Reaches-to-Grasping

Michael Wang

What you should get out of this session

- What type of units do we need when we talk about perception-action coupling? Why do we need them? How do we connect them?
- (What are the two types of scaling relationship in action analysis?)
- (What is one important lesson do we learn from the second type of scaling relationship?)

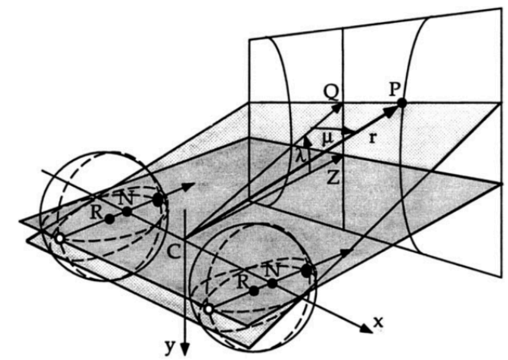
Last time - affordances

- Affordances are
  - <u>Properties</u> of surfaces, objects, and events
  - <u>Relational</u> – relationship between properties of the environment and properties of animals.
  - <u>Functional</u> – about action capabilities, what actions are afforded
  - <u>Perceptible</u> – one can directly perceive visual information that specifies affordances. They are not something to be found in the dictionary. They must be discovered.
  - <u>Real</u> – affordances are always there. They are not phenomenal (i.e. only exist when you see the environment).

Question remains

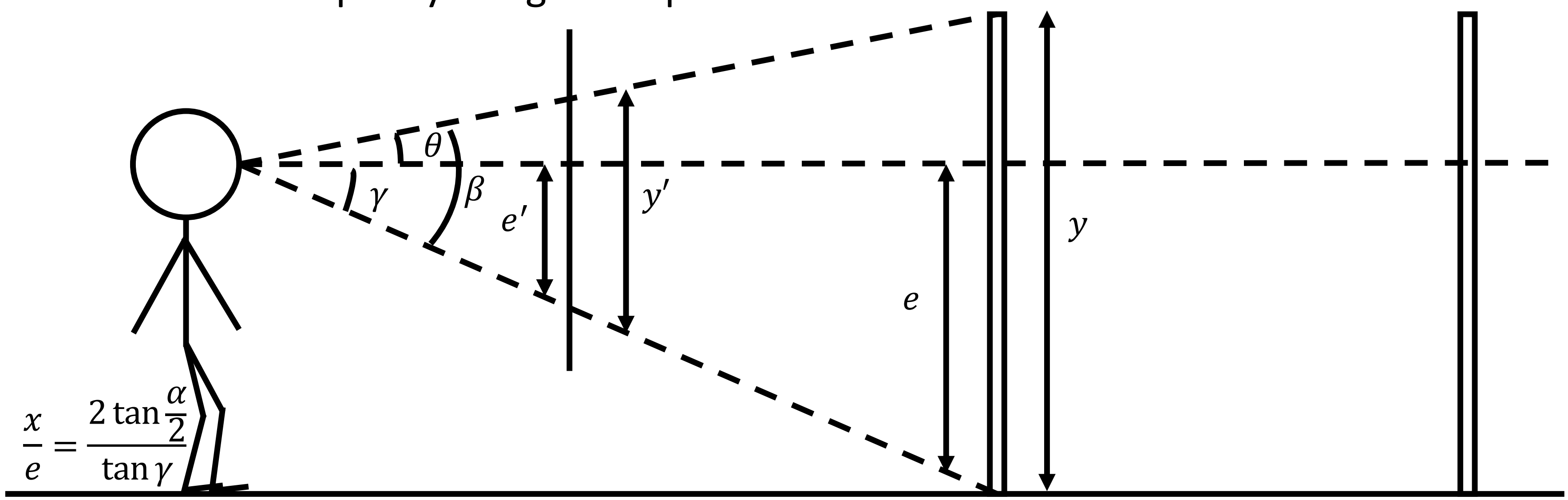
- How do we know the relationship between animal and the environment?
  - Optical information is inherently angular
  - There are no linear extents in optical patterns that can be described as being metric (e.g., meters or feet).

