Faculty of
Human Movement Sciences

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Why we don't mind to be inconsistent

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Three points

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- Perceptual space (internal representation) is inconsistent, so not a useful concept.
- Our actions don't mind inconsistencies between visual attributes.
- Our actions don't mind lack of calibration between senses.

How do we perceive and act?

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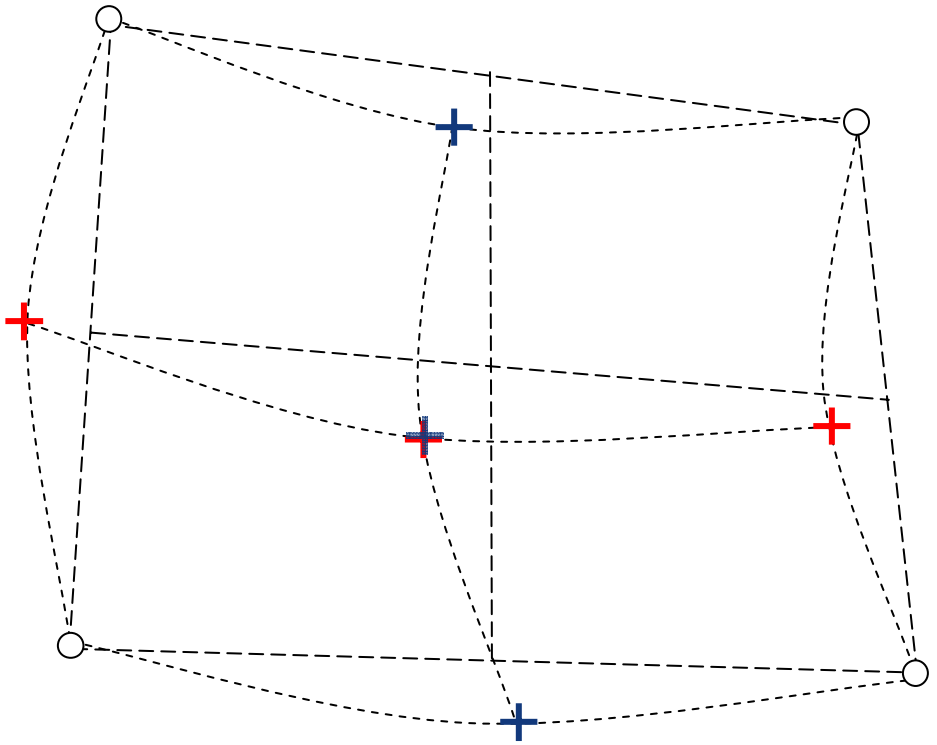
- Let's start with some assumptions
- We are aware of the space around us
- This perceptual space gives us information how to move: distances, directions, locations

- Obvious question: is perceptual space a veridical representation of the physical space?

Is perceptual space affine?

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.



Todd, Oomes, Koenderink, Kappers
(Psych Sci, 2001)

- Task: find middle of middle of the corners
- Space is not perceived veridical
- Double bisection independent of order: affine space

Bayes/Helmholtz view on perception

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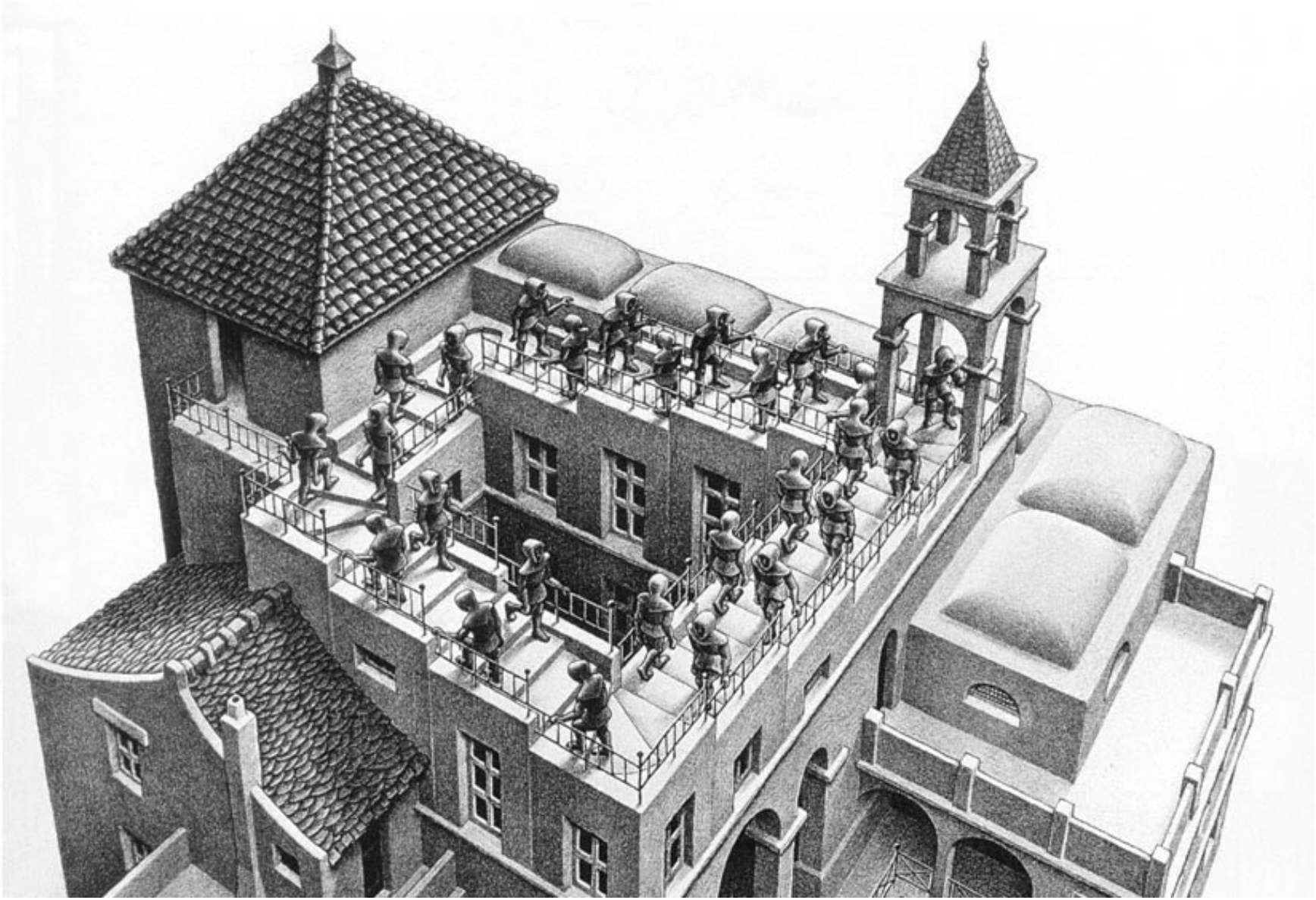
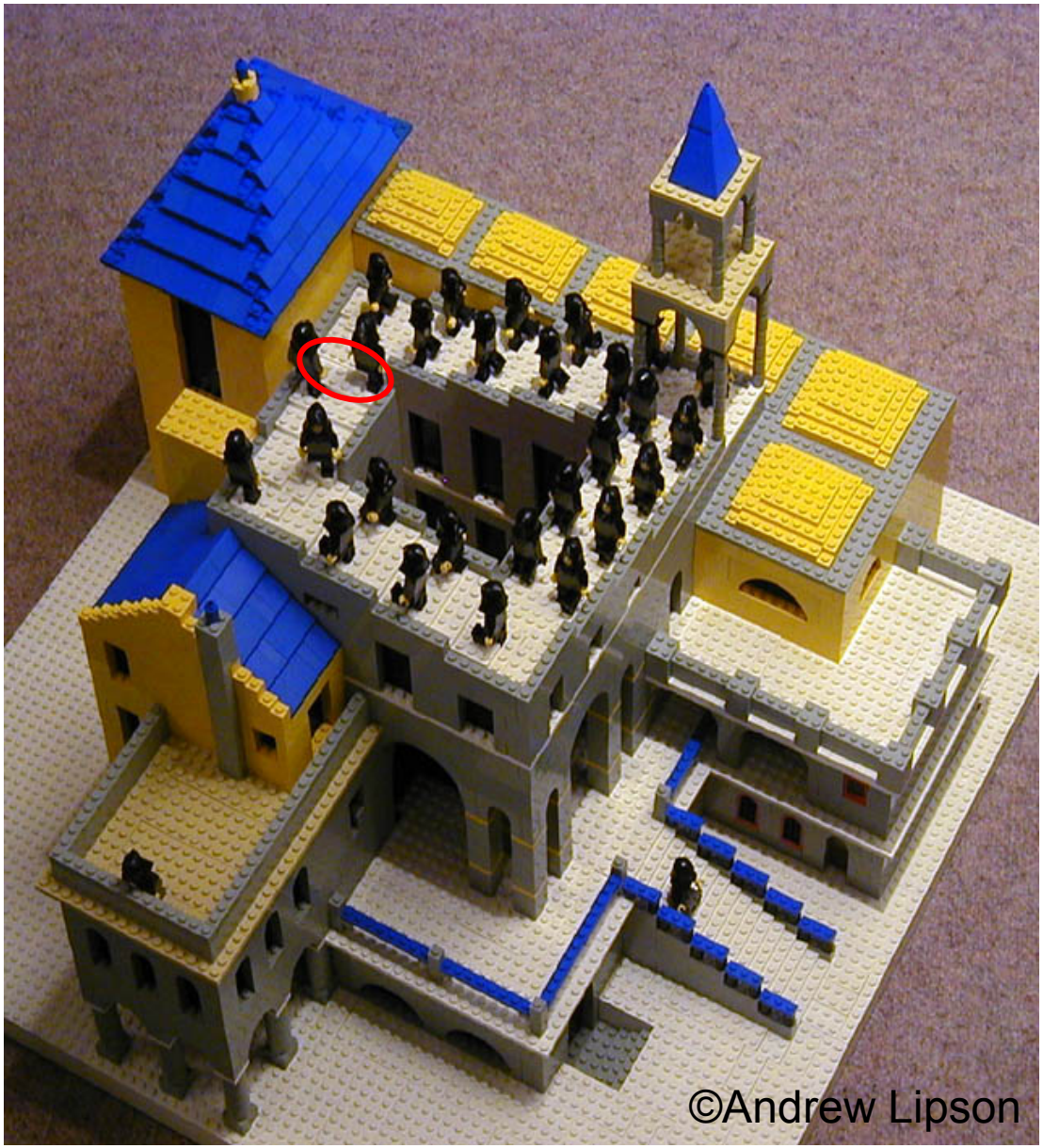
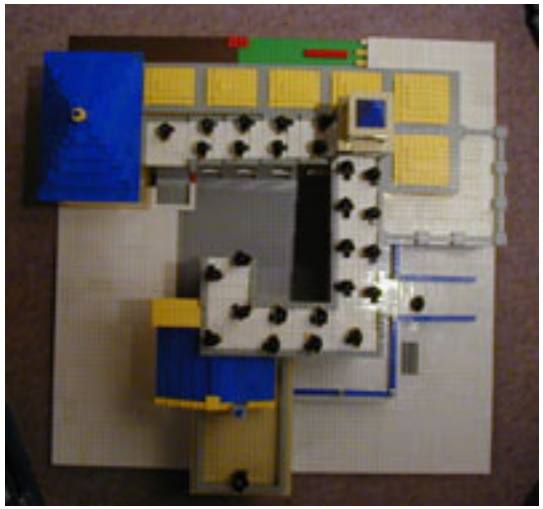
- What we perceive is **not** what corresponds best with what our sensors tell us.
- What we perceive is the most likely situation that corresponds with what our sensors tell us.
- So, the Bayesian view on perception predicts that we never perceive situations that we know that cannot exist.

