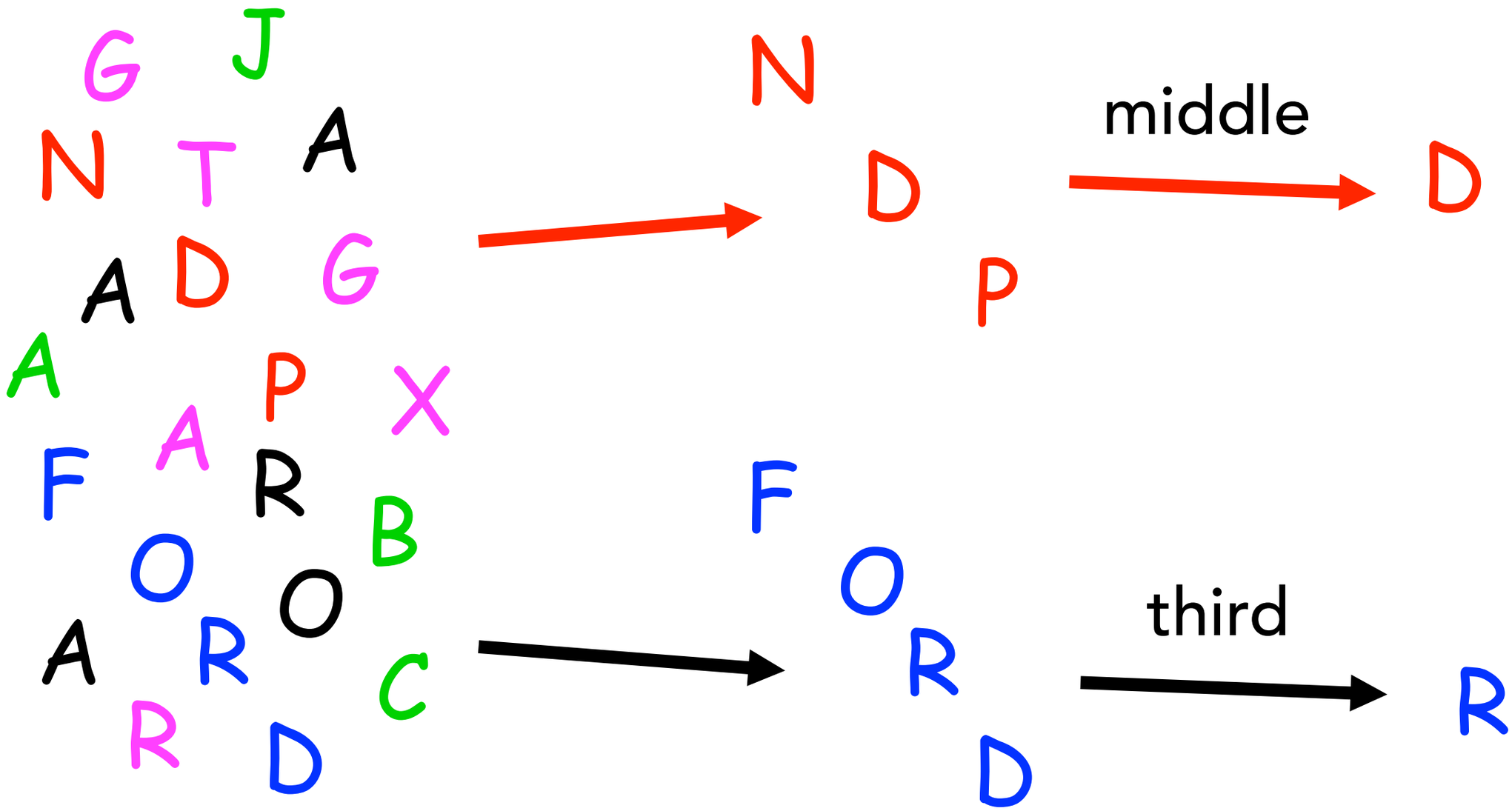
The Language of Vision

Patrick Cavanagh
Glendon College

Attention = selection



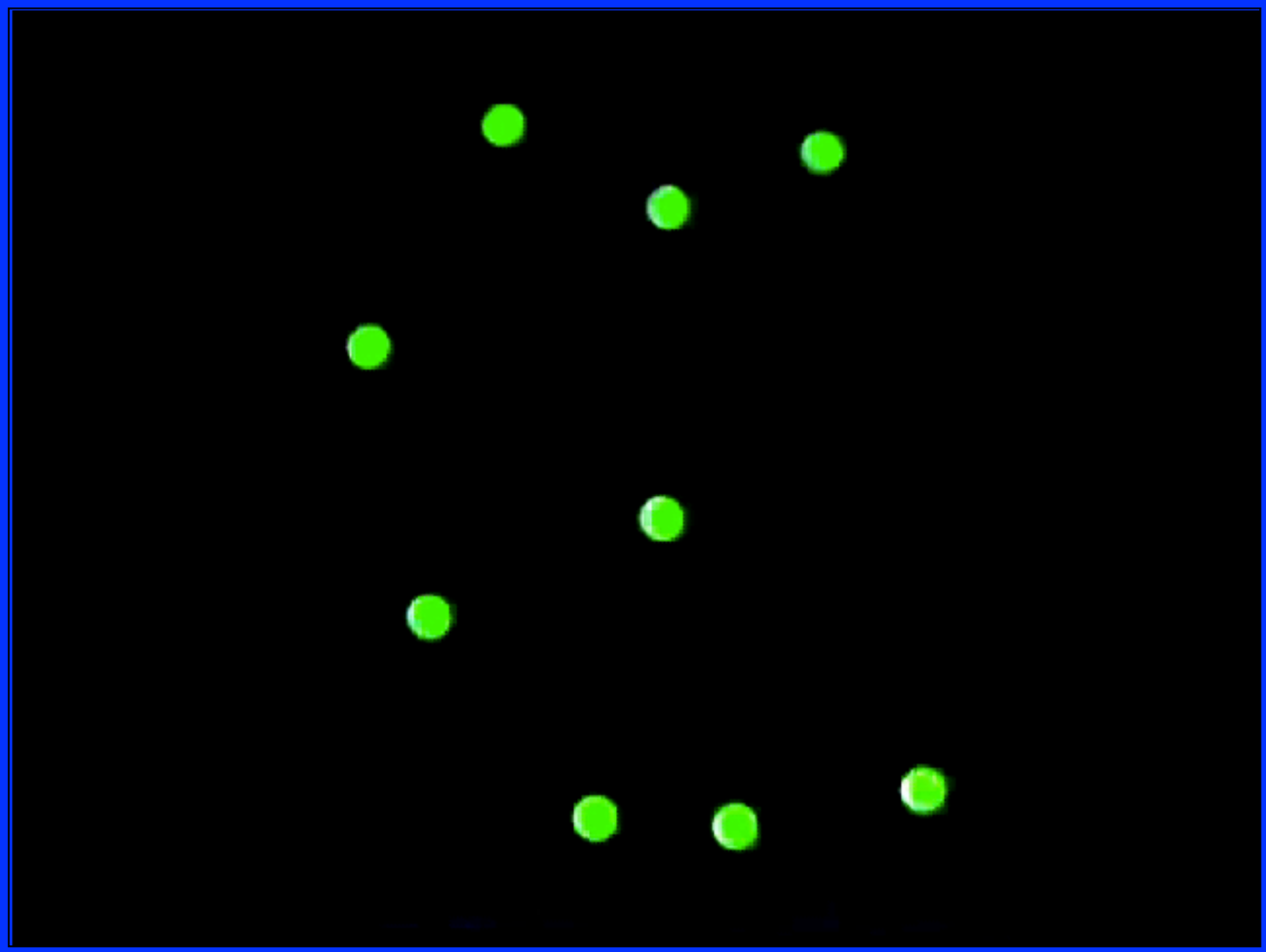
Selection
by color

Selection
by location

Multifocal Attention

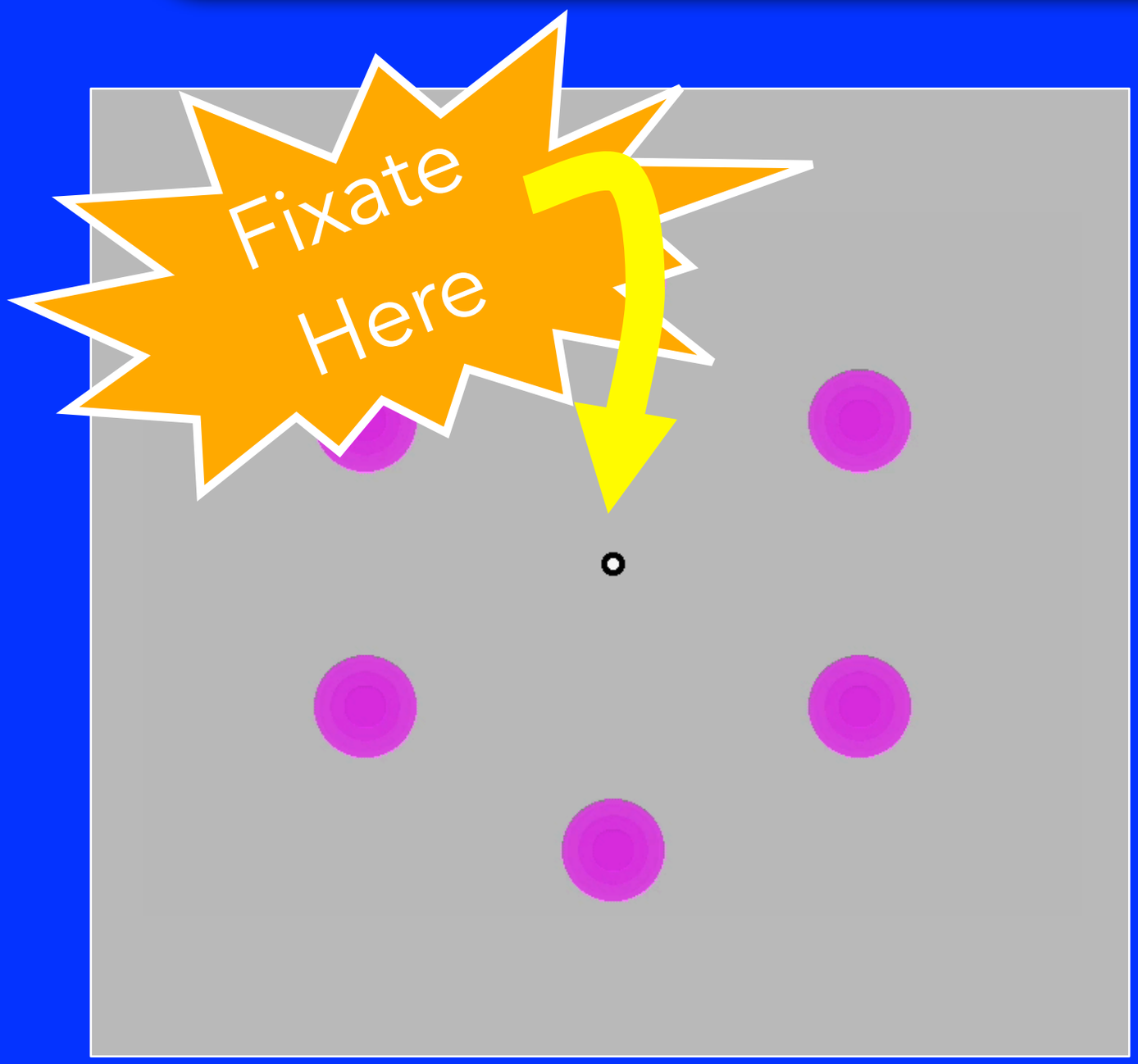
Classically, single focus of attention

BUT most subjects can track 4 or 5 targets

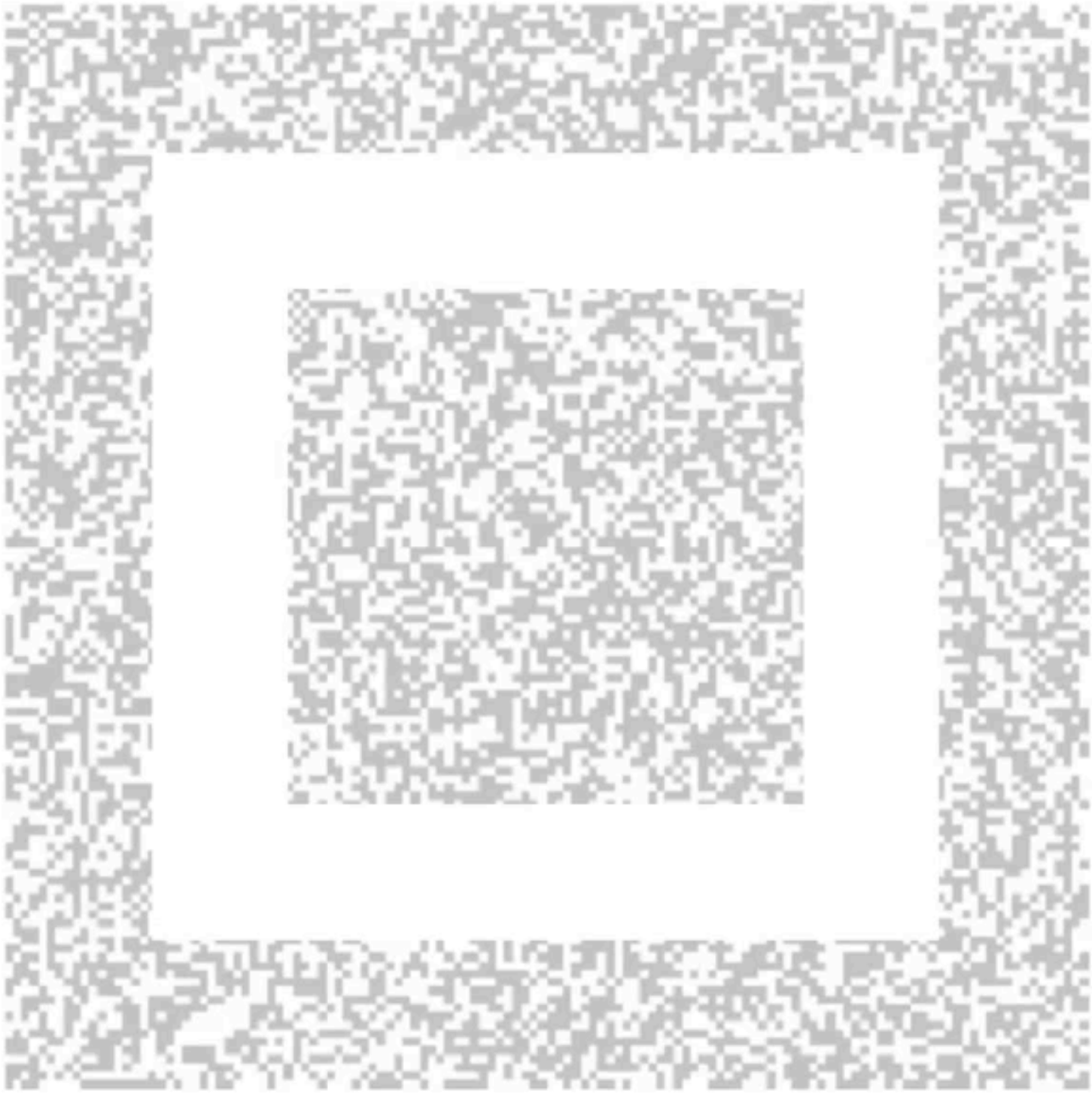


Pylyshyn &
Storm, 1988

Use moving attention to isolate and integrate brief events



Example: Inspect the afterimage of a rapidly flickering target without attending to the target



The Language of Vision

Vision exports descriptions to other modules in the brain

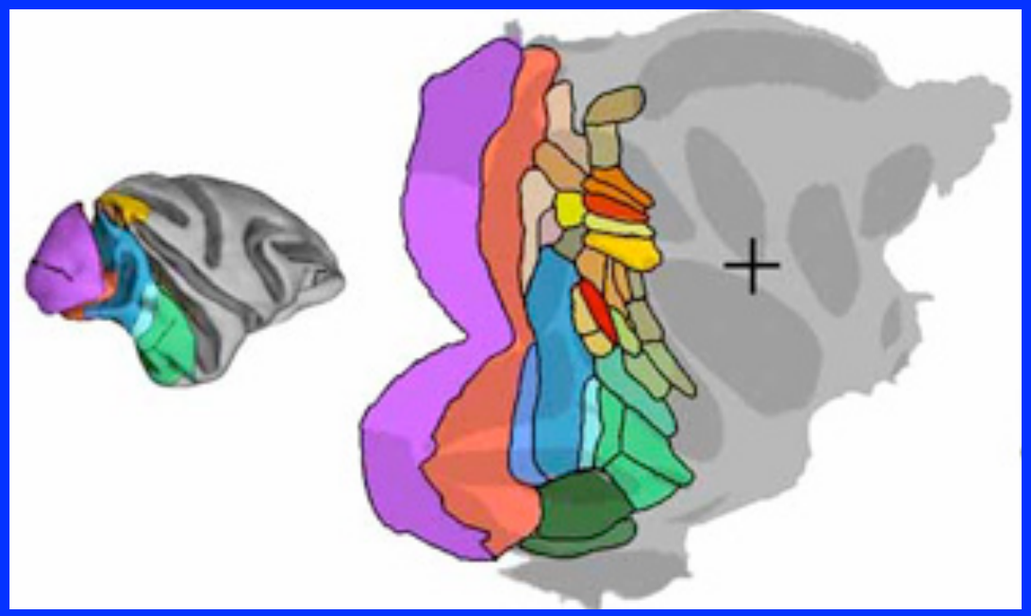