$$\tan \delta_\mu = \frac{IPD \cos \mu}{r^2 - \frac{IPD^2}{4}}$$



We still have our body

- Remember, we always have our body
- Linear bodily extents are an intrinsic part of the viewing geometry
  - Eye-height scaling: elevation angle specifies distance in eye-height units
  - Binocular disparity: vergence specifies distance in IPD units



$$\frac{x}{e} = \frac{2 \tan \frac{\alpha}{2}}{\tan \gamma}$$

Units

- Measurement units that we are familiar with
  - Centimeters, meters etc.
  - Inch, feet, etc.
  - (These units are human constructs anyways, like time…)
- Instead, try to think about measurement units that are intrinsic to human perception
  - IPD
  - Eye-height

Affordances vs. Effectivity

- Affordances
  - Properties of an object (in relation to the action capabilities of an animal that enable specific actions for that animal).
  - Requires perceptual information.
- Effectivity
  - Action-relevant properties of the animal (that allow the animal to perform the action using the object).
  - Entails action units.
- Both are action relevant properties.

Calibration

- Targeted actions require units
  - Walking – stride length
  - Reaching – arm length
- Perceptual information must be mapped to action units.
  - The unit of visual distance information (e.g., eye-height, IPD) must be mapped to the unit of action (e.g., stride length, arm length).
- This mapping requires calibration because it can change (Bingham & Pagano, 1998).
  - Calibration is of a mapping from embodied units of perception to embodied units of action.

What is Reaches-to-Grasping?

- An extremely common action that you perform everyday, if not every waking hour.
- A rather complicated process that involves two goals:
  - Collision avoidance
    - One needs to open the aperture between finger(s) and thumb wide enough to avoid hitting the object with the fingers before they can encircle the object.
  - Targeting
    - Place the fingers and thumb accurately on specific object surfaces (Bootsma et al, 1994).
- There are also other variations of the task that yield task-specific variations in the timing structure of the movement.
  - Reach at a faster speed.
  - Reach with a tool that enlarges/shrinks your grasp aperture and/or expands/shrinks your reach distance.

Why do we care?

- It sheds light onto human movement control
  - Functional relationship between the properties of graspable objects and the timing of the movements.
  - Targeted reaching entails both feed-forward control and online visual guidance.
- It is a measure for 3D shape perception
  - You have to form your grasp aperture in accordance to the perceived size of the object to be grabbed.
- It is a measure for distance perception
  - You have to modulate when to reduce your grasp aperture and reaching speed to close in on the object to be grabbed (and avoid collision).

Measuring Reaches-to-Grasping

- What do we measure
  - Thumb
  - Index finger
  - Wrist
- What do we use
  - miniBIRD – DC magnetic tracking (addresses the occlusion problem)
  - Alternatively, you can also use more advanced motion capture systems with active markers (e.g. OptiTrack, Vicon, Qualisys, etc.).

The Geometry of Reaches-to-Grasping

3D View

Top View

Frontal View

The Geometry of Reaches-to-Grasping

Pre-Reach

- Maximum grip, **MG**
  - The effective size of the actor's hand. Measured by having people picking up the longest rod they can using their thumb and index finger.
  - This should be measured *functionally*.
- Maximum object extent, **MOE**
  - The maximum length diagonal through the object, equals to the Pythagorean of the object width and the length of the grasp surface.
- Available aperture, **AA**
  - = MG – MOE

The Geometry of Reaches-to-Grasping

Mid-Reach

- Maximum grasp aperture, **MGA**
  - Occurs during the approach of the hand to the target object when the grasp aperture is the maximum.
  - Reflects the **collision avoidance goal**.
- Safety margin, **SM**
  - = MGA – MOE