However: an impossible percept



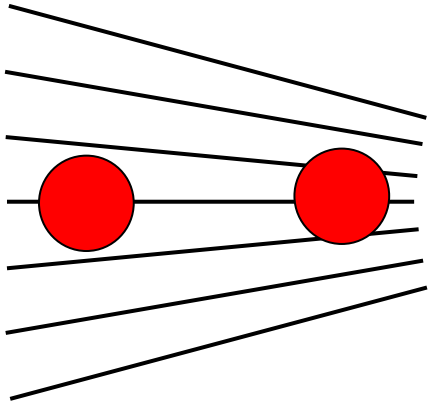
Impossible building in Lego

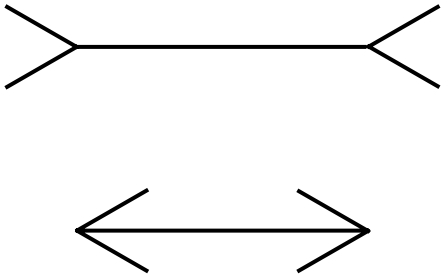




- There is a corresponding possible situation in the real world
- Why don't we see it? (answer follows)

Perceptual space and illusions



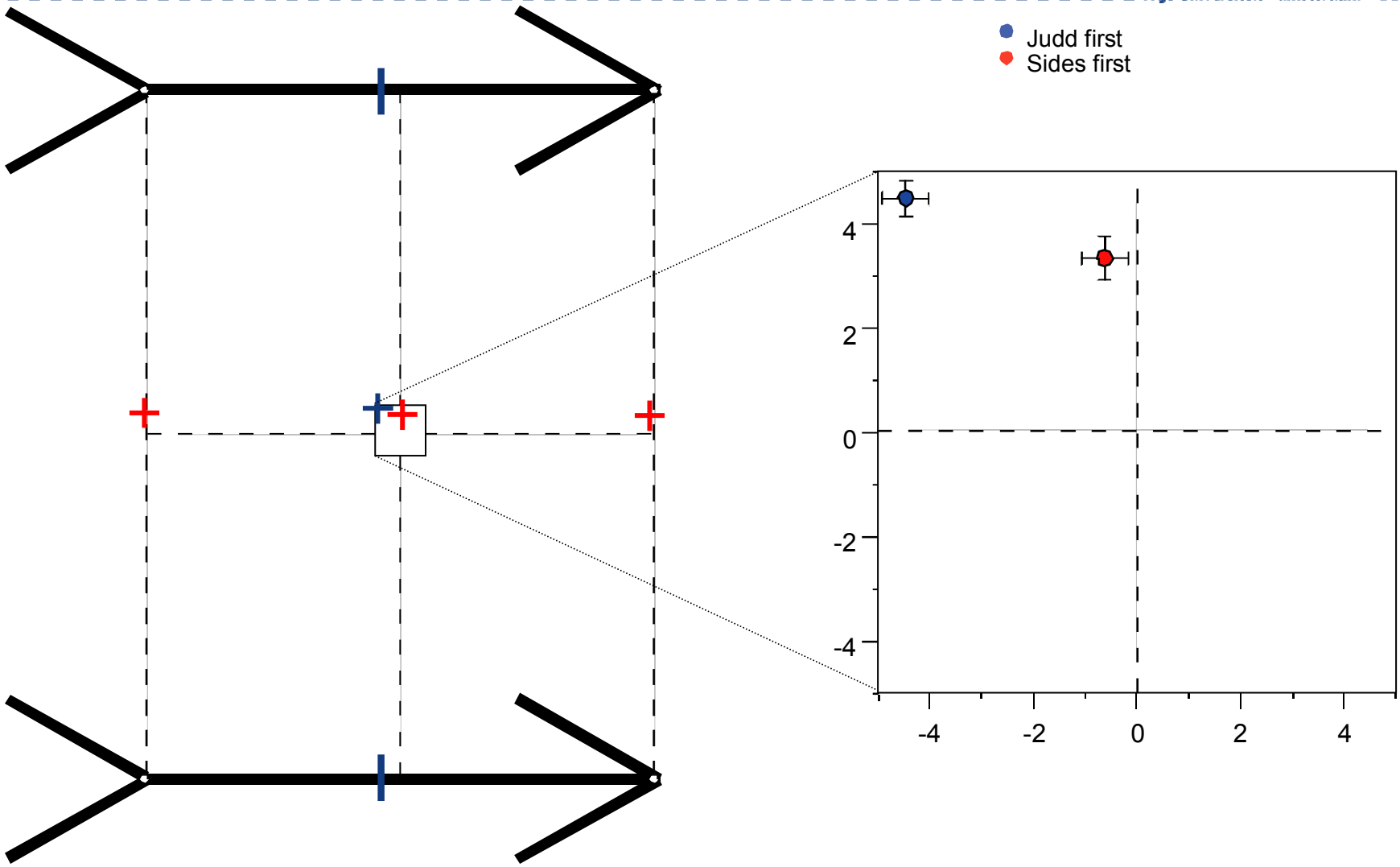


QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Ponzo Müller-Lyer Hering

- Do illusions deform visual space?
- Use test of Todd et al. (2001)

Judd-illusion and space

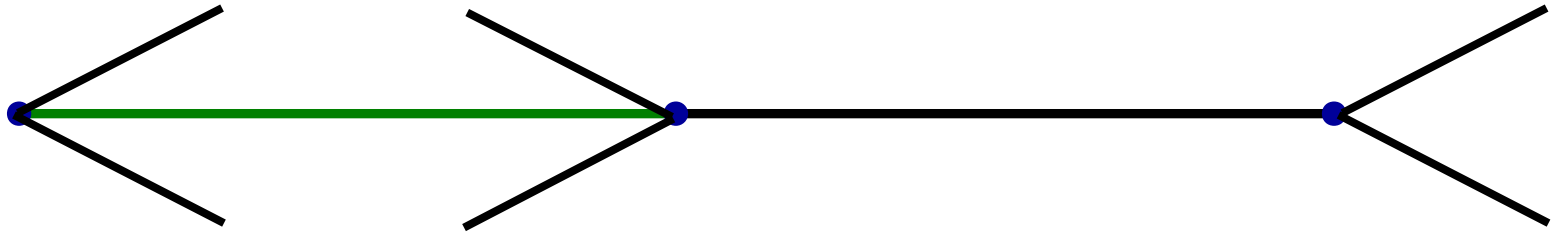


⌘ There is no usable perceptual space

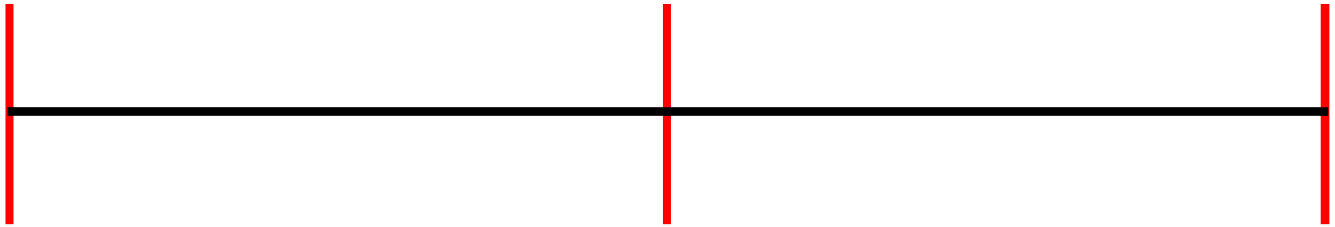
What is the cause of inconsistency?

- Where is the tree?
- Perspective tells that the tree is behind the horse.
- Occlusion tells us that the tree is in front of the horse.
- The spatial relationship depends on which **information source** used.

