

CSE 440: Introduction to HCI

User Interface Design, Prototyping, and Evaluation

Lecture 06:
Human Performance

James Fogarty
Daniel Epstein
Brad Jacobson
King Xia



Tuesday/Thursday
10:30 to 11:50
MOR 234

Hall of Fame or Shame?

Add/Update Shipping Information

We found an error while verifying your shipping address.

We've marked the problem in red for you.

Update the address book of

Required information is marked in **GREEN CAPS**.

[HELP](#) for questions about shipping.

NICKNAME:

MYSELF

Please assign a "nickname" for the person you're shipping to.
You may change or delete this information at any time.

FIRST NAME:

DOUGLAS

MIDDLE INITIAL:

LAST NAME:

ADDRESS:

245 SAN JOSE RD

(International use only)

CITY:

LOS GATOS

STATE/PROVINCE:

California

Includes APO and FPO. Use "Other" if country is not USA or Canada.

ZIP/POSTAL CODE:

95333

COUNTRY:

Select a country

SHIPPING METHOD:

In the U.S.: [HELP](#)

☒ Standard UPS

(2 business days plus

International: [HELP](#)

☐ Canada Canada Post

(4-10 business days)

Hall of Shame!

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Based on a major retailer

In study, people could not get past this screen, why?

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Based on a major retailer

In study, people could not get past this screen, why?

Color deficiency

Can not distinguish between red and green

How to fix?

Redundant cues

Today

Human Performance

Visual System

Model Human Processor

Fitts's Law

Gestalt Principles



Contextual Inquiry Review

Friday: 6 Tasks Informed by Contextual Inquiry

These are Examples of What?

Popsicle-stick bridge

$$x = x_0 + v_0t + \frac{1}{2}at^2$$

ACT-R

Goffman's Negotiated Approach

Norman's Execution-Evaluation Cycle

Models

We have said models describe phenomena, isolating components and allowing a closer look

Today is a closer look at modeling humans

Capture essential pieces

Model should have what it needs but no more

Thus avoid underfitting or overfitting model

Allow us to measure

Collect data, put in model, compare model terms

Allow us to predict

The better the model, the better the predictions

Creating a Model

How would you go about creating a model?

Creating a Model

How would you go about creating a model?

One approach:

Observe, Collect Data, Find Patterns,
Draw Analogies, Devise Model,
Test Fit to Data, Test Predictions, Revise

Fundamentally an inductive process

Today

Some example models of human performance

Visual System

Model Human Processor

Fitts's Law

Gestalt Principles

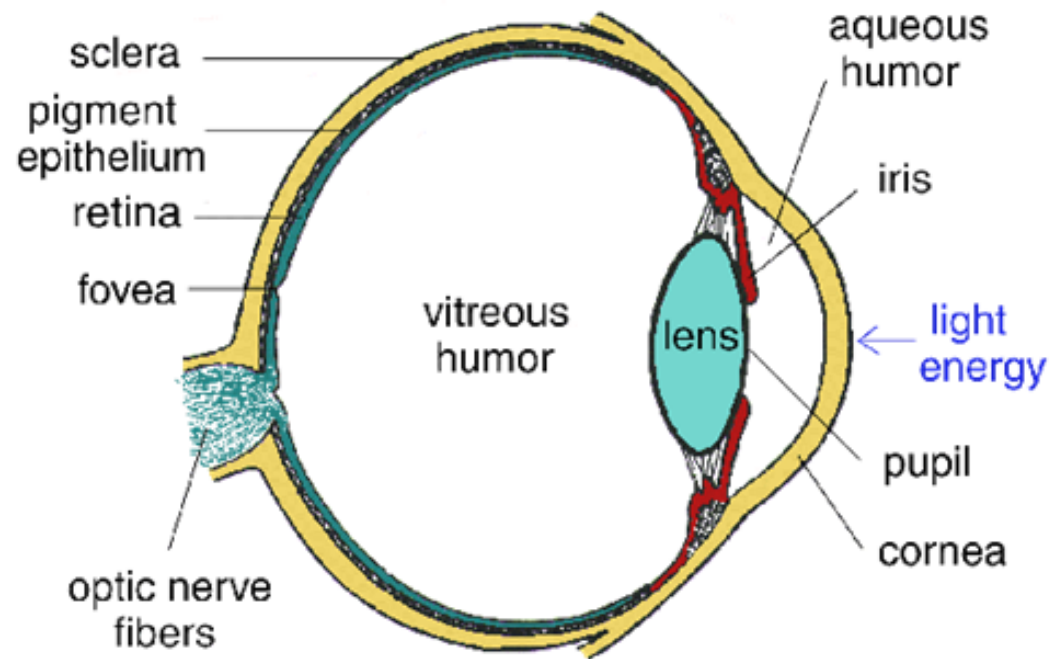
Biological Model

Higher-Level Model

Model by Analogy

Predict Interpretation

Human Visual System



Light passes through lens, focused on retina

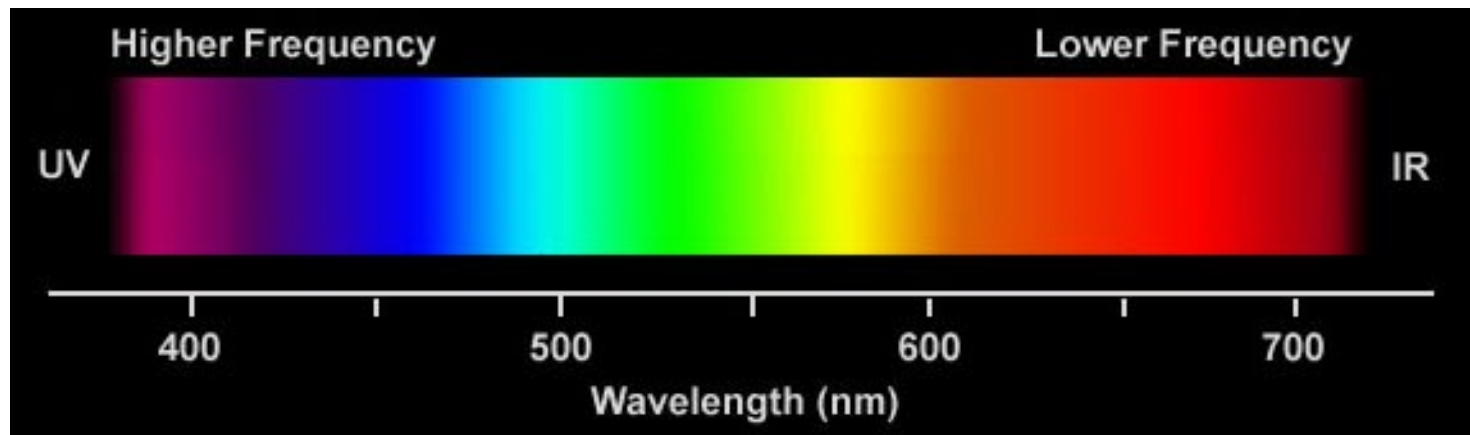
Blind Spot?