The Geometry of Reaches-to-Grasping

Stability Component

- Lateral position of MGA, **MGA POS**
  - The difference between the center of the object and the center of MGA.
  - A measure of the accuracy of the targeting portion of reach-to-grasp.
  - Computed as the distance from the center of MGA to the vertical plane formed between the midpoints of grasp aperture at the initiation of the reach and at the FGA.
- Safety margin’s variability, **SM SD**
  - Reflects the variability of the grasping movement.
  - Computed as the standard deviation of SM for a given object.
- Total variability, **TV**
  - = SM SD + MGA POS

The Geometry of Reaches-to-Grasping

End-Reach

- Terminal grasp aperture, **TGA**
  - Occurs when the hand velocity drops to zero with the hand at the target object but prior to the fingers closing in on the object.
  - Occurs before FGA.
  - Computed as the distance between the fingers when the velocity of the wrist drops below 5 cm/s.
  - Reflects the **targeting goal**.
- Final grasp aperture, **FGA**
  - Occurs when the fingers (thumb and index finger) are in contact with the object to be grasped.
  - Occurs after TGA.
  - Computed as the distance between the fingers when the velocity of the index finger falls below 3 cm/s.

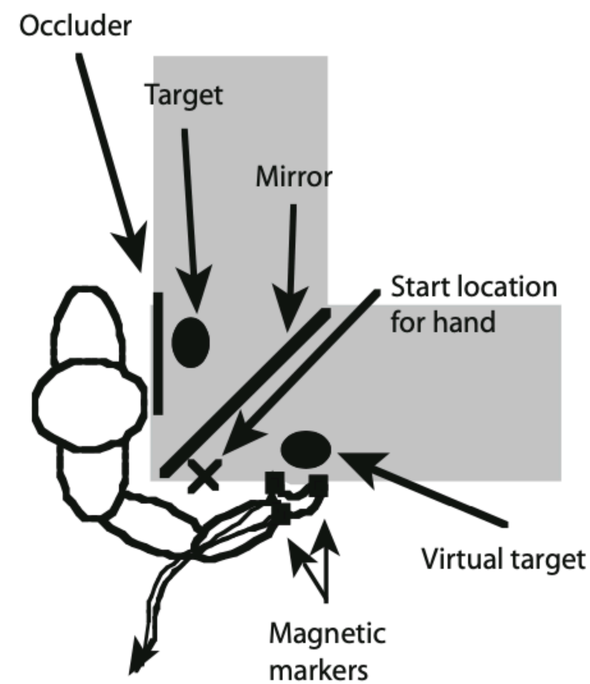
The Geometry of Reaches-to-Grasping

Time Components

- Movement time, **MT**
  - Time between the start (wrist velocity exceeds 5 cm/s) and the end (wrist velocity falls below 5 cm/s) of the reach.
- Time of MGA, **TMGA**
  - Time between the start of the reach and MGA, normed by MT.
- Time of peak velocity, **TPV**
  - Time between the start of the reach and when the wrist achieves maximum velocity, normed by MT.