– Jackendoff, Mandler, etc.

The format is a language

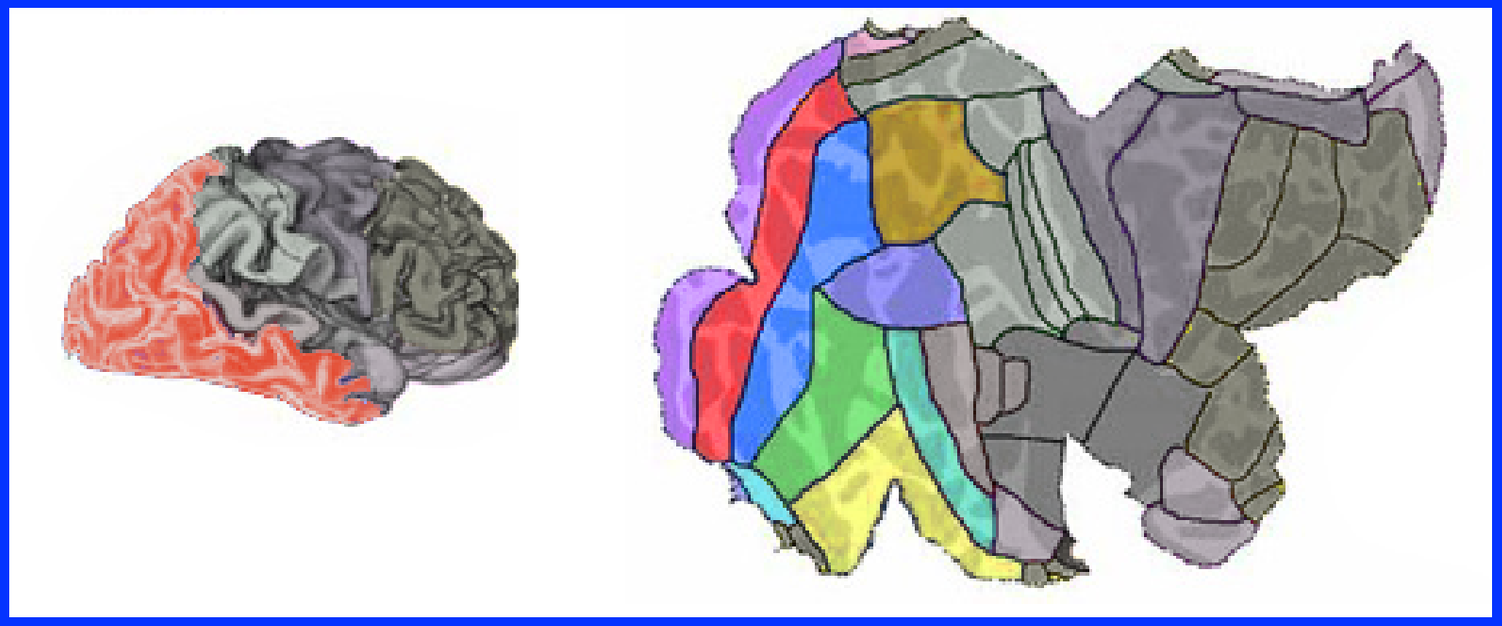
– Fodor, Logan, Sereno

Language transmits conceptual representations from one person to another

Modules



Monkey
Visual
Cortex



Human

Central routing

"Attentive" Narrative System

Scheduling Overhead

Auditory task

Vision

Daydreaming

Franconeri, Alvarez, & Cavanagh, TICS 2013

Planning

Emotions

Real Language

Declarative Memory

Other Senses

Selection

Primary Visual System

Other "low-level" channels

eg

Motor System

Retinal Input

Similarities between language and vision

Both describe the properties of the same world

How does vision communicate with the rest of the brain?

