# Advanced HCI
# Lecture 2
# Adaptive Interaction & Perceptual-Motor Control

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# change blindness

# Three lectures

- Lecture 2
  - Adaptive Interaction
  - Perceptual-motor control
- Lecture 3
  - Decision making
- Lecture 4
  - Social cognition and collaboration

# Adaptive Interaction

# Interaction

- People interact with computers so as to achieve **goals**.
- These include, work-related goals, health, entertainment, social and collaborative goals.

http://www.cultofmac.com/174776/why-your-doctor-doesnt-want-you-using-iphone-and-ipad-health-apps/

# Adaptive Interaction

- People achieve any one goal in a multiplicity of ways.
- For example, some people choose to type fast and not worry about errors, others may choose to type more slowly and make fewer errors.
- Similarly, while some are meticulous about filing emails in folders, others leave everything in their inbox.
- Some choose to broadcast all Facebook messages to all friends and family, others define social circles and limit communication.
- Each of these choices can be thought of as a **strategy**.

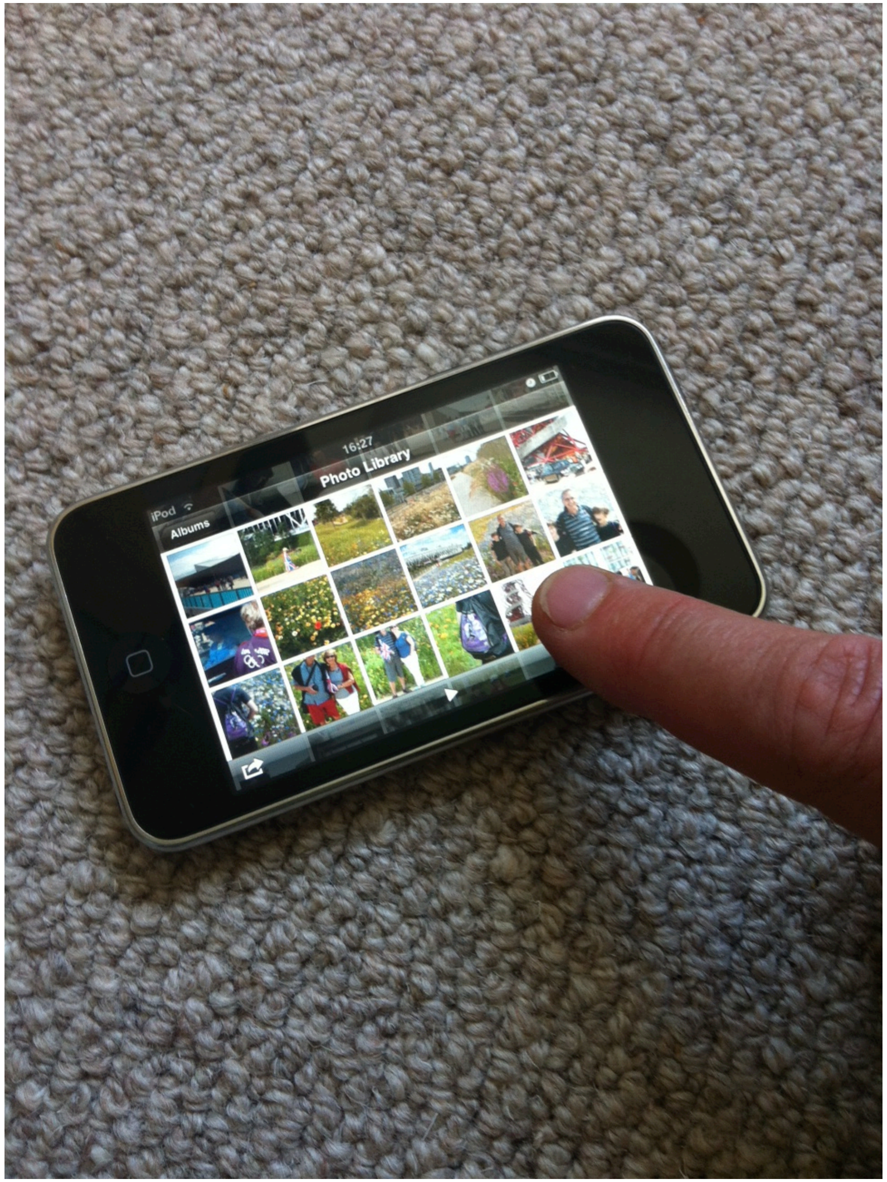
# Adaptive Interaction

- **People choose what to do by finding strategies that exist within the space defined by three things:**
- **The environment**. Bounds imposed by the environment including computers, tablets, smartphones etc.
- **Bounds** imposed by human psychology, including memory, vision, and motor-systems.
- A **utility function**. People have goals, preferences, tasks. They must weight various trade-offs including, for example, speed and accuracy.

# Perceptual-motor control

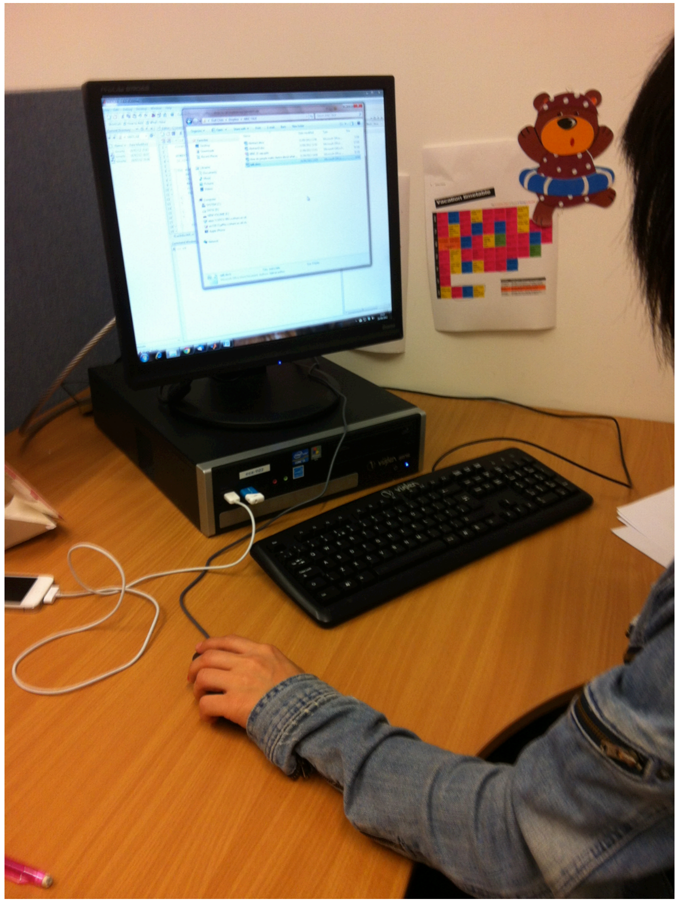
# perceptual-motor control

- The starting point for HCI is an understanding of perceptual-motor control.
- While there are other means of controlling interfaces, including direct thought control(!), it is still the case that interaction with a machine is usually achieved by manipulating and touching buttons and displays under visual guidance.
- Desktop computers still use a mouse.
- Tablets and smartphones use a growing range of gestures.



# Perceptual-motor control

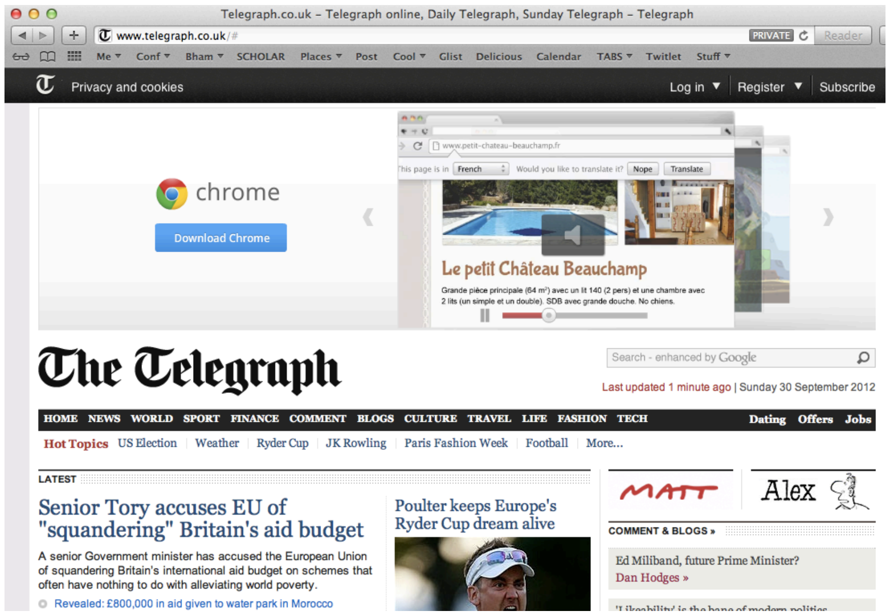
- How do people point to an icon or move a mouse pointer to a target?
- How do people detect when a warning light is activated on a display?
- Easy to take for granted but actually these are complex control problems.
- how do people make use of information from the fovea, parafovea, touch, and proprioception during movement?
- how do people control the forces applied by the muscles in the arm, hand, and eye so as to guide a pointer to the target?