Brentano illusion: 2D inconsistency

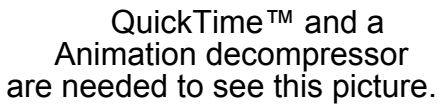


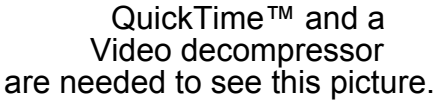
QuickTime™ and a GIF decompressor are needed to see this picture.



⌘ The perceived length changes without a change in alignment of positions.

Motion after effect





- After-effect opposite to perceived motion
- After effect is motion, not position change.

Why inconsistent perception?

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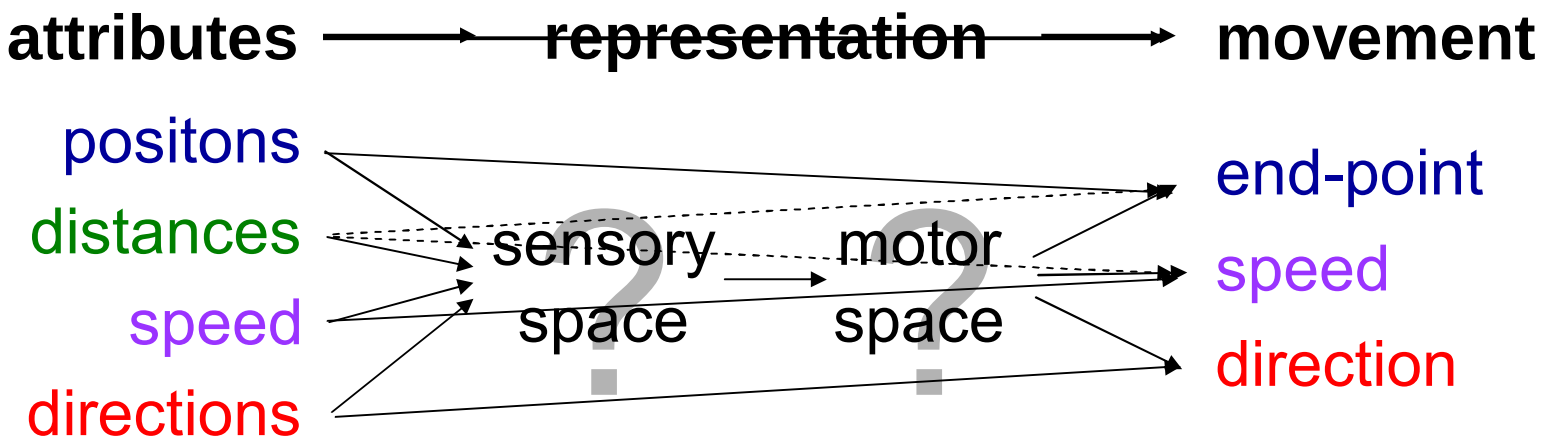
- Sources of information a for different attributes are different.
  - Position: position on retina + orientation eye
  - Length: size on retina + estimated distance
- Inconsistency is not a problem if you don't build an internal representation.
- Which attribute is used depends on reliability for task at hand.
  - Speed of processing (i.e. position faster than speed)
  - Precision/noise

Handling of spatial information



⌘ The brain doesn't take snapshots, but detects information (possibly inconsistent) about attributes (direction, distance, speed, position etc).

Summary 1

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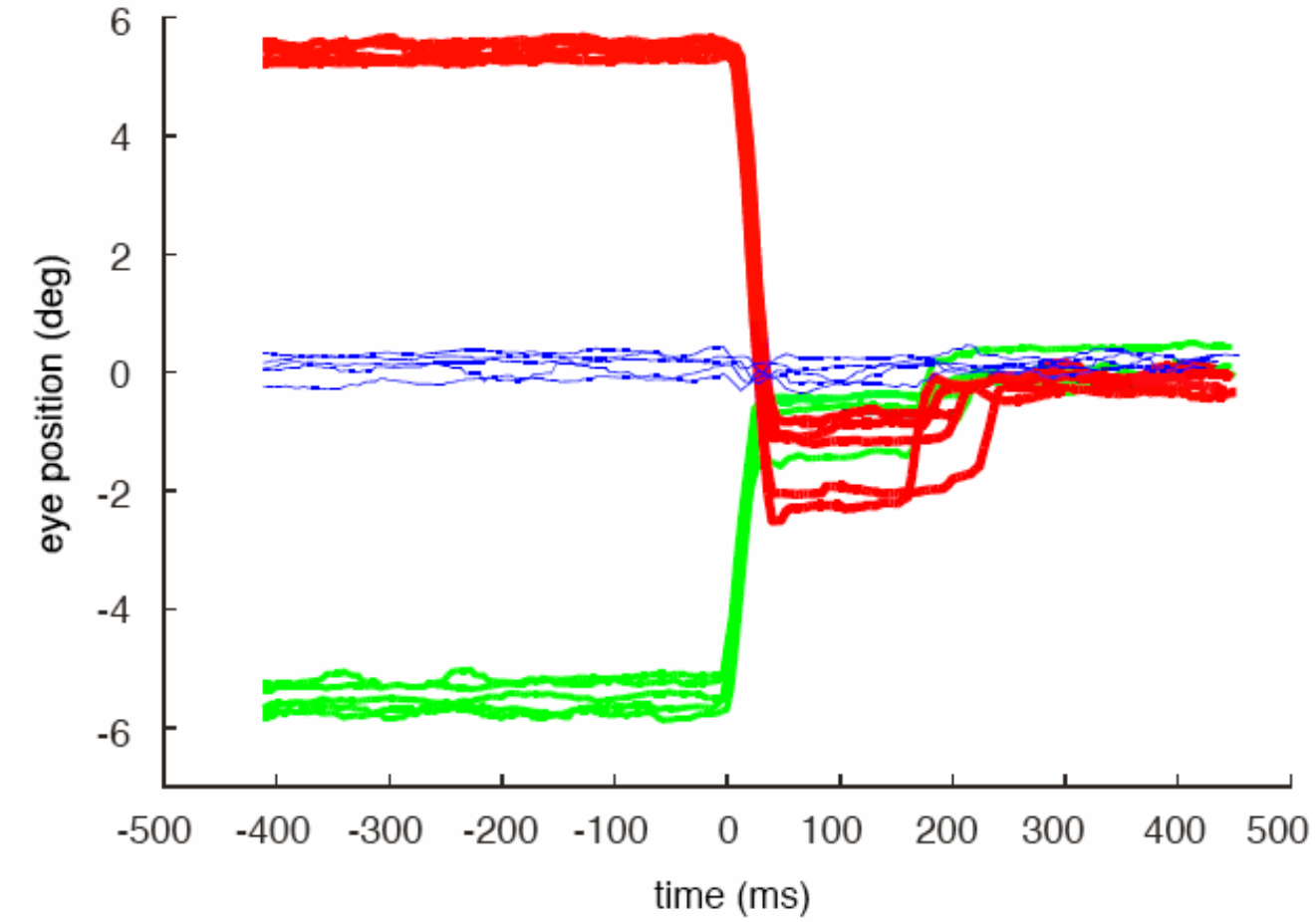
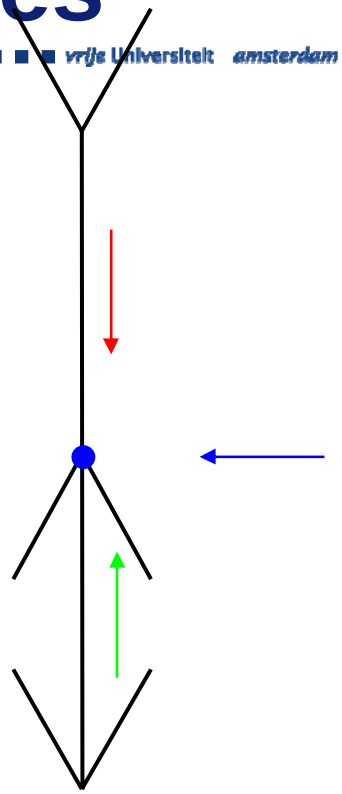
- The hypothesized visual space is not useful.
  - You cannot use distances, directions.
- We shouldn't use the concept visual space.

- New hypothesis: vision is not used to construct visual space, but only used to give us information about attributes: distances, directions, locations
- We do not reconstruct the world, so inconsistencies don't matter.

- Do these inconsistencies affect our actions?