Who does the talking

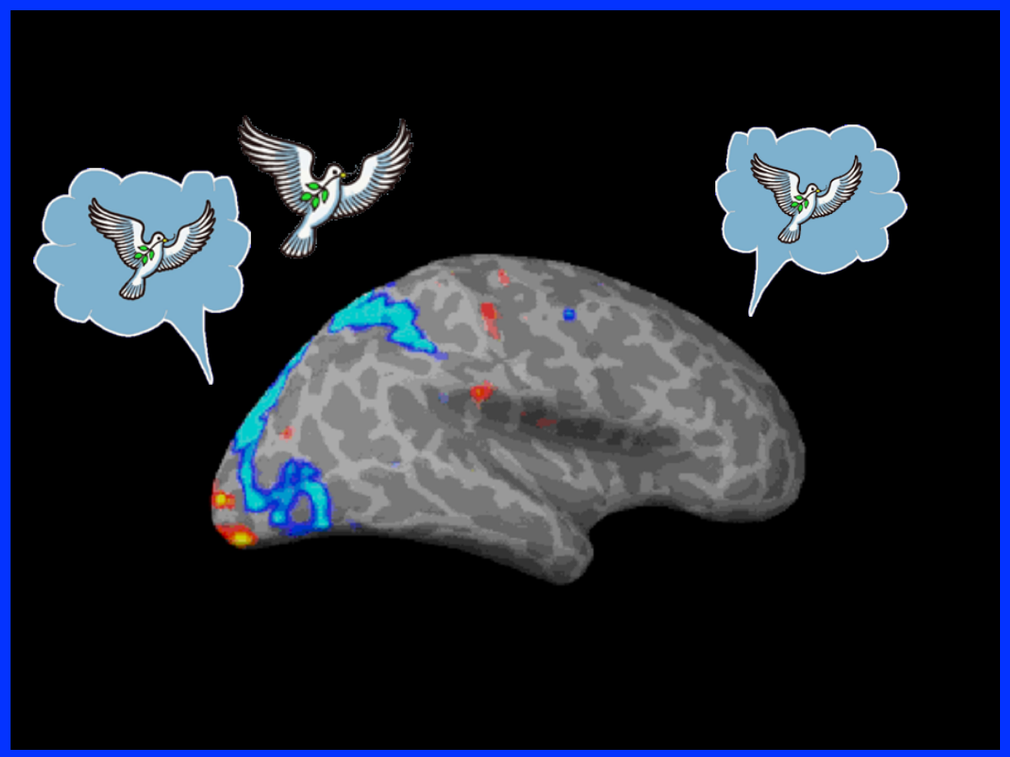
→ pre-attentive vision

→ visual attention

Who is listening

→ other brain modules

How does vision communicate with the rest of the brain?



What is the message?

Pictures and movies?

Labels for events?

Formatted, language-like description?

(Gregory, Sereno, Fodor, Logan, Miller & Johnson-Laird)

Properties of Language

compositionality / productivity:
combinations produce unbounded set of descriptions

arbitrariness: no link between symbol and referent

displacement: reference to something not present

recursion : the man’s lips; the man who was running fell

Why Language?

If not pictures, how about labels?

Label each event with a different symbol

A closed set

e.g., Monkey danger, leave, food calls

With more labels, probability of forgetting increases

Effective limit of Q labels

Why Language?

Event a combination of two labels: NV

Now describe $(Q/2)^2$ events

More efficient but requires grammar
(Nowak et al, *Science*, 2001, *Nature*, 2002)

“Language” not an option, it is the only choice

What is the visual narrative?

Perhaps only “conscious vision” is broadcast to other modules

Only attended content

Description sent out (to memory, language, planning) is then low-bandwidth

Evidence: Change blindness

(Rensink, Simon, O’Regan)

Language of Vision

- Nouns = objects
- Verbs = actions
- Prepositions = spatial, temporal relations

Language of Vision

Jim throws the rock at John

noun verb noun preposition noun

Red knocks green into black

Nouns

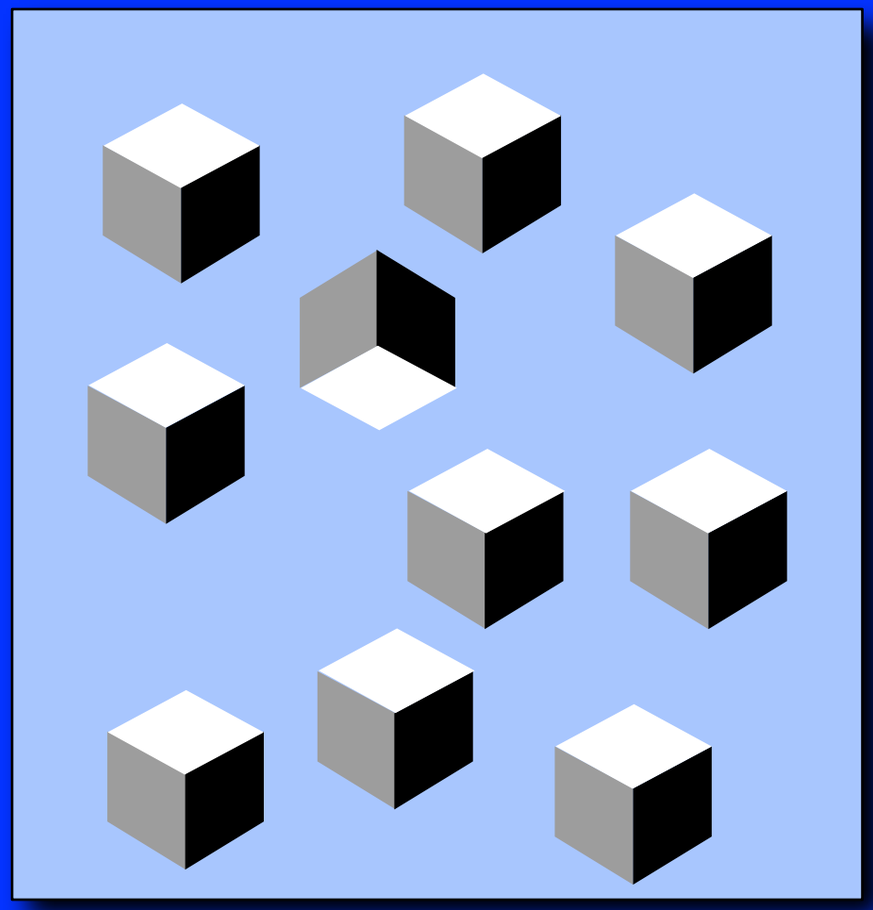
Vision is knowing what is where by looking (Marr)

Many objects rapidly labeled by visual system.

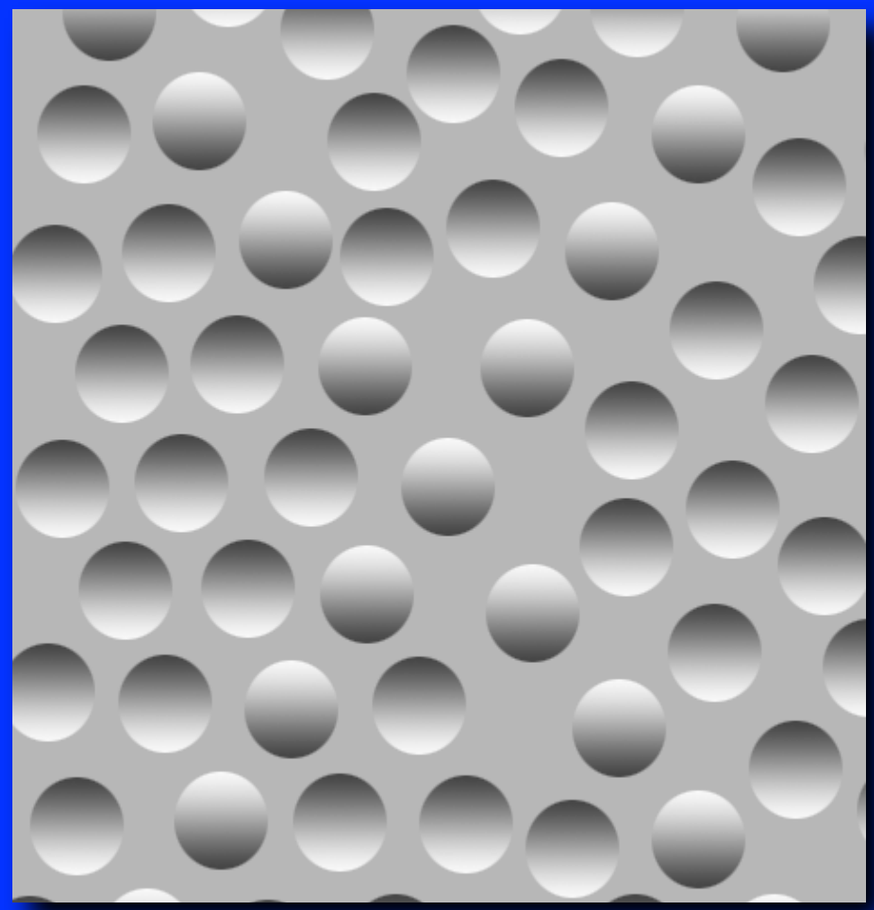
Brady, Konkle, Alvarez & Oliva. Visual long-term memory has a massive storage capacity for object details. PNAS, 2008.

Nouns

Some objects identified rapidly, in parallel, pre-attentively



Enns & Rensink, *Science* 1992



Klefner &Ramachandran, 1992

Nouns

Visual “nouns” may be labelled pre-attentively.

They are labels for the objects not pictures of them.

Vision has verbs

Tenses: past (motion), present, and future (intentions)

Verbs (familiar actions, “sprites”) are identified by integrating patterns across time --> slow

Reusable: Mary walks, John walks, Dots walk

Not available in primary vision

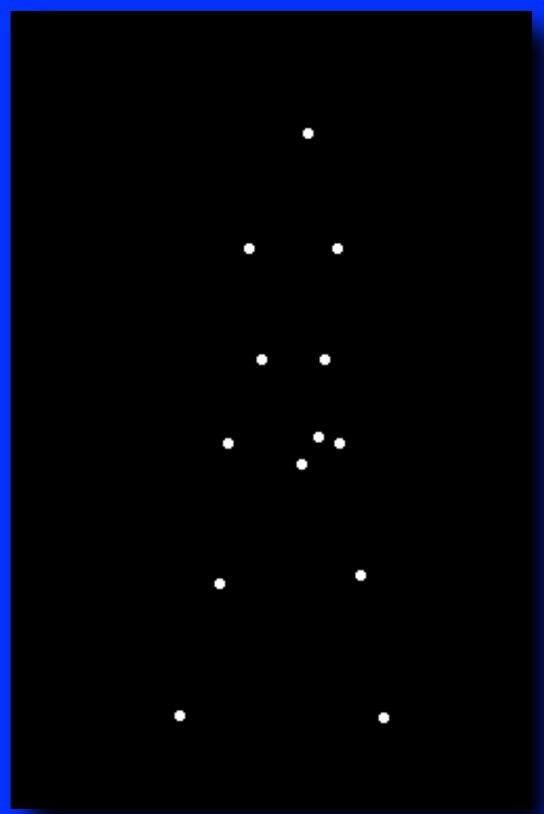
Are they visual or cognitive inferences?