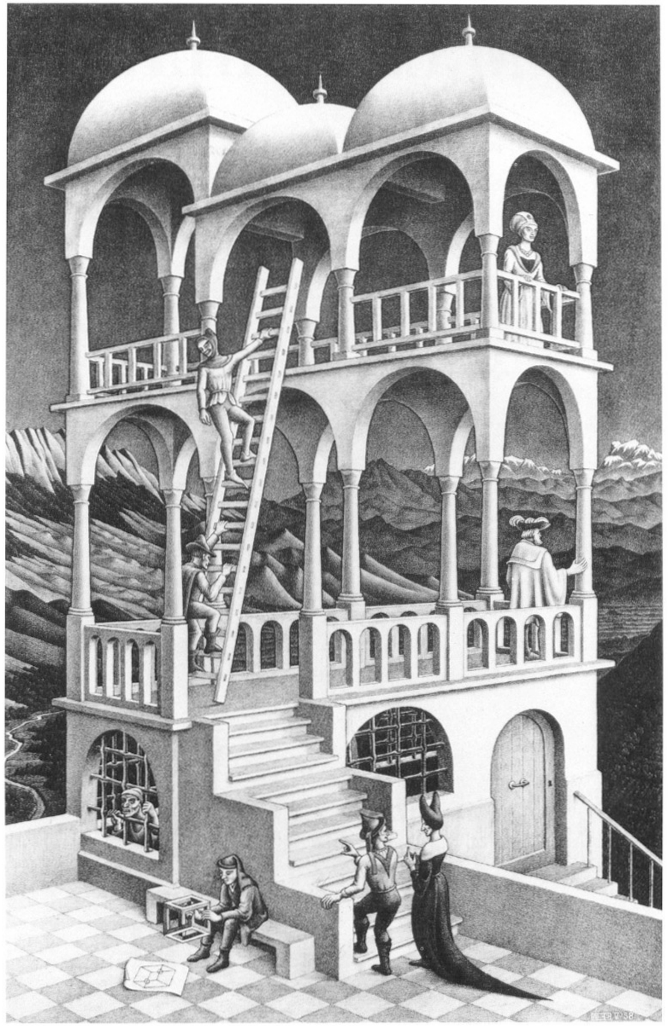
# human vision for HCI

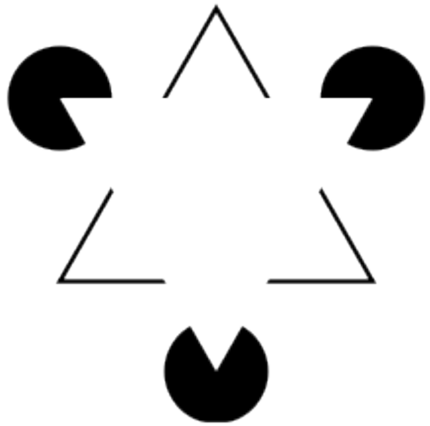
# environment

the environment imposes priors.

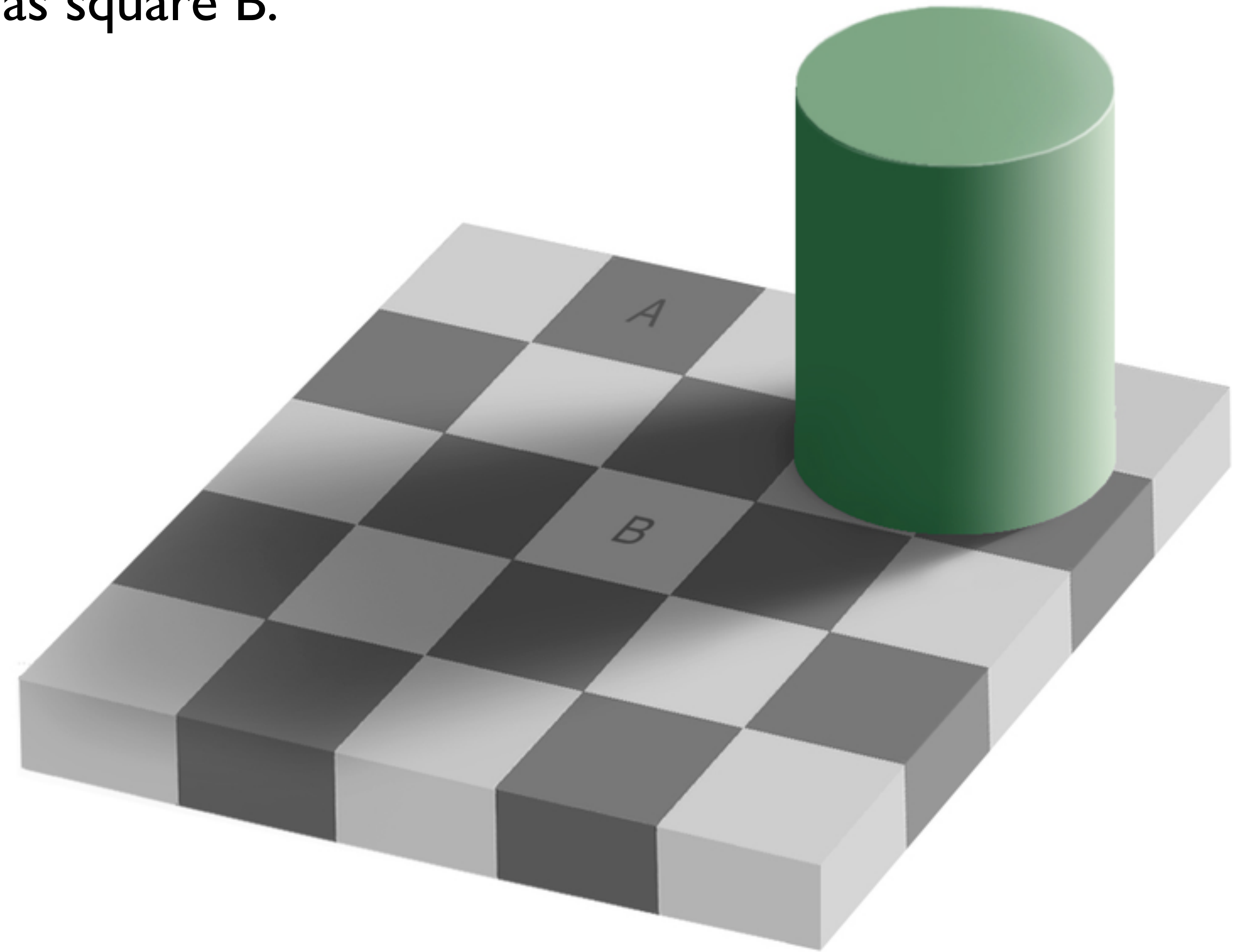


# cognitive illusions show us that the brain infers structure in the world given expectations.

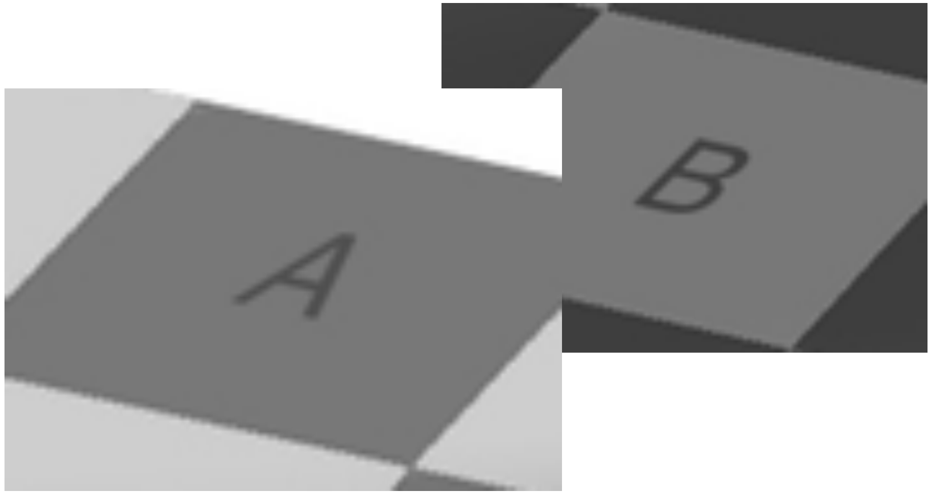




- Square A is exactly the same shade as square B.




wikipedia.org




*if you do not believe me then do this test yourself on my overheads tonight.*

- What happens here is that the brain uses the various elements of the image -- including the green cylinder, its shadow, and the checkerboard -- to infer the probable grayness of each image element.
- What you see, in your mind, is NOT a raw unprocessed image. It is not like a photograph in the head. Rather, your brain computes a representation of the world that is influenced both by information from the eye and by prior expectations about what is likely to be out there.