Brentano illusion and saccades

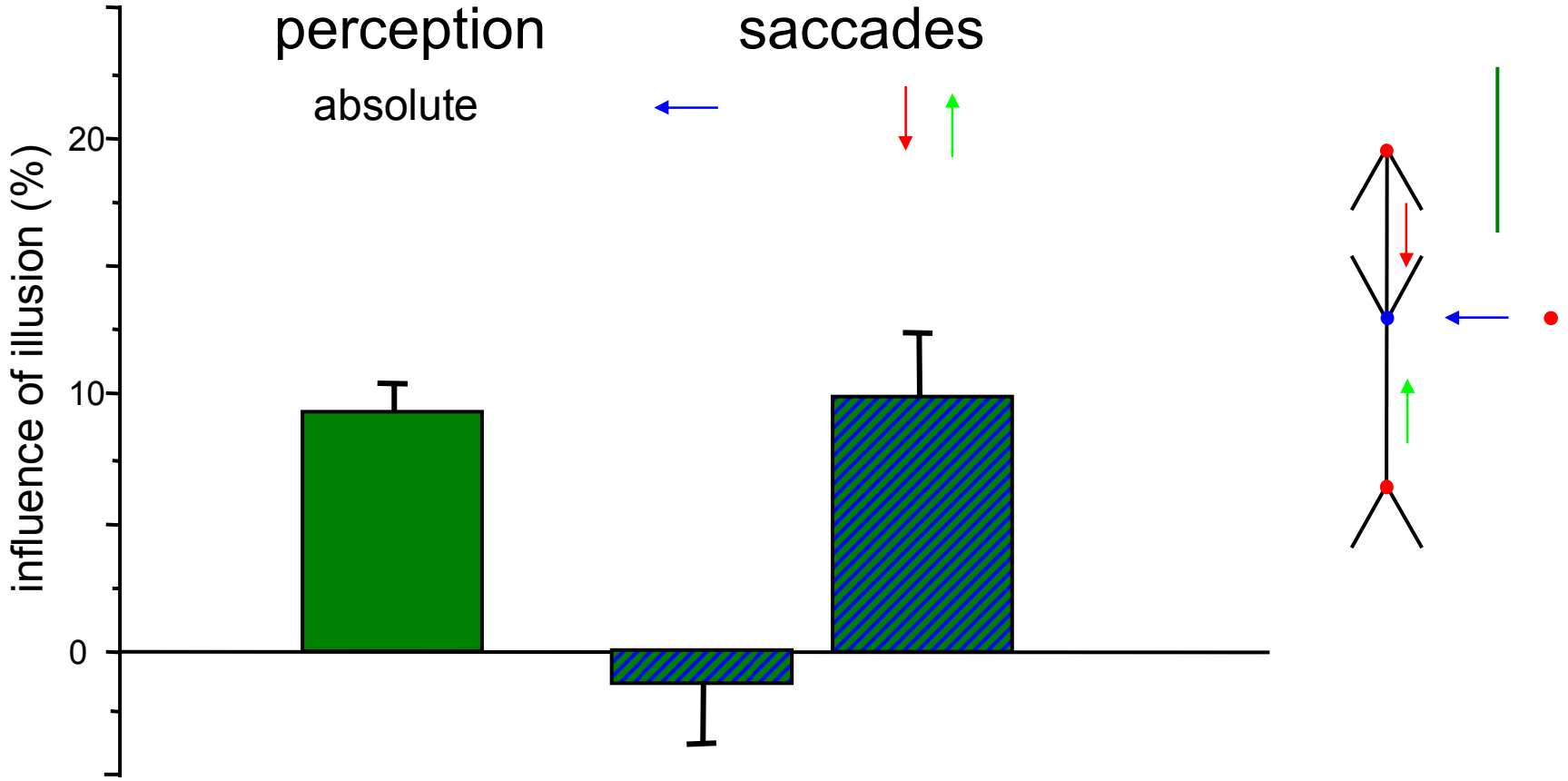




- Subjects make errors following illusion
- Correction saccade after 200ms

de Grave et al. (EBR, 2006)

Saccades and Brentano illusion



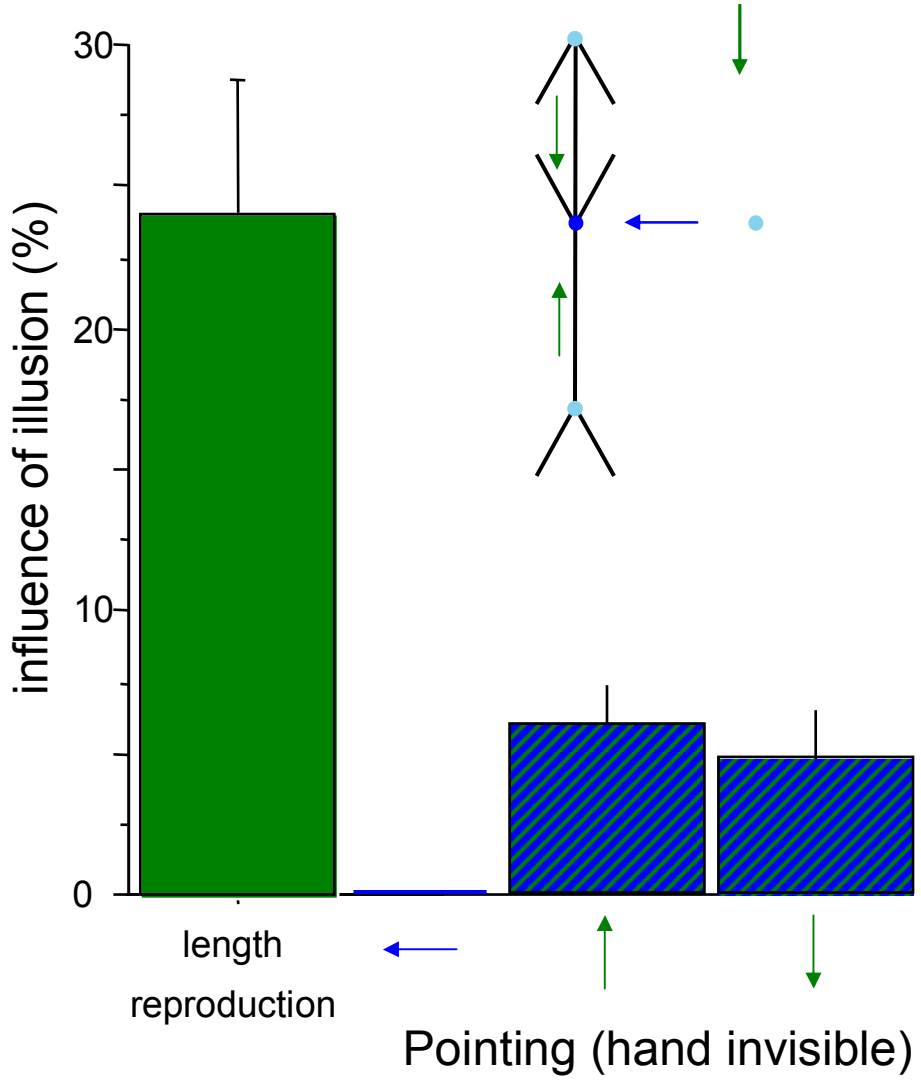
- Saccades along the illusion are influenced as much as absolute perceptual judgments.
- Thus: length is used.

de Grave et al. (EBR, 2006)

The hand experiment

de Grave et al. (EBR, 2004)

Results pointing to Brentano

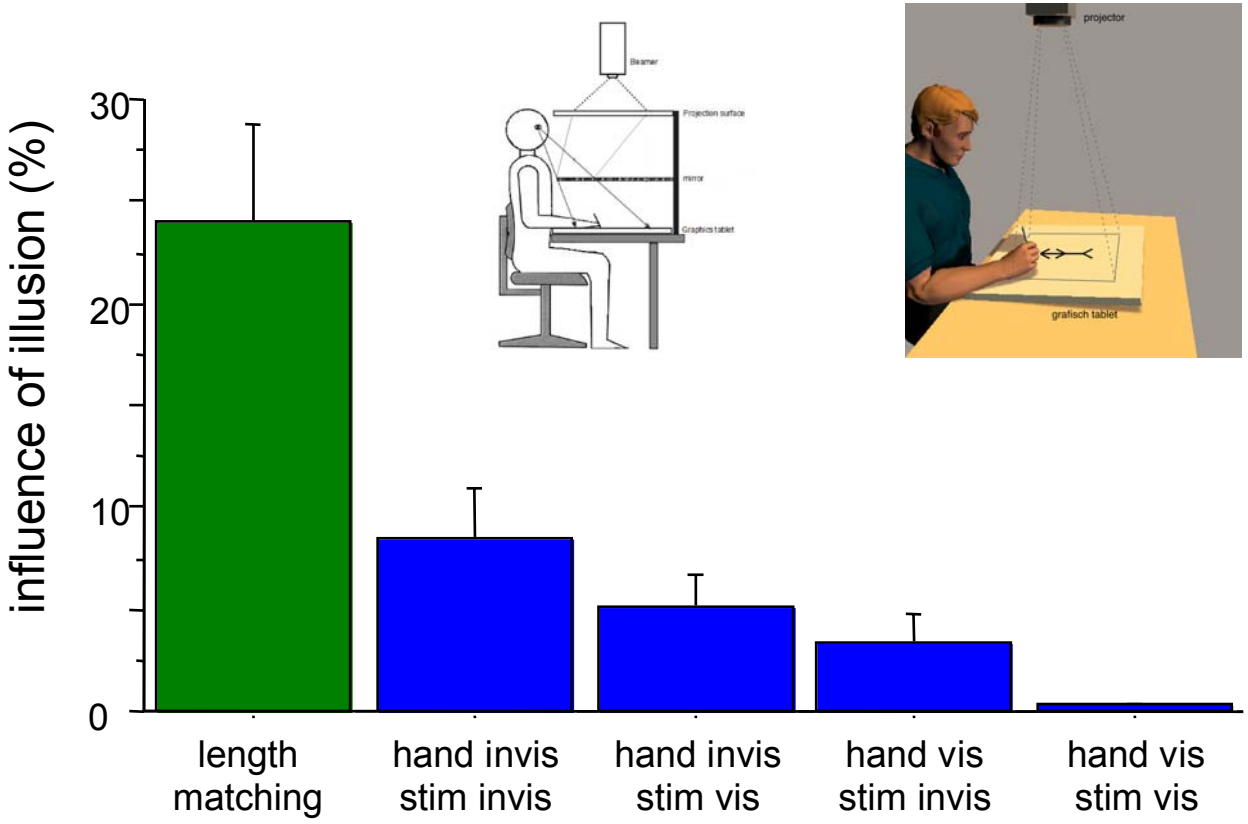


Movements are only influenced by illusion if the length can be used.