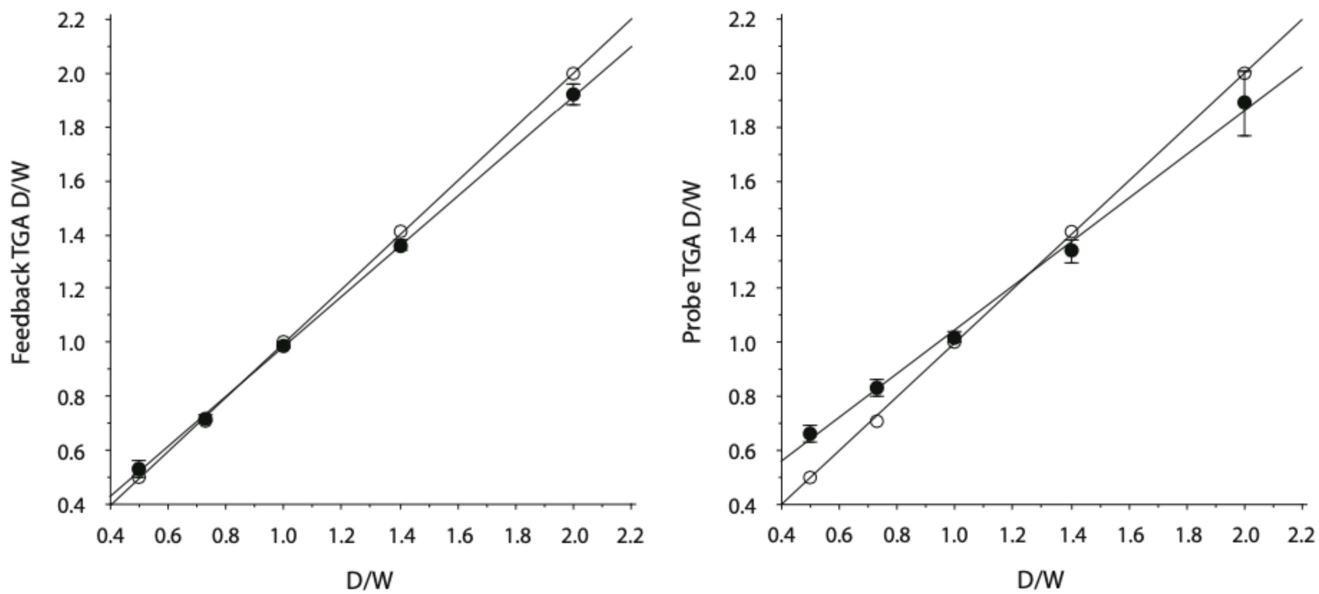
Calibration and 3D Shape Perception

- Trial types
  - (Haptic) feedback trials
    - Participants see and grasp an actual object.
    - They could not see their hands.
    - (Two identical objects required.)
  - Probe trials
    - Participants could only see and grasp the virtual target.
    - I.e., try to grasp the object that they see but cannot touch.
    - They could not see their hands.
- Grasping measures
  - First grasp object’s width
  - Then grasp object’s depth