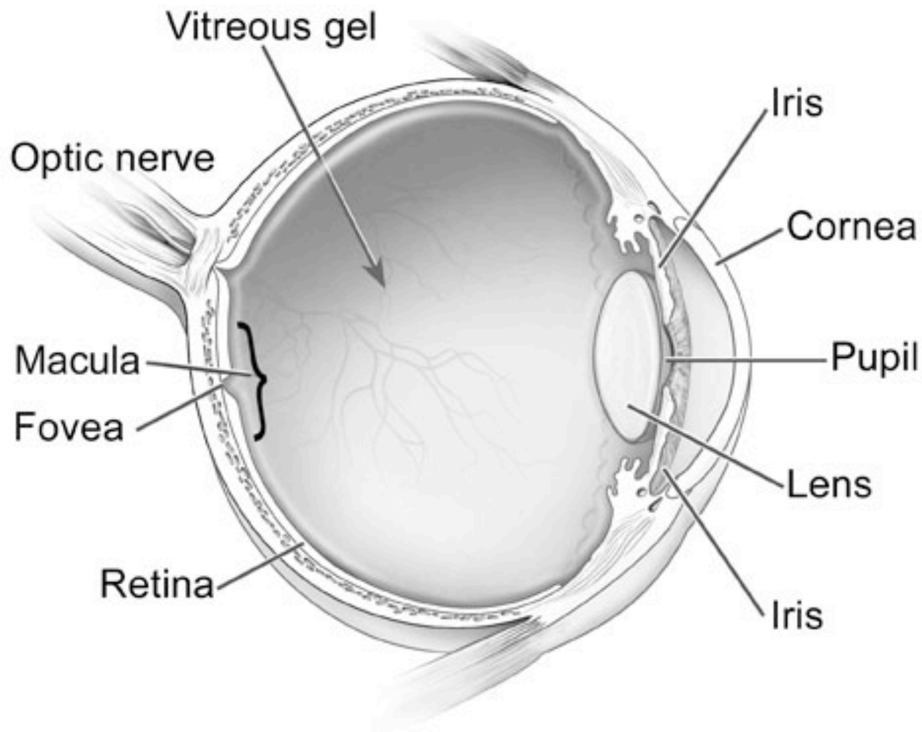
# the world is probabilistic

- smoking is not guaranteed to cause cancer but it does increase the risk of contracting cancer.
- an object that you "see" in the world is not guaranteed to be the object that you think it is. A color is not guaranteed to be the same as another color. An object is not guaranteed to be exactly where you think it is.
- we will look in much more depth at how the brain represents uncertainty in subsequent lectures.

bounds

# the fovea and parafovea

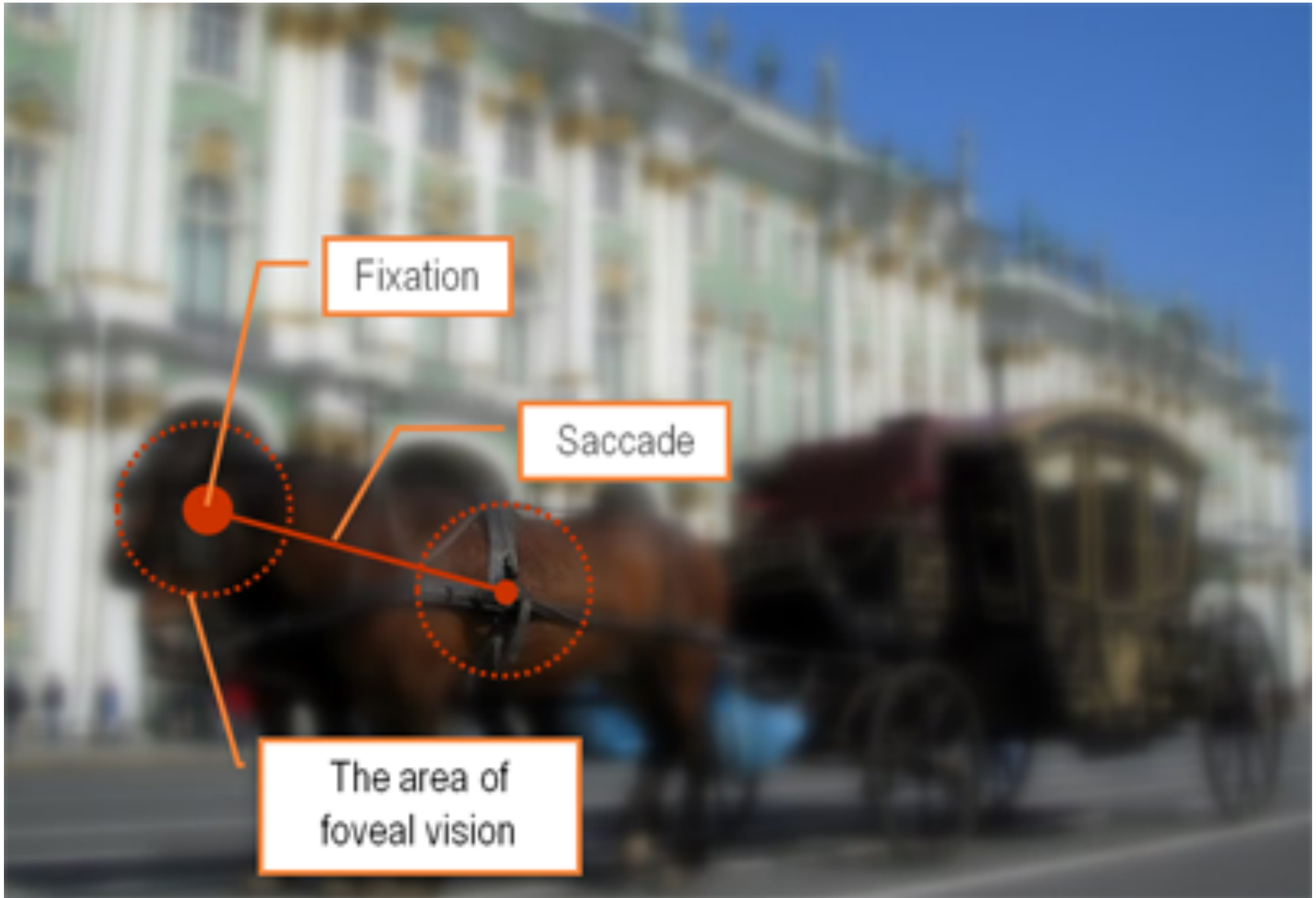
- The acuity with which we see an object is partly determined by whether the image of the object is on the fovea (high resolution) or the parafovea (relatively low resolution).