Familiar Action Units: Sprites

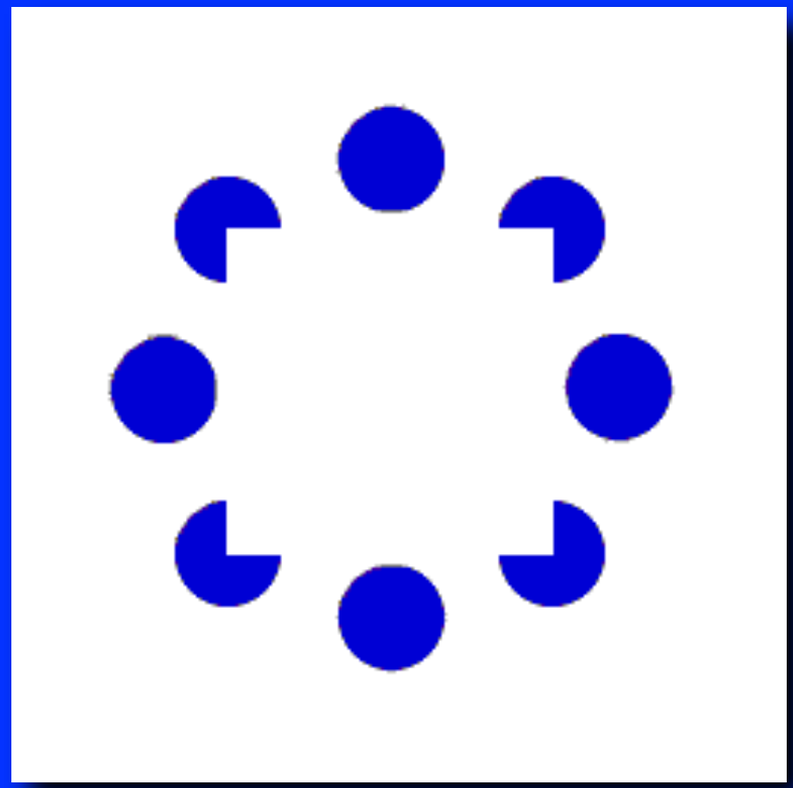
Cavanagh, Labianca, & Thornton, 2001

Flexible descriptions which embody object constraints

Online animation to fit changing image data



Reusable: Mary walks, dots walk



OR

Choice of trajectory

Like recognizing and following along with melodies

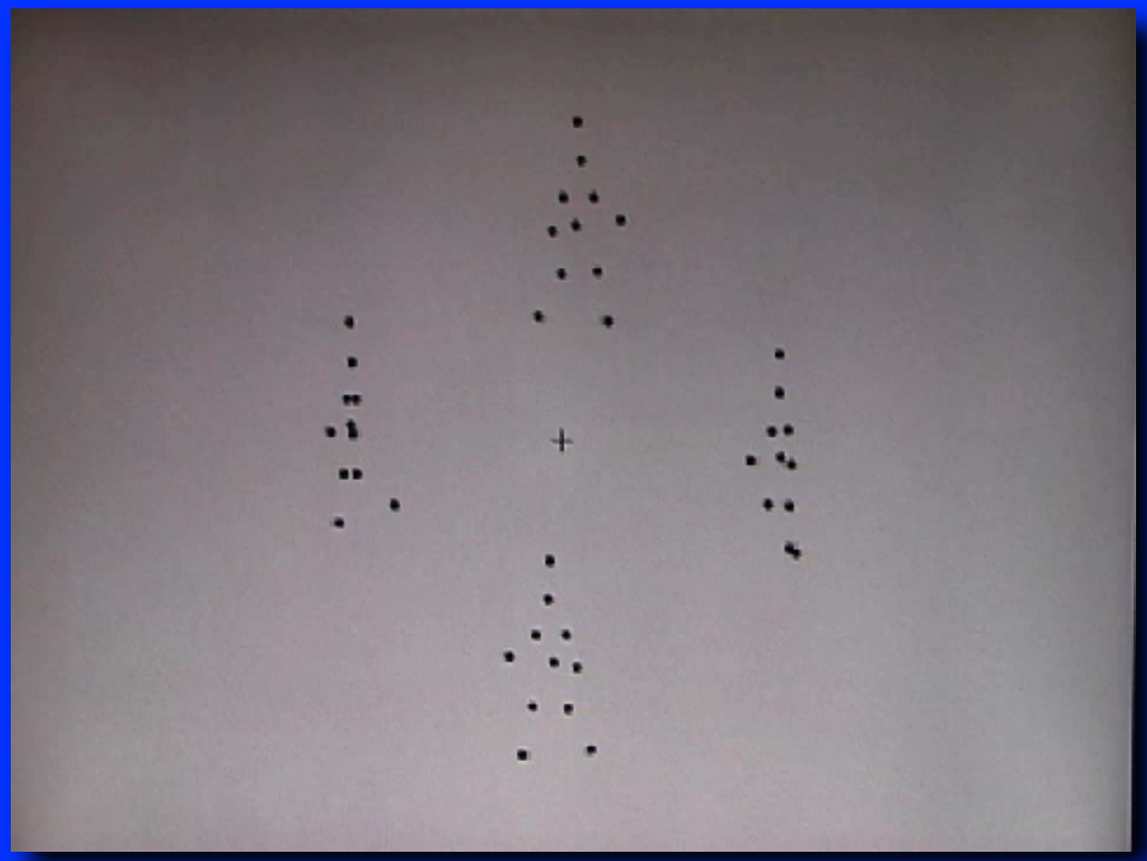
Once triggered, memory fills in any gaps

Sprites are the units of high-level motion, the “verbs of vision”

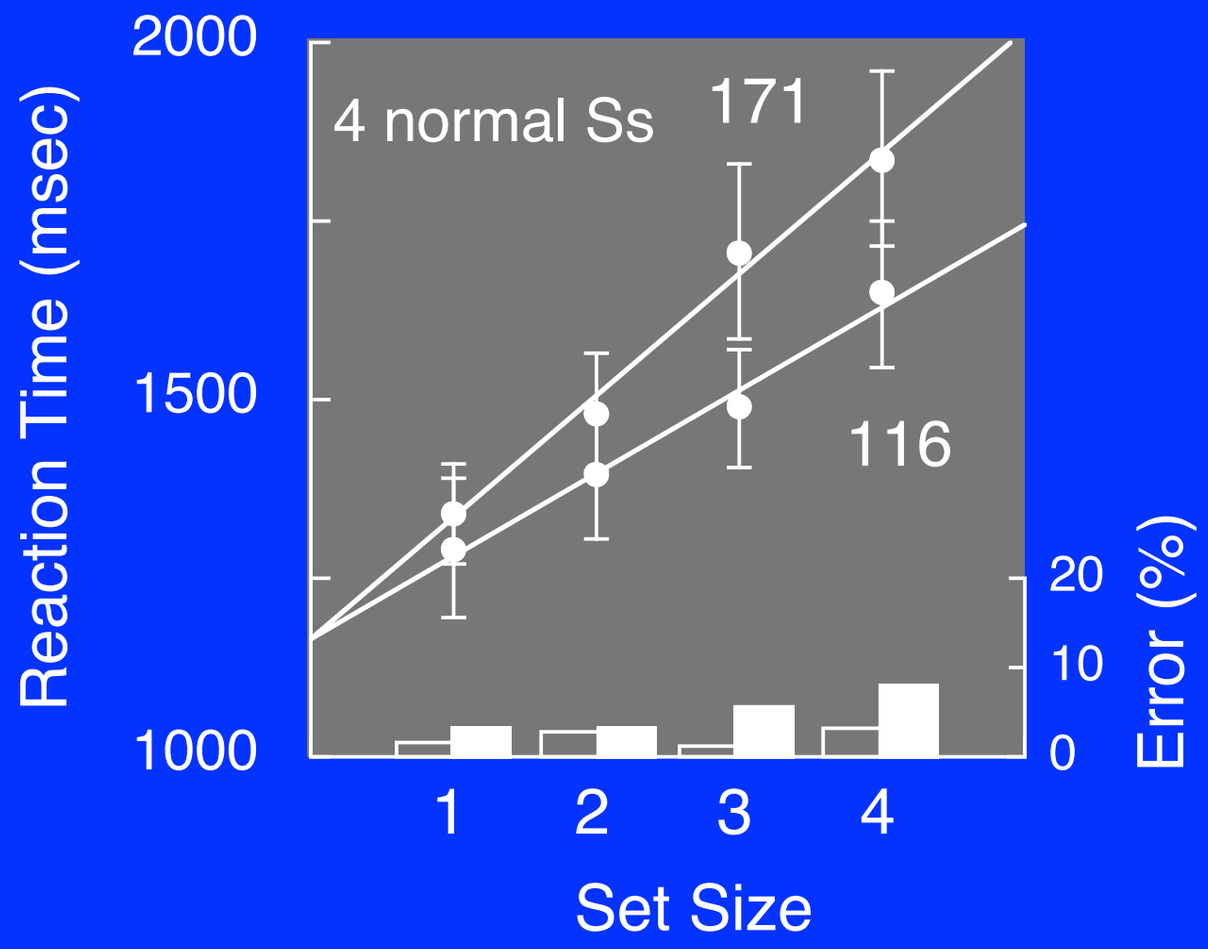
Rather than the left, right, up and down, etc of low-level motion

--> Roll, bounce, slap, break, flutter, glide

Can we process several "verbs" at once?



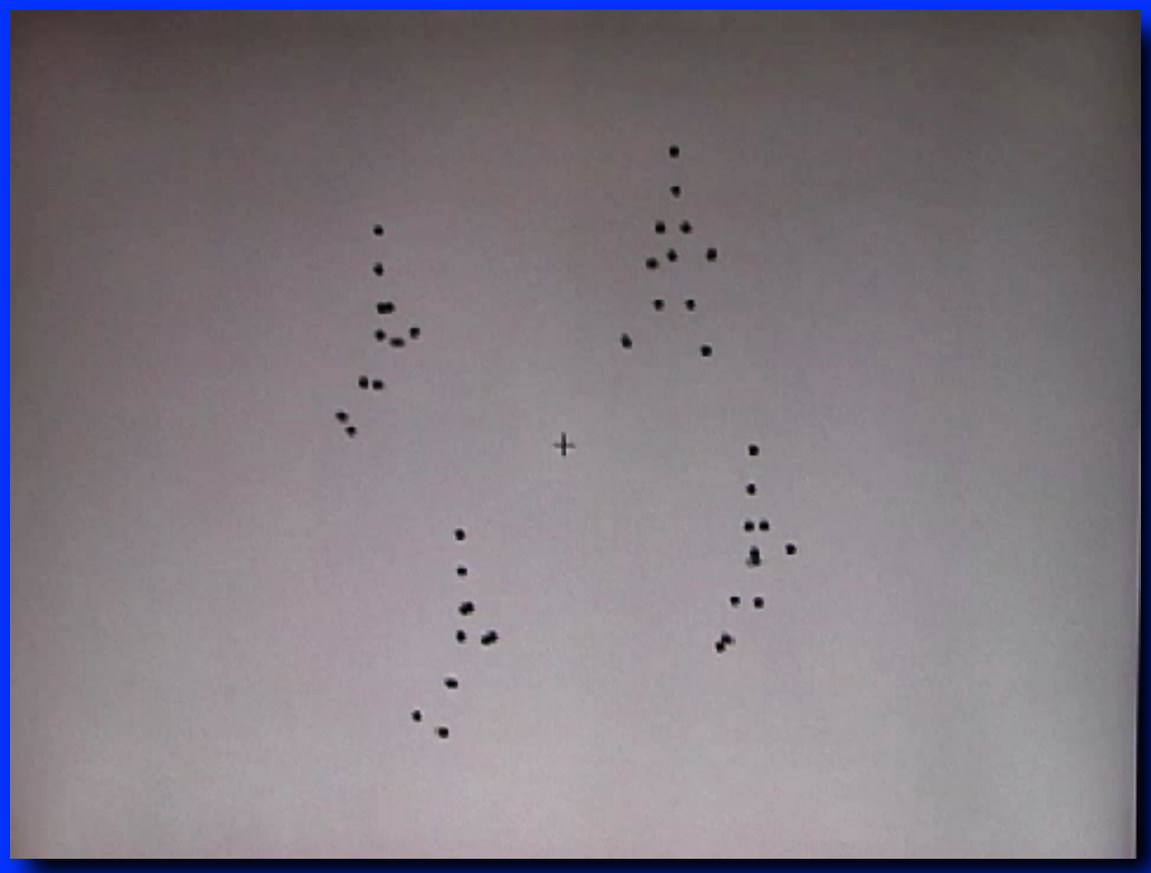
Visual search task:
Find rightward walker among leftward



Search is slow

Cavanagh, Labianca, & Thornton, 2001

Verb: Walk



Find walker among scrambled figures

In both cases, identifying walker requires attention.