Blind Spot

a	b	c	d	e	f	g	h
i	j	k	l	m	n	o	p
q	r	s	t	u	v	w	x



Visible Spectrum



Retina

Covered with light-sensitive receptors

Rods (120 million)

- Sensitive to broad spectrum of light

- Sensitive to small amounts of light

- Cannot discriminate between colors

- Sense intensity or shades of gray

- Primarily for night vision & perceiving movement

Cones (6 million)

- Used to sense color

Retina

Center of retina has most of the ... ??

Retina

Center of retina has most of the cones

Allows for high acuity of objects focused at center

Retina

Center of retina has most of the cones

Allows for high acuity of objects focused at center

Edge of retina is dominated by ... ??

Retina

Center of retina has most of the cones

Allows for high acuity of objects focused at center

Edge of retina is dominated by rods

Allows detecting motion of threats in periphery

Retina

Center of retina has most of the cones

Allows for high acuity of objects focused at center

Edge of retina is dominated by rods

Allows detecting motion of threats in periphery

What does that mean for you?

Retina

Center of retina has most of the cones

Allows for high acuity of objects focused at center

Edge of retina is dominated by rods

Allows detecting motion of threats in periphery

What does that mean for you?

Peripheral movement is easily distracting

Color Perception via Cones

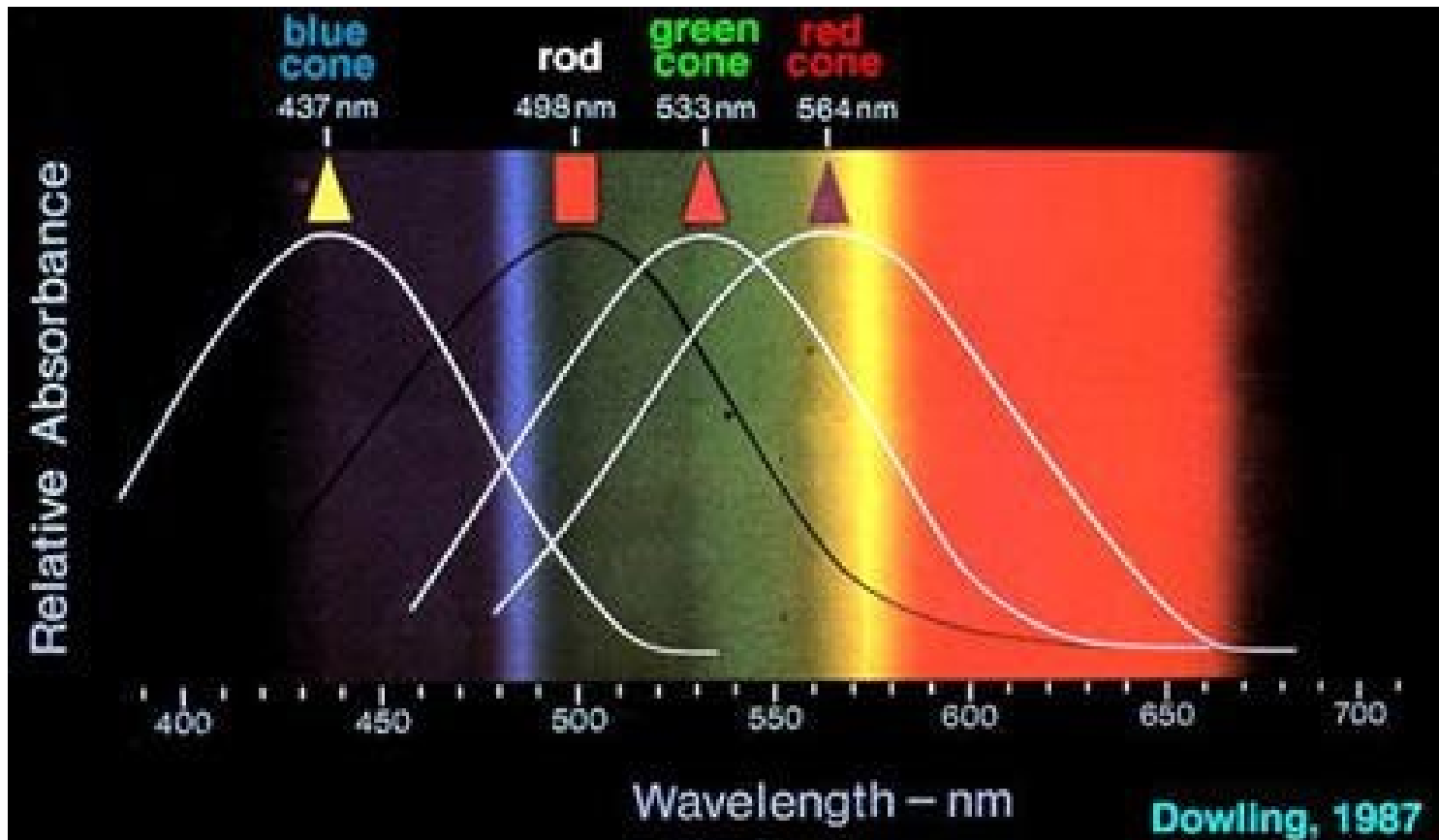
Photopigments used to sense color

3 types: blue, green, “red” (actually yellow)

Each sensitive to different band of spectrum

Ratio of neural activity stimulation for the three types of gives us a continuous perception of color

Color Sensitivity



Distribution of Photopigments

Not distributed evenly

Mainly reds (64%), Very few blues (4%)

Insensitivity to short wavelengths (i.e., blue)