- http://www.ncbi.ie/information-for/eye-health-and-eye-care/your-eye

# fixations and saccades

- See EyeTracking.Me by Tommy Strandvall.
- 



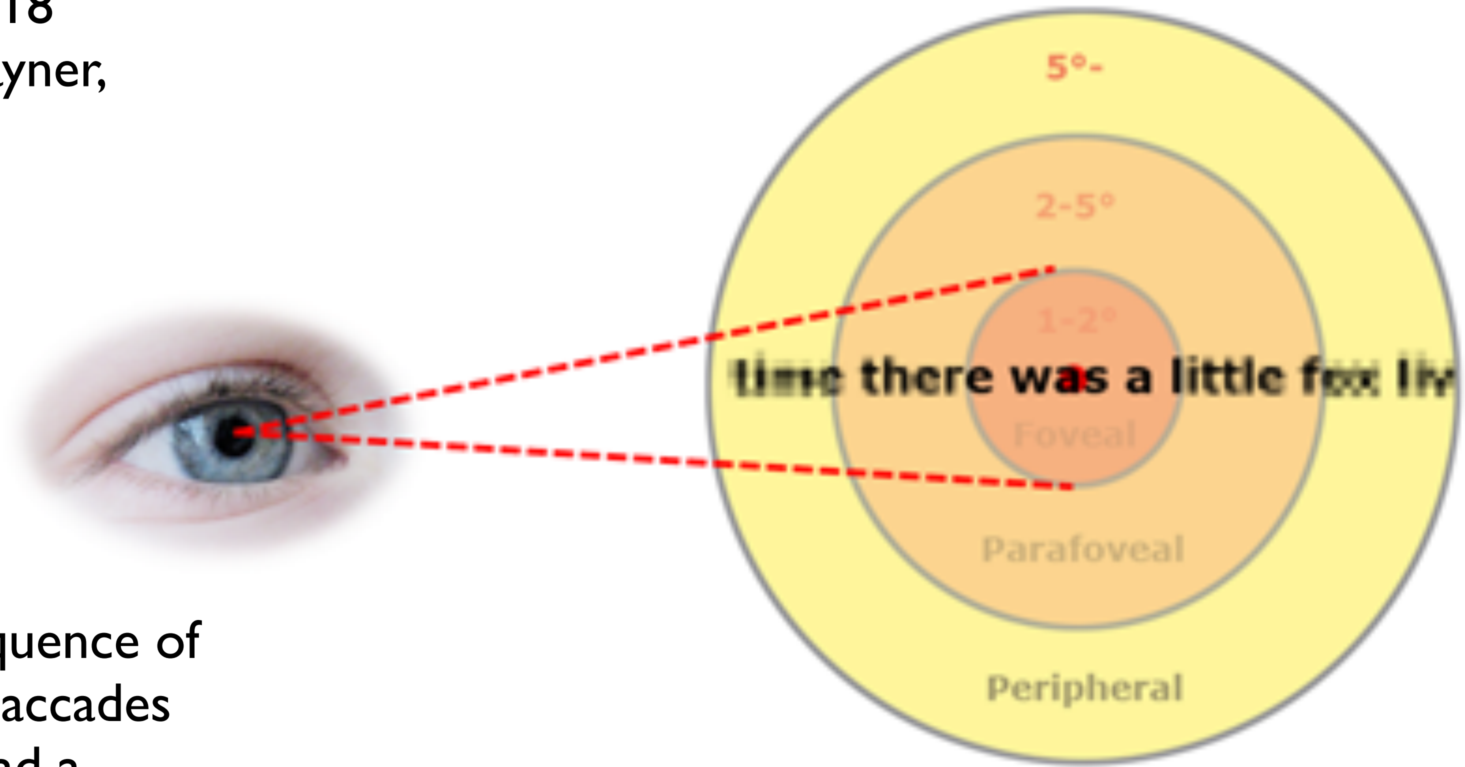

http://eyetracking.me/?page_id=9

# there are minimum time requirements for how long it takes make eye movements

- For reading,
- Saccade duration is between150 and 175ms (Rayner, 2008).
- Fixation durations vary between 100 and over 500ms.
- where a millisecond (ms) is 1/1000th of a second.

# letter perception

- When we are reading we have a perceptual span of about 18 characters (Rayner, 1998).

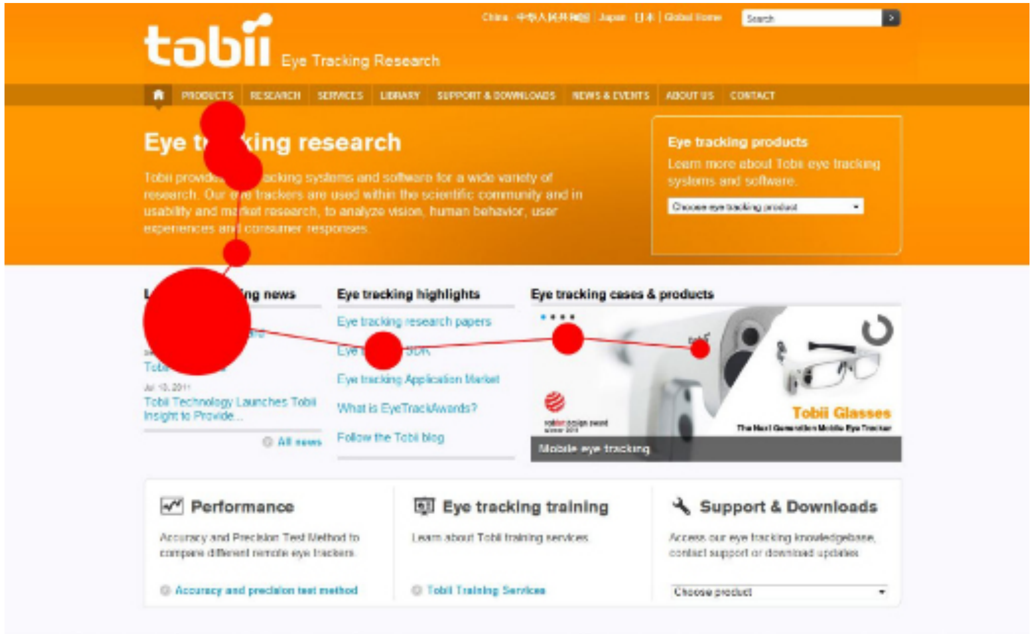



http://eyetracking.me/?page_id=9

- we make a sequence of fixations and saccades in order to read a sentence.

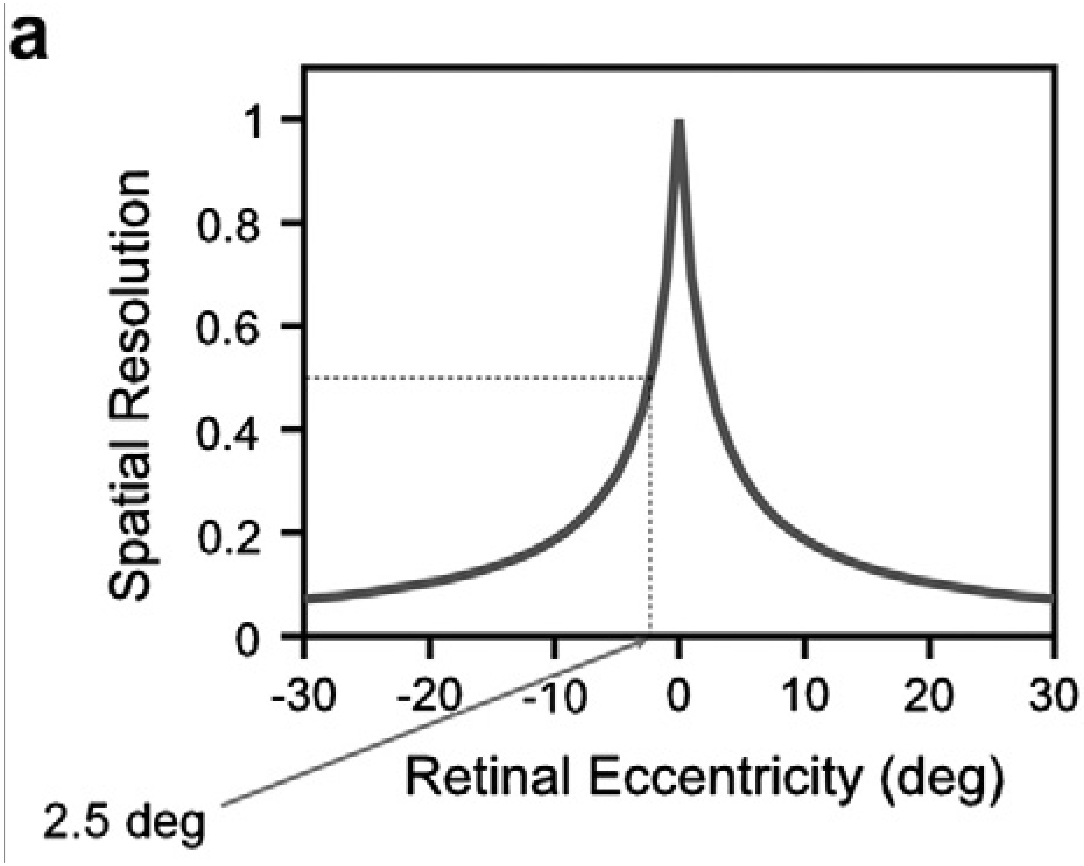
# fixations and saccades

- We can measure individual fixation dwell times and patterns of saccadic eye movements.



# Spatial resolution with eccentricity from the fovea

- Geisler (2011) Figure 3.
- At 2.5 degrees of visual angle the spatial resolution has dropped to 50%.



# example

- Geisler (2011) Figure 3.
- Top panel is an original image.
- In the bottom image spatial resolution is degraded by 50%

# Parafoveal vision

- focus on the red "C" of the word "Cognitive" on the right. Can you read the words on the left most white book?
- Move your eyes one book to the left? etc.
- Notice how acuity  for books to the left increases as your eyes move to the left.
- Also notice that you can attend to somewhere other than where you are fixated.

