Similarity

Danielle Navarro

http://compcogscisydney.org/psyc2071/

Structure

- Introduction to similarity
- Simple theories of similarity
  - Geometric models
  - Featural models
- Richer theories of similarity
  - Structure alignment
  - Stimulus transformation

https://flic.kr/p/d5ifKh

Perceptual and conceptual foundations for similarity

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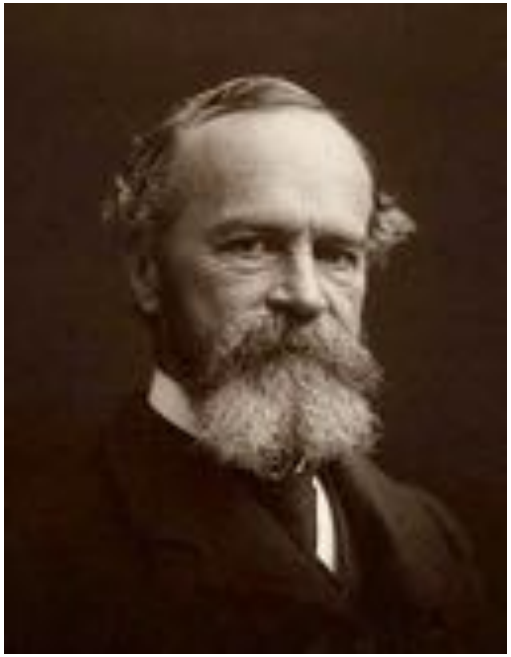
♫ One of these things is not like the others // Three of these things are kind of the Same ♫

this sense of Sameness is the very keel and backbone of our thinking

- William James (1890)



Shared perceptual features
produce a sense of "likeness"

But we can set aside superficial differences to see a "structural" similarity

http://slightlywarped.com/animals-that-look-like-famous-people/

But we can set aside superficial differences to see a "structural" similarity

http://slightlywarped.com/animals-that-look-like-famous-people/

Similarity is not a purely perceptual phenomenon

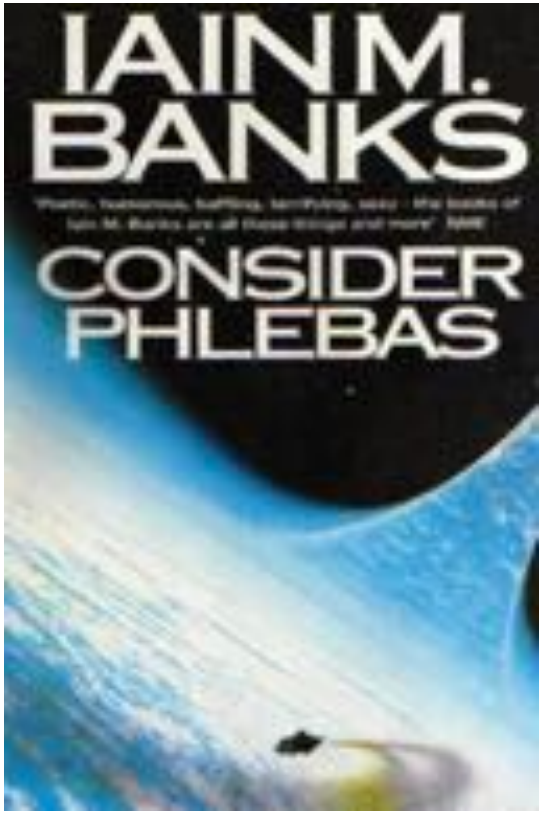
The ship didn't even have a name. It had no human crew because the factory craft which constructed it had been evacuated long ago. It had no life-support or accommodation units for the same reason. It had no class number or fleet designation because it was a mongrel made from bits and pieces of different types of warcraft; and it didn't have a name because the factory craft had no time left for such niceties.

The dockyard threw the ship together as best it could from its depleted stock of components, even though most of the weapon, power and sensory systems were either faulty, superseded or due for overhaul. The factory vessel knew that its own destruction was inevitable, but there was just a chance that its last creation might have the speed and the luck to escape.

The one perfect, priceless component the factory craft did have was the vastly powerful—though still raw and untrained—Mind around which it had constructed the rest of the ship. If it could get the Mind to safety, the factory vessel thought it would have done well. Nevertheless, there was another reason—the real reason—the

Perceptually, these are *drastically* different stimuli!

We have a sense of similarity driven purely by conceptual connections

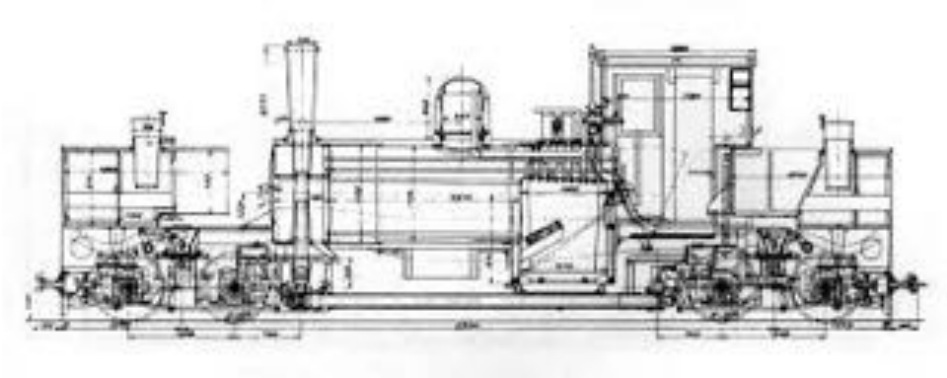


Both are:

- Science fiction
- Space opera
- Post-scarcity society

Similarity can do perceptual and conceptual work at the same time

DNA has a physical similarity to a zipper, which the visual system detects immediately



The genetic information in DNA is like a blueprint, which is a conceptual relationship

Similarity helps us form categories and make generalisations

“The snowflake problem”

No two people are the same
No two events are the same
No two objects are the same
Nothing is the *same* as anything else

"The snowflake problem"

No two people are the same
No two events are the same
No two objects are the same
Nothing is the *same* as anything else

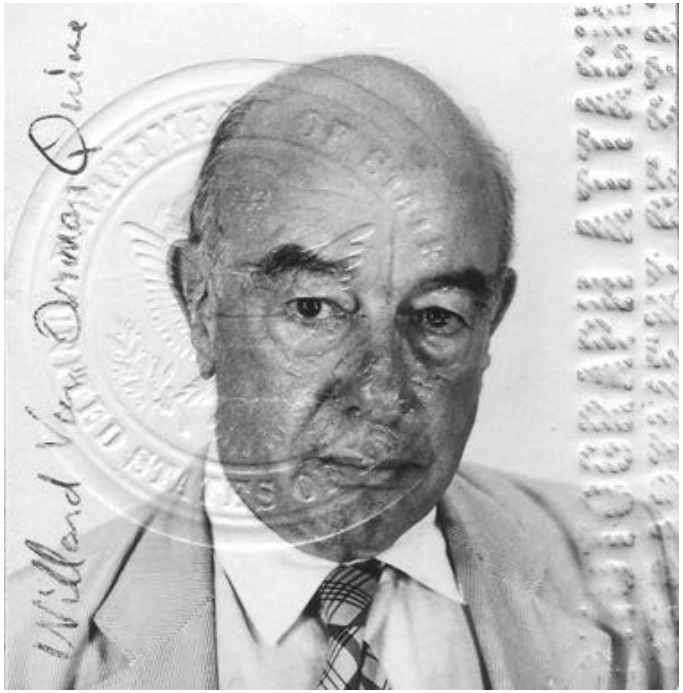
Why believe anything at all about the world or the future then?

What's the point of guesses or predictions if everything is unique?

Because things *are* similar?

"Similarity, is fundamental for learning, knowledge and thought, for only our sense of similarity allows us to order things into kinds so that these can function as stimulus meanings. Reasonable expectation depends on the similarity of circumstances and on our tendency to expect that similar causes will have similar effects"

- Willard Van Orman Quine, 1969



"Similarity, is fundamental for learning, knowledge and thought, for only our sense of similarity allows us to order things into kinds so that these can function as stimulus meanings. Reasonable expectation depends on the similarity of circumstances and on our tendency to expect that similar causes will have similar effects"

These similar things are grouped into a category called "tomato"

"Cricket balls" form a different category that means something rather different to us

"Similarity, is fundamental for learning, knowledge and thought, for only our sense of similarity allows us to order things into kinds so that these can function as stimulus meanings. Reasonable expectation depends on the similarity of circumstances and on our tendency to expect that similar causes will have similar effects"

Tomatos are tasty

Cricket balls are not tasty

Although I've never seen this particular tomato before, it is probably like other tomatoes I have eaten and so is edible.."

- Greg Murphy 2002

(Marcus Taft's lectures will talk more about these ideas)

Overall it's probably a good thing that we use similarity to inform our choices

How do we measure similarity?

Measuring similarity

- *Confusability*: probability of mistaking A for B

Measuring similarity

- *Confusability*: probability of mistaking A for B

Measuring similarity

- *Confusability*: probability of mistaking A for B

Measuring similarity

- *Confusability*: probability of mistaking A for B

Is this the picture you saw?

Measuring similarity

- *Confusability*: probability of mistaking A for B

A mistaken identity is a "confusion"
and occurs for more similar items

Measuring similarity

- *Confusability*: probability of mistaking A for B
- *Reaction time*: time taken to distinguish A from B

Measuring similarity

- *Confusability*: probability of mistaking A for B
- *Reaction time*: time taken to distinguish A from B

Dissimilar = Easy = *Fast*

Measuring similarity

- *Confusability*: probability of mistaking A for B
- *Reaction time*: time taken to distinguish A from B

Similar = Hard = *Slow*

Measuring similarity

- *Confusability*: probability of mistaking A for B
- *Reaction time*: time taken to distinguish A from B
- *Forced choice*: is X more like A or more like B?

Measuring similarity

- *Confusability*: probability of mistaking A for B
- *Reaction time*: time taken to distinguish A from B
- *Forced choice*: is X more like A or more like B?

A X

OR

X B

Measuring similarity

- *Confusability*: probability of mistaking A for B
- *Reaction time*: time taken to distinguish A from B
- *Forced choice*: is X more like A or more like B?
- *Likert scales*: how similar is A to B?

Measuring similarity

- *Confusability*: probability of mistaking A for B
- *Reaction time*: time taken to distinguish A from B
- *Forced choice*: is X more like A or more like B?
- *Likert scales*: how similar is A to B?

Extremely dissimilar 1 2 3 4 5 6 7 Extremely Similar

Measuring similarity

- *Confusability*: probability of mistaking A for B
- *Reaction time*: time taken to distinguish A from B
- *Forced choice*: is X more like A or more like B?
- *Likert scales*: how similar is A to B?
- etc

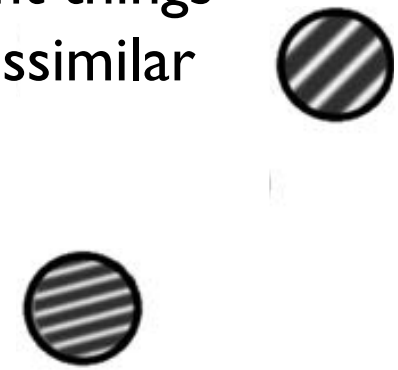
Different methods produce subtly different data, but these are all reasonably effective ways of eliciting similarity data