Lee et al., 2008

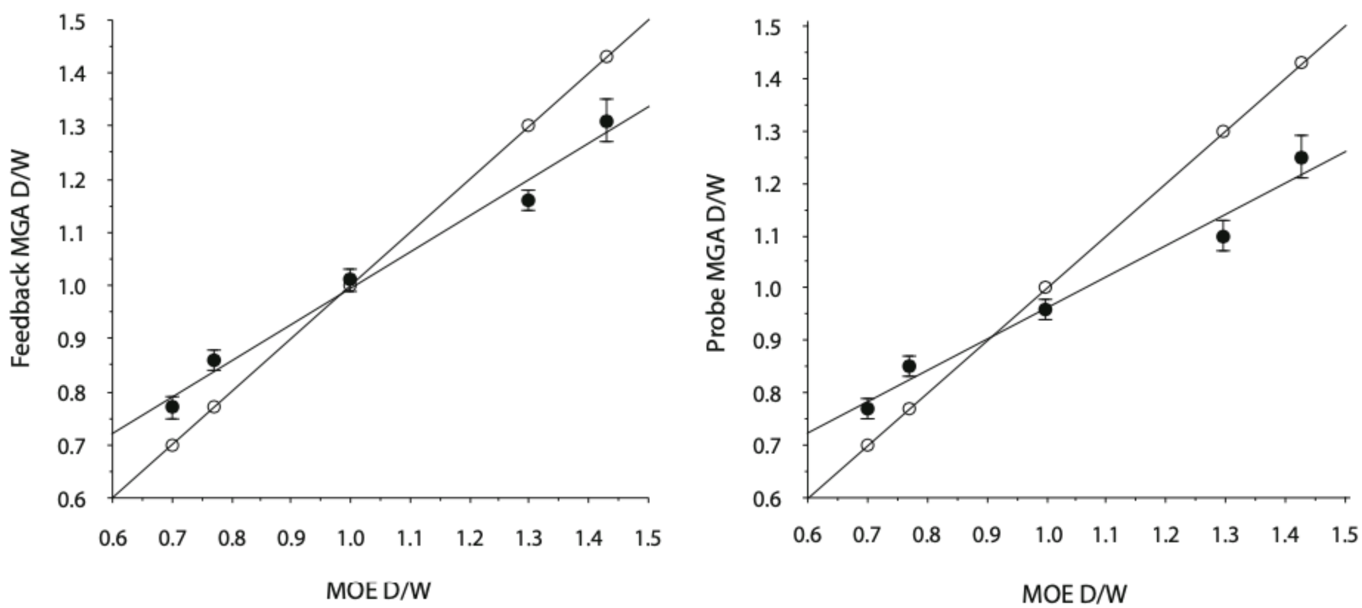
Haptic Feedback



Lee et al., 2008

Open circles: correct target aspect ratio
Filled circles: judged aspect ratio

Haptic Feedback



Lee et al., 2008

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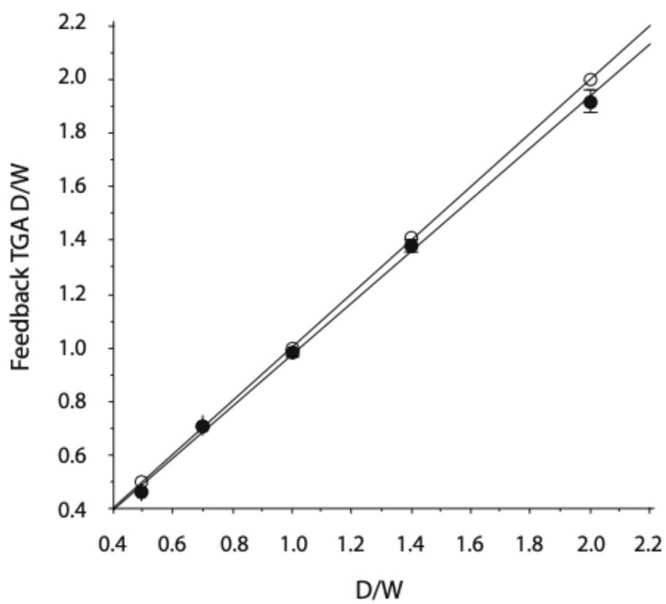
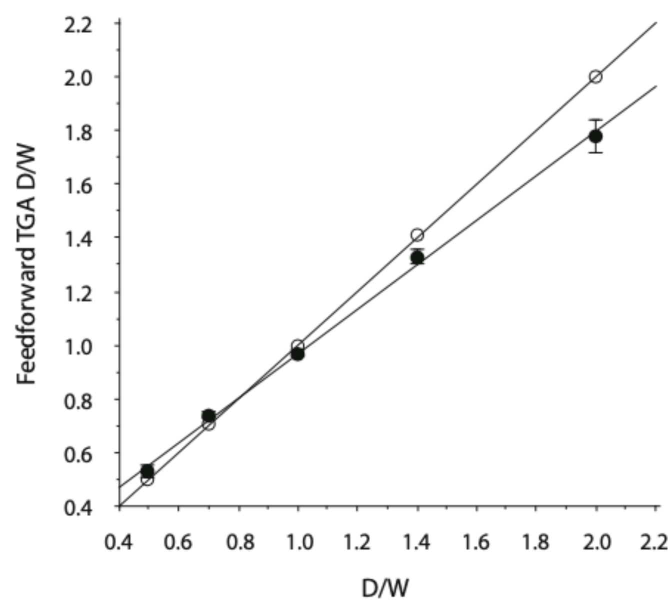
(Visual) Feedback vs Feedforward

There is always haptic feedback.