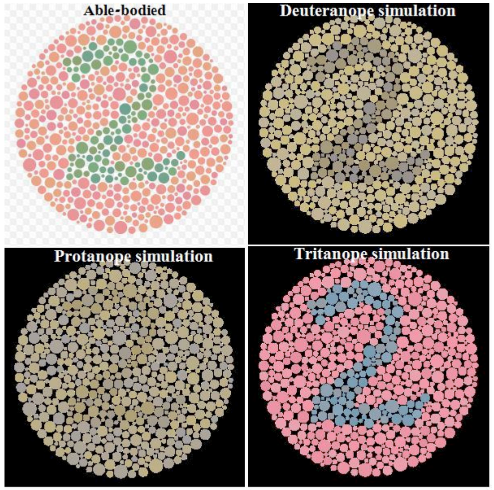
# change blindness

# … and many more bounds

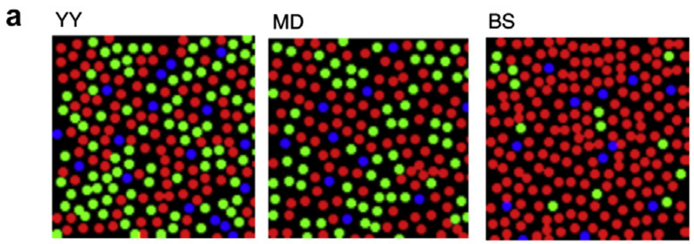
- color perception
- depth perception
- motion perception
- etc.
- bounds vary between individuals
- disability imposes bounds.

dog.vision.com

apisuk.com



wikipedia

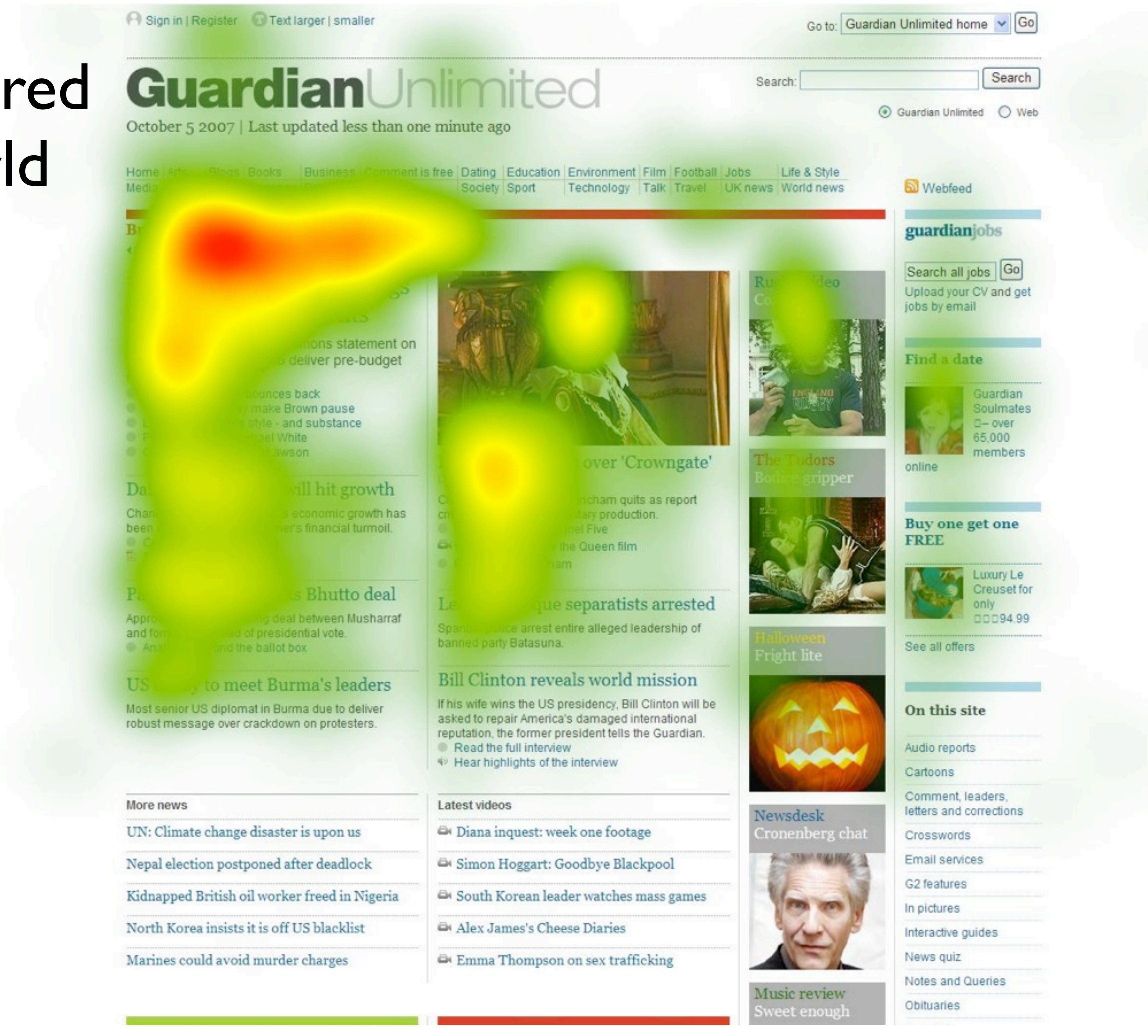


variation in cone arrangement across three individuals (as cited in Geisler,2011)

# utility

# people choose to look where they expect to find *useful* information

- eye movements are required to bring more of the world into the fovea and gather higher resolution information.
- typical patterns of eye movements can be monitored with an eye tracker.
- they reveal where people expect to find useful information.




http://wel.cs.manchester.ac.uk/studies/saswat/images/guardian_dynamic.jpg

# trade-offs, discounting and diminishing returns

- a utility function represents trade-offs between things that are useful to us.
- a utility function might be determined by evolutionary fitness but people can show flexibility in the kinds of utility function that they are willing to adopt.
- utility functions might represent trade-offs between speed, accuracy, energy consumption, wealth.
- utility functions are often discounted. Future rewards are worth less than rewards in the present.
- gains in rewards also have diminishing utility. The difference between nothing and £1 million is worth more to a person than the difference between £10 million and £11 million.

# information gain

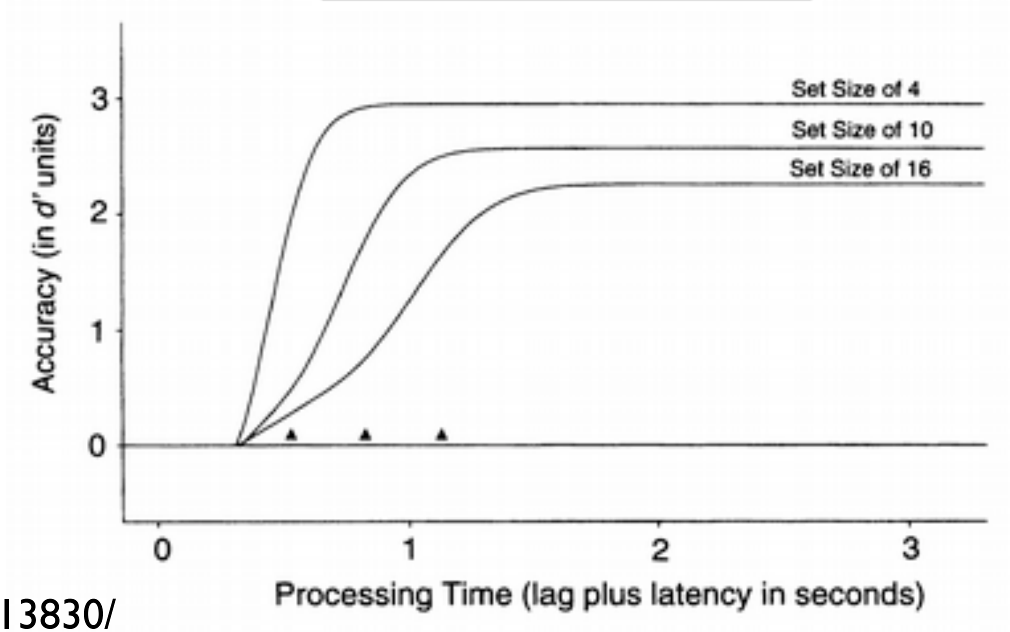
- Information gain is one key contributor to the utility of vision.

# Multi-attribute utility functions

- Multi-attribute utility function for speed and accuracy
  - utility = speed x W1 + accuracy x W2
- Time and money.
  - utility = money x W1 - time x W2
- How people combine multiple attributes is an open research question (Vlaev, Seymor, Dolan, Chater, 2009; Talmi, 2009).

# speed versus accuracy in a feature search task

- Is there an O present?
- The figure shows accuracy versus how accuracy versus processing time for a feature search task. The figure shows how accuracy improves with processing time but then reaches a plateaux.


McElree and Carrasco (1999)
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3313830/

# Adaptive Interaction and Vision

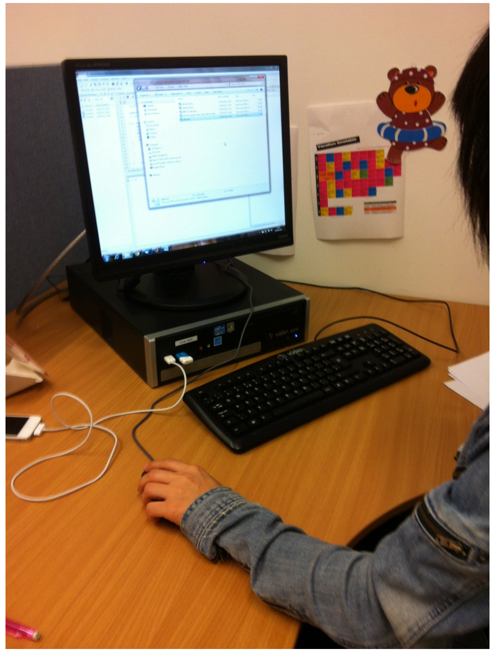
- **People choose what to do by finding strategies that exist within the space defined by three things:**
- **The environment**. Bounds imposed by the environment including computers, tablets, smartphones etc.
- **Bounds** imposed by human psychology.
- A **utility function**. People have goals, preferences, tasks. They must weight various trade-offs including, for example, speed and accuracy.