Simple theories of similarity I: Geometric models

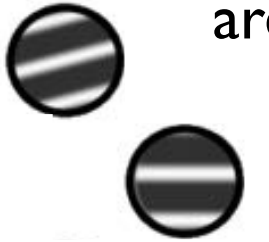
Distant things
are dissimilar

Nearby things
are similar

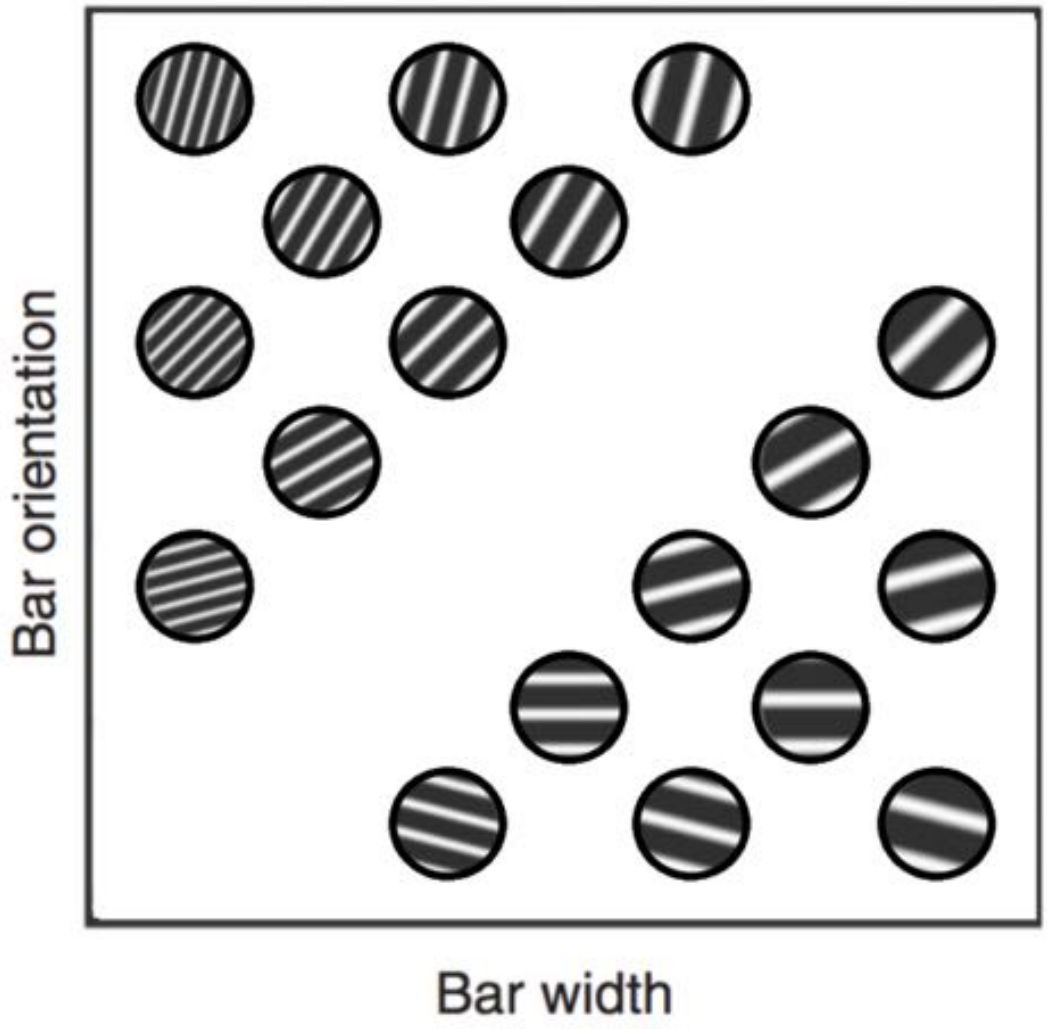
Distant things
are dissimilar



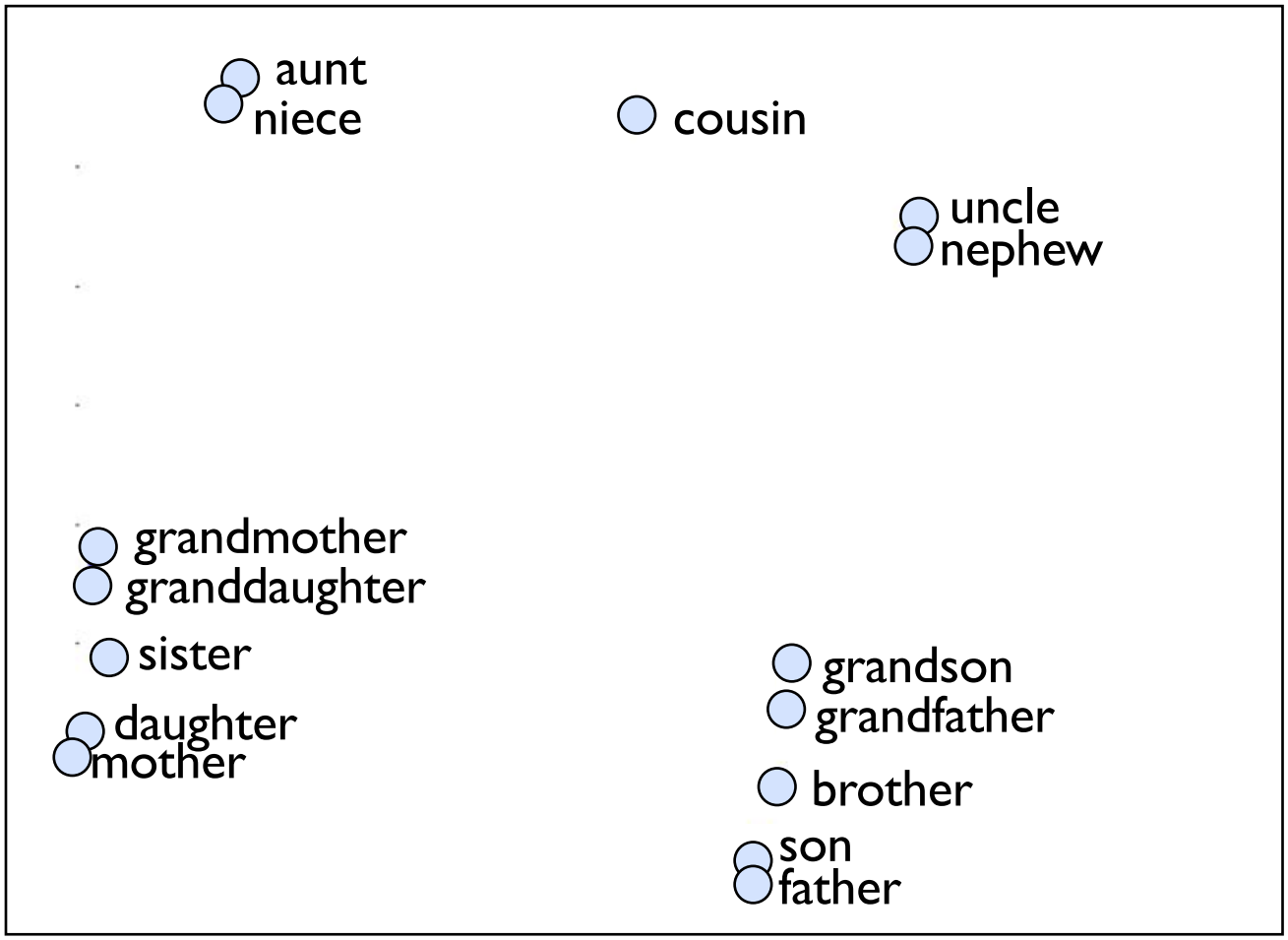
Nearby things
are similar

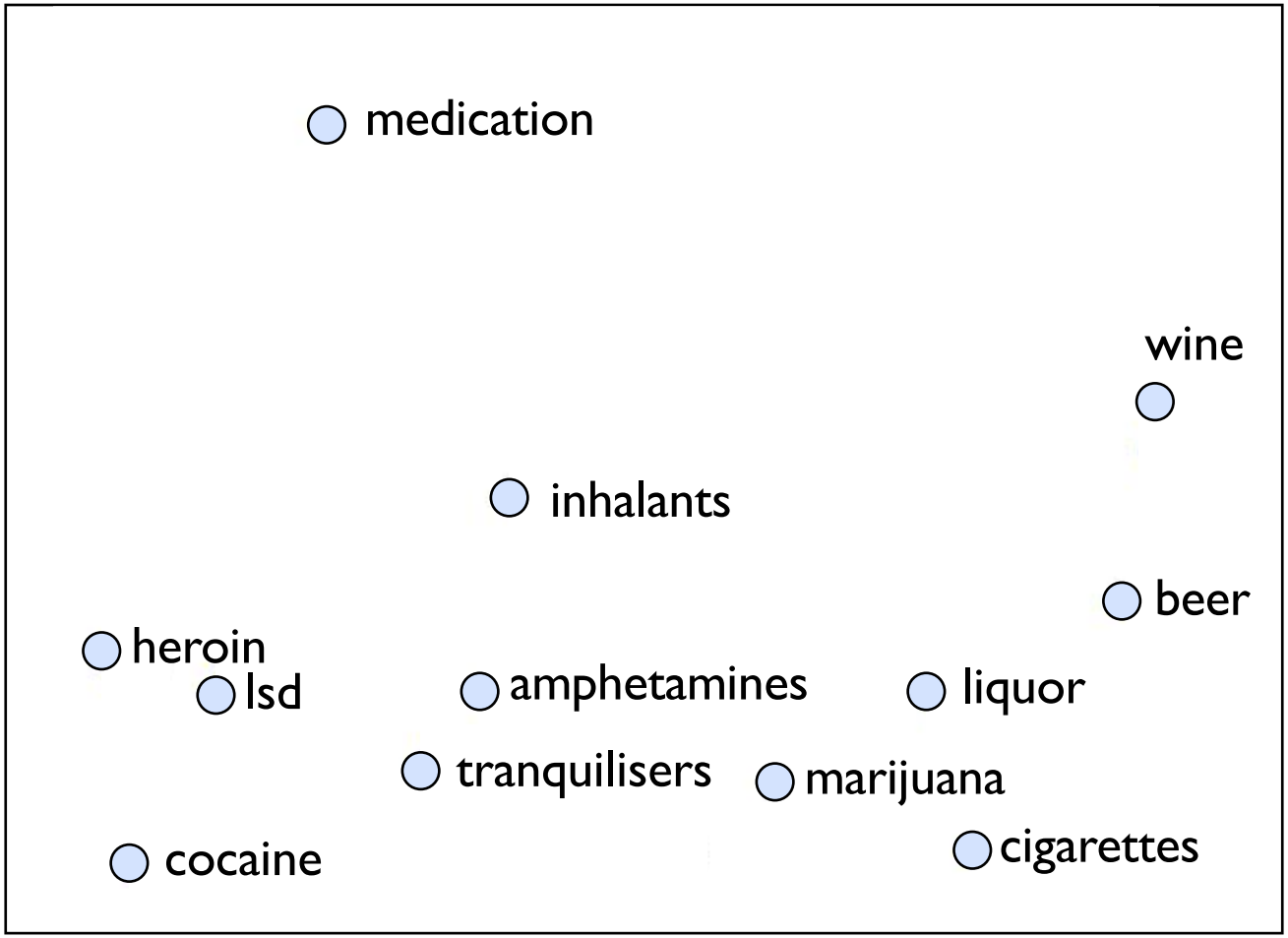


Geometric models



We have a "psychological space" with similar objects placed nearby


aunt
niece
cousin
uncle
nephew
grandmother
granddaughter
sister
daughter
mother
grandson
grandfather
brother
son
father


medication
wine
inhalants
beer
heroin
lsd
amphetamines
liquor
tranquilisers
marijuana
cocaine
cigarettes

Some empirical evidence?

Similarity helps us generalise from one stimulus to another?

Nearby thing is probably edible

I *know* this is edible

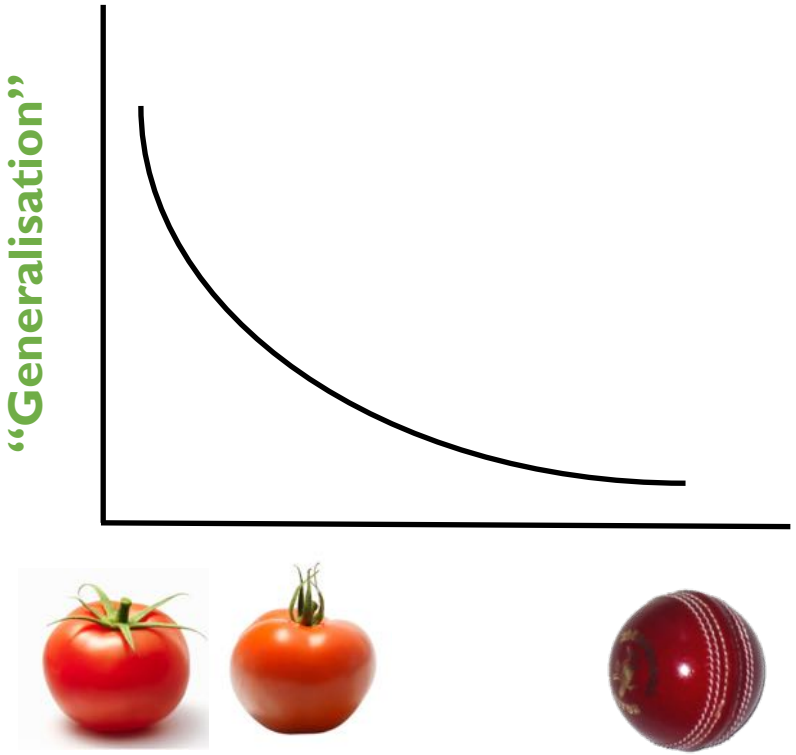
Similarity helps us generalise from one stimulus to another?

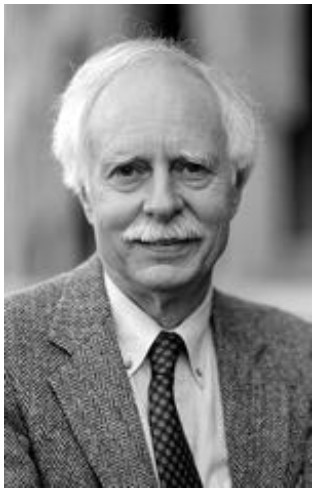
Distant thing is probably not edible?

???