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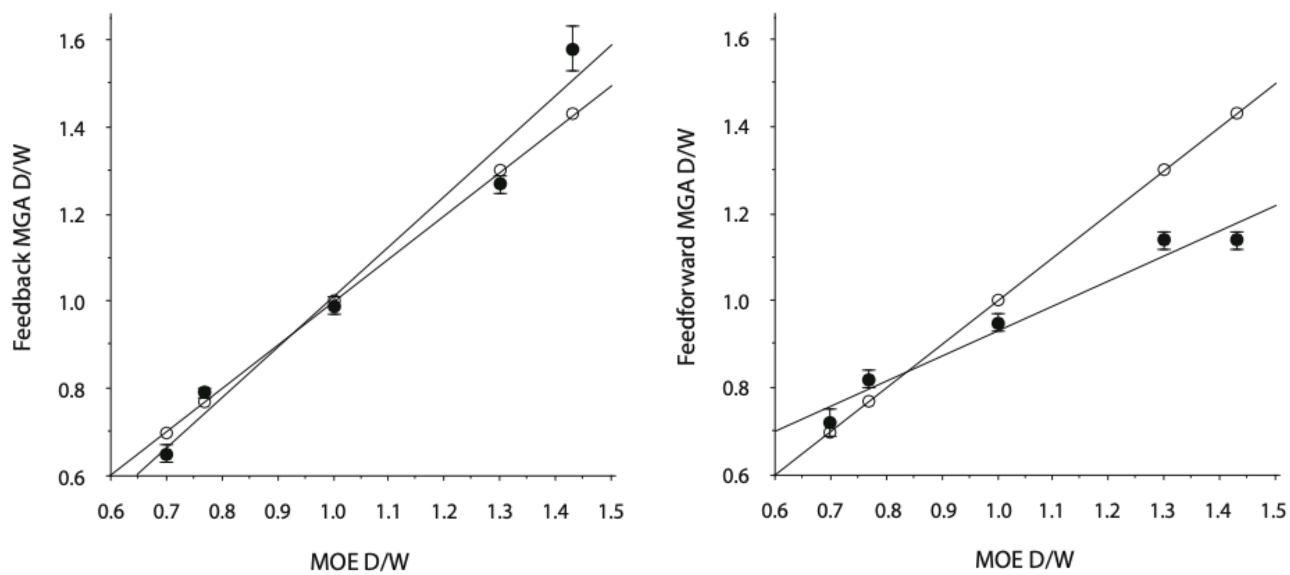

Lee et al., 2008

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Invariance over Transformation

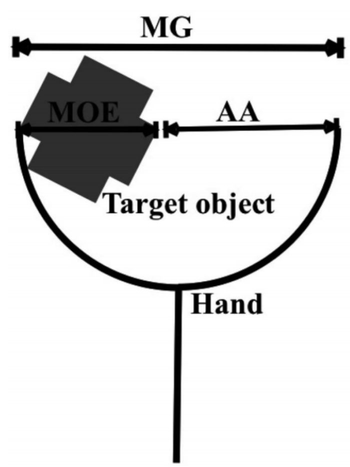
- Studying affordances and effectivity means to identify the invariant relationship between the environment and the animal.
  - Recall: Warren's stair-climbing and aperture-passing experiments
- Geometrical scaling vs. Dynamical Scaling
  - Geometrical scaling – the invariant geometrical relationship between the organism and the environment (e.g., leg length and riser height).
    - Focuses on measurements such as length and width.
  - Dynamical scaling – the invariant relationship between an actor's error tolerance and variability/stability of the action.
    - Focuses on measurements such as safety margin and standard deviation.