# human motor control

environment

# motor movements

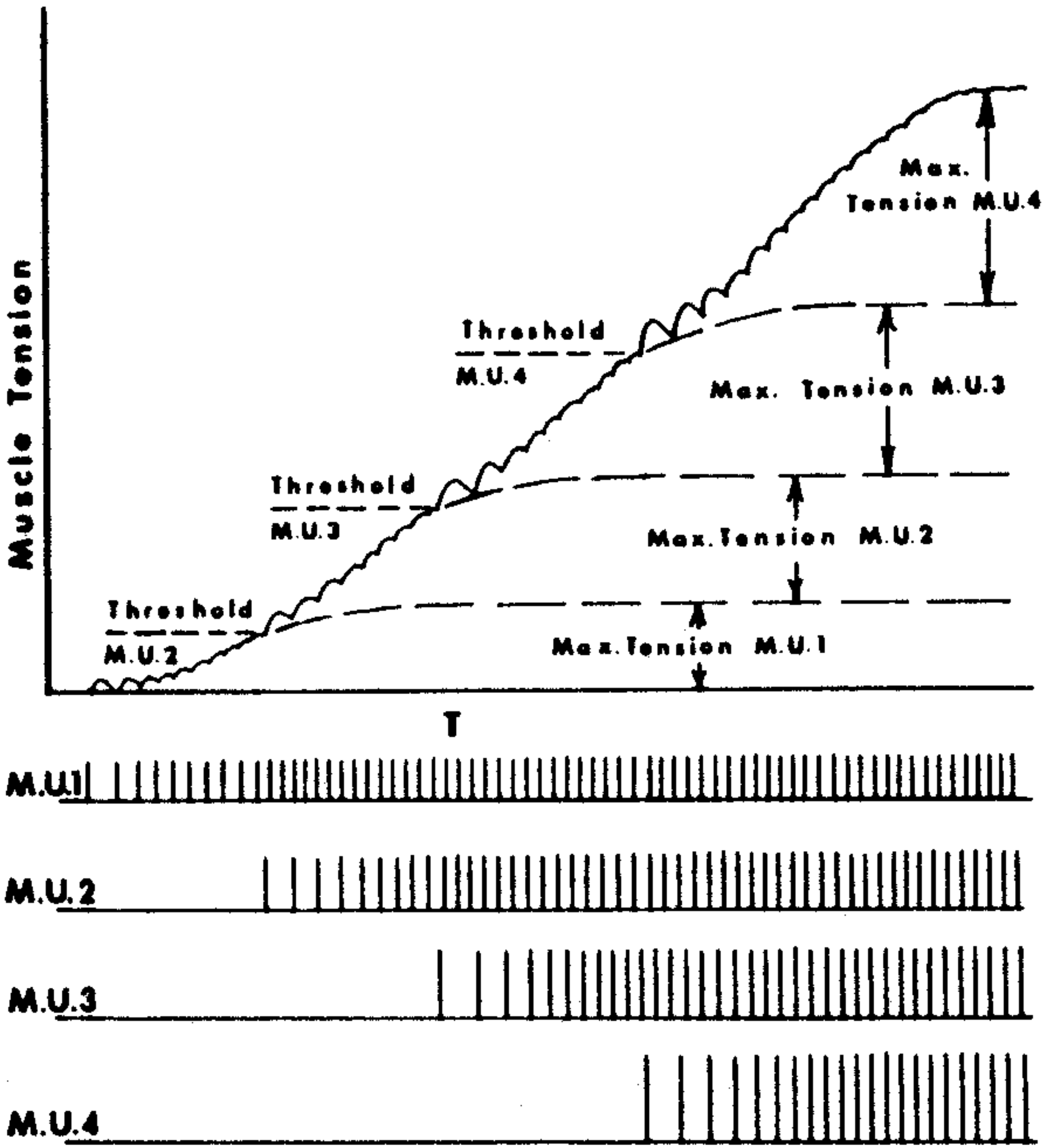
- The various kinds of devices used to interact with computers present various motor control problems to people.
- A mouse movement is constrained in 2-dimensions. The end point is unconstrained by the environment.
- Pointing to a tablet involves a 3-dimensional movement but the end point is constrained by the surface.
- Different strategies are required for a person to solve each of these problems.



# bounds

# motor units

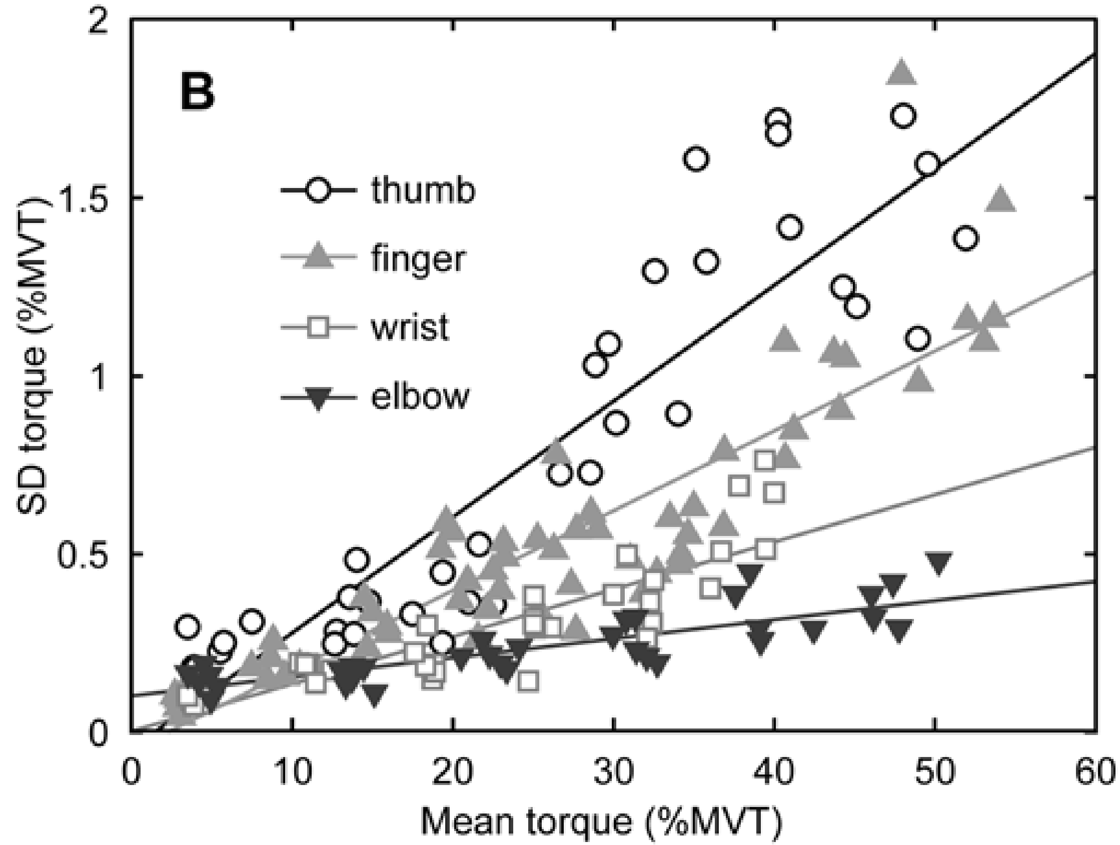
- The smallest subunit that can be controlled is called a motor unit. It is innervated separately by a single motor neuron.
- Under the control of a motor unit there are between 3 and 2000 muscle fibres depending on the fineness of control required (Winter, 1990).
- Muscles of the fingers, face, and eyes have small numbers of short fibres (giving fine control) whereas muscles of the leg have a large number of long fibres (giving relatively coarse control).




- size principle of the recruitment of muscle units. small units, MU1, are recruited first. Then larger units up to MU4. Muscle force (tension) increases and reaches a plateau for each group.

# variation in force due to different muscle groups

- A given force can be more accurately generated by a stronger muscle than a weaker muscle (Hamilton, Jones and Walpert, 2004).
- the variation of torque decreases systematically as the maximum voluntary torque increases.



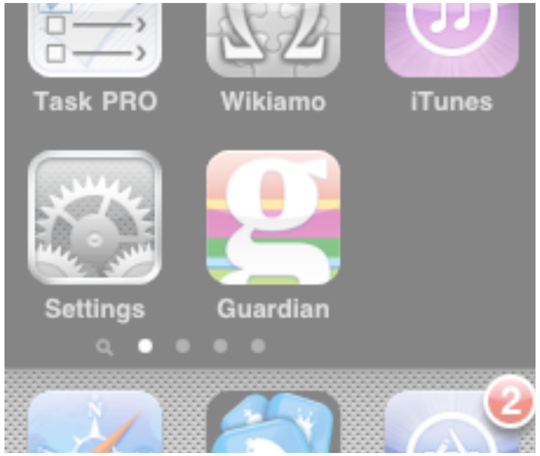

Relationship between mean torque and standard deviation of torque for subject PD, plotted as a percentage of maximum voluntary torque. Thirty- six symbols are plotted for each muscle indicating the mean and standard deviation on each trial. Solid lines indicate the linear regression sd = a mean + b all fits were significant at p<0.001. The slope parameter a gives the coefficient of variation for each muscle

# utility

# utility and energy consumption

- utility in motor movement is usually modelled as energy expenditure (Todorov, 2004).
- These models select movements that minimize the energy consumption of the muscles. Though others might minimize time or variation.
- We think of running, walking, playing sport as energy consuming but normal hand and arm movements also require energy.
- The brain calculates ways to use muscles that minimizes energy use.