I know this is edible

The "universal" law of generalisation

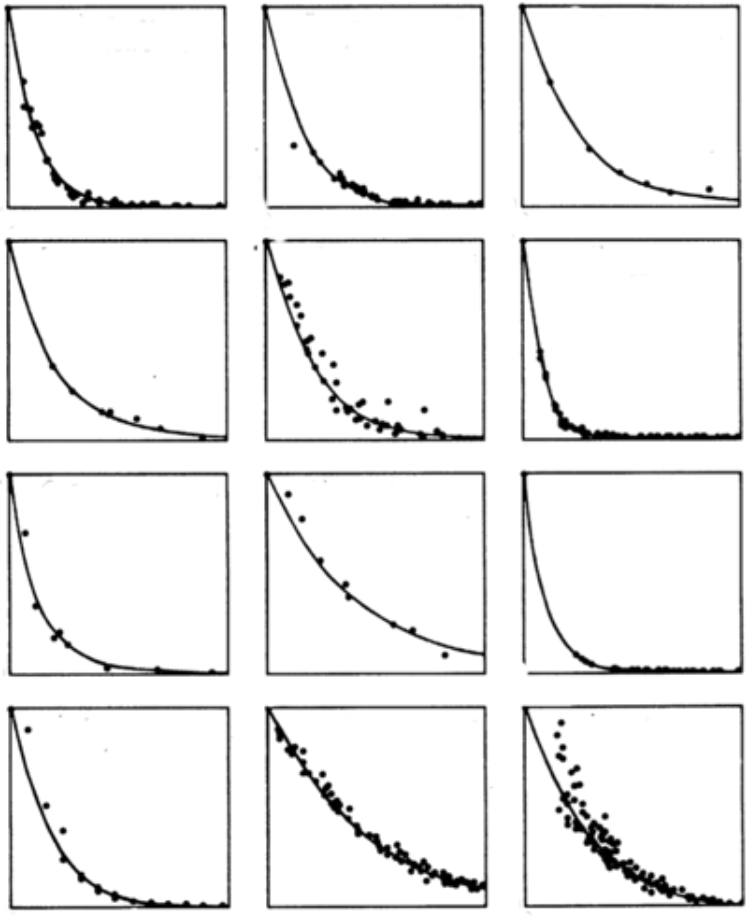




Roger Shepard

The probability of generalising from one stimulus to another decreases *exponentially* as a function of dissimilarity (i.e. distance)

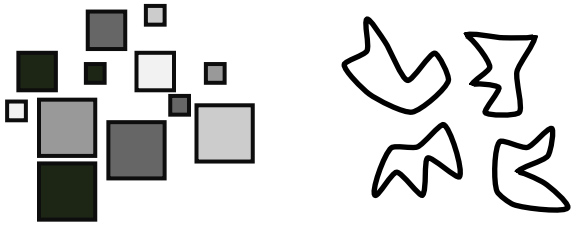
The "universal" law of generalisation



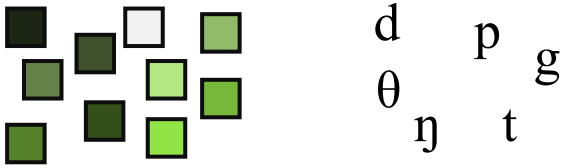
"Generalisation"

"Psychological distance"

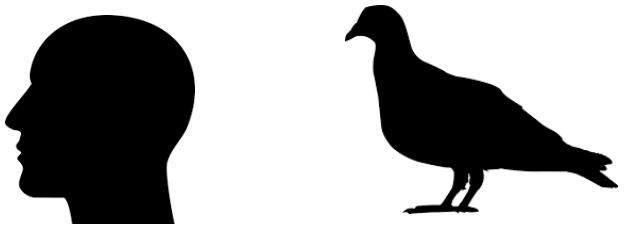
Invariance across stimulus types



Invariance across sensory modalities

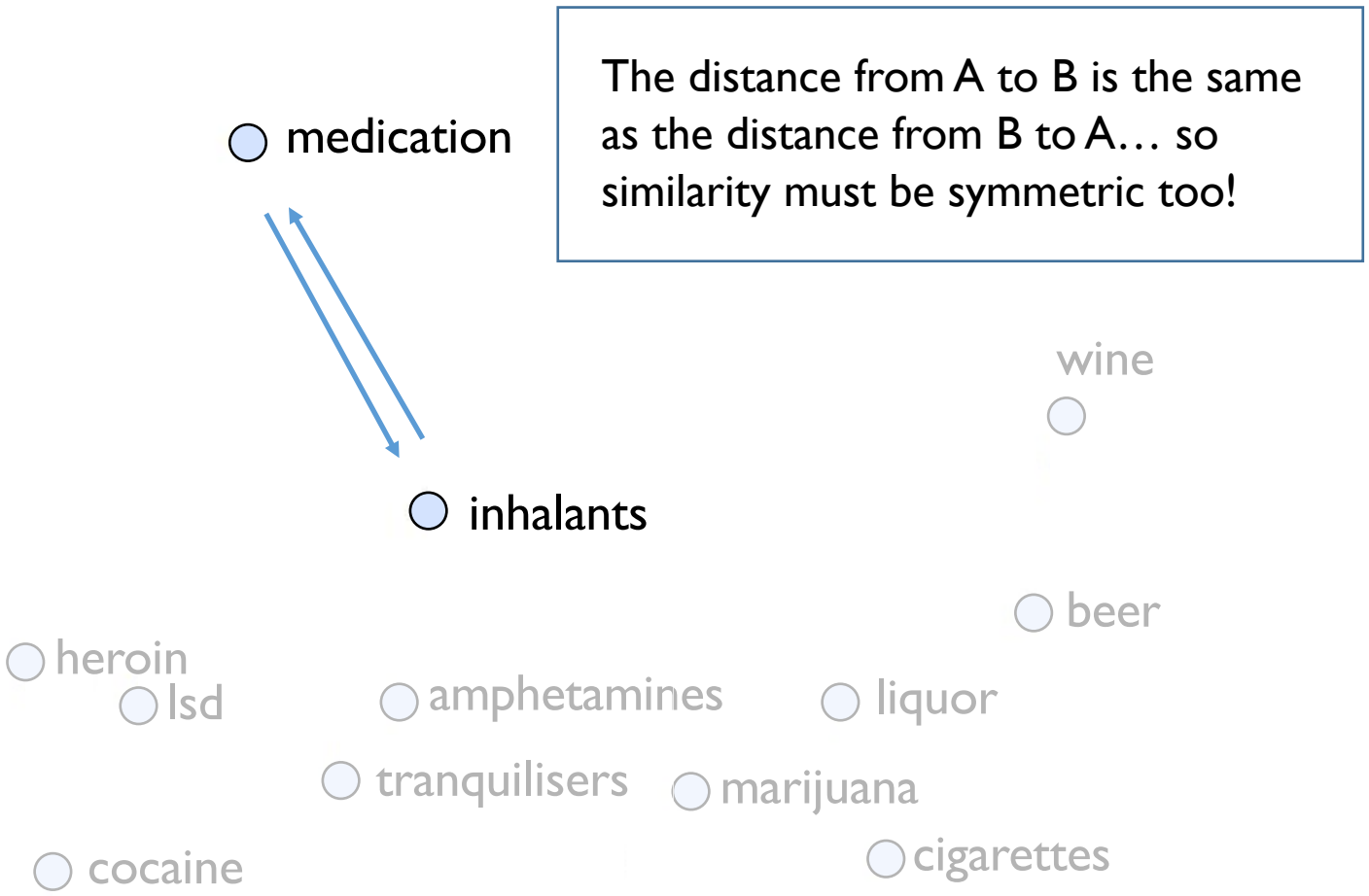


Invariance across species



Problems with the geometric approach

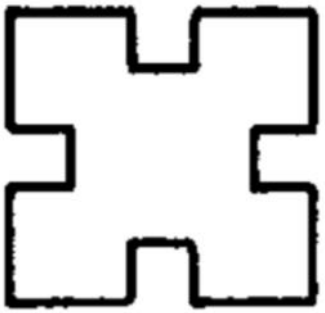
The symmetry constraint



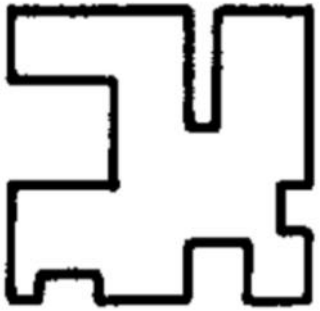
Which feels more appropriate?

(Tversky 1977)

A



B



"B is similar to A"

OR

"A is similar to B"

An okapi is like a horse

OR

A horse is like an okapi

Simple theories of similarity II: Featural models

Featural similarity

farms

domesticated

tail

fast

quadruped

strong

brown

mane

hooves

friendly

quadruped

hooves

stripy

tail

brown

Asymmetric knowledge

strong

mane

domesticated

friendly

farms

fast

quadruped

brown

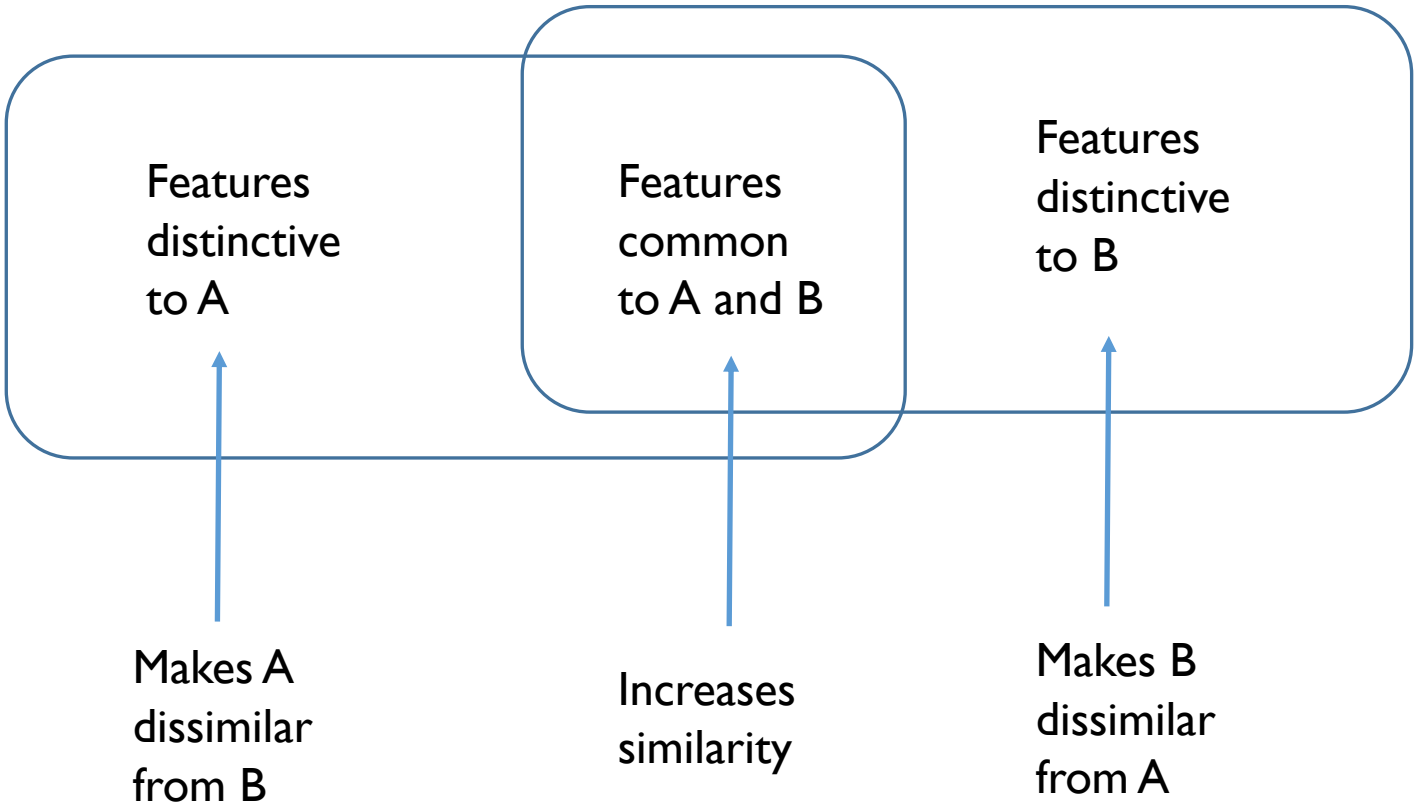
hooves

tail

stripy

Common and distinctive features

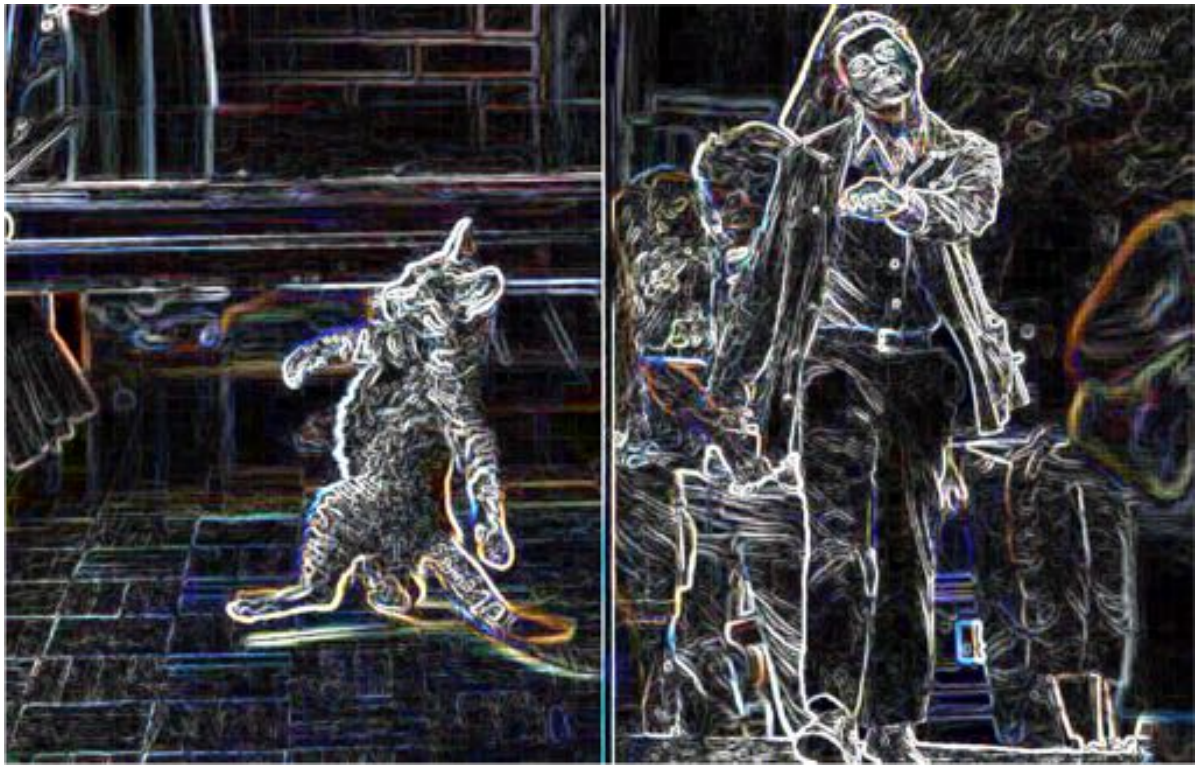
(Tversky 1977)