No blue cones in retina center

Fixation on small blue object yields “disappearance”

Lens yellows with age, absorbs short wavelengths

Sensitivity to blue is reduced even further

Color Sensitivity & Image Detection

Most sensitive to center of spectrum

To be perceived as the same, blues and reds must be brighter than greens and yellows

Brightness determined mainly by red and green

$$Y = 0.3 \text{ Red} + 0.59 \text{ Green} + 0.11 \text{ Blue}$$

Shapes detected by finding edges

We use brightness and color difference

Implication

Blue edges and shapes are hard



Color Sensitivity & Image Detection

Most sensitive to center of spectrum

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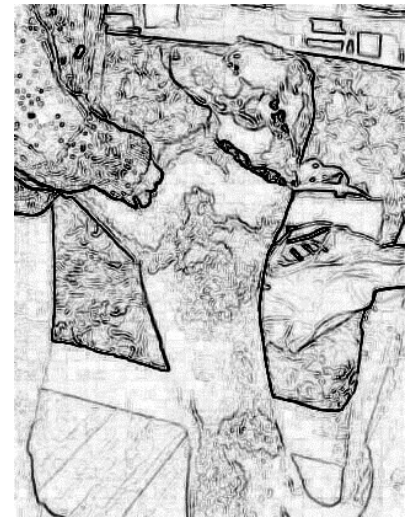
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Shapes detected by finding edges

We use brightness and color difference

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Focus

Different wavelengths of light focused at different distances behind eye's lens

Constant refocusing causes fatigue

Saturated colors (i.e., pure colors) require more focusing than desaturated (i.e., pastels)

Focus

Different wavelengths of light focused at different distances behind eye's lens

Constant refocusing causes fatigue

Saturated colors (i.e., pure colors) require more focusing than desaturated (i.e., pastels)

The Falklands Society

Color Deficiency

Trouble discriminating colors

Affects about 9% of population

Two main types

Different photopigment response most common

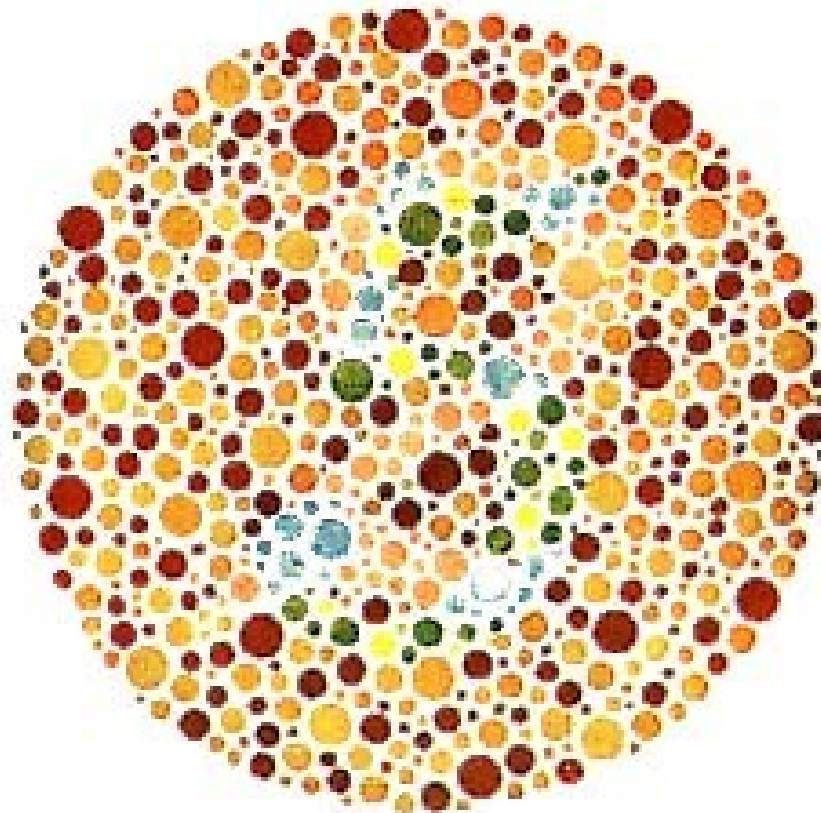
Reduces capability to discern small color differences

Red-Green deficiency is best known

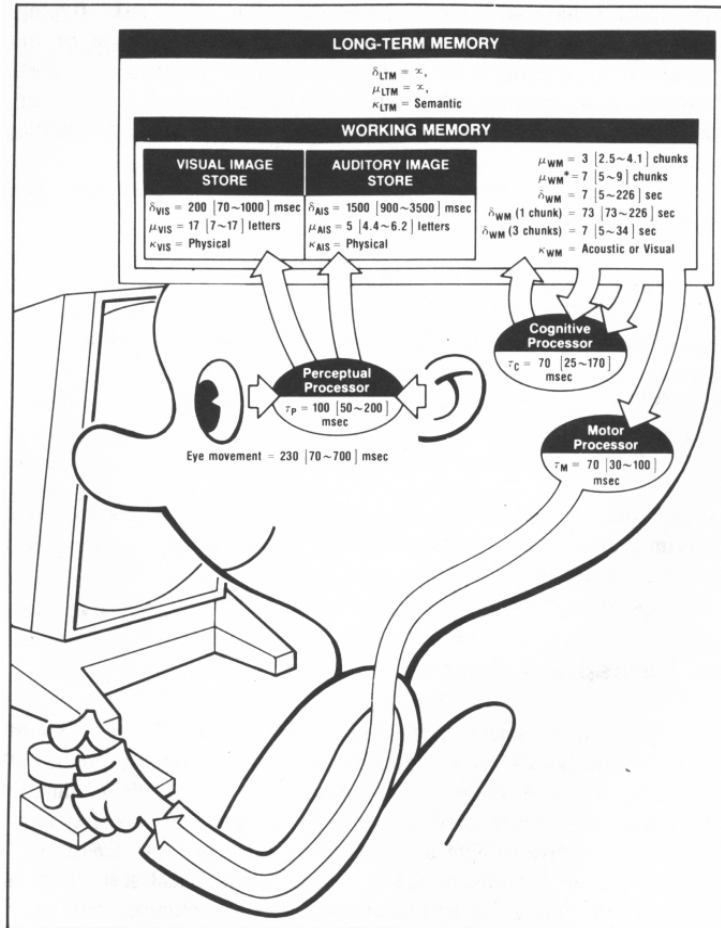
Lack of either green or red photopigment,
cannot discriminate colors dependent on red and green