The effect of illusion on movements is only 25% of effect on length reproduction.
Movements are mainly coded by end-positions

de Grave et al. (EBR, 2004)

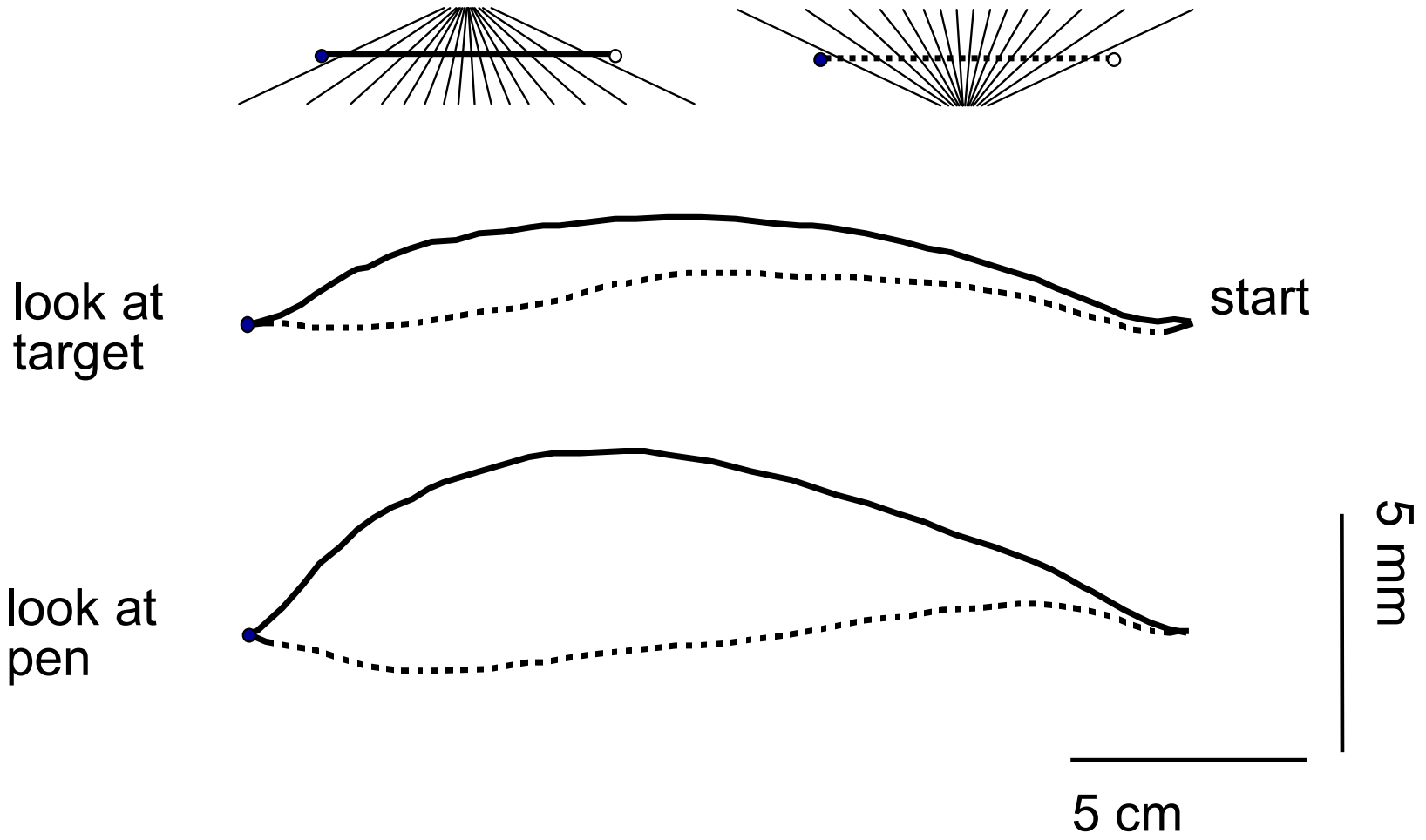
Results Brentano illusion



Subjects rely more on size information when less position information is available.

de Grave et al. (EBR, 2004)

A straight line in the Hering illusion

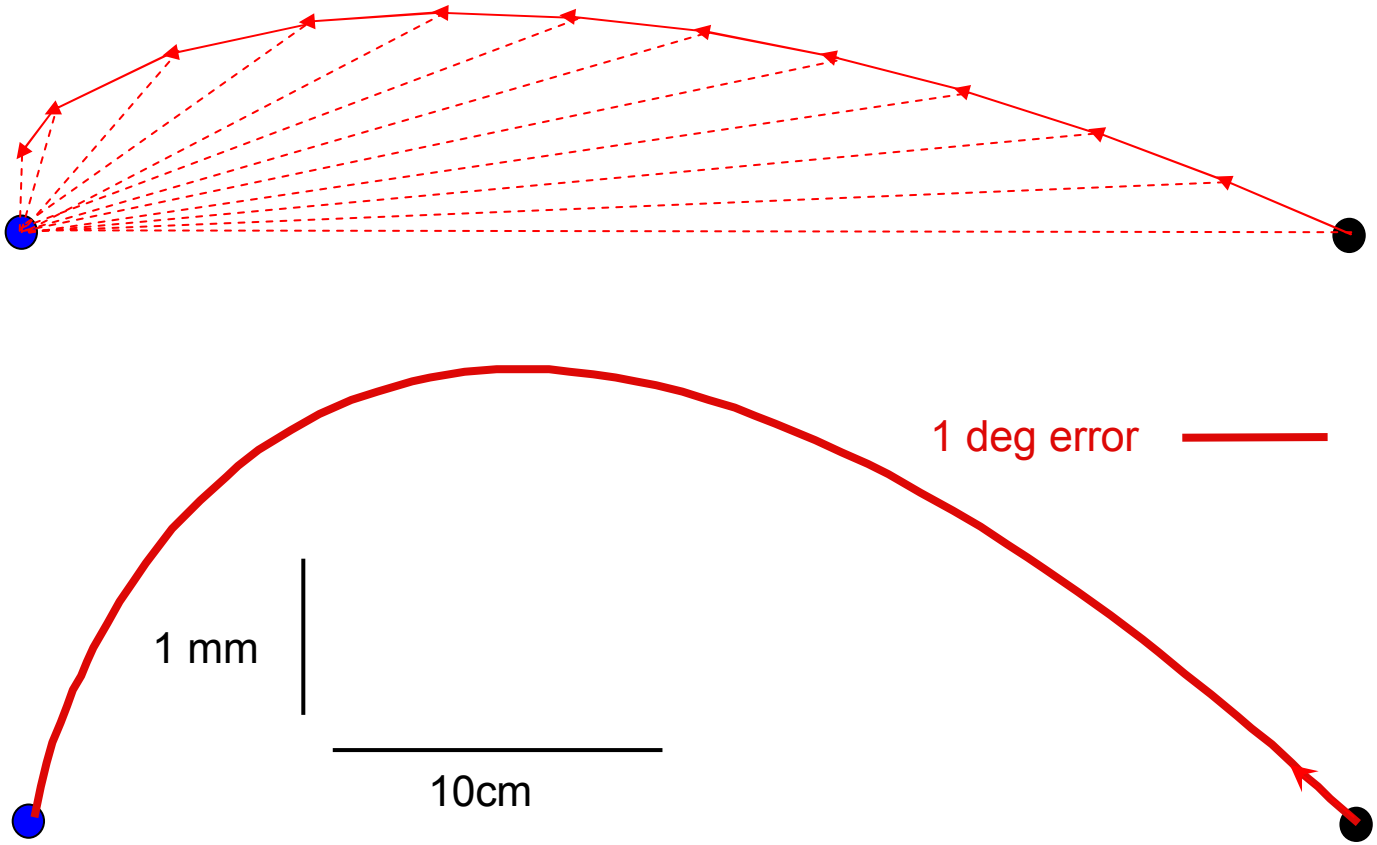


- Asymmetric effect on path: effect larger in second part of the movement.

