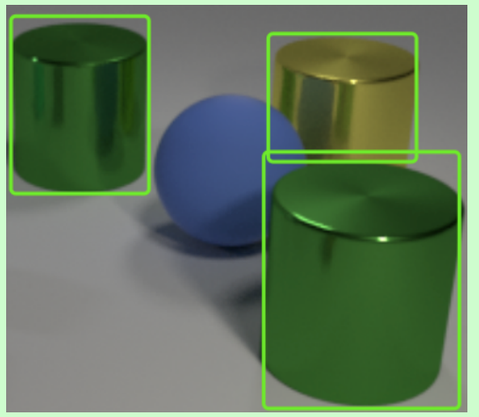


Image source: Johnson et al. 2017

Application from a Top-Down point of view: Metaconcepts Help Learning Concepts

(II) Metaconcept “same-kind” supports learning from biased data

Learning Metaconcepts

Same kind

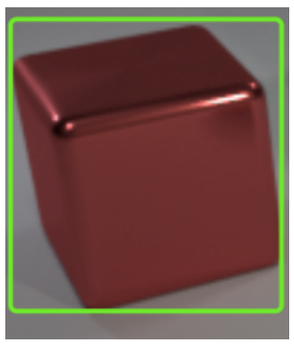
Q: Are concepts “cylinder” and “sphere" of the same kind?
A: Yes

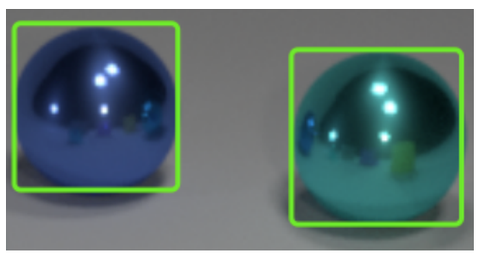
Red

Cube

Cylinder

Sphere





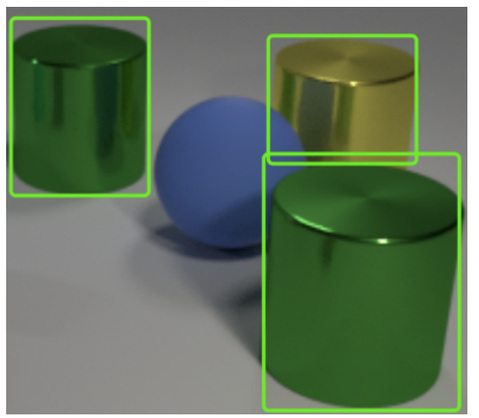


Image source: Johnson et al. 2017

Application from a Top-Down point of view: Metaconcepts Help Learning Concepts

(II) Metaconcept “same-kind” supports learning from biased data

Q: Are concepts “sphere” and “cube" of the same kind?
A: Yes

Q: Are concepts “red” and “cube" of the same kind?
A: No

Metaconcept “same kind” provides extra constraint on concepts, and helps debiasing the corrupted concept