Richer theories of similarity: Structure alignment

Removing the colour features
leaves the similarity intact

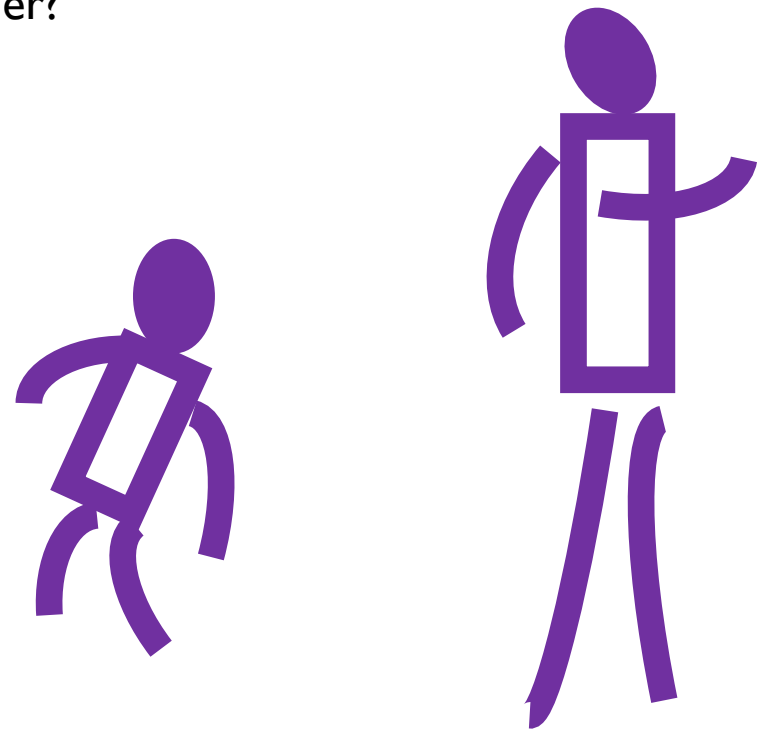
Blurring out the high-frequency spatial information leaves the similarity (mostly) intact

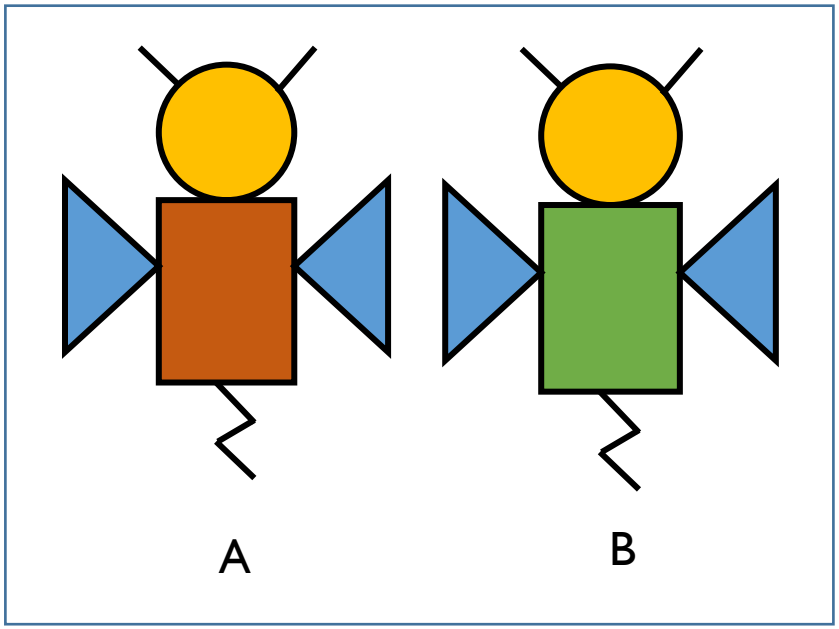


Filtering out everything except the high frequency information leaves the similarity intact

Deleting everything except a very rubbish cartoon leave the similarity intact

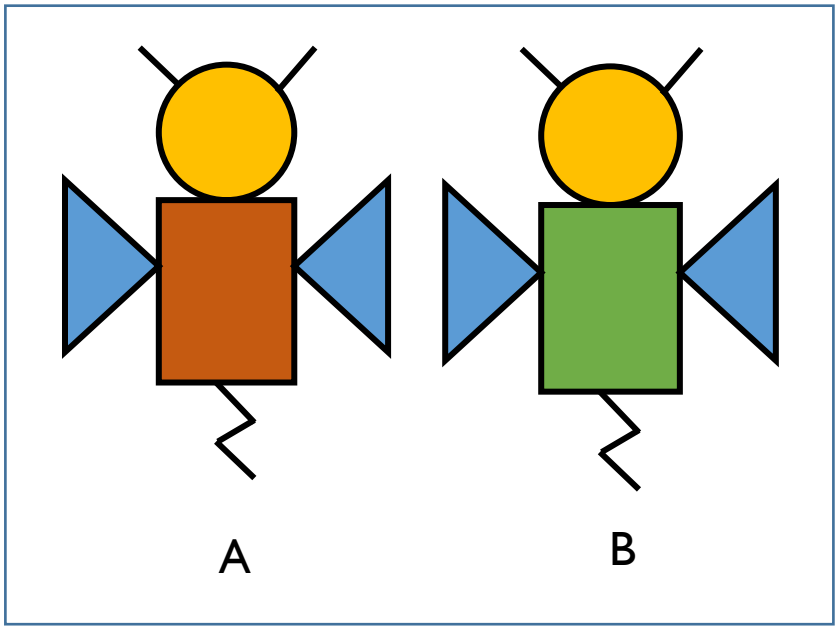
The structure does the work – what are the parts of each image and how do they related to each other?

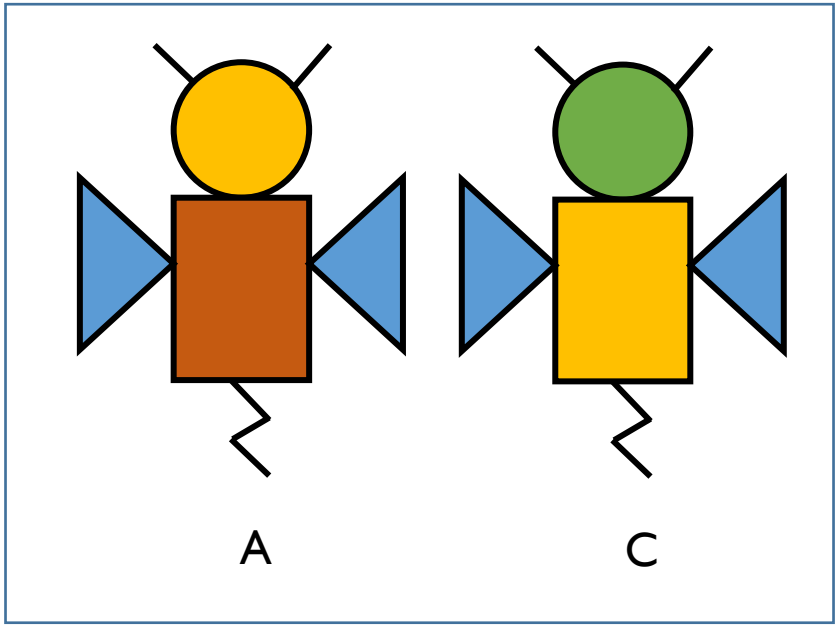


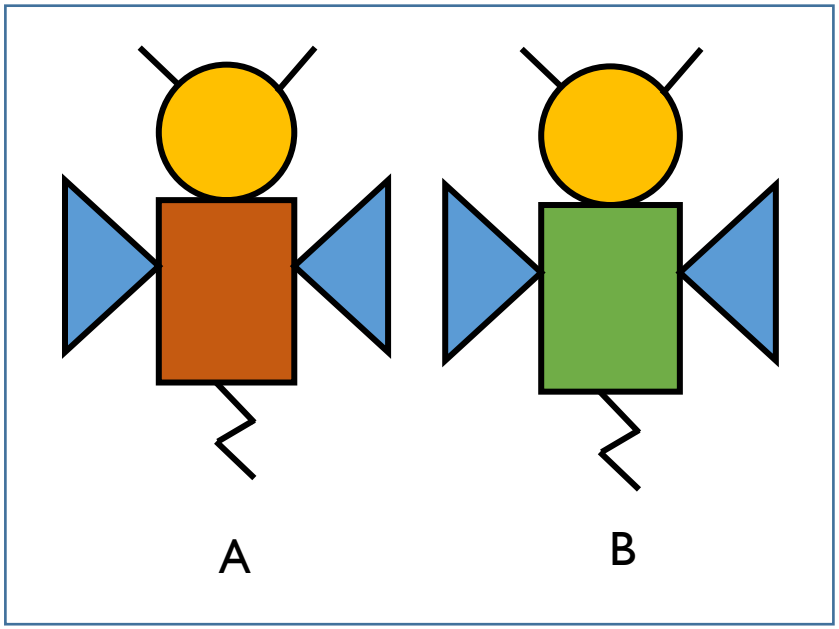


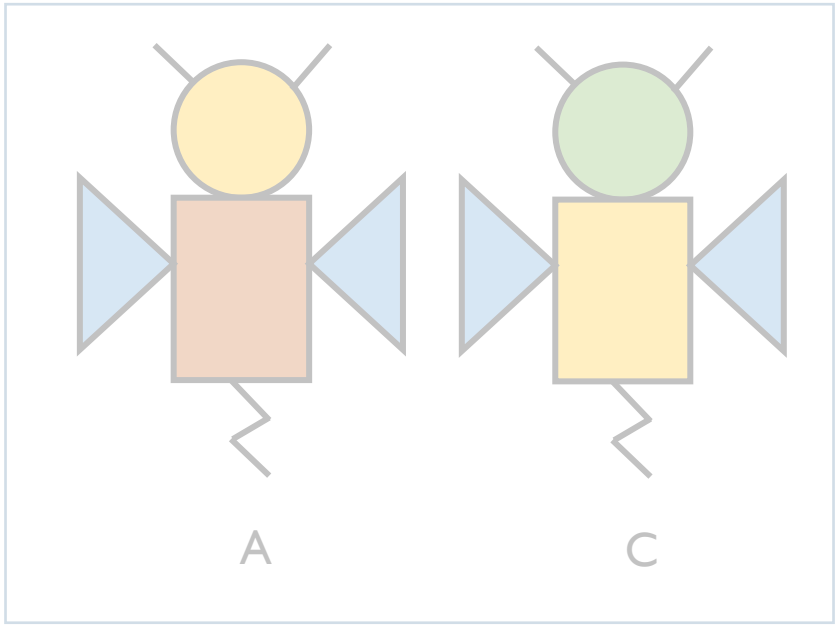
Here are a pair of “butterflies”

Which of these pairs is more similar?