Geometrical Invariance

$$SM = P \times AA$$

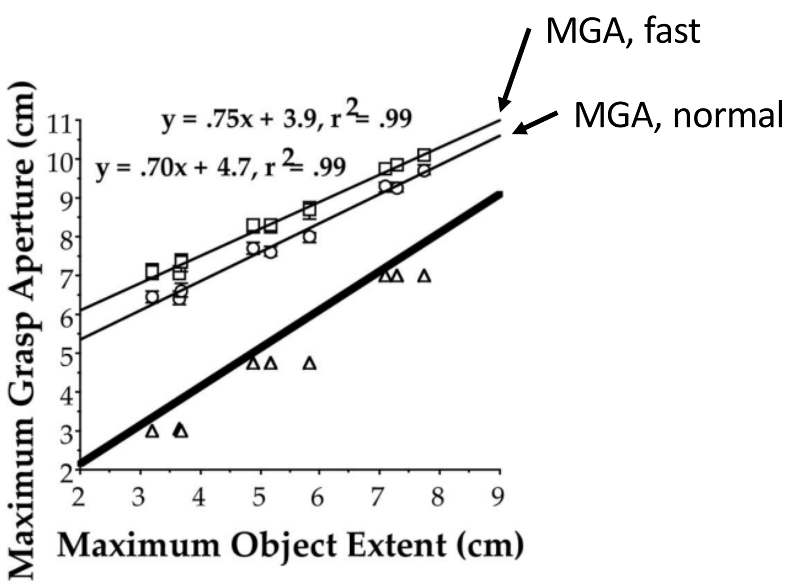
Or

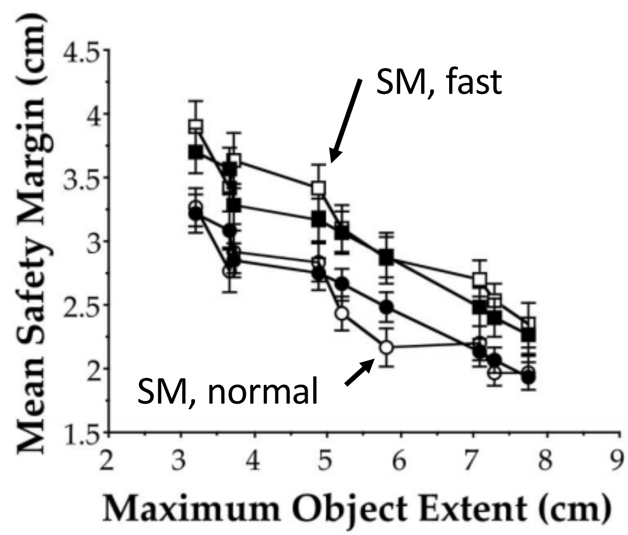
$$\overbrace{MGA - MOE}^{What\ is\ used} = P \times \left(\overbrace{MG - MOE}^{What\ is\ available} \right)$$



Bingham, Snapp-Childs, Fath, Pan, & Coats (2014)

Geometrical Invariance

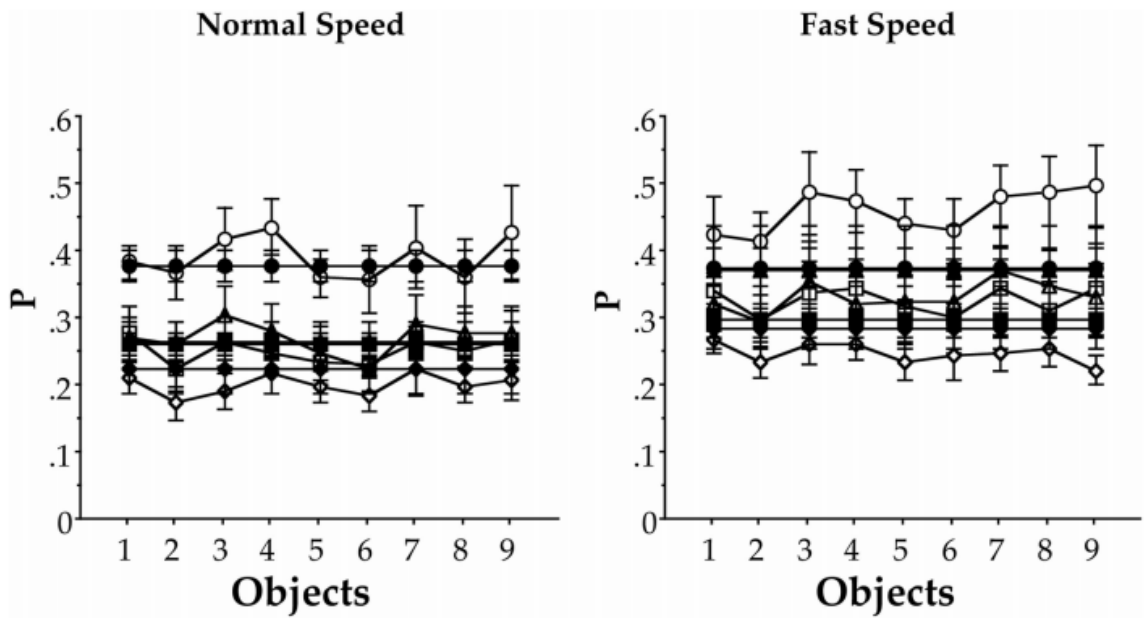




Bingham, Snapp-Childs, Fath, Pan, & Coats (2014)