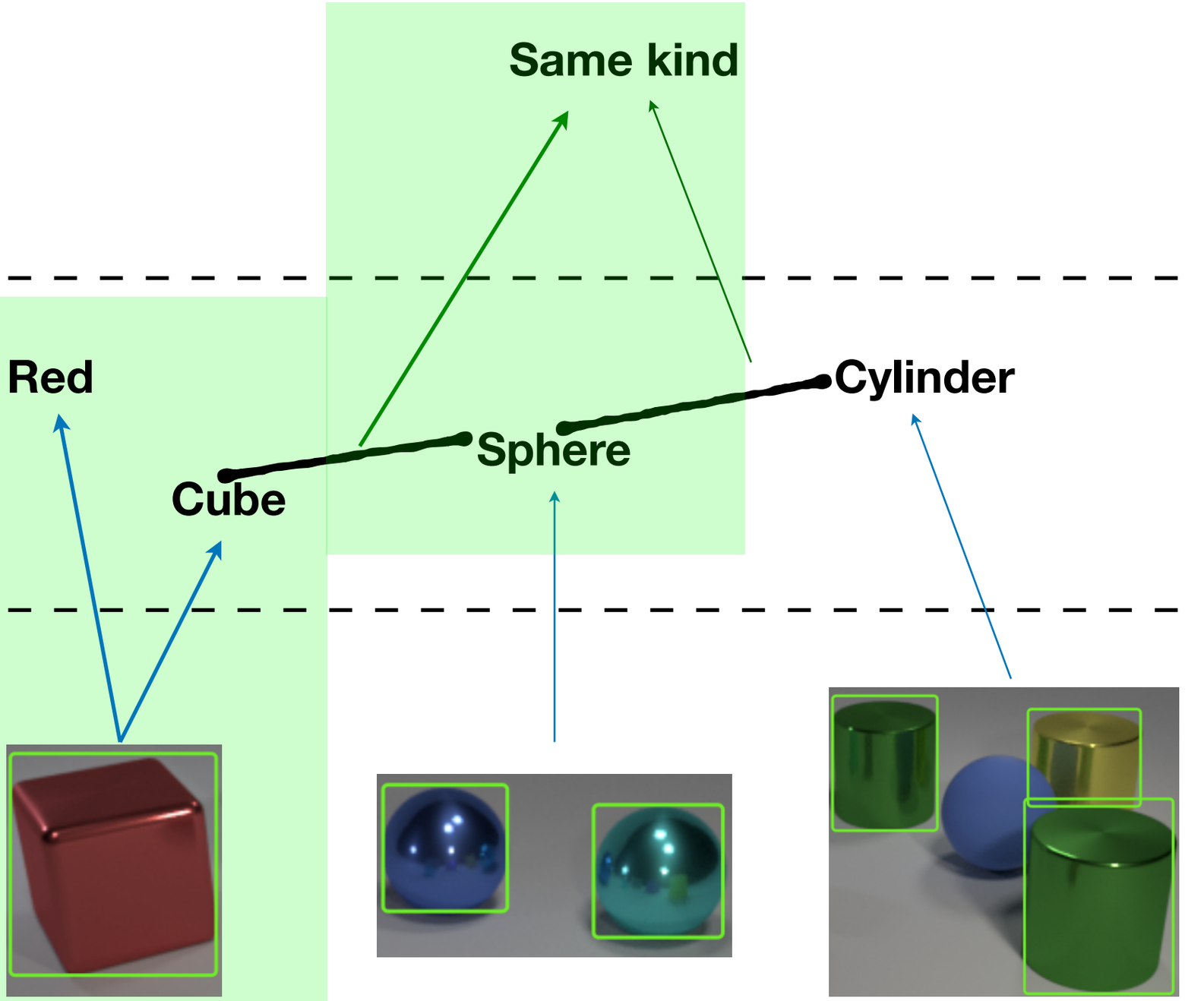


Image source: Johnson et al. 2017

Application from a Top-Down point of view: Metaconcepts Help Learning Concepts

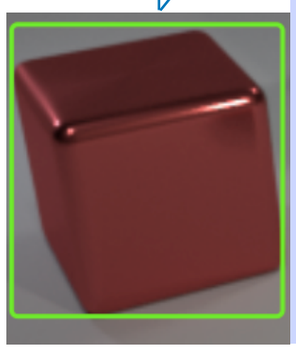
(II) Metaconcept "same-kind" supports learning from biased data

Same kind

Red

Cube

Now the model should correctly classify "cube" concept on objects



Q: Is there any cube in the image?
A: Yes

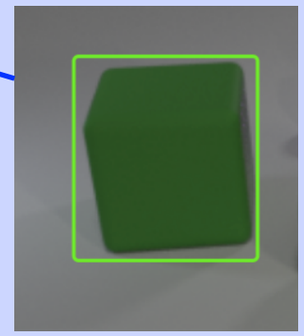


Image source: Johnson et al. 2017

Open Questions

- Are metaconcepts based purely on probabilistic relations, or on their “meanings”?
  i.e., when we say that “concepts ‘red’ and ‘yellow’ are of the same kind”, is it simply because they are negatively correlated on data, or because we really understand what ‘hue’ means?

- What is the best way of modeling probabilistic relations between concepts?
  What is the best way of modeling humans’ understanding of “hue” and “shape”?