Also known as color blindness

Red-Green Deficiency Test



The Model Human Processor



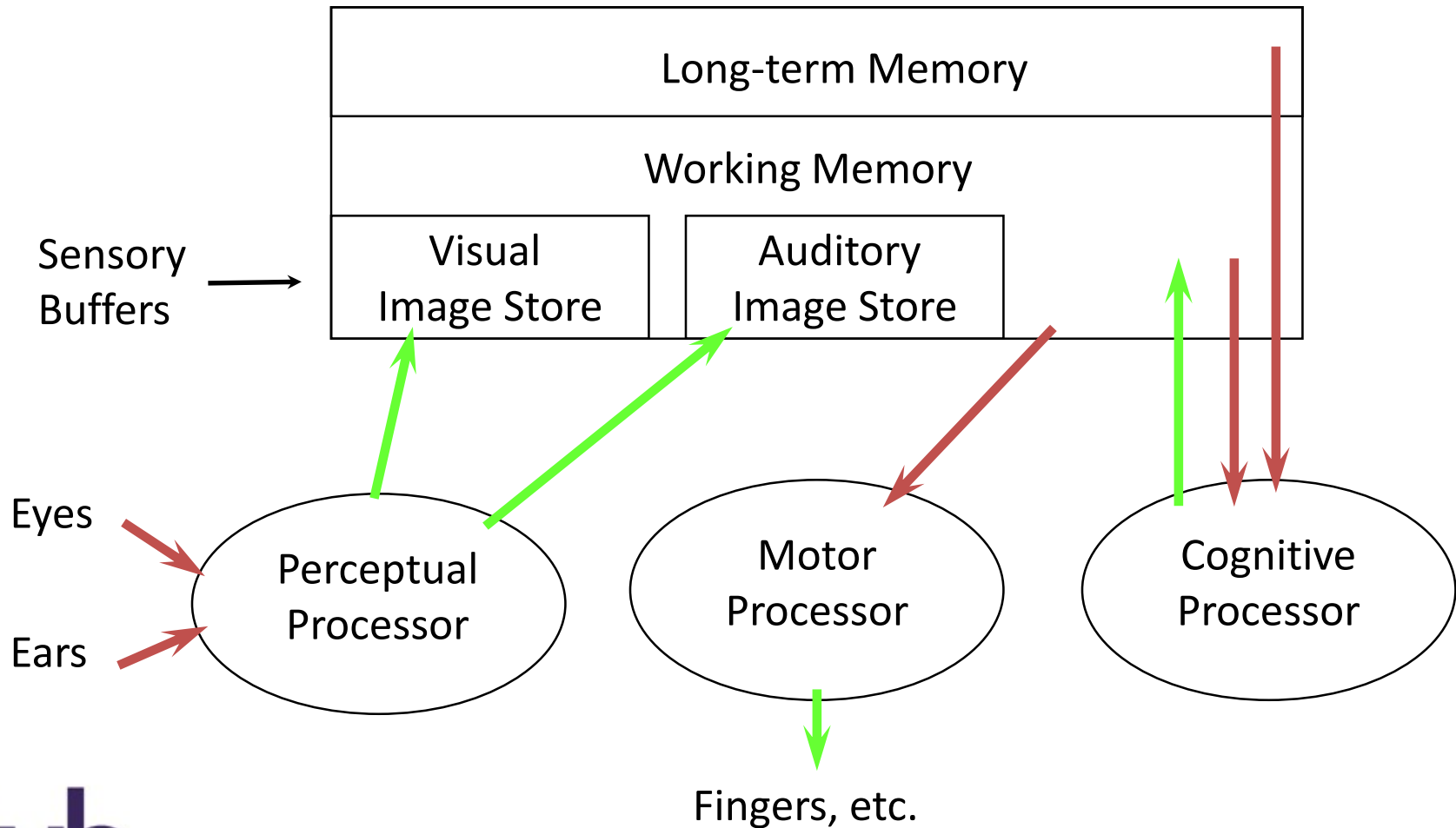
Developed by Card,
Moran, & Newell (1983)

Based on empirical data

Summarizing human
behavior in a manner easy
to consume and act upon

Same book that named
human computer interaction

The Model Human Processor



Basics of Model Human Processor

Sometimes serial, sometimes parallel

Serial in action and parallel in recognition

Pressing key in response to light

Driving, reading signs, hearing all simultaneously

Parameters

Processors have cycle time, approximately 100-200ms

Memories have capacity, decay time, and type

A Working Memory Experiment

BMCIACSEI

BM CIA CSE I

IBM CIA CSE

Memory

Working memory (also known as short-term)

Small capacity (7 ± 2 “chunks”)

6174591765 vs. (617) 459-1765

IBMCIACSE vs. IBM CIA CSE

Rapid access ($\sim 70\text{ms}$) and decay ($\sim 200\text{ ms}$)

Pass to LTM after a few seconds of continued storage

Long-term memory

Huge (if not “unlimited”)

Slower access time ($\sim 100\text{ ms}$) with little decay

Activation Experiment

Volunteer

Activation Experiment

Volunteer

Start saying colors you see in list of words

When slide comes up, as fast as you can

There will be three columns of words

Say “done” when finished

Everyone else time how long it takes

red

yellow

blue

green

red

green

yellow

blue

yellow

green

blue

red

blue

red

green

Activation Experiment

Do it again

Say “done” when finished

ivd

olftcs

fwax

ncudgt

zjdcv

lxngyt

mkbh

xbts

cfto

bhfe

cnhdes

fwa

cnoftg

uhths

dalcrd

Activation Experiment

Do it again

Say “done” when finished

red

blue

green

yellow

blue

red

yellow

green

blue

yellow

green

red

green

blue

yellow

Model Human Processor Operation

Recognize-Act Cycle of the Cognitive Processor

On each cycle, contents in working memory initiate actions associatively linked in long-term memory