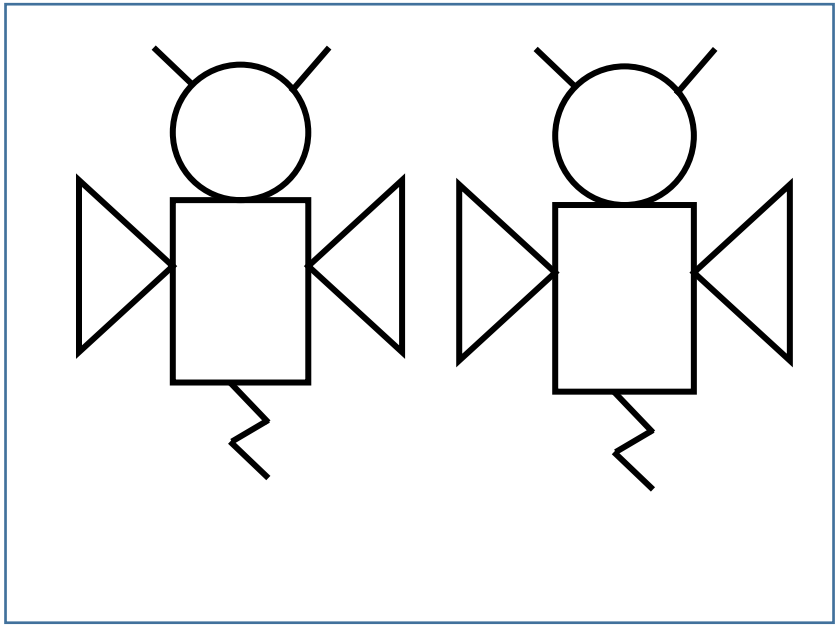




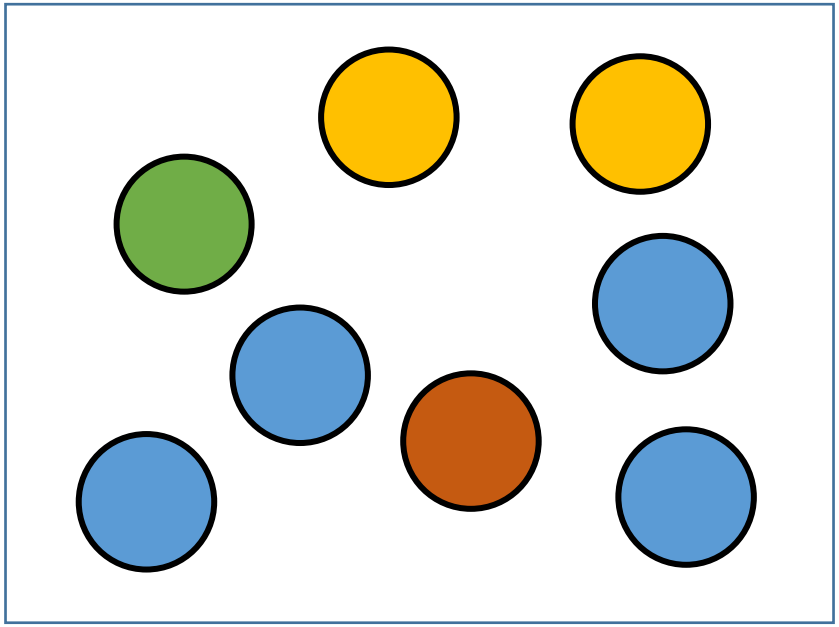

A
B


A
C

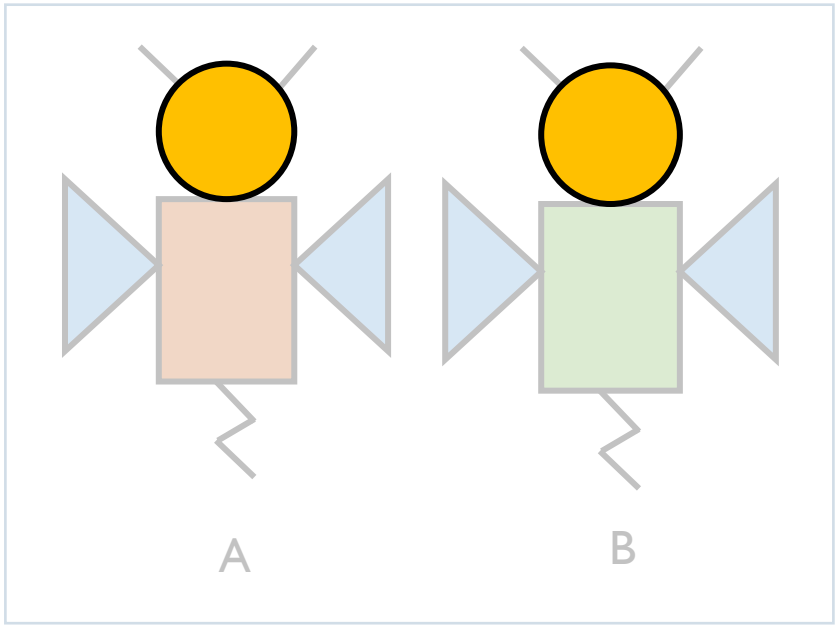
It's always the same body parts

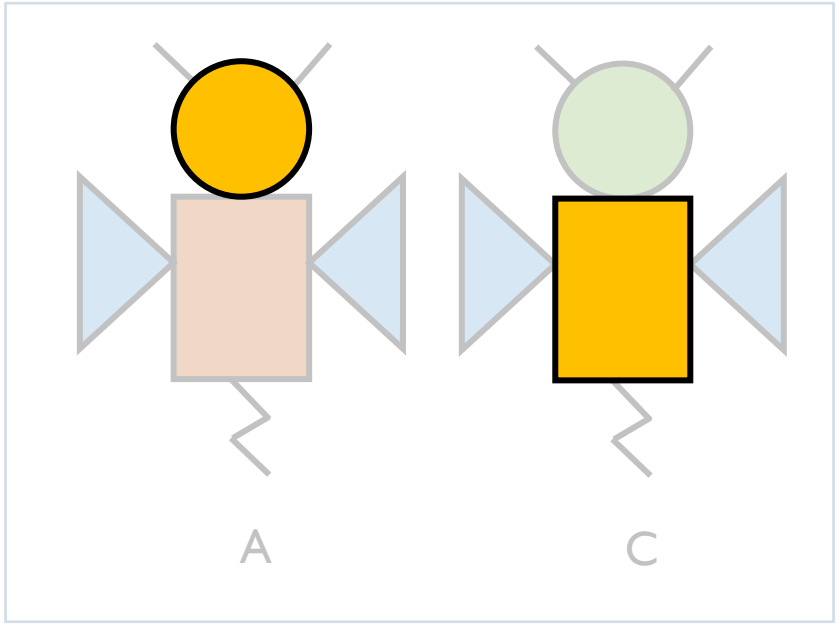


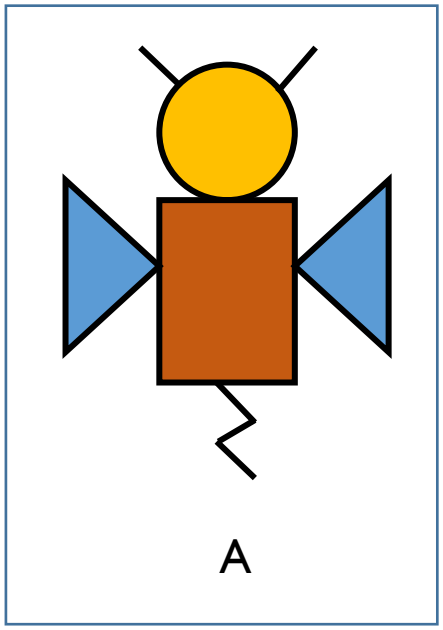
And always the same colours



But they're *bound* into objects in different ways in both cases



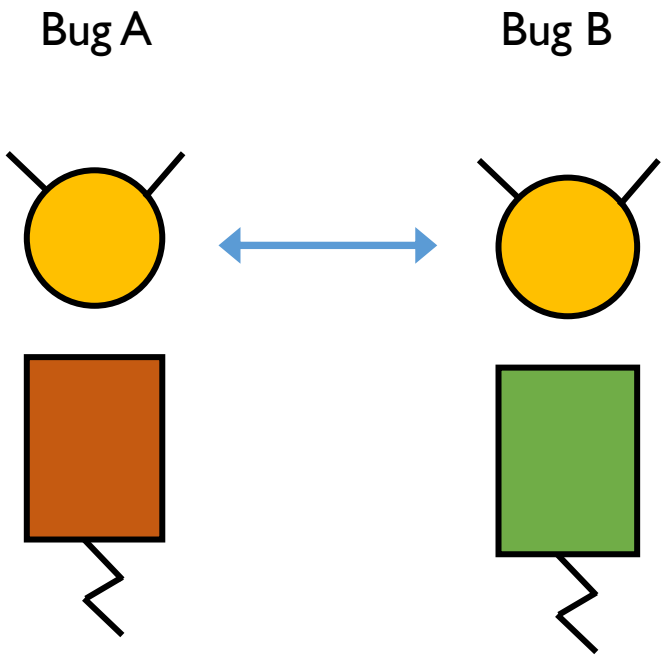





```
A = {
  head: yellow
  body: brown
  wings: blue
}
```

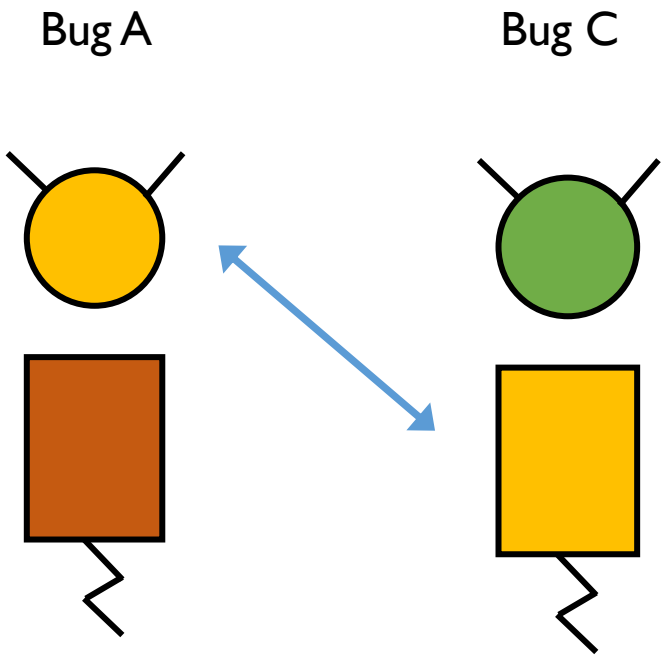
Object descriptions need to say something about this structure

Similarity?



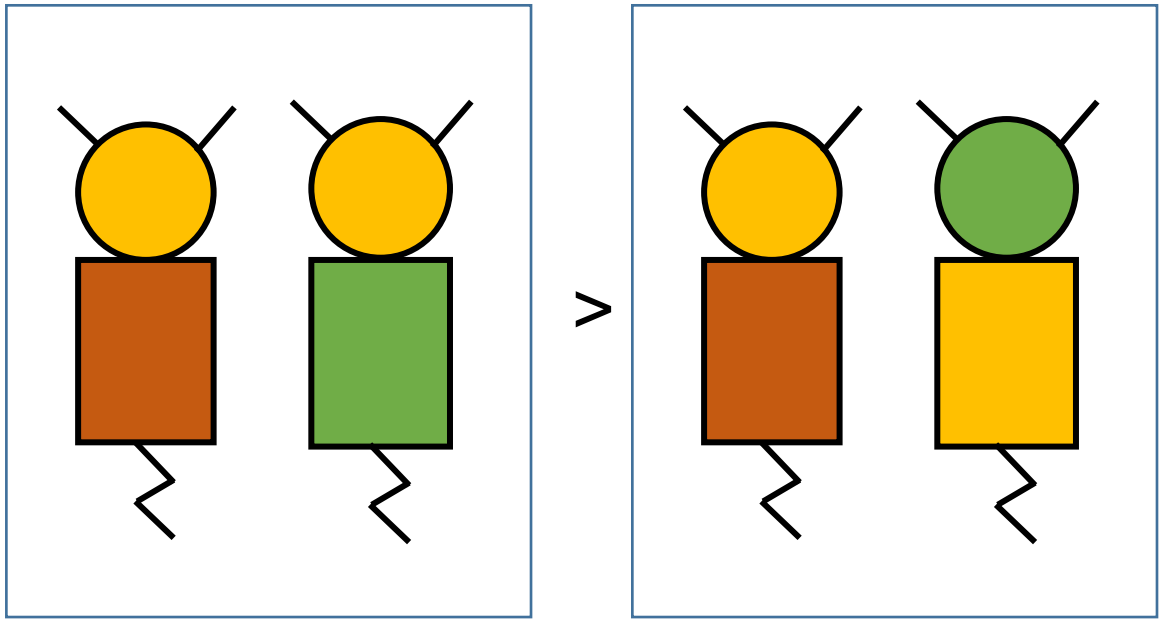
When two objects share a feature (e.g., yellow), and that feature appears in the same slot (e.g., head), it is referred to as a "**match in place**" (MIP)

Similarity?



When the shared feature appears in a different location it is a "**match out of place**" (MOP)

Empirical prediction

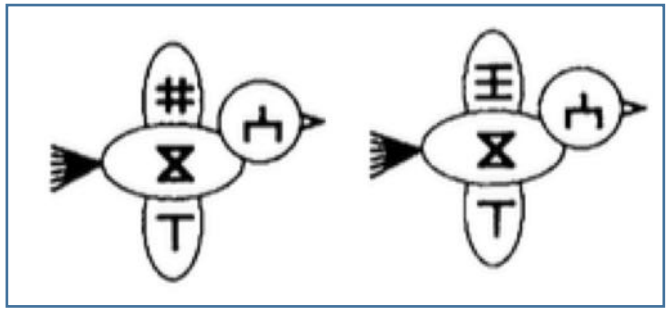


1 MIP > 1 MOP

If structure is important for similarity, MIPs should have a bigger influence than MOPs

To the laboratory!!!

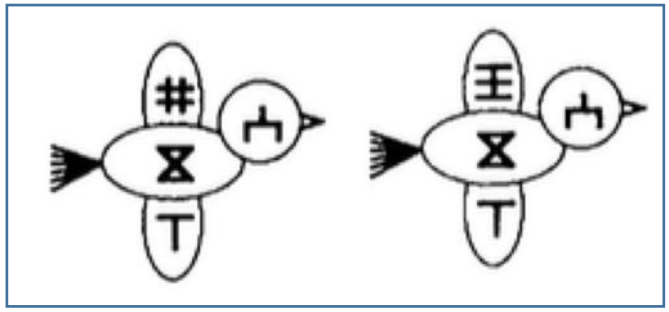
3 MIPS + 0 MOPS

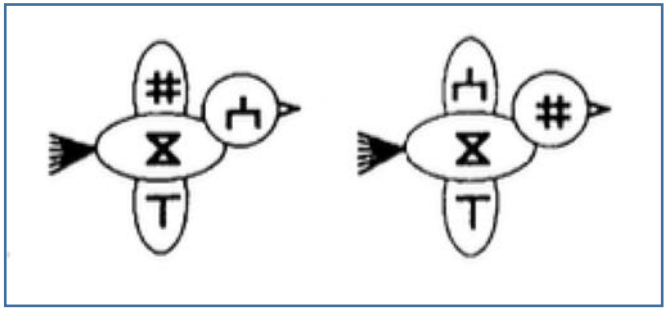


Experiment! The task is to rate the similarity between these

Goldstone (1994)