Smeets & Brenner, Vis. Cogn., 2004

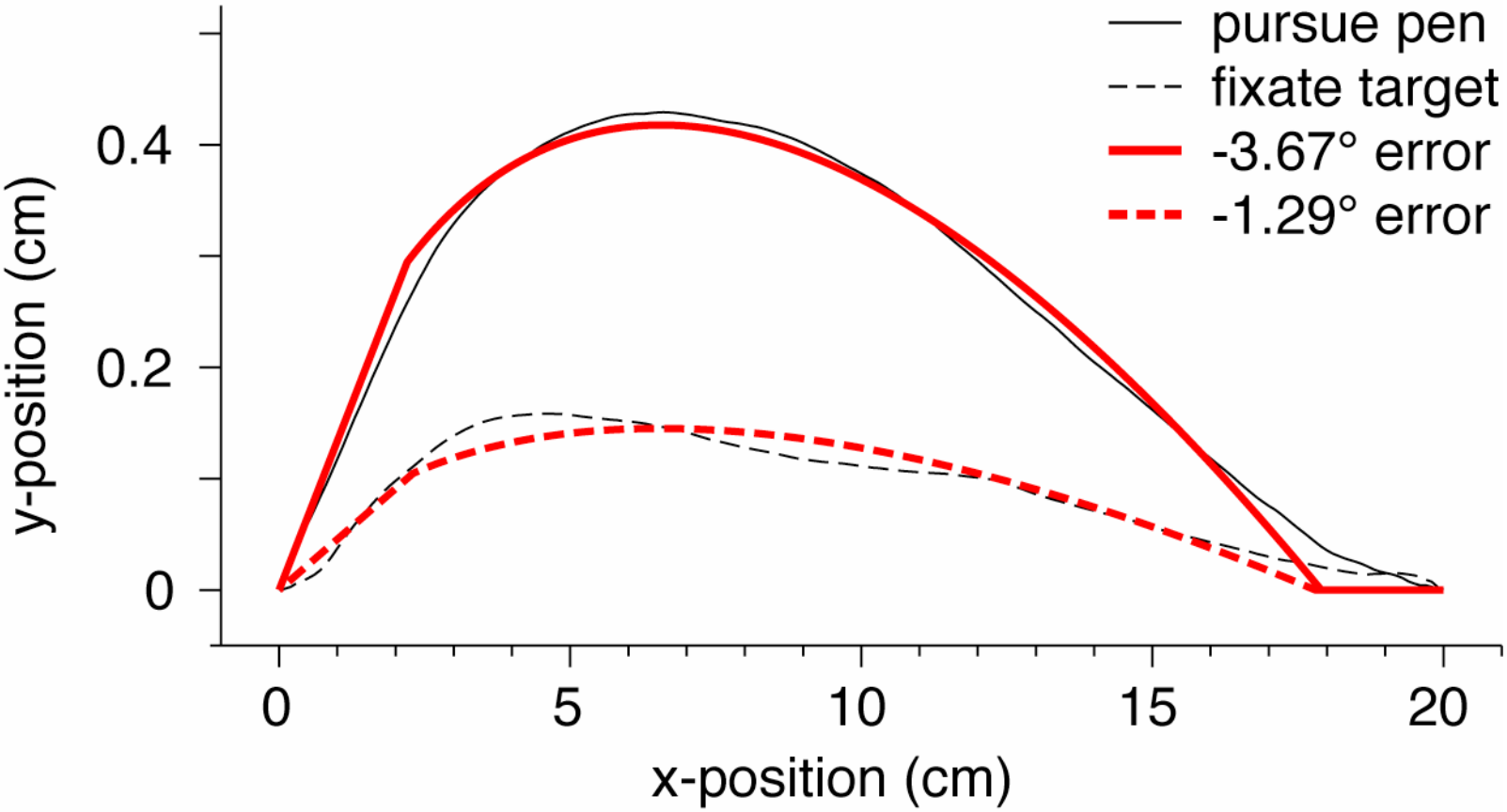
Explanation Hering Illusion

- Directions, not positions, are misperceived
- Movement with a fixed directional error



Smeets & Brenner,
Vis. Cogn., 2004

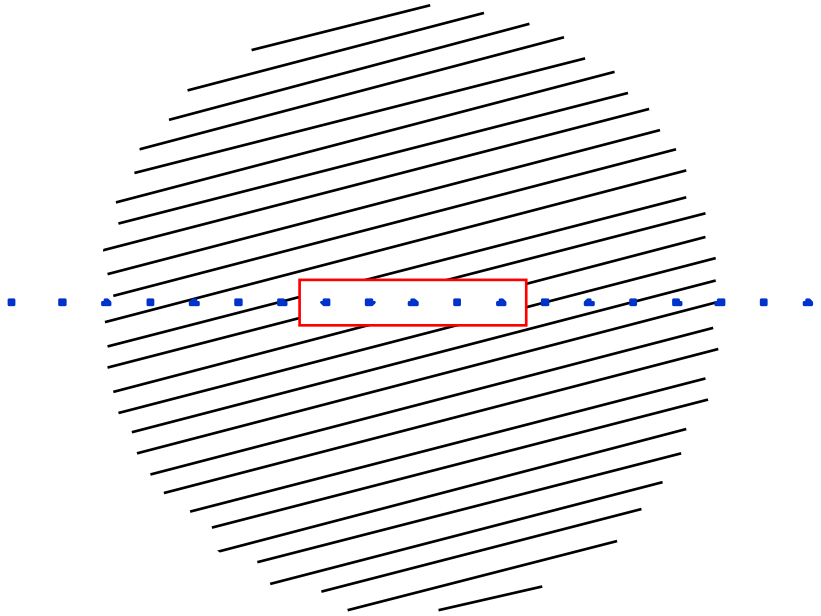
Explanation Hering illusion



- Perceived directions are inconsistent with perceived positions

Smeets & Brenner,
Vis. Cogn., 2004

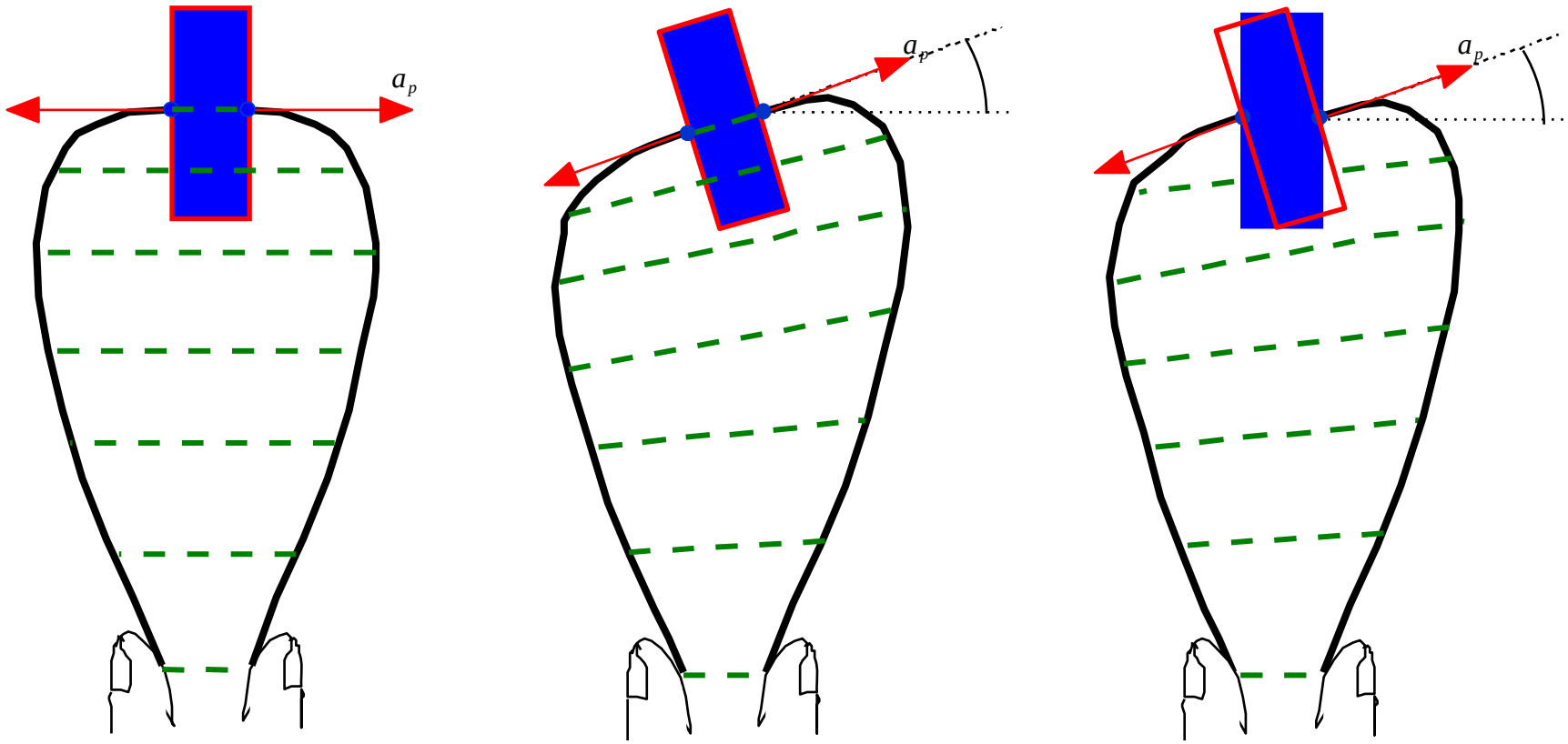
Grasping an orientation-illusion



⌘ Orientation-illusion influences perception of direction, not perception of positions.

Smeets et al, EBR, 2002

Effect orientation-illusion on grasp



⌘ Illusion changes direction of approach;
end-positions finger and thumb unchanged.

Smeets et al, EBR, 2002

Summary 2

- Illusions affect only a few spatial attributes
- Illusions influence motor control if the affected attributes constitute reliable information for aspects of motor control.
- The inconsistencies are no problem for motor control.

- Are different senses calibrated?

Where is my hand?

- Where I see it (if I can see it)
  - If not: where I feel it
- What if felt and seen position inconsistent?

- At the optimal combination of felt and seen position.

- To test this, we must know what optimal combination is ….

Combining information

- Information has limited precision (variance σ^2).
- Two sources (b, c) of information determine a.
- Averaged information

$$a = \frac{1}{2}b + \frac{1}{2}c \Rightarrow \sigma_a^2 = \frac{\sigma_b^2}{4} + \frac{\sigma_c^2}{4} \Leftrightarrow \sigma_a = \frac{\sqrt{\sigma_b^2 + \sigma_c^2}}{2}$$

- Averaging more information sources reduces uncertainty (by a factor $\sqrt{2}$ if $\sigma_b = \sigma_c$)

Optimal combination

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- a is weighted average of two estimates (b, c)

$$a = wb + (1 - w)c$$

$$\sigma_a^2 = w^2\sigma_b^2 + (1 - w)^2\sigma_c^2$$

- What is the best weight w?

  Minimal σ_a -> derivative equals zero:

$$\frac{d\sigma_a^2}{dw} = 0 \Leftrightarrow 2w\sigma_b^2 - 2\sigma_c^2 + 2w\sigma_c^2 = 0$$

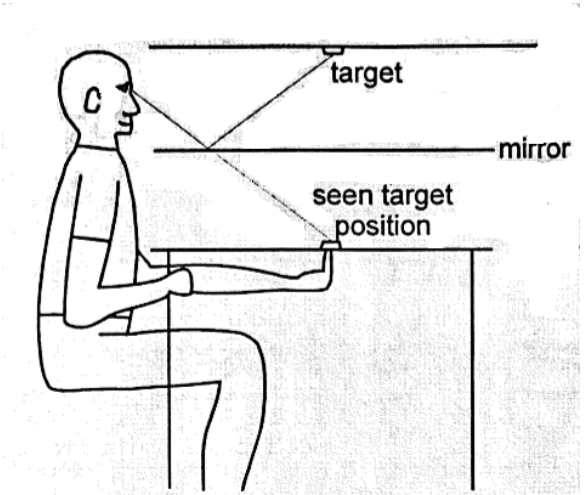
$$w\sigma_b^2 + w\sigma_c^2 = \sigma_c^2$$

$$w = \frac{\sigma_c^2}{\sigma_b^2 + \sigma_c^2} \qquad 1 - w = \frac{\sigma_b^2}{\sigma_b^2 + \sigma_c^2}$$

- The larger the variance, the smaller the weight

Experiment by van Beers et al.