Geometrical ~~In~~variance

Open Symbols - Geometrical scaling
Circle – small handed females
Squares – large handed females
Triangles – small handed males
Diamonds – large handed males



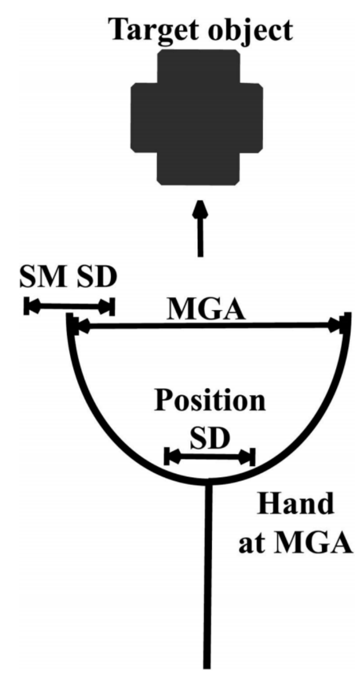
Bingham, Snapp-Childs, Fath, Pan, & Coats (2014)

Dynamical Invariance

Action stability, measured using variability

$$P = \delta \times \frac{TV}{\overline{\overline{AA}}}$$

Where δ scales the geometrical invariant to the dynamical invariant, representing **risk tolerance**.



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Dynamical Invariance

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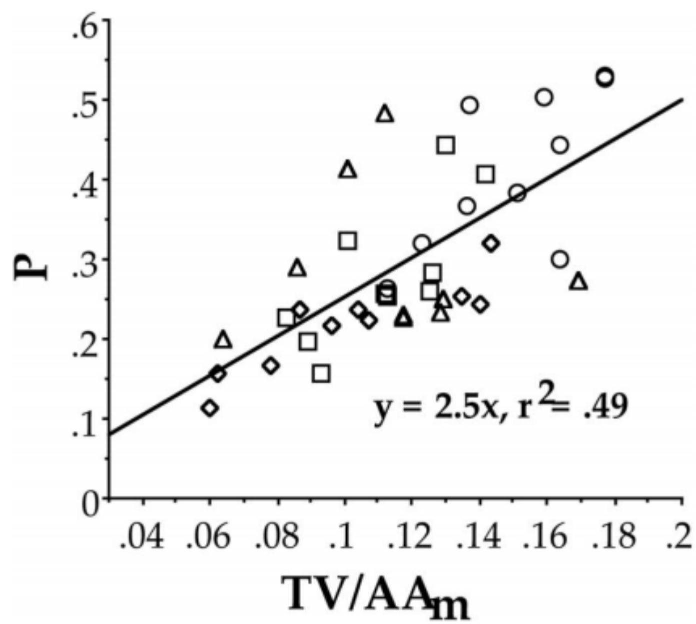

Bingham, Snapp-Childs, Fath, Pan, & Coats (2014)

What you should get out of this session

- What type of units do we need when we talk about perception-action coupling? Why do we need them? How do we connect them?
  - Units of visual perception (IPD, eye-height) and units of action (stride length, arm length).
  - We can describe perception and action based on their intrinsic measurement.
  - Calibration
- (What are the two types of scaling relationship in action analysis?)
  - (Geometrical and dynamical scaling)
- (What is one important lesson do we learn from the second type of scaling relationship?)
  - (When doing action analysis, always look at variability.)

See you during your presentation!

- Best of luck!
- And thank you for a great course!