Verb tense: present progressive

Perceiving motion includes a comparison between the present and the past

Present progressive?

Past tense

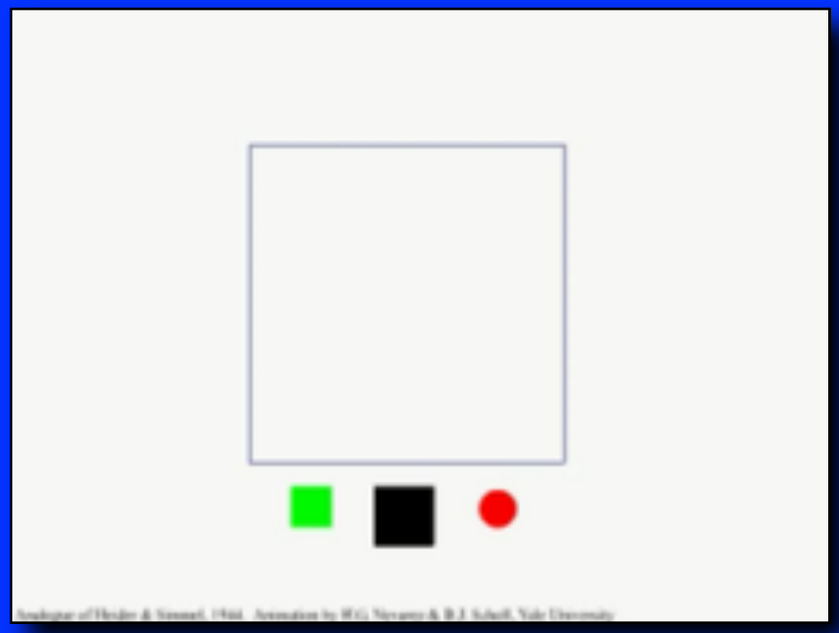
Terminated motion or action: past tense

Visual or cognitive?

Future

Visual or cognitive?

Intentions & Agency



Goals guiding current and future action.

Cause and effect.

Tenses, intentions, and causality: are these visual computations, or cognitive deductions?

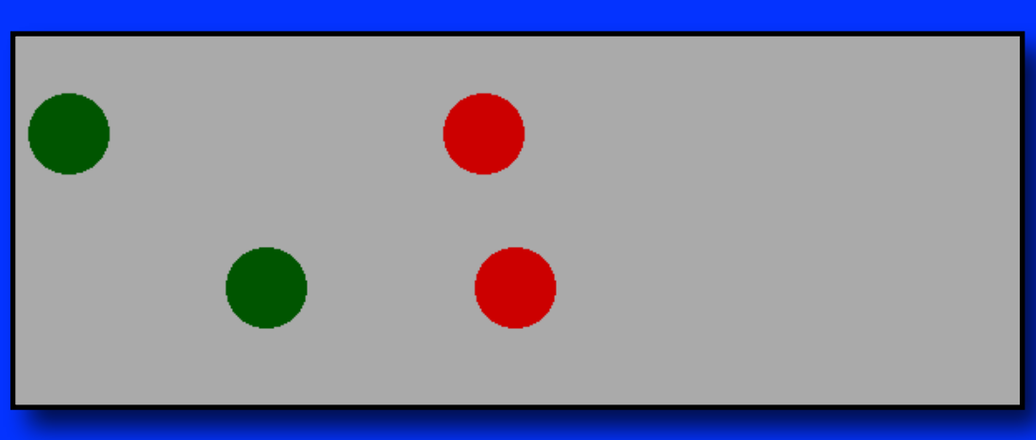
Most likely visual, at least for causality

(Rolfs, Dembacher, & Cavanagh, Curr Bio, 2013)

Visual adaption of the perception of causality

Rolfs, Dambacher, & Cavanagh, Curr Biol, 2013

Causality

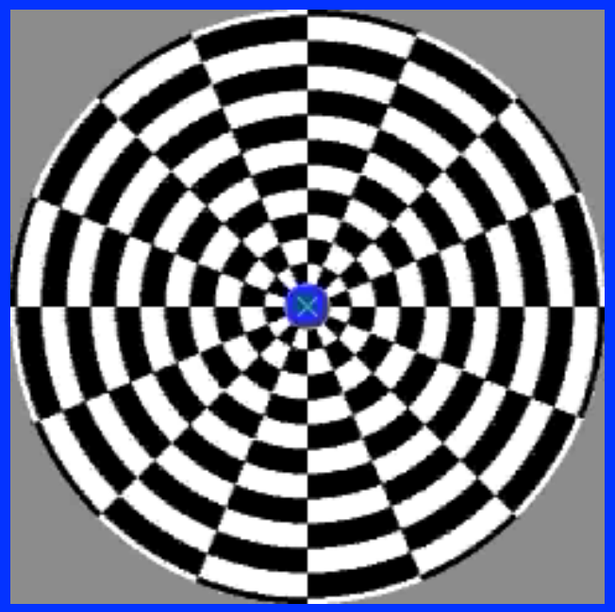


pass vs collision events
noncausal vs causal

How can we tell if this is visual?

Visual adaption of the perception of causality

Rolfs, Dambacher, & Cavanagh, Curr Biol, 2013



Visual computation: show adaptation

Extended exposure

Effect is negative and local

Moves with eyes (retinotopic)