# putting perceptual and motor control together



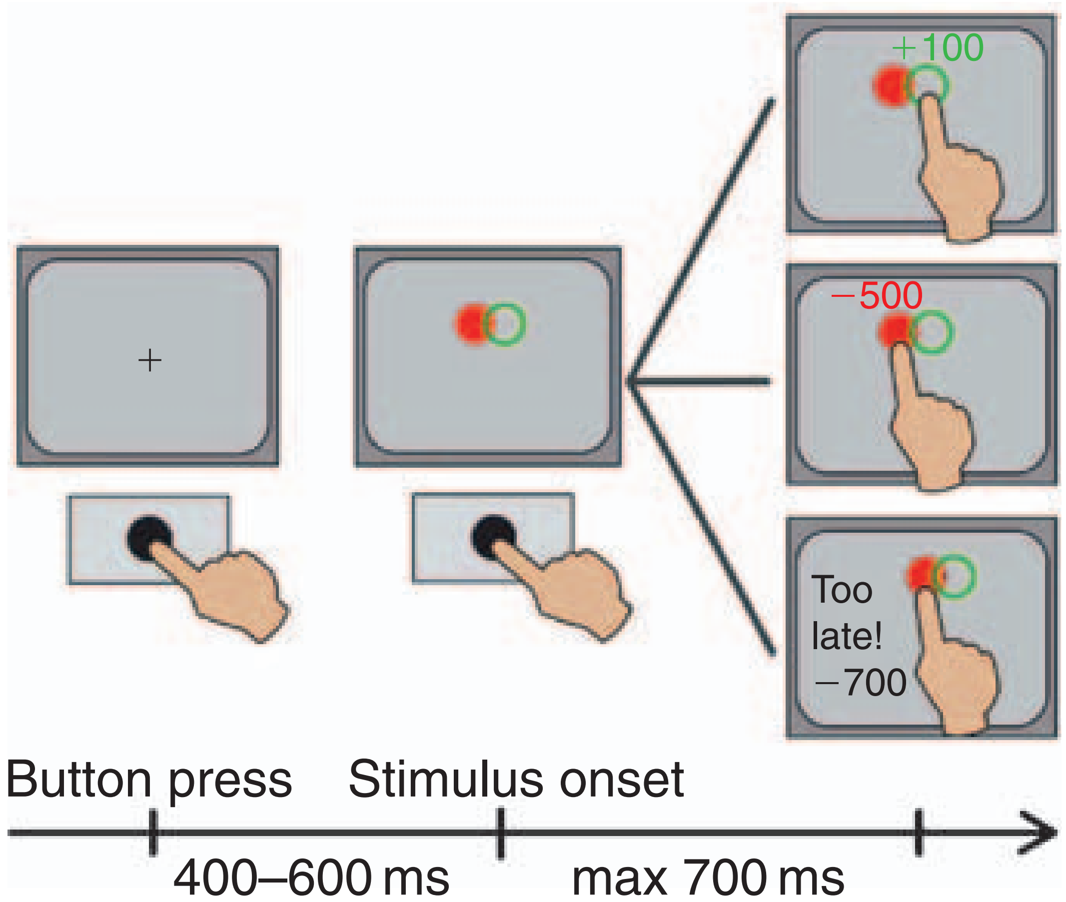

+

- Your task is to press the "Guardian" icon.
- Your eyes start focused on the crosshair.
- Make the required eye movements, pick your aim point, and press the button.
- Achieving this goal requires your brain to process the verbal instructions, choose an aim point, control muscles in your face and eyes, muscles in your hand, arm, and upper body. All of this activity needs to be coordinated so as to press a button.

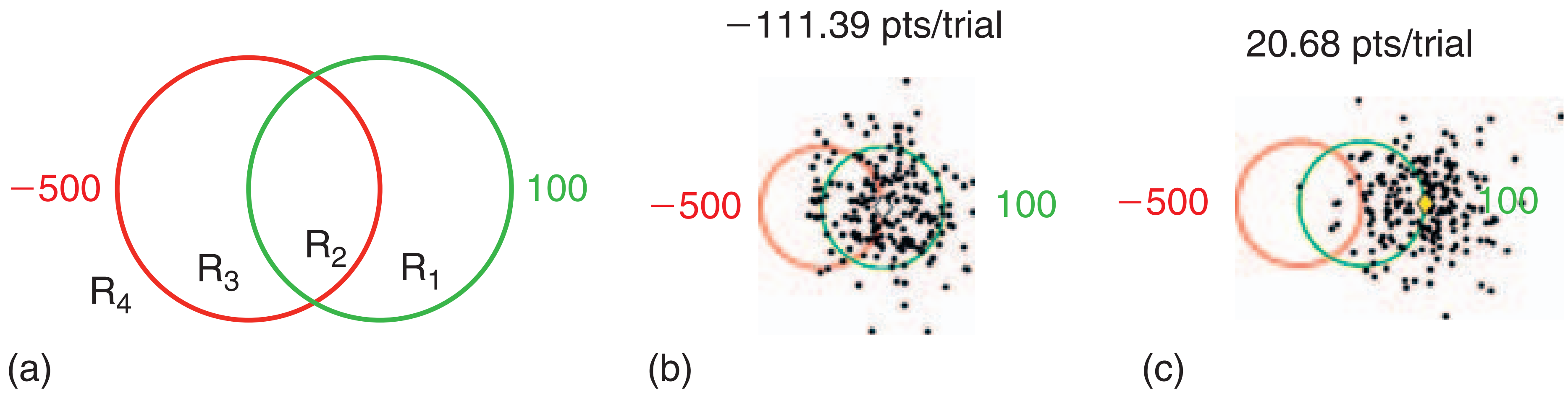
# Modeling

- We can use what we know about vision and motor control to predict and explain performance on this task.