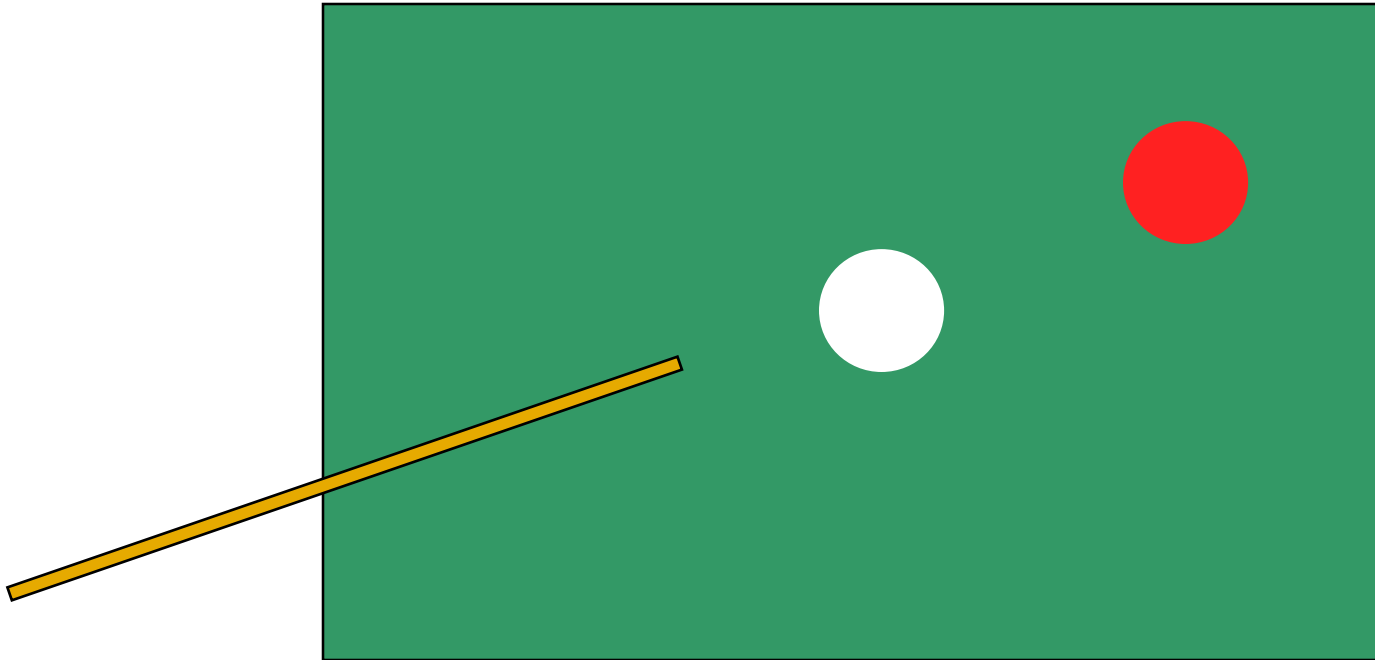
Actions modify the contents of working memory

Discrimination Principle

Retrieval is determined by candidates that exist in memory relative to retrieval cues

Interference created by strongly activated chunks

Perceptual Causality



How soon must the red ball move
after cue ball collides with it?

Perceptual Causality

Stimuli that occur within one cycle of the perceptual processor fuse into a single concept

Requirement

If you want to create the perception of causality, then you need to be sufficiently responsive

Caution

Two stimuli intended to be distinct can fuse if the first event appears to cause the other

Fitts's Law (1954)

Models time to acquire targets in aimed movement

Reaching for a control in a cockpit

Moving across a dashboard

Pulling defective items from a conveyor belt

Clicking on icons using a mouse

Very powerful, widely used

Holds for many circumstances (e.g., under water)

Allows for comparison among different experiments

Used both to measure and to predict

Fitts's Law (1954)

James's use of 's is correct,
but others may say Fitts' Law

Models time to acquire targets in aimed movement

Reaching for a control in a cockpit

Moving across a dashboard

Pulling defective items from a conveyor belt

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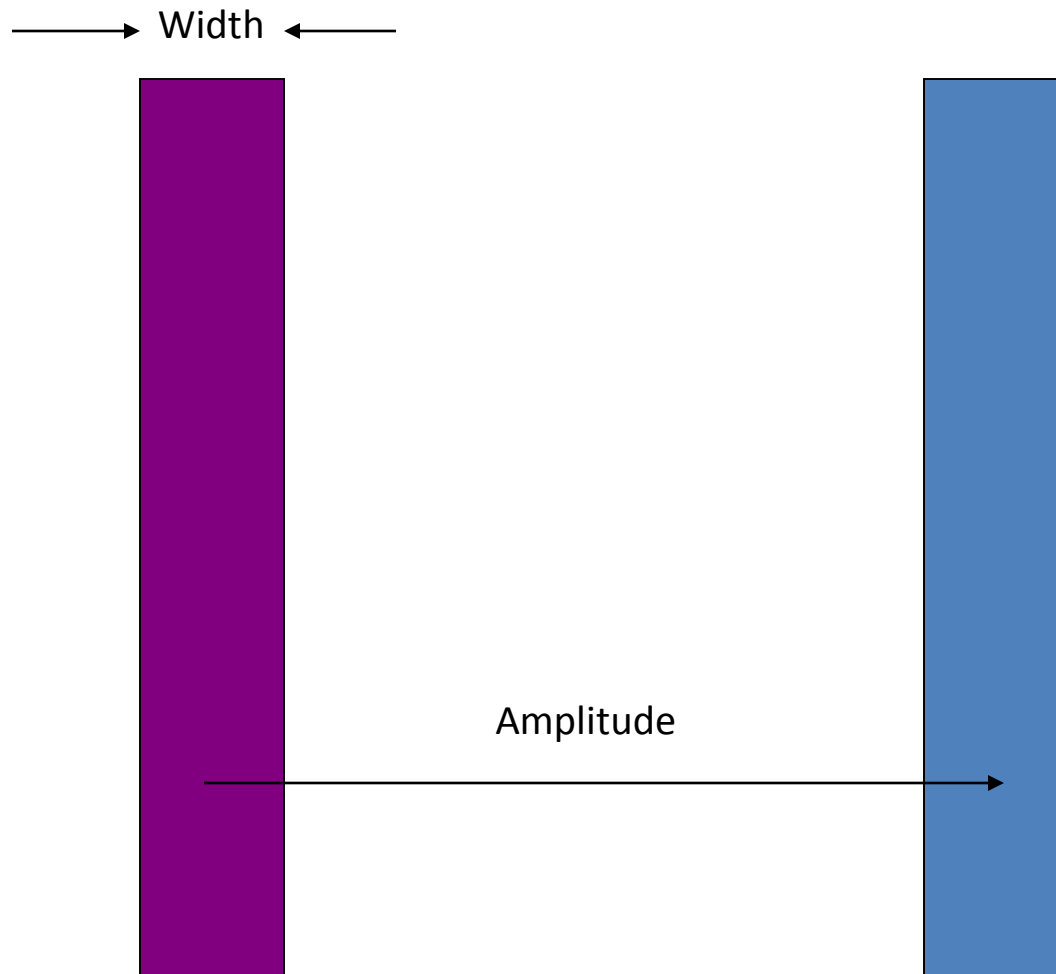
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Reciprocal Point-Select Task