vs cognitive processes

Repetition: learning, priming, or boredom

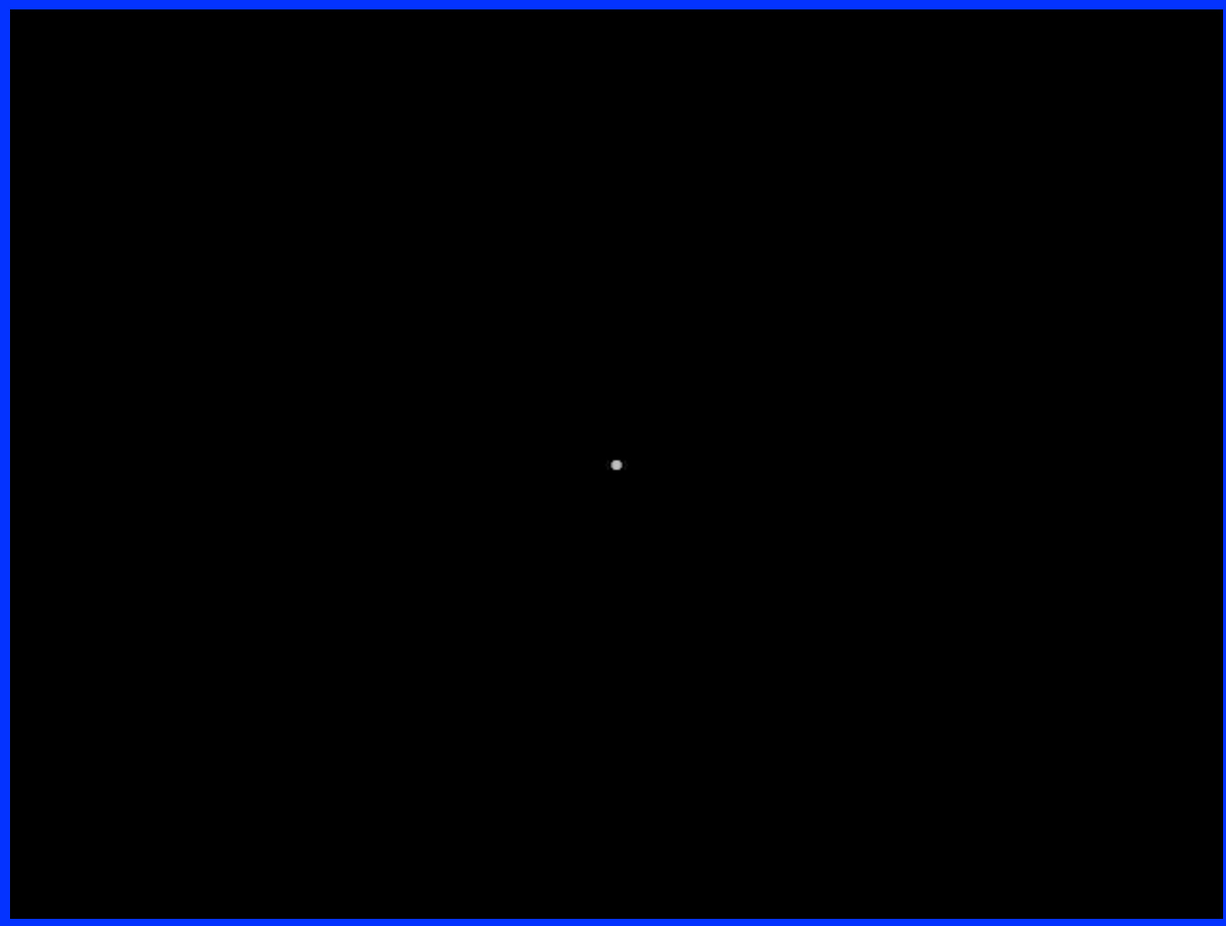
Effects are global

Do not move with eyes

Visual adaption of the perception of causality

Rolfs, Dambacher, & Cavanagh, Curr Biol, 2013

Causal adaptation stimuli, launching

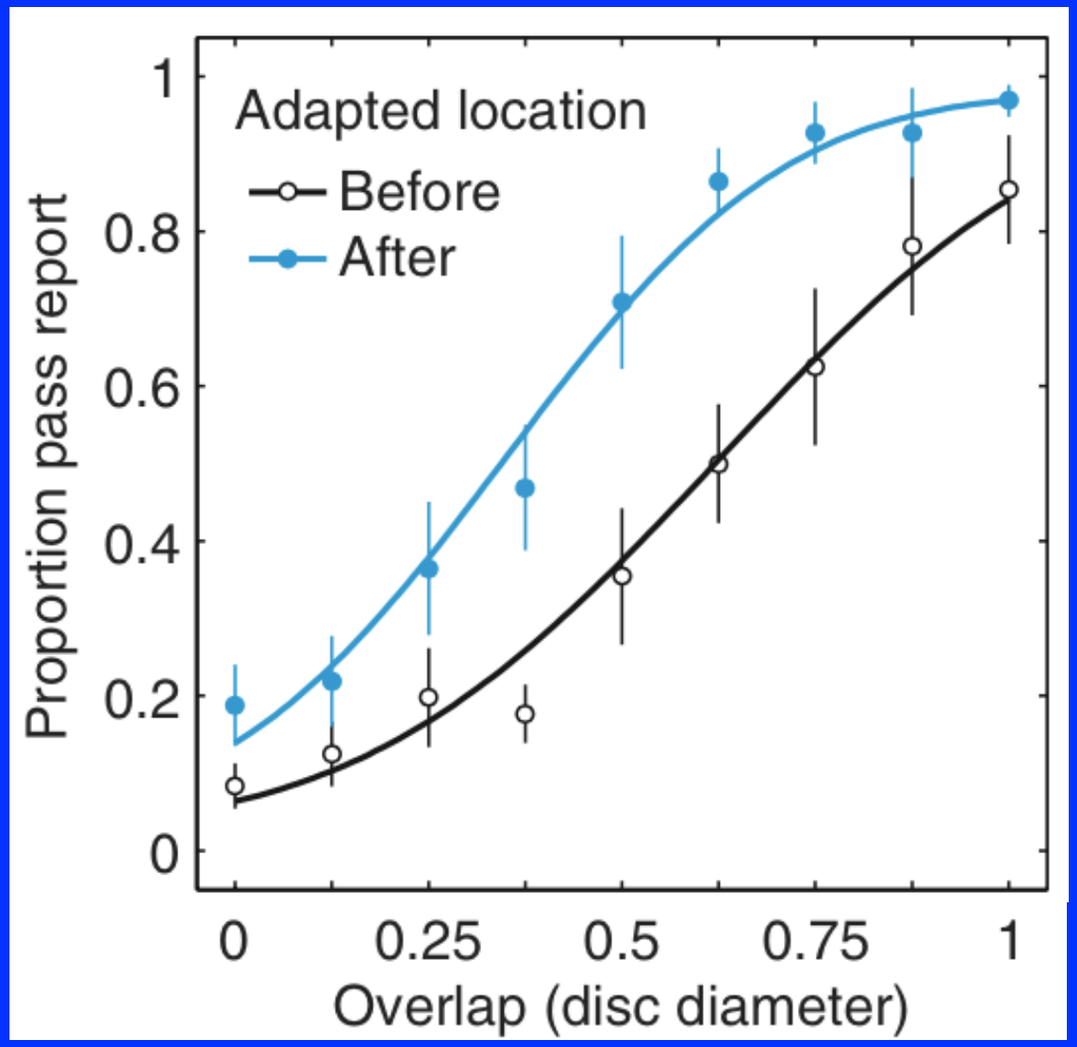


Ambiguous tests

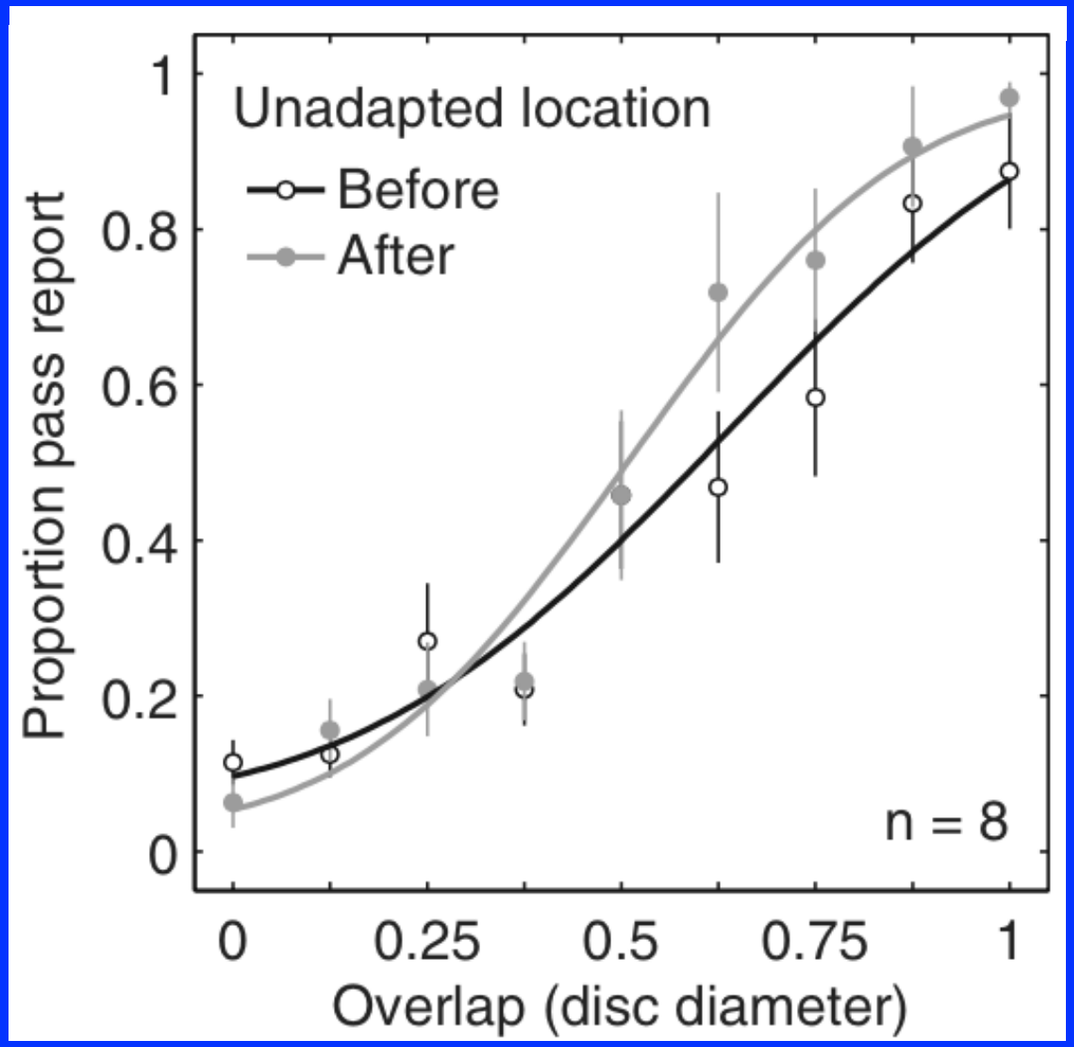
Various amount of overlap

Visual adaption of the perception of causality

Rolfs, Dambacher, & Cavanagh, Curr Biol, 2013



Adaptation to causal events made tests appear less causal



Critically, only at the adapted location

Vision has verbs

Visual verbs have some tenses: past (motion), present, and future (intentions)

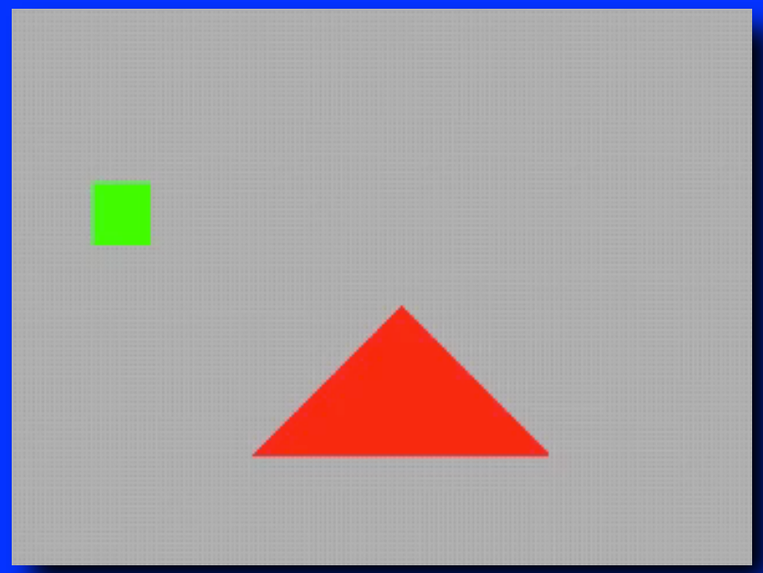
Verbs require attention: one at a time

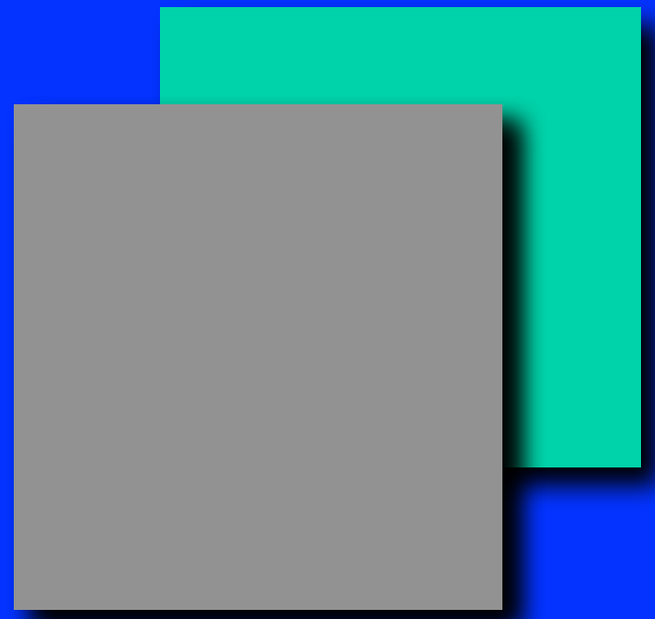
These may be visual computations, not general cognitive inferences

Prepositions

Spatial and temporal relations between two selections.

Prepositions

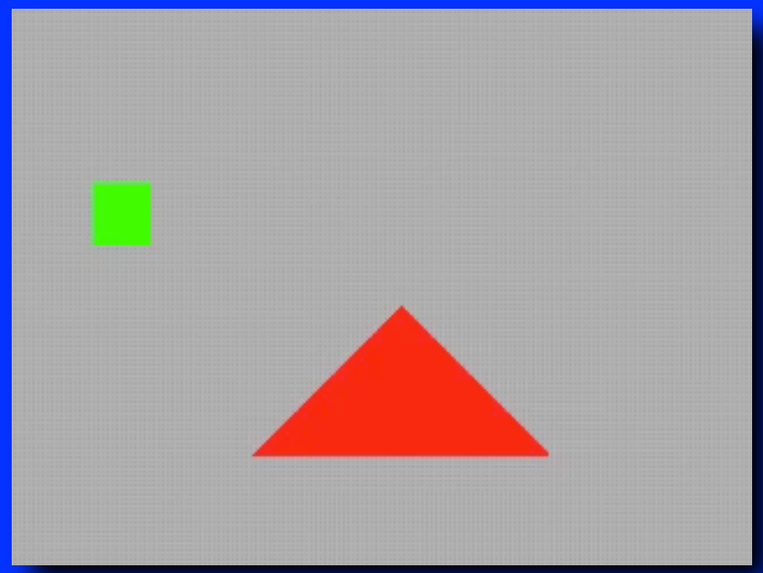


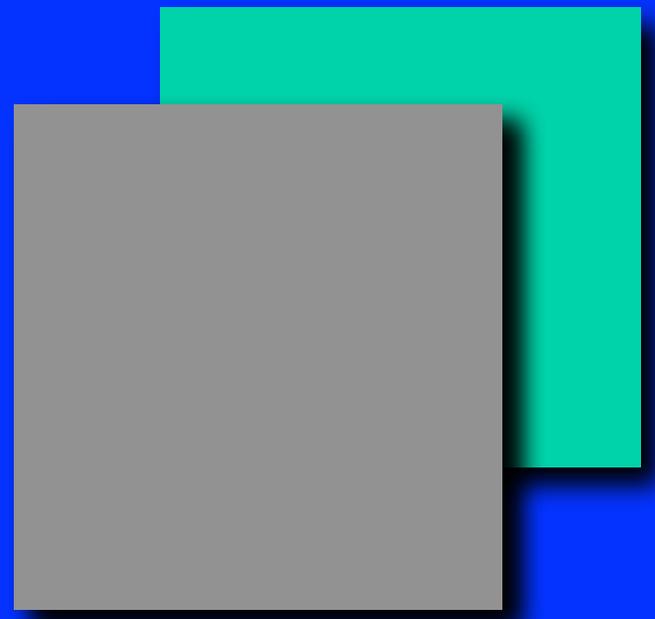


Michotte, 1954

Behind: Tokens in the visual description refer to an item that is not present, occluded

Prepositions





Michotte, 1954

Behind: Tokens in the visual description refer to an item that is not present, occluded

Displacement: reference to an item not present

Prepositions

Behind: Is what you expect to find behind

Richard Wiseman

Visual or cognitive?