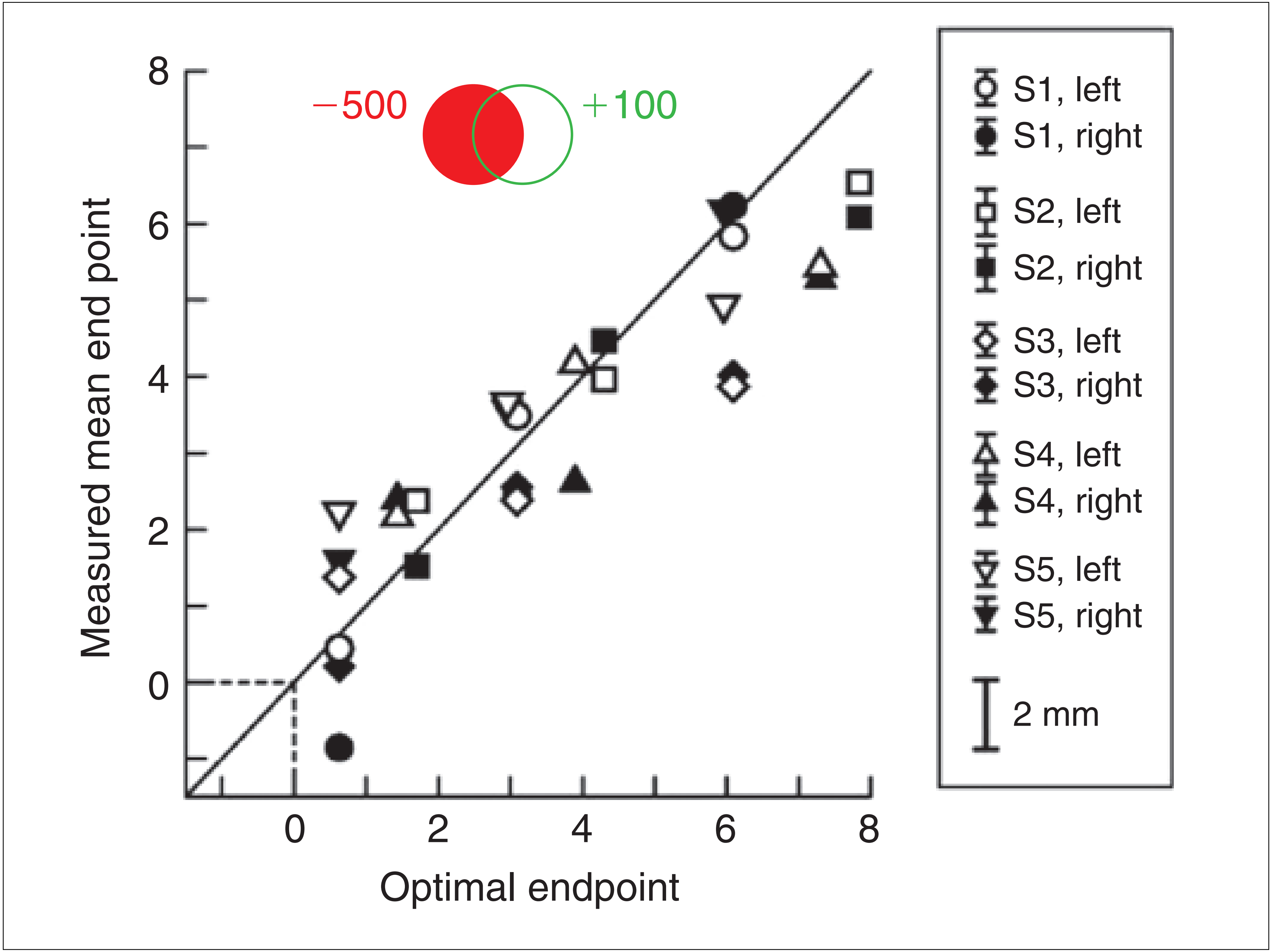
# example: targeting




from Trommershauser, Maloney, Landy (2008)



−500
100
$R_4$
$R_3$
$R_2$
$R_1$
(a)
−111.39 pts/trial
−500
100
(b)
20.68 pts/trial
−500
100
(c)

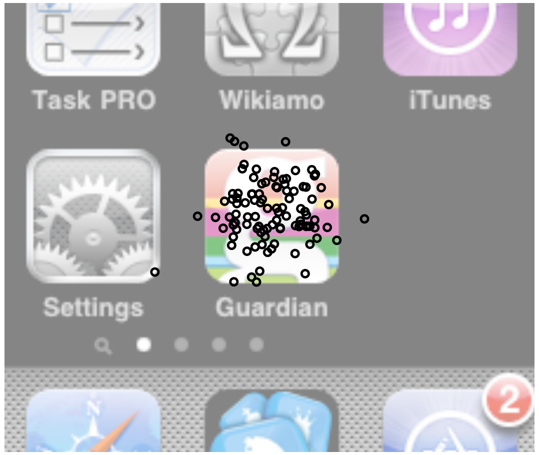


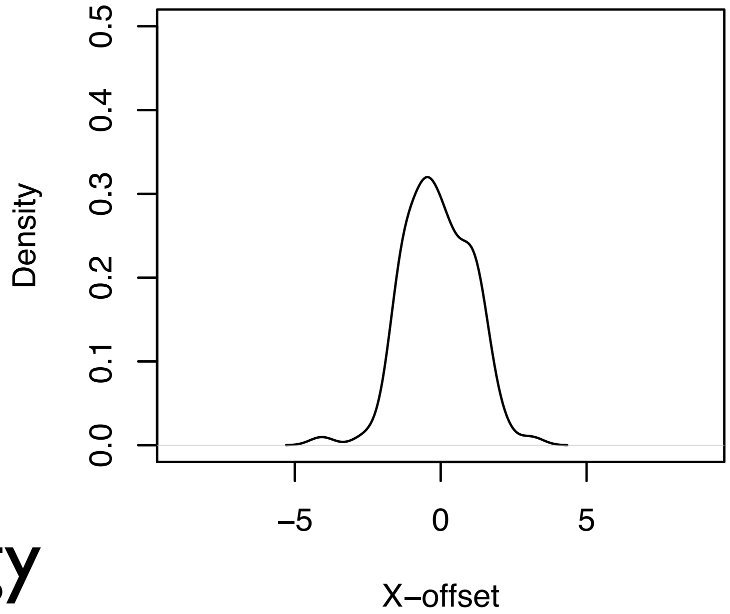
−500
+100
Measured mean end point
Optimal endpoint
0
2
4
6
8
S1, left
S1, right
S2, left
S2, right
S3, left
S3, right
S4, left
S4, right
S5, left
S5, right
2 mm

# key features

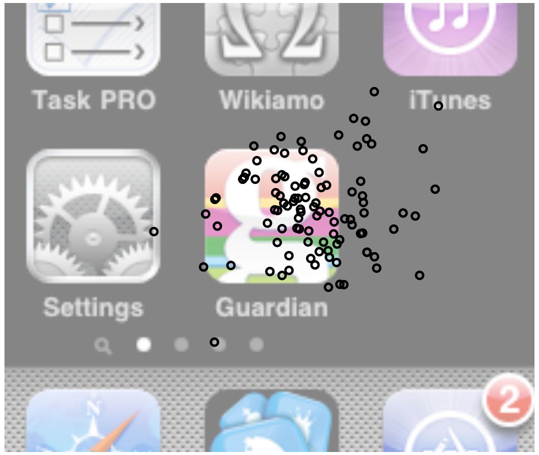
- **environment**: simple button arrangement, some with adjacent buttons some without.
- **bounds**: targeting variance; size and location of buttons; cut-off duration.
- **utility** = hits - penalties

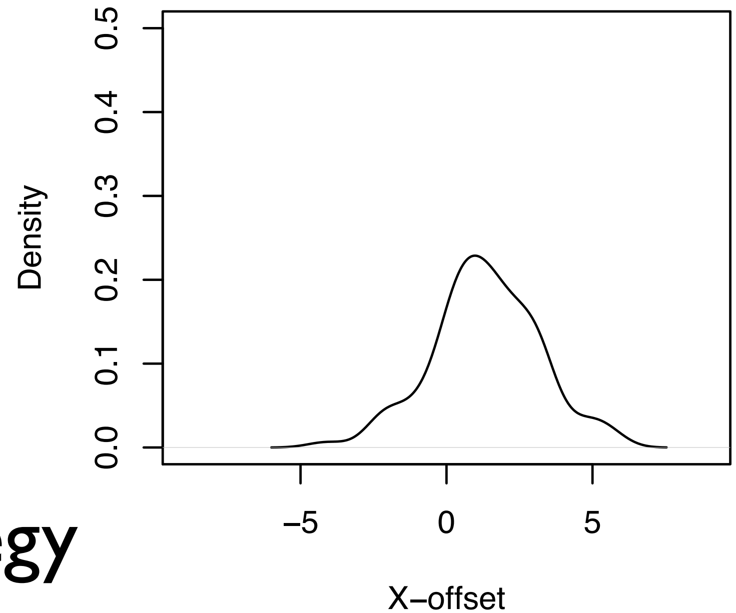
- These imply a set of **strategies**...






low variance strategy

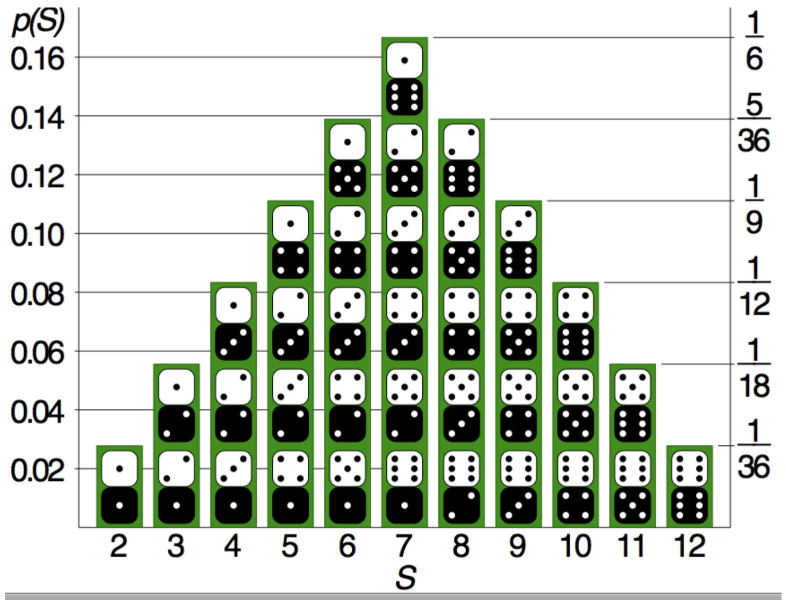





high variance strategy

# probability density functions (p.d.f.)

- Are crucial to understanding human behavior.
- Consider the simple pdf for throwing two dice.
- We will see a lot more pdfs in the next two lectures.



# Reading


- Trommershauser, J., Maloney, L., & Landy, M.S. (2008). Decision making, movement planning and statistical decision theory. *Trends in Cognitive Science, 12*, 8, 291-297.
- Rayner, K (1998). Eye Movements in Reading and Information Processing: 20 Years of Research. *Psychological Bulletin*, vol. 124, pp. 372–422.

# practical

- Use scholar.google.com
- Search for papers on “Human-Computer Interaction” & “Gaze Tracking”
- Start to build a web site using Wordpress...