Closed Loop versus Open Loop

What is closed loop motion?

What is open loop motion?

Closed Loop versus Open Loop

What is closed loop motion?

Rapid aimed movements with feedback correction

Fitts's law models this

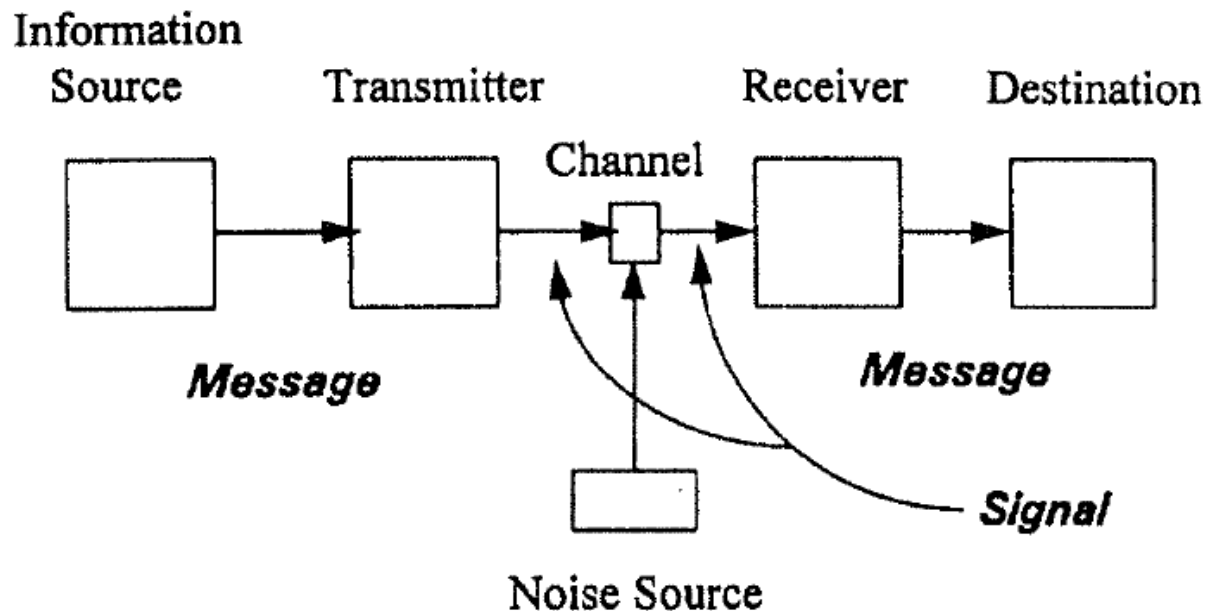
What is open loop motion?

Ballistic movements without feedback correction

Example: Throwing a dart

See Schmidt's Law (1979)

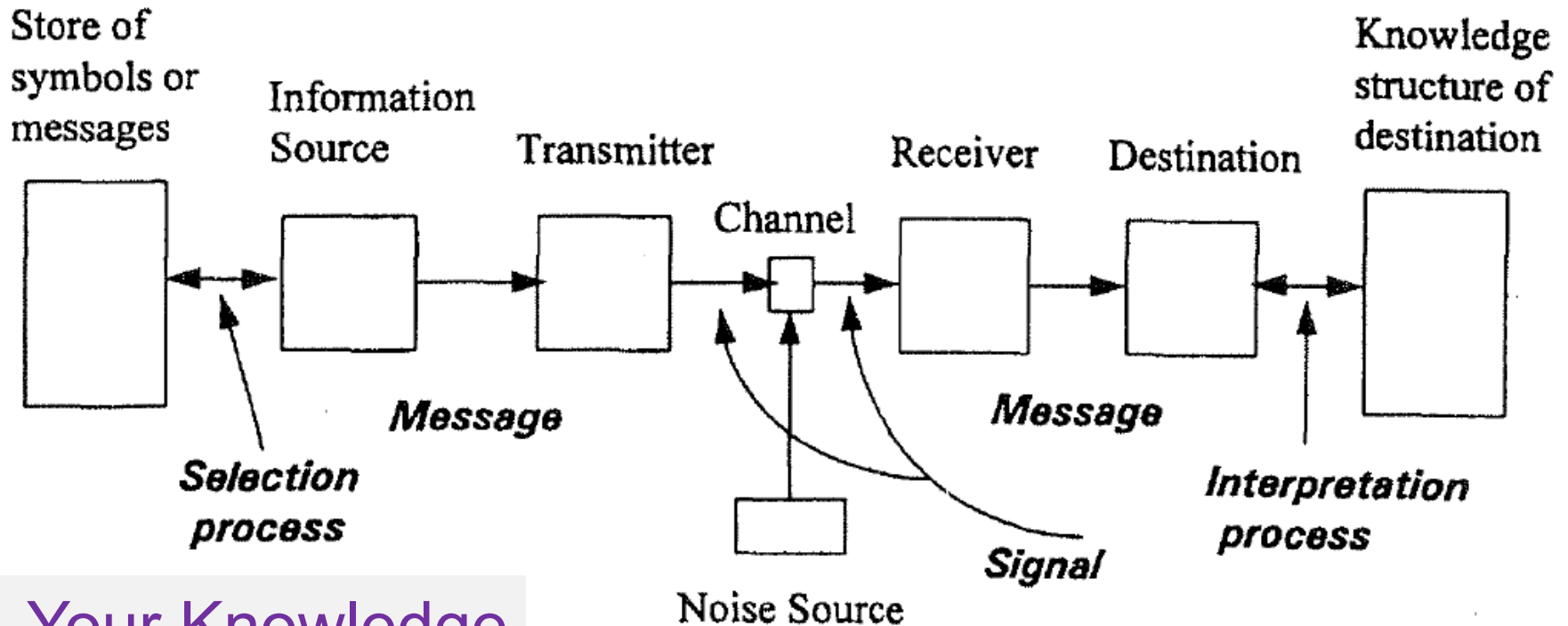
Model by Analogy



Analogy to Information Transmission
Shannon and Weaver, 1959

Model by Analogy

The Interface



Your Knowledge

Analogy to Information Transmission
Shannon and Weaver, 1959

Fitts's Law

$$MT = a + b \log_2(A / W + 1)$$

What kind of equation does this remind you of?

Fitts's Law

$$MT = a + b \log_2(A / W + 1)$$

What kind of equation does this remind you of?

$$y = mx + b$$

$$MT = a + bx, \text{ where } x = \log_2(A / W + 1)$$

x is called the Index of Difficulty (ID)

As “A” goes up, ID goes up

As “W” goes up, ID goes down

Index of Difficulty (ID)

$$\log_2(A / W + 1)$$

Fitts's Law claims that the time to acquire a target increases linearly with the log of the ratio of the movement distance (A) to target width (W)

Why is it significant that it is a ratio?

Index of Difficulty (ID)

$$\log_2(A / W + 1)$$

Fitts's Law claims that the time to acquire a target increases linearly with the log of the ratio of the movement distance (A) to target width (W)

Why is it significant that it is a ratio?

Units of A and W don't matter

Allows comparison across experiments

Index of Difficulty (ID)

$$\log_2(A / W + 1)$$

Fitts's Law claims that the time to acquire a target increases linearly with the log of the ratio of the movement distance (A) to target width (W)

ID units typically in “bits”

Because of association with information capacity and somewhat arbitrary use of base-2 logarithm

Index of Performance (IP)

$$MT = a + b \log_2(A / W + 1)$$

b is slope

$1/b$ is called Index of Performance (IP)

If MT is in seconds, IP is in bits/second

Also called “throughput” or “bandwidth”

Consistent with analogy of the interaction as an information channel from human to target

A Fitts's Law Experiment

“Beating” Fitts’s law

It is the law, right?

$$MT = a + b \log_2(A / W + 1)$$

So how can we reduce movement time?

Reduce A

Increase W

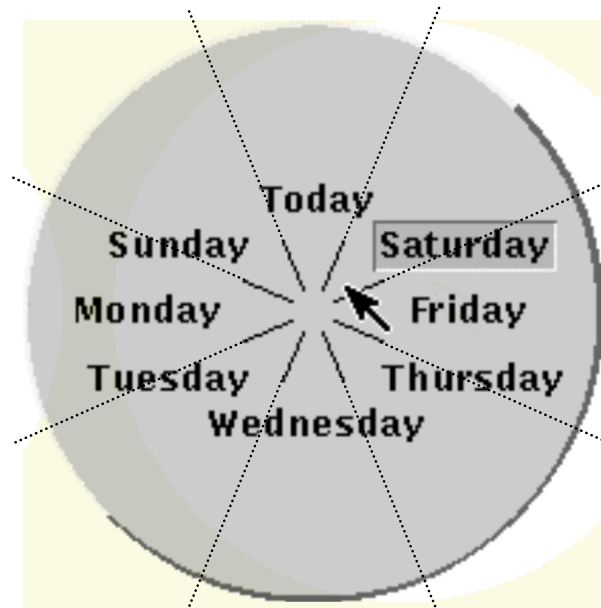
Fitts's Law Examples

Which will be faster on average?

Pop-up Linear Menu



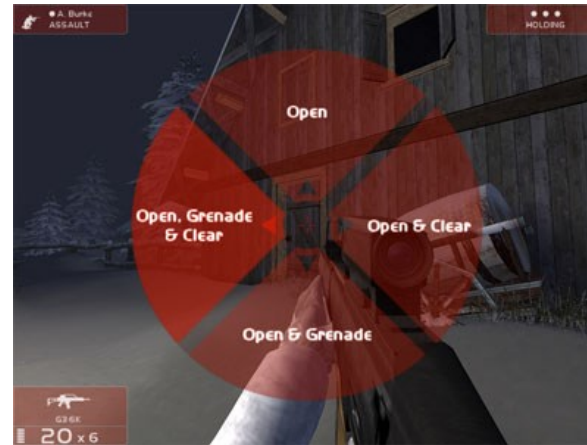
Pop-up Pie Menu



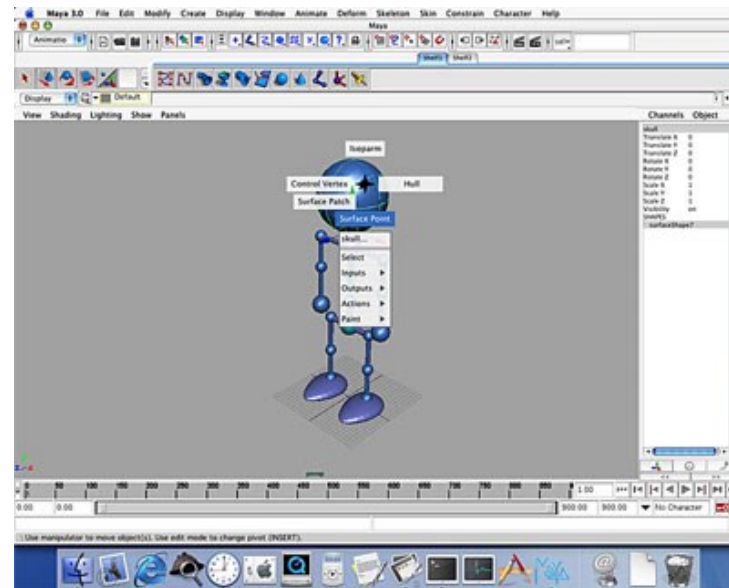
Pie Menus in Use



The Sims



Rainbow 6



Maya

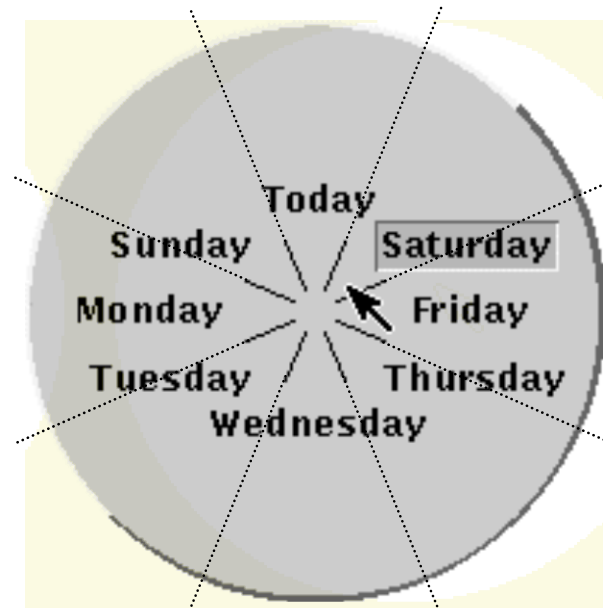
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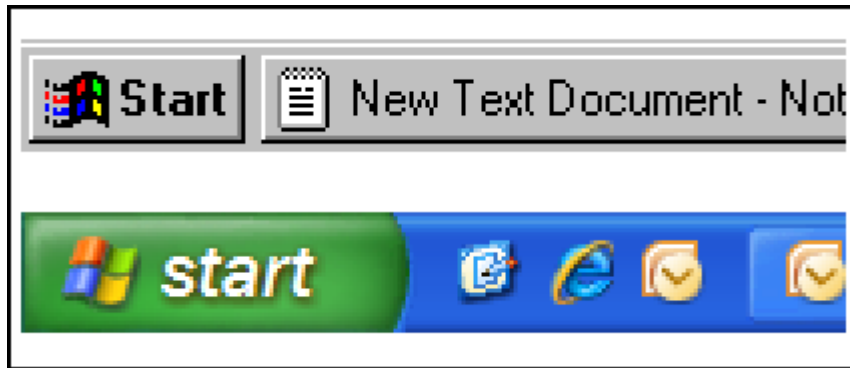


Pop-up Pie Menu



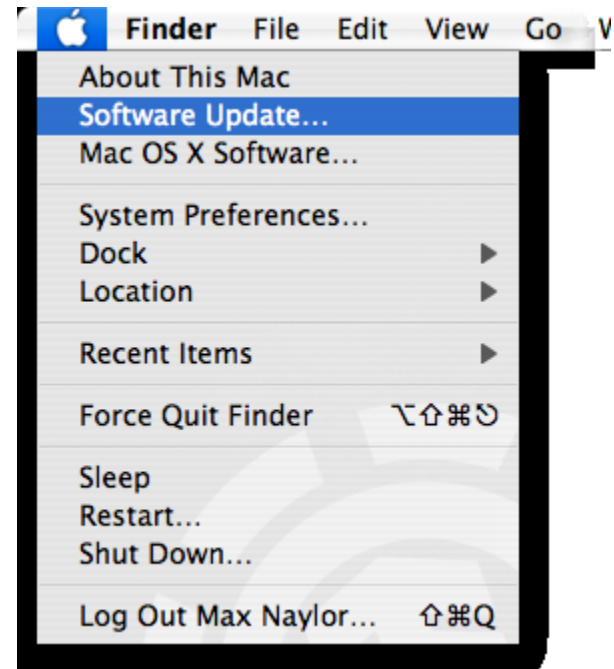
What about adaptive menus?

Fitts's Law in Windowing



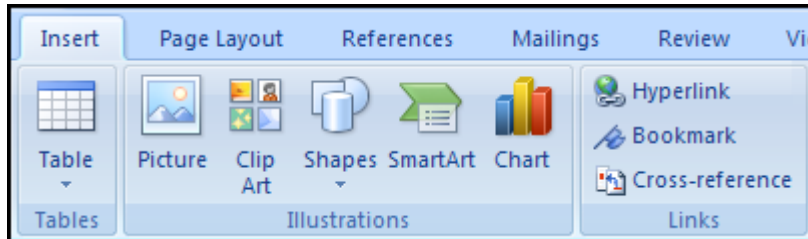
Windows 95: Missed by a pixel

Windows XP: Good to the last drop

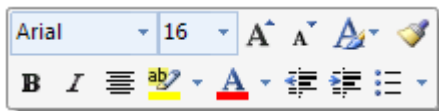


Macintosh Menu

Fitts's Law in MS Office 2007

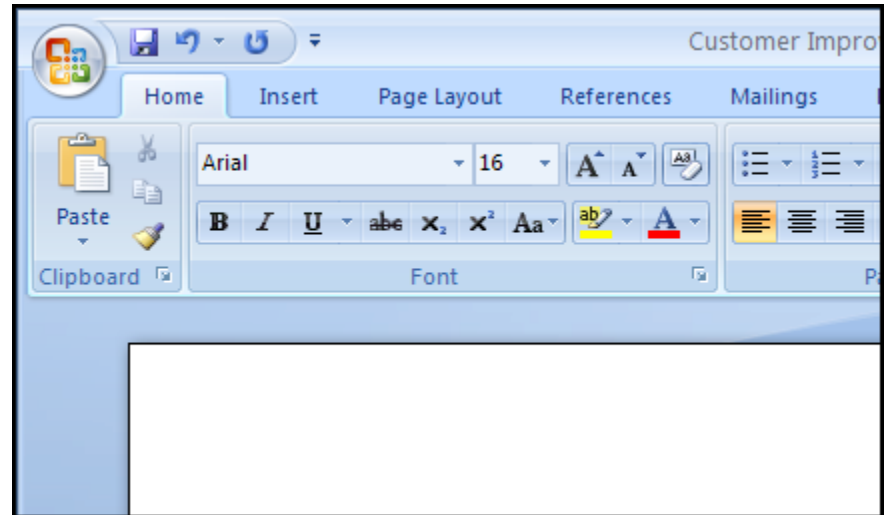


Larger, labeled controls
can be clicked more quickly



Text

Mini toolbar is close to the cursor



Magic Corner:

Office Button in the upper-left corner

Bubble Cursor