- Compare precision pointing to
  1. Visual target
  2. The other (vis+prop) hand

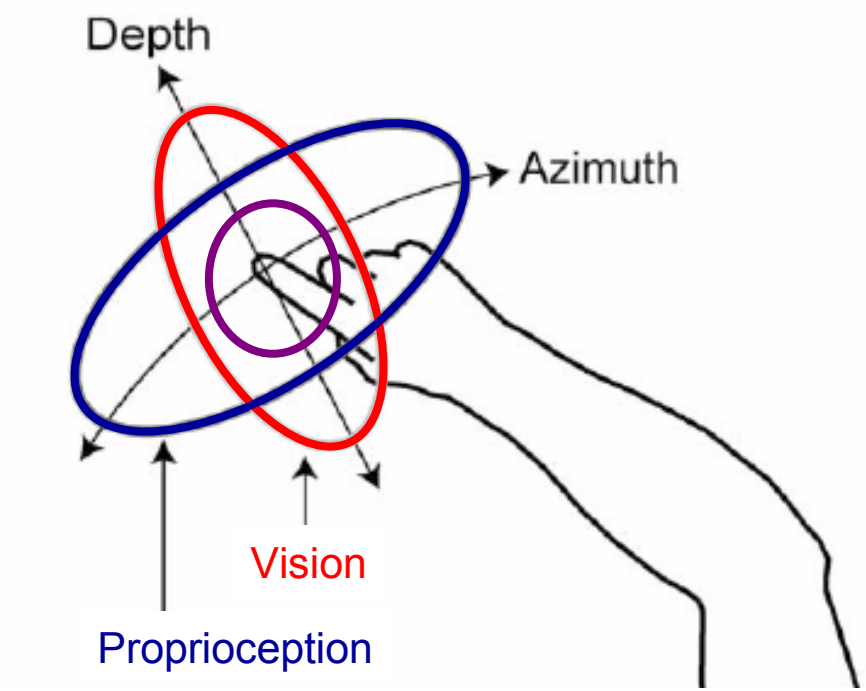


QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

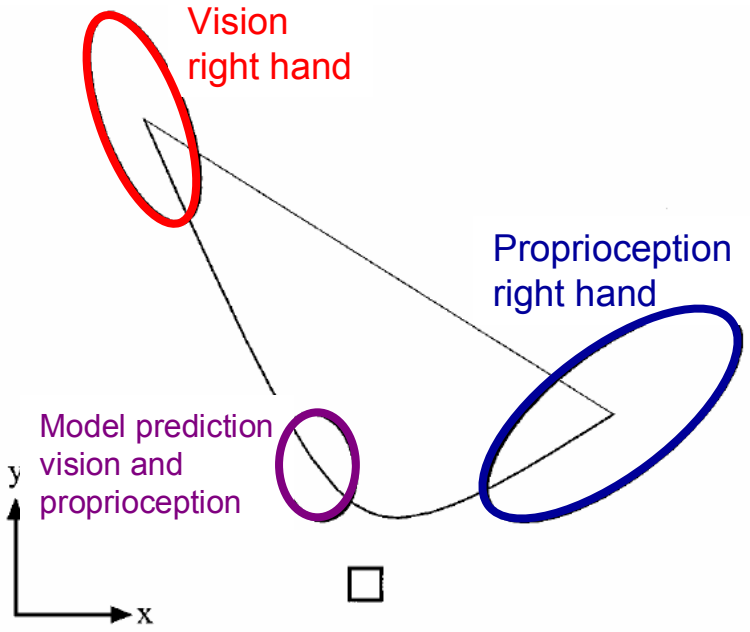
- Prediction:
  - If you perceive your hand where you see it, $\sigma_1 = \sigma_2$
  - If you use combined info for visible hand: $\sigma_1 > \sigma_2$
- Result: $\sigma_1 > \sigma_2$: combined info is used

van Beers et al., 1996

Optimal combining position info



Van Beers et al., 2002



Van Beers et al., 1999

- Both proprioception and vision can also have systematic errors.

Where is the target?

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- At its visual estimated location
  - Consequence: if hand is at target, we would not perceive the hand at the same location as the target!!
- At a combination of visual and proprioceptive information:

Visual target = Eye orientation + Position target relative to eye

Proprioceptive target = Hand position + Position target relative to hand (vision)

Where is my hand if it is out of view?

- Possibility 1:
  - Hand position switches to proprioceptive estimate
  - *Prediction:* immediate error
- Possibility 2
  - Visual estimate of hand slowly degrades
  - *Prediction:* combined estimate drifts to proprioception

Visual hand = Eye orientation + Position hand relative to eye

Proprioceptive hand = Hand position

This part degrades if hand moves out of view

Target when hand out of view?

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- At its visual estimated location
  - Consequence: if hand is at target, we do not perceive the hand at the same location as the target!!
- At a combination of visual and proprioceptive information:

Visual target = Eye orientation + Position target relative to eye

Proprioceptive target = Hand position + Position target relative to hand (vision)

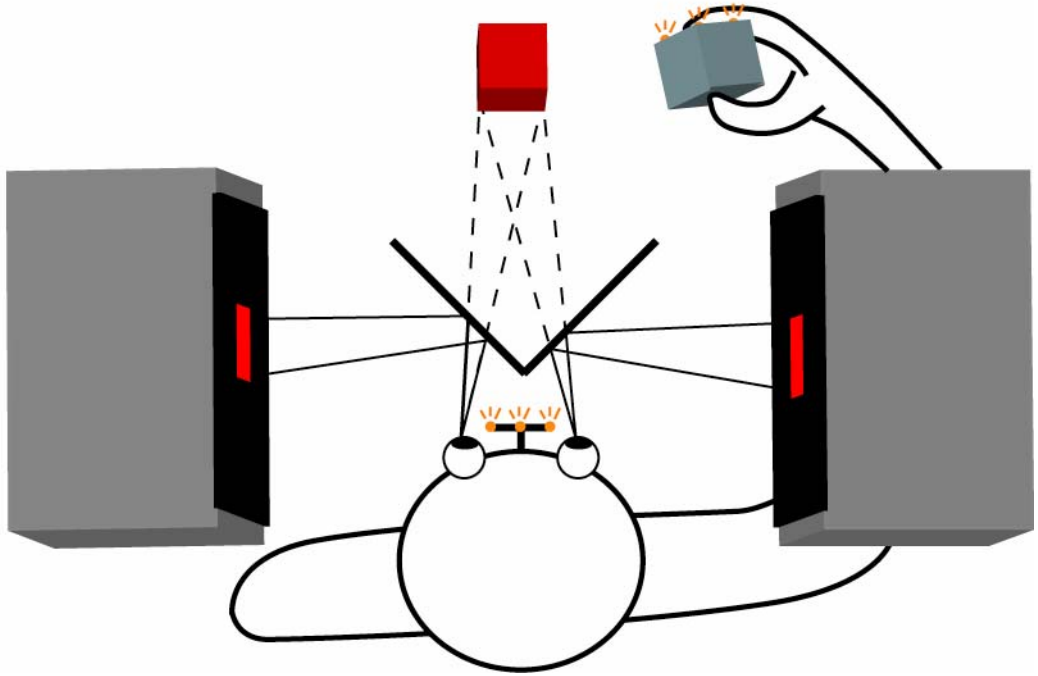
This part degrades if hand moves out of view

A strange adaptation experiment....

- Start in the dark
- Adapt to veridical
- Measure after-effect.