3 MIPS + 0 MOPS



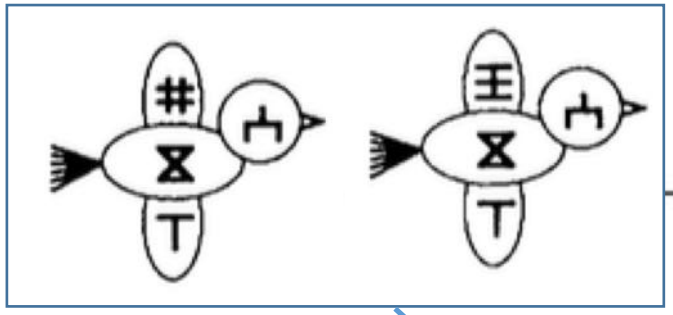


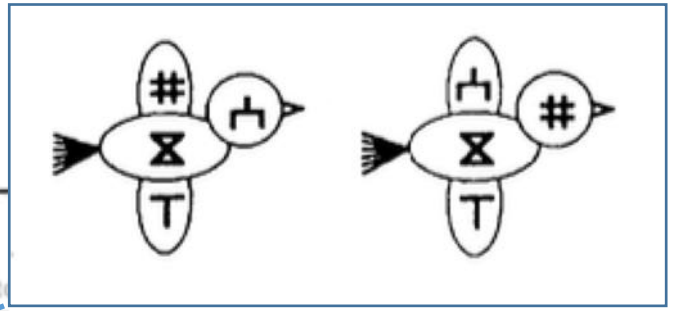
2 MIPS + 2 MOPS

Experiment! The task is to rate the similarity between these

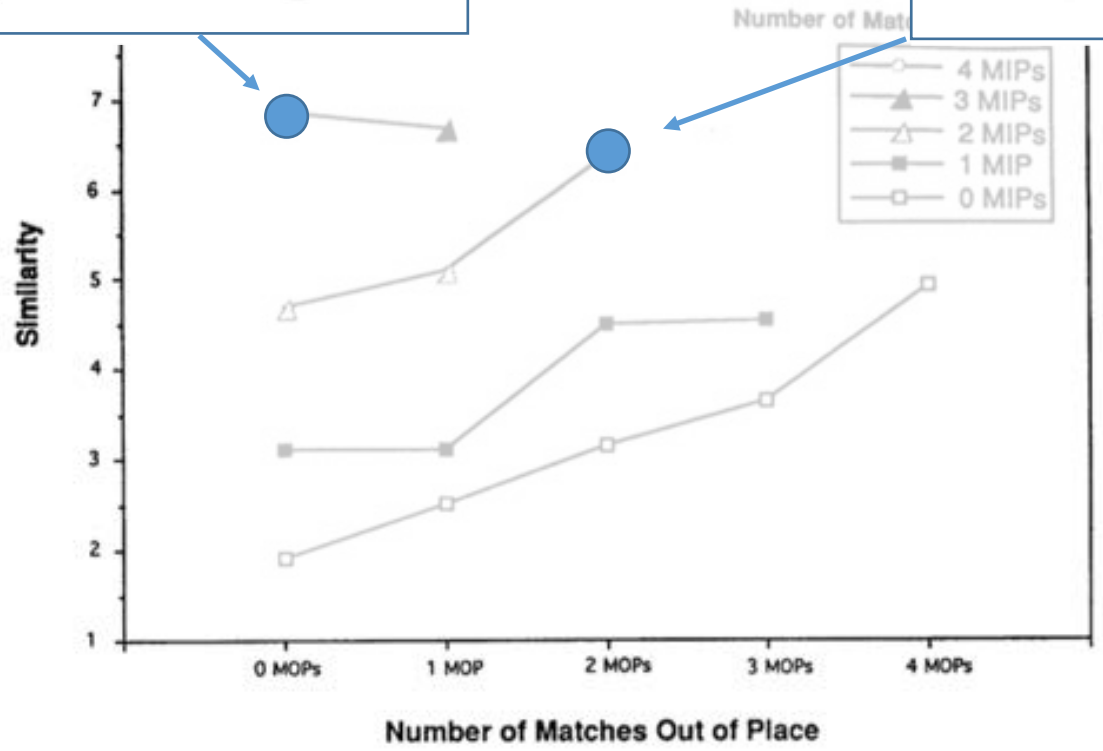
Goldstone (1994)

3 MIPS + 0 MOPS



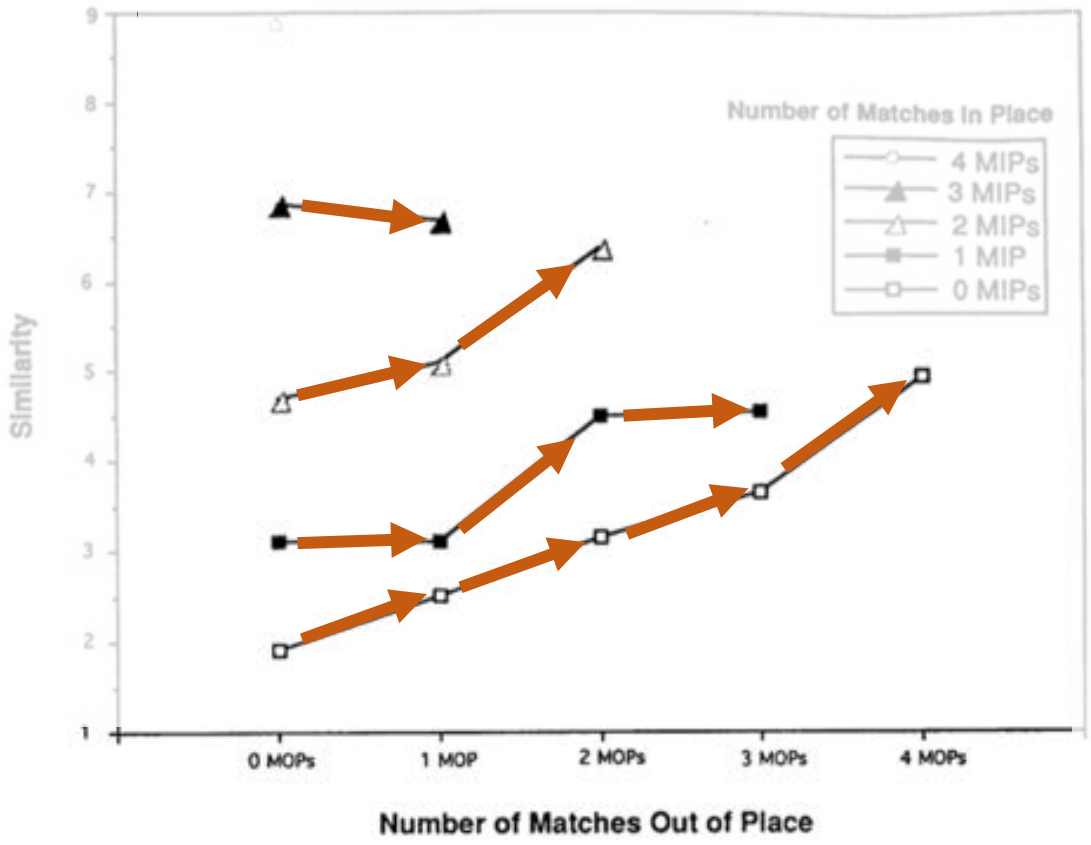


2 MIPS + 2 MOPS



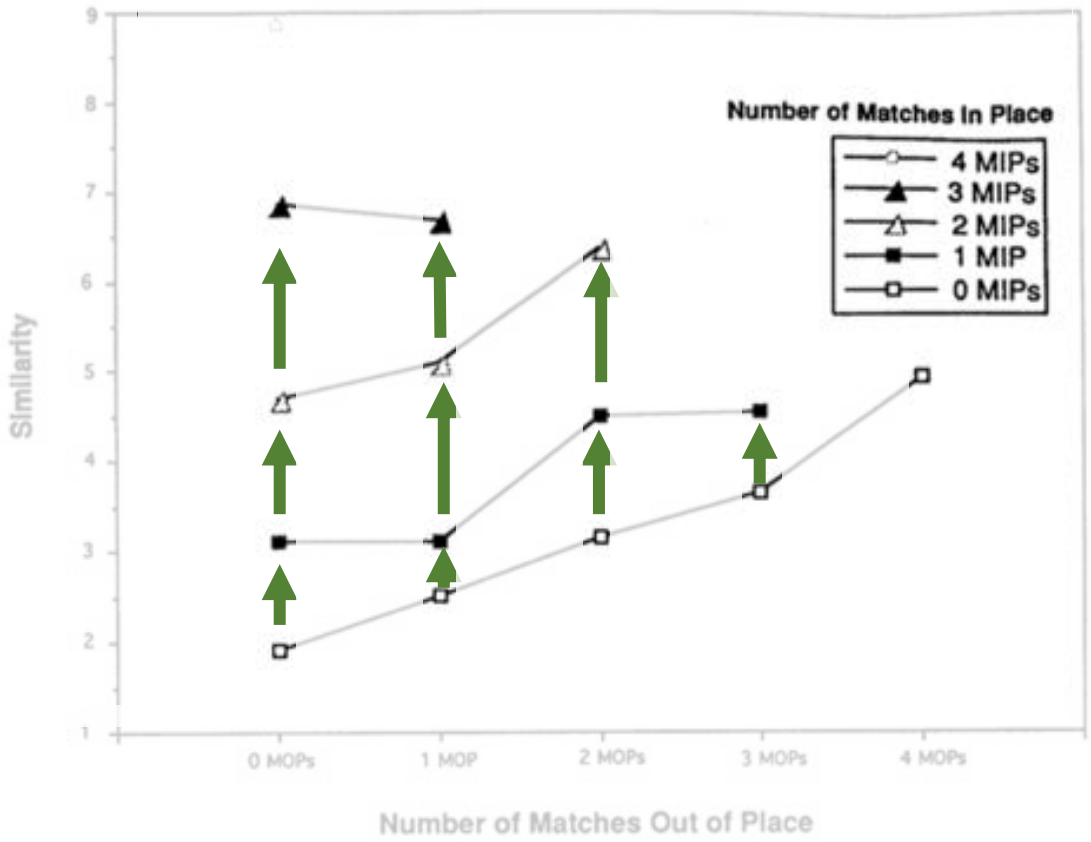
Goldstone (1994)

Adding a **MOP** causes similarity to increase



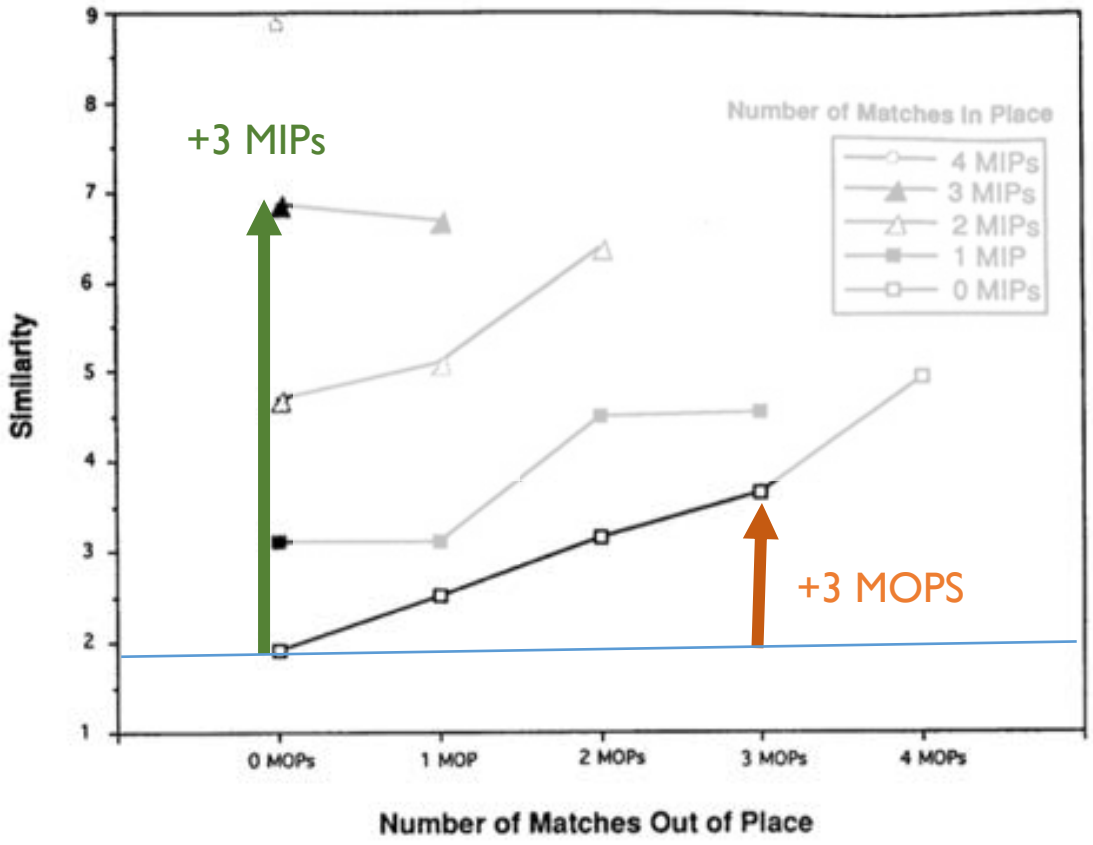
Goldstone (1994)

Adding a **MIP** also causes similarity to increase



Goldstone (1994)

Structure matters a lot!

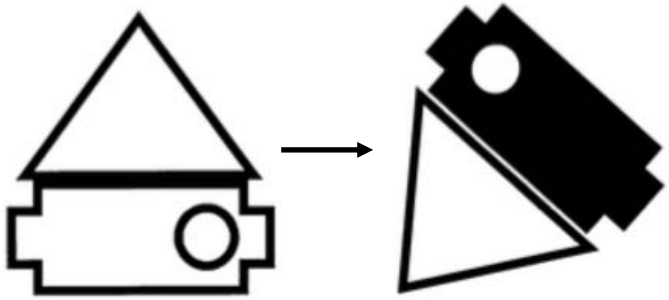


MIPs have a bigger effect than **MOPs**

Goldstone (1994)

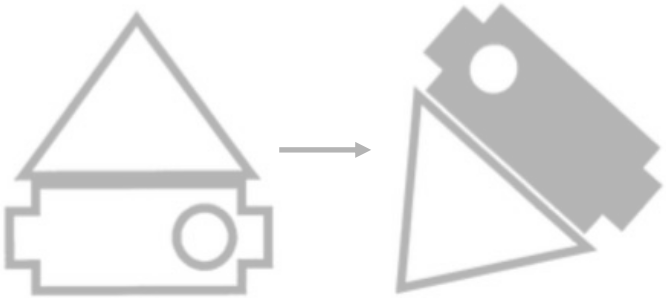
Richer theories of similarity II: Stimulus transformation

Similarity mirrors *processes*

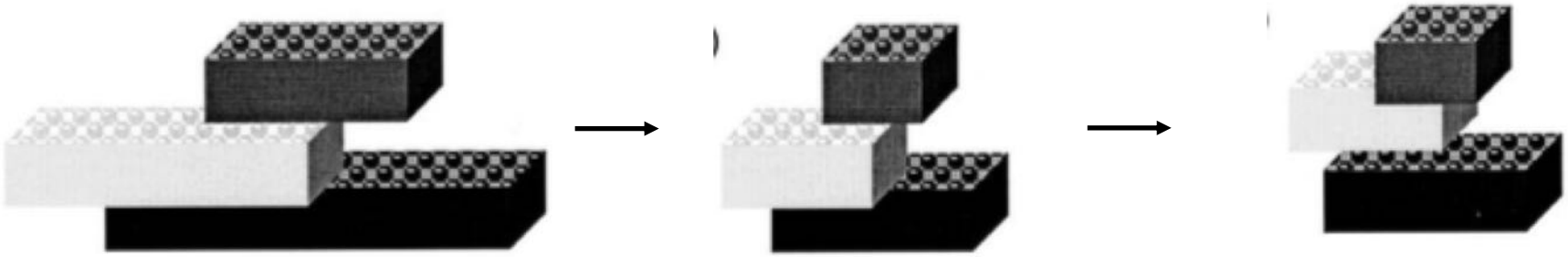


Rotate object, create black, apply black

Similarity mirrors *processes*



Rotate object, create black, apply black



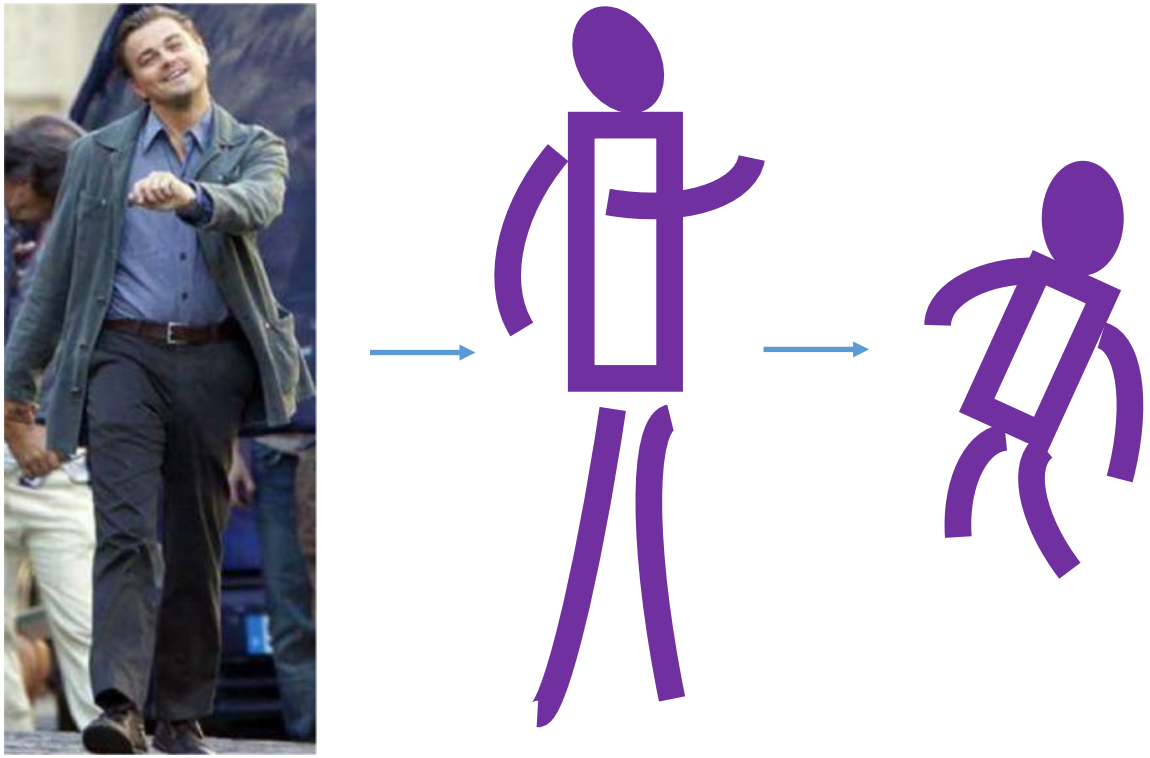
Squash

Split

Similarity mirrors *processes*

Delete the human

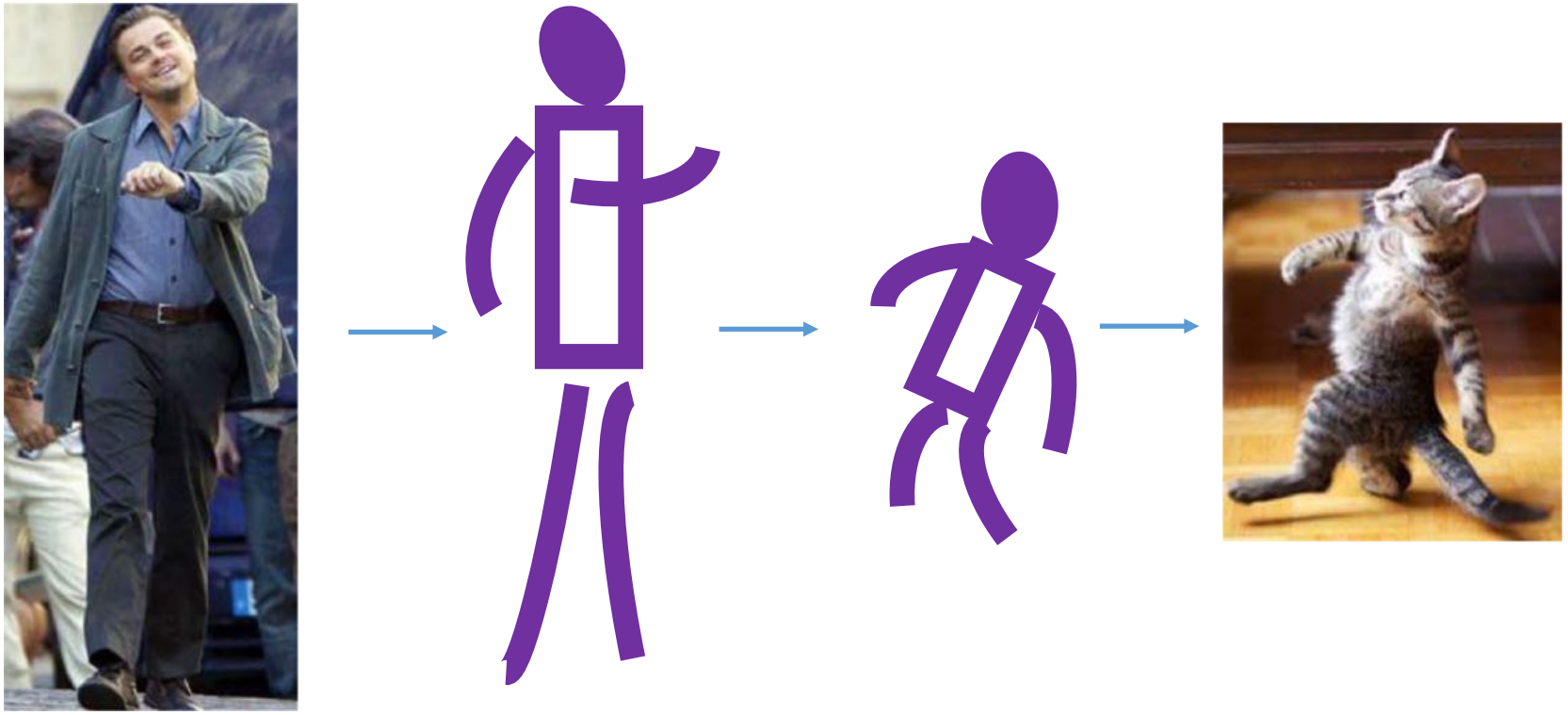
Similarity mirrors *processes*



Delete the human

Shrink and rotate
the skeleton

Similarity mirrors *processes*



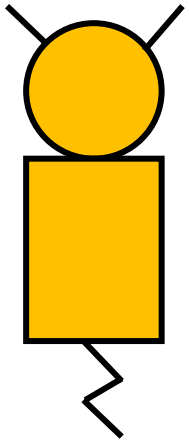
Delete the human

Shrink and rotate the skeleton

Draw the cat

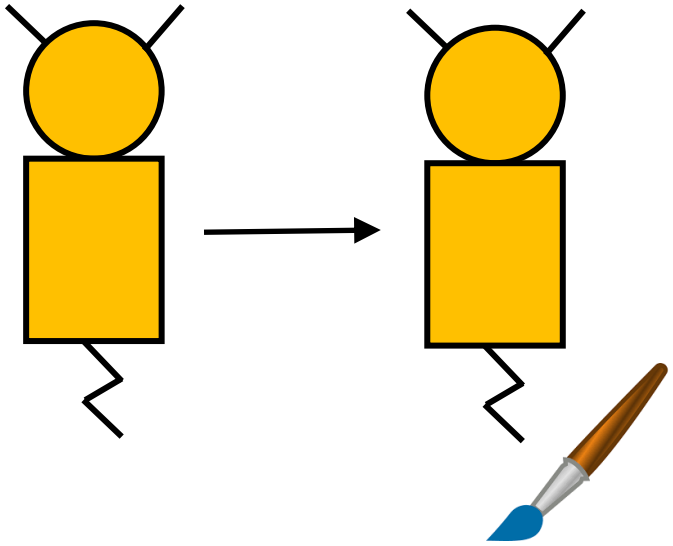
Stimulus transformations

Hahn, Chater & Richardson (2003)



Stimulus transformations

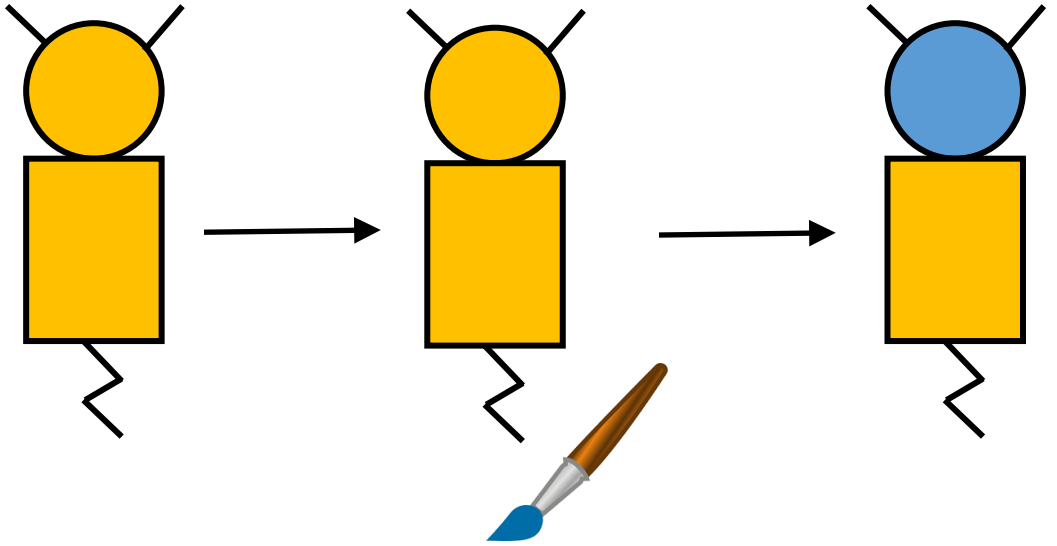
Hahn, Chater & Richardson (2003)



Step 1: "**create**" blue
from a mental palette

Stimulus transformations

Hahn, Chater & Richardson (2003)

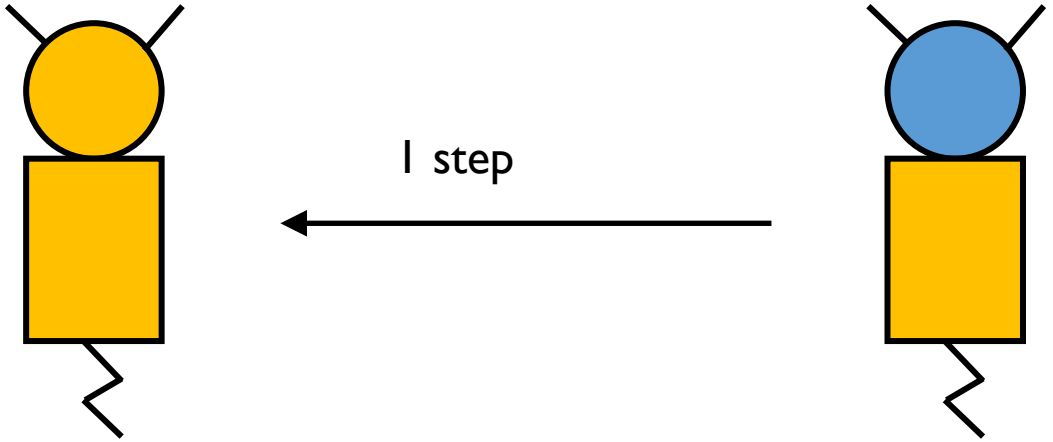


2 steps

Step 1: "**create**" blue from a mental palette

Step 2: "**apply**" blue where needed

Asymmetric similarity

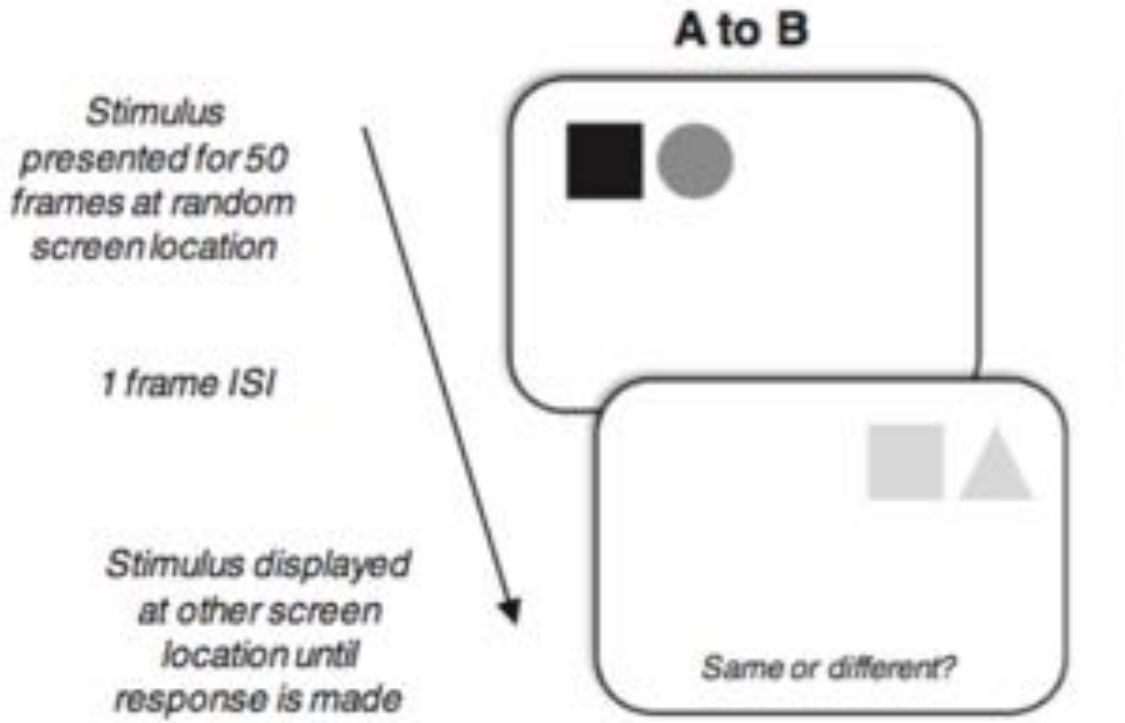


Going back the other way we don't need to "create" yellow because it's already there!

Recall:

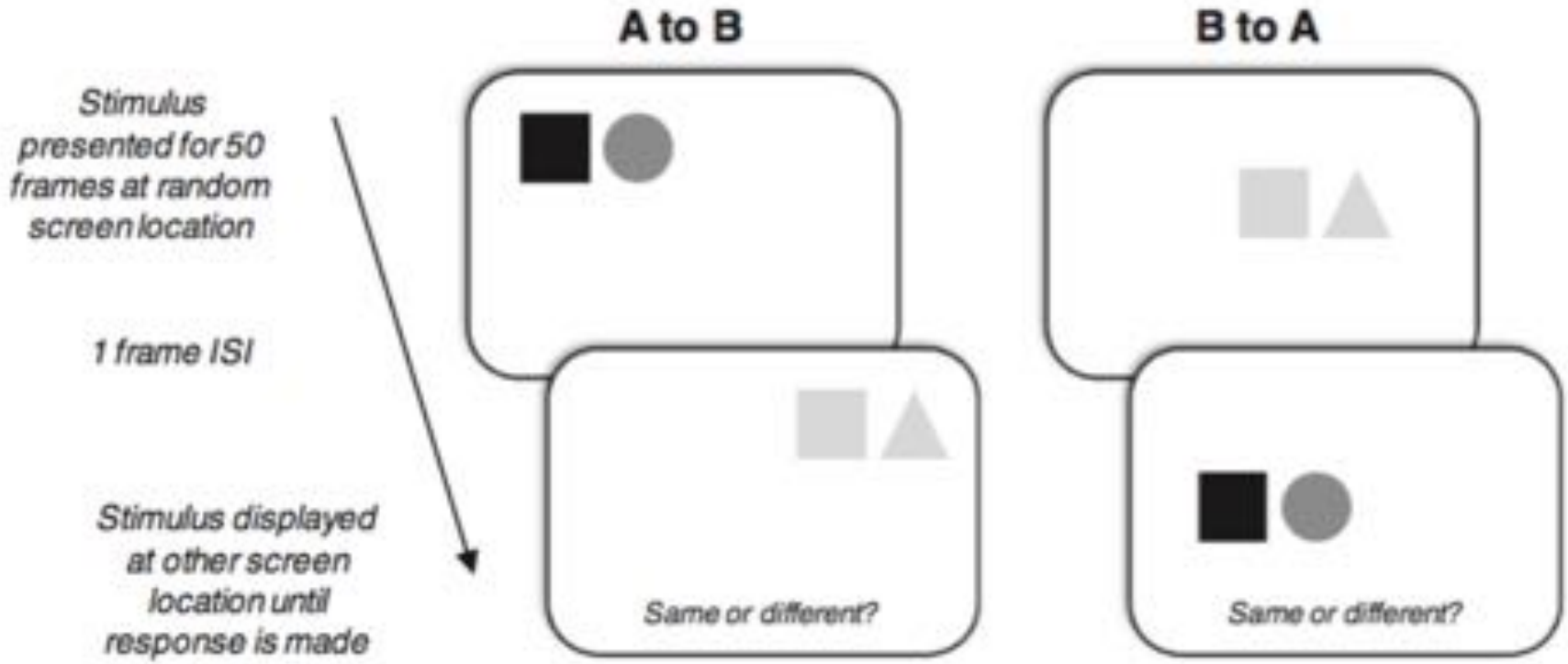
Hodgetts and Hahn (2012)

(speeded "same vs different" judgment)



Hodgetts and Hahn (2012)

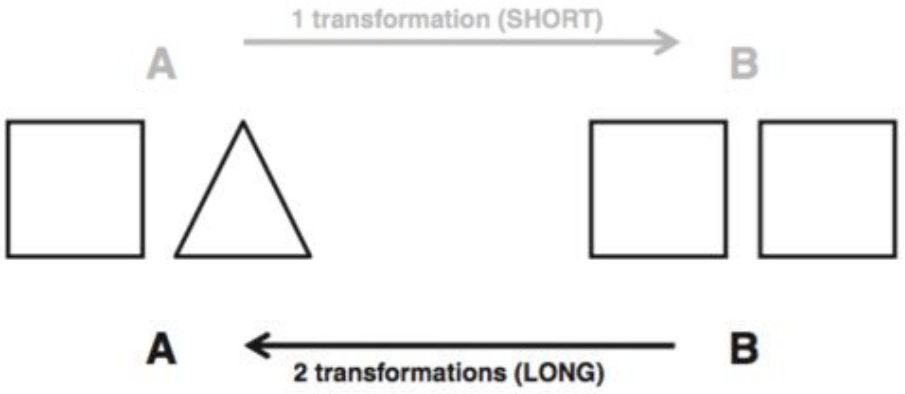
(speeded "same vs different" judgment)



Hodgetts and Hahn (2012)

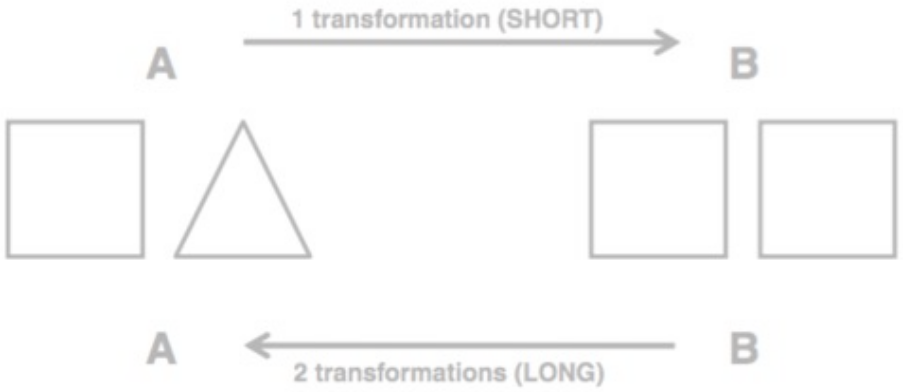
SHORT ⇒ more similar, more confusable, slower RT

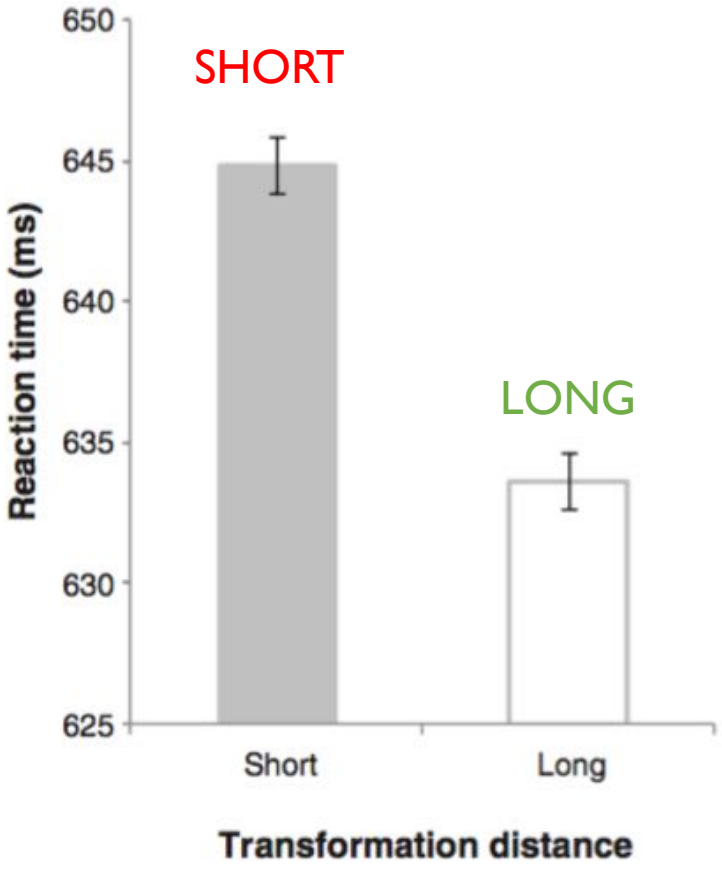
Hodgetts and Hahn (2012)



LONG ⇒ less similar, less confusable, faster RT

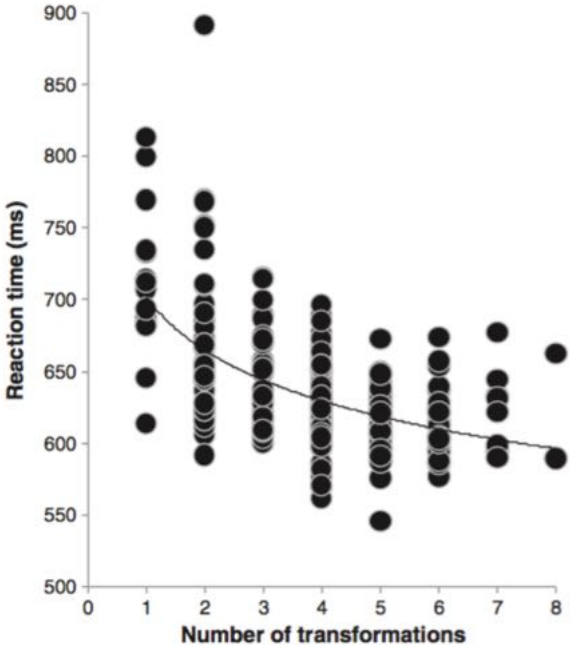
Hodgetts and Hahn (2012)

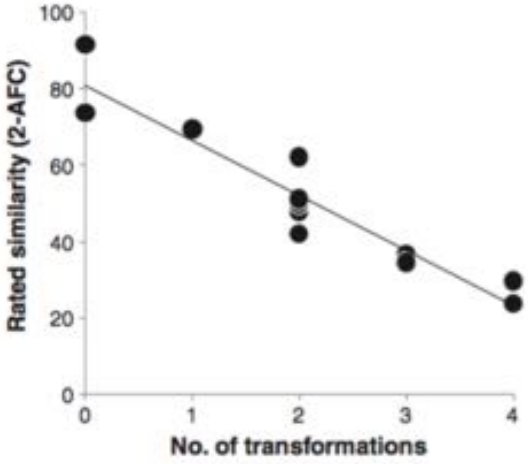


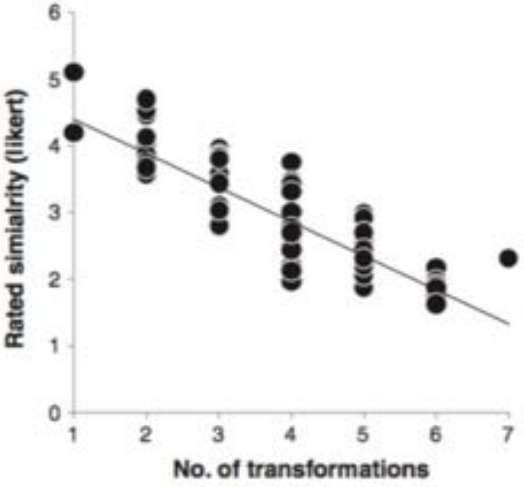


Various replications using different methods

(see Hodgetts & Hahn 2012)







Response time

Forced choice task

Similarity rating

Summary

- Intro
  - What similarity is
  - How it is measured
- Geometric similarity
  - "Universal" law of generalisation
  - Symmetry prediction
- Featural similarity
  - Asymmetry due to different knowledge
- Structure alignment
  - MIPs and MOPs
  - Goldstone experiment
- Stimulus transformation
  - Asymmetry due to different structure
  - Hodgetts & Hahn experiment