Sentence: Events
Who is doing what to whom.

Actual events are continuous
But we see a start and end, an action
and the agents and objects
Event perception, Zacks et al,, 2001

Language of Vision

Assigning possible components is easy

Any evidence for grammar or syntax?

Language of Vision

Is there a grammar?

What would ungrammatical vision be like?

Impossible events, magic?

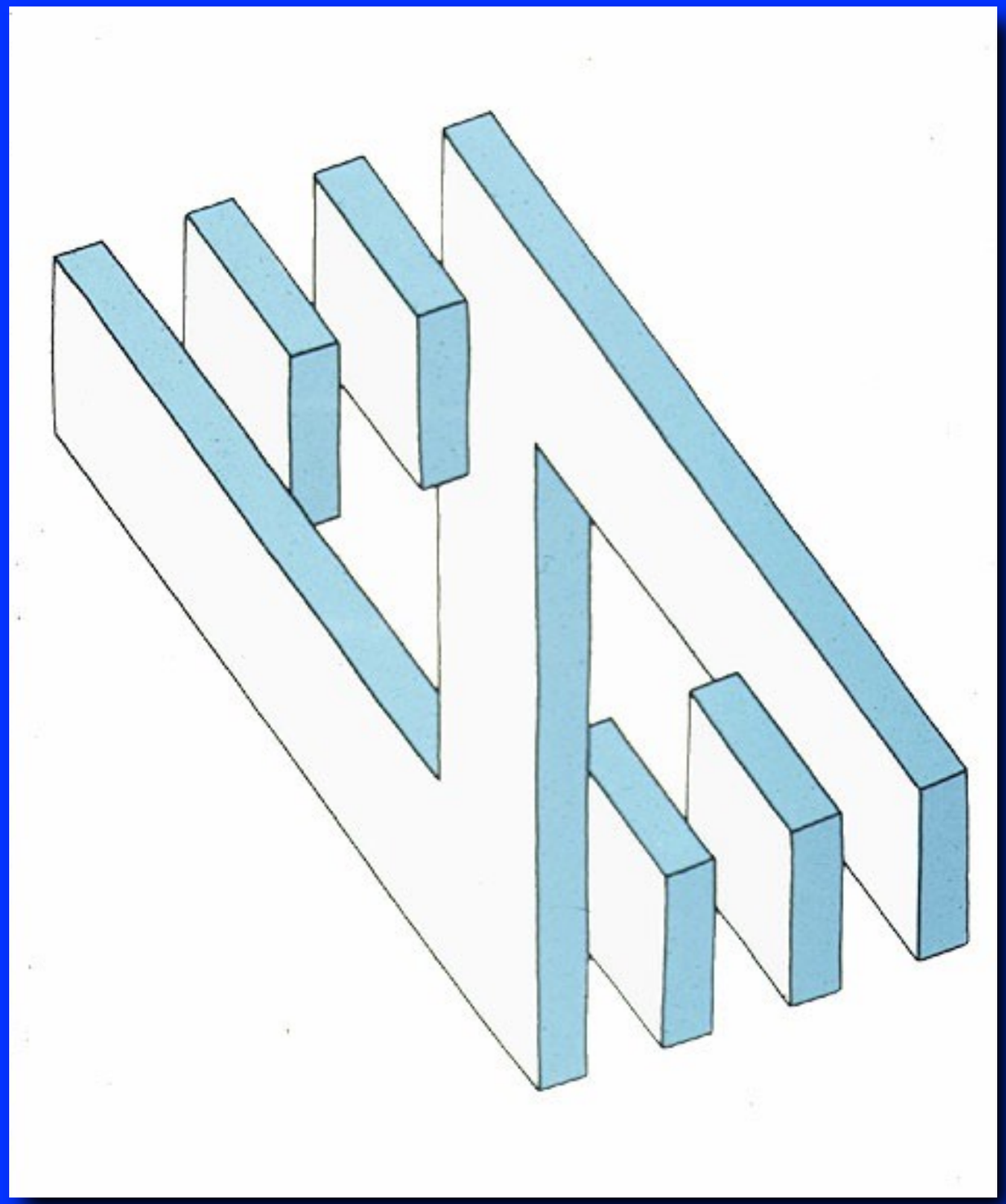
Deduce that it is impossible,

or see that it is impossible

Impossible, but we do not see this a visual error.

Physics of mirrors only roughly captured in visual grammar

Never get right description

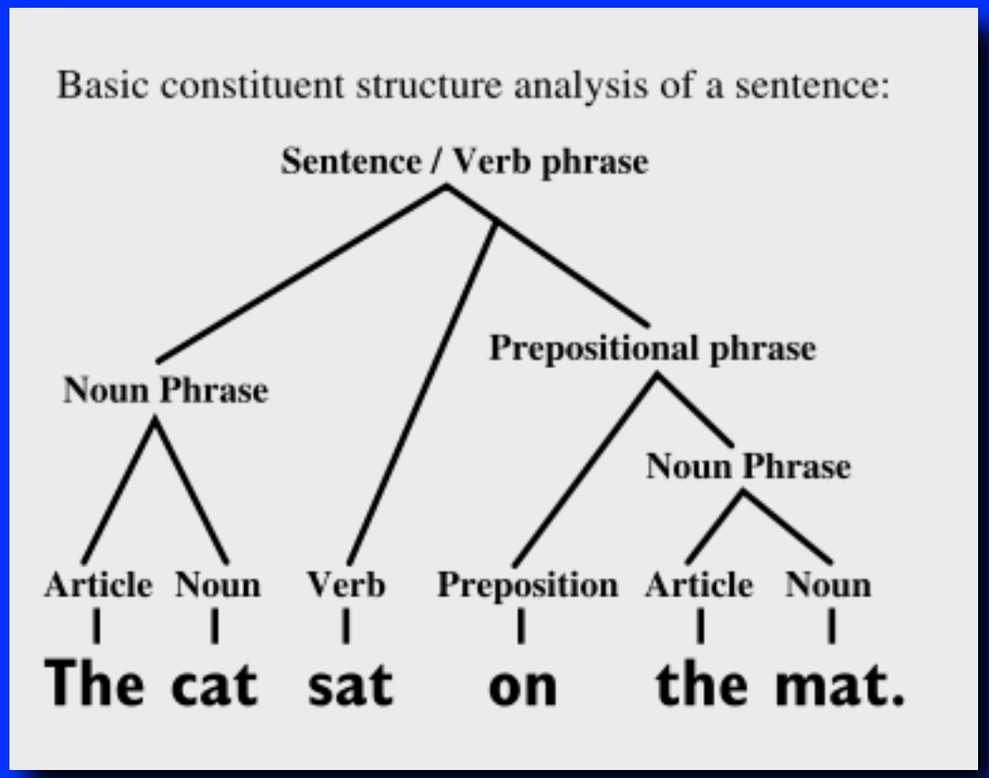


Again, impossible but error not detected by vision.

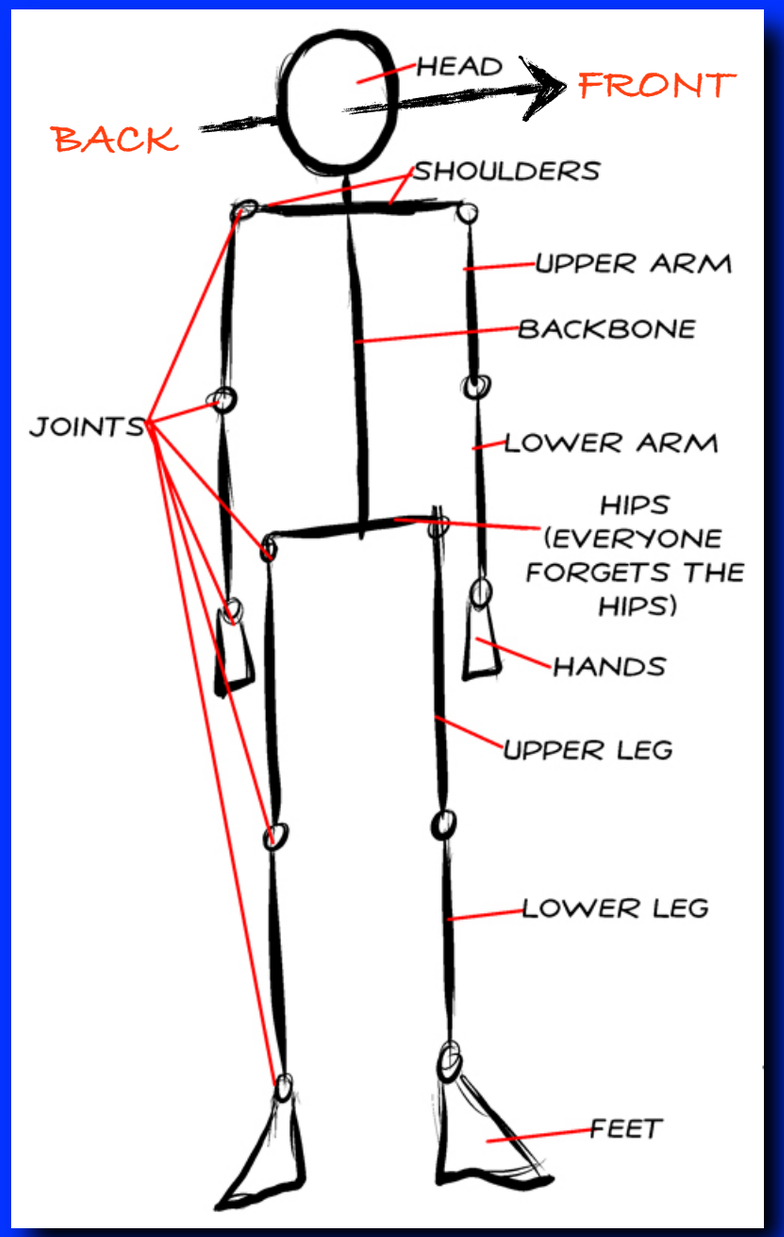
Local syntax OK

“I am writing to you with my sword raised and a pistol in each hand.”
Aaron Burr

Linguistic syntax

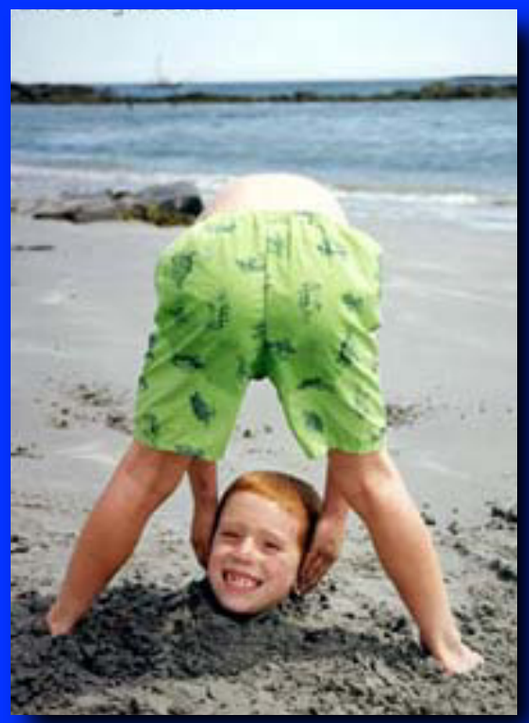


Visual syntax



Fu. Syntactic (Linguistic) pattern recognition. 1982.