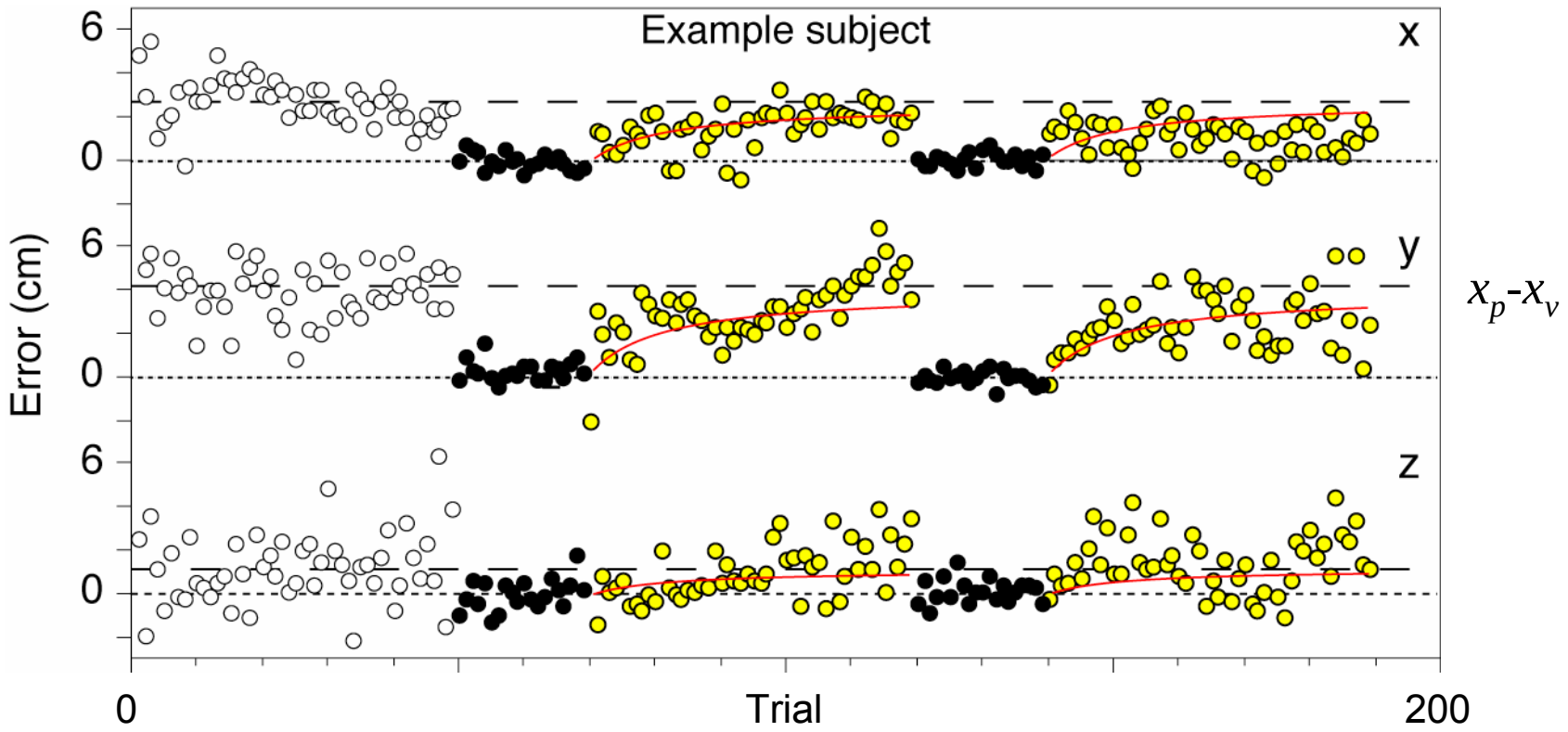
Prediction:

- Initially no errors (seems adapted)
- But drift back to original error



(Smeets et al., PNAS, 2006)

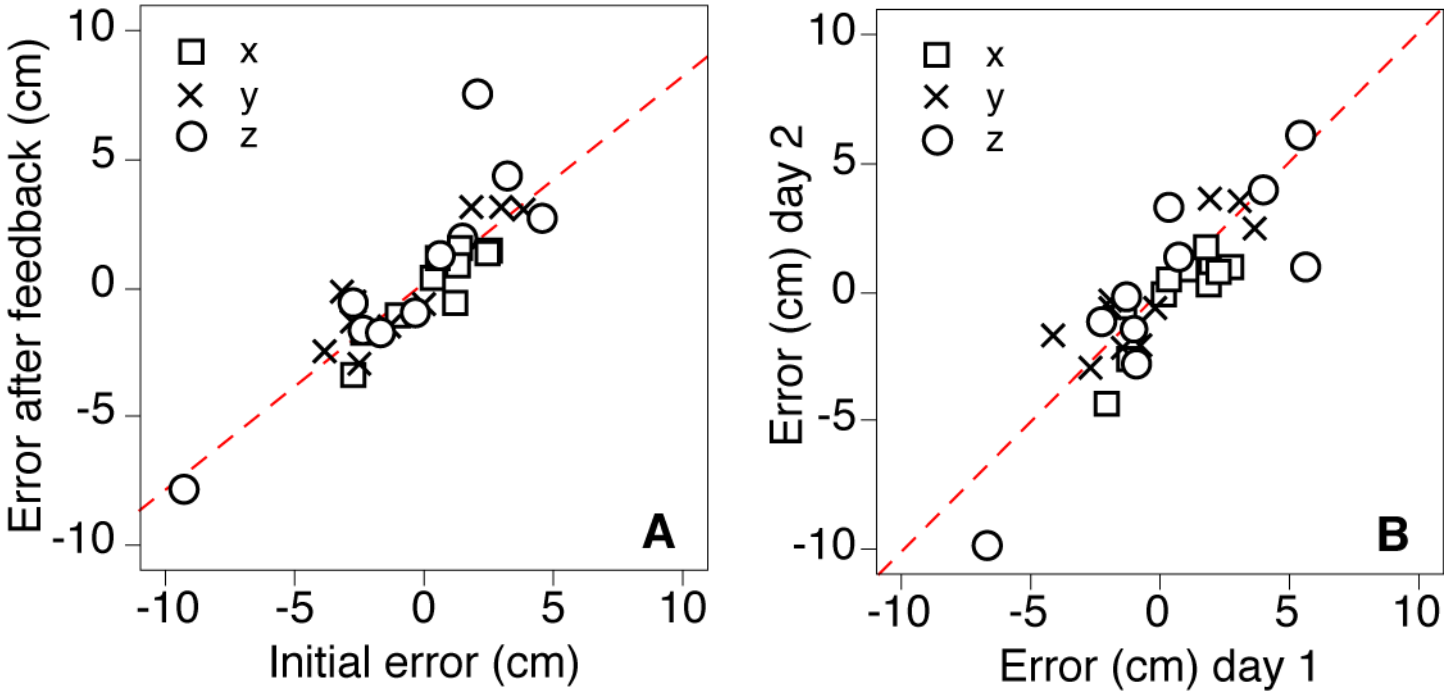
A single experiment and subject



⌘ Seems roughly according to predictions

(Smeets et al., PNAS, 2006)

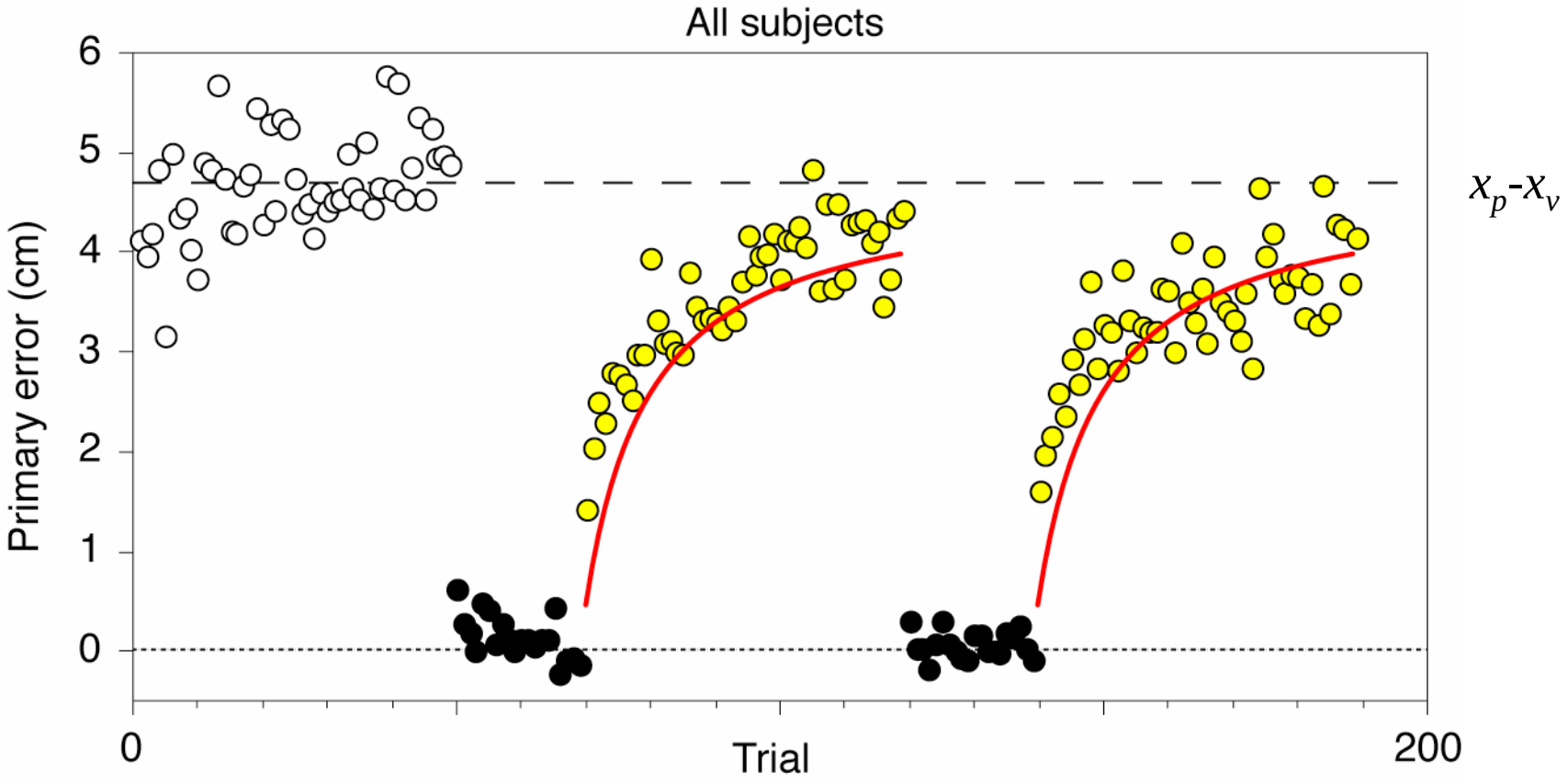
Subjects have different errors



- The drift error corresponds with initial error
- The error is consistent across days

(Smeets et al., PNAS, 2006)

Averaged across subjects



⌘ Model predicts time-course of drift well

(Smeets et al., PNAS, 2006)

Summary

- Perceptual space is not a useful concept.
- Attributes are processed independently.

- Different aspects of behaviour are based on different attributes (depending on reliability).
- Therefore, inconsistency between attributes is not a problem for our actions.

- Senses might be inconsistent with each other.
- They are combined to determine attributes accurately for goal-directed movements.