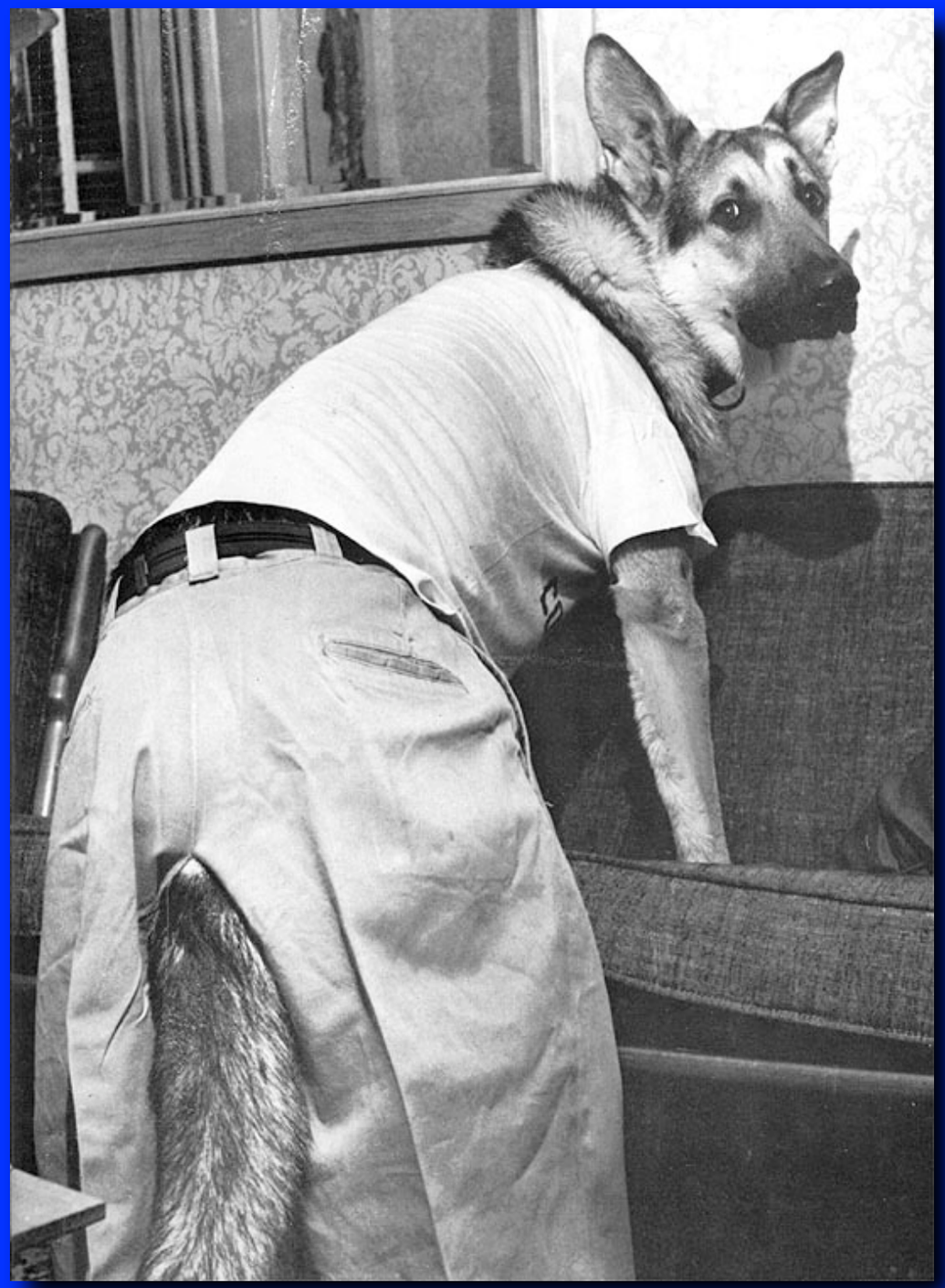
Visual syntax



Vision detects an error

Mistake in syntax

Visual syntax



Man ?? Dog.

“Phrase structure”
seems incomplete

Eventually get right
description

Visual syntax

Which body goes with this head?

Visual syntax

Some structural errors only verified cognitively

Development

A visual Language Acquisition System.

Picks up regularities in the visual input stream to determine objects, actions, spatial and temporal relations.

Infers nouns, verbs, prepositions

Regularities come from the physics of the world but system not specialized for physics but only regularities

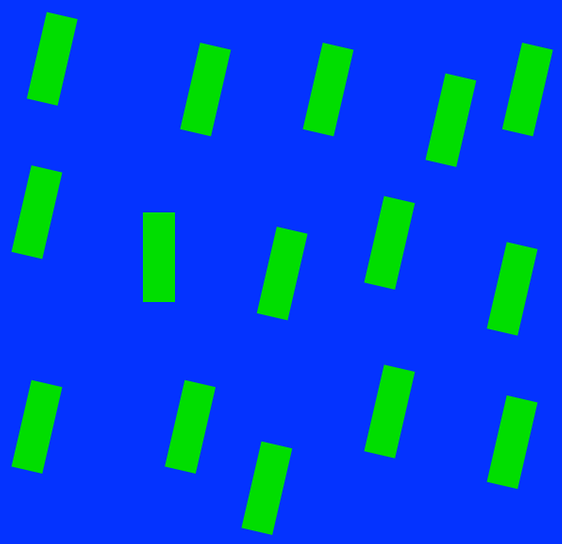
Common Mechanism?

Did the Regularity Acquisition System extend to the gestural and then spoken stream.

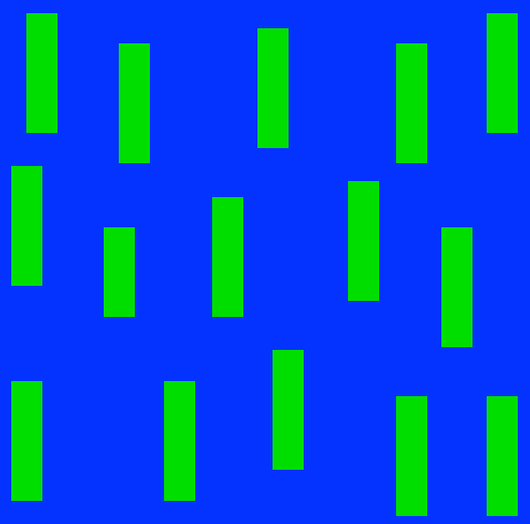
Is vision the “Ur” language? (Gregory, Sereno)

Look for similarities in acquisition system and development: fossils of visual structure

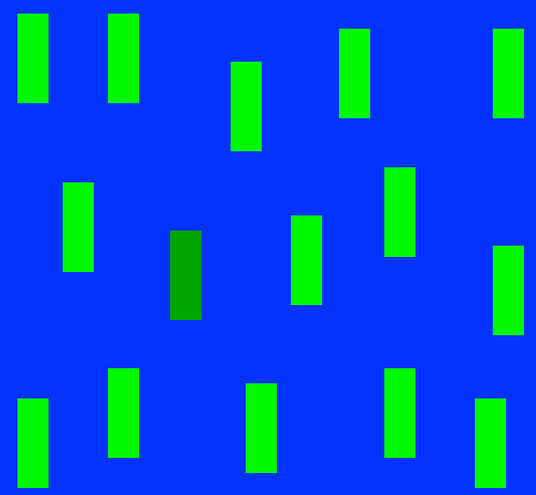
Asymmetry in Visual Search



Tilted in vertical
easier than vertical in tilted



Long in short
easier than short in long



Bright in dim
easier than dim in bright

Asymmetry in Lexical Marking

Antonyms: bright/dim, long/short, wide/narrow

Often one is base term, it names the dimension

Long - short --> length

Bright - dim --> brightness

Tilted - vertical --> tilt

The other is *marked:* short = {long}¯

Takes longer to process in speech

Possible evidence of visual syntax retained in spoken language structure?

Recursion

Powerful property of language

One sentence can be embedded in another

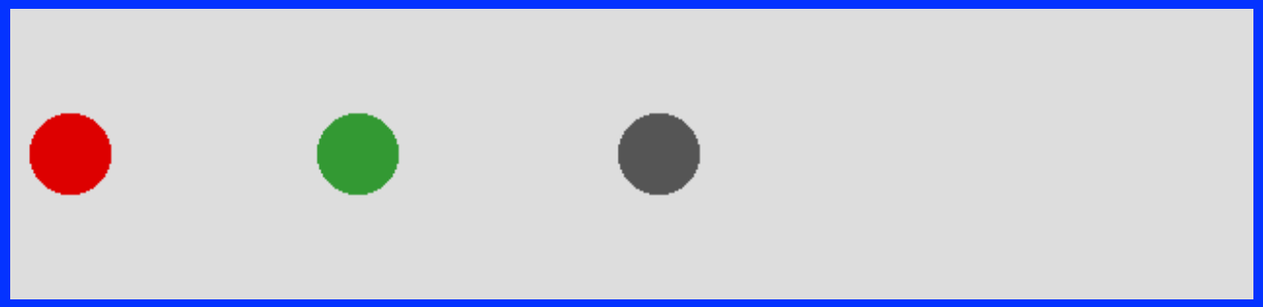
The man that jumps is happy

A noun phrase can be embedded in another

The man's lips

Does vision allow multiple embedded messages?

Recursion



The green disc that was hit by
the red knocks the black disc.

Recursion

picture spaces embedded in picture spaces

Recursion

See an object and its embedded history at the same time

The soda can that had been crushed is lying on the floor
The stones that are under water

Recursion

The train that failed to stop crashed to the pavement below

➔ See the object *and* the processes that produced the deviation from its canonical form

Conclusions

Attention exports a description of visual events to the mind in a “language” format

Language format more efficient

Rules for acquisition of visual grammar may have been the seed for mechanisms of acquisition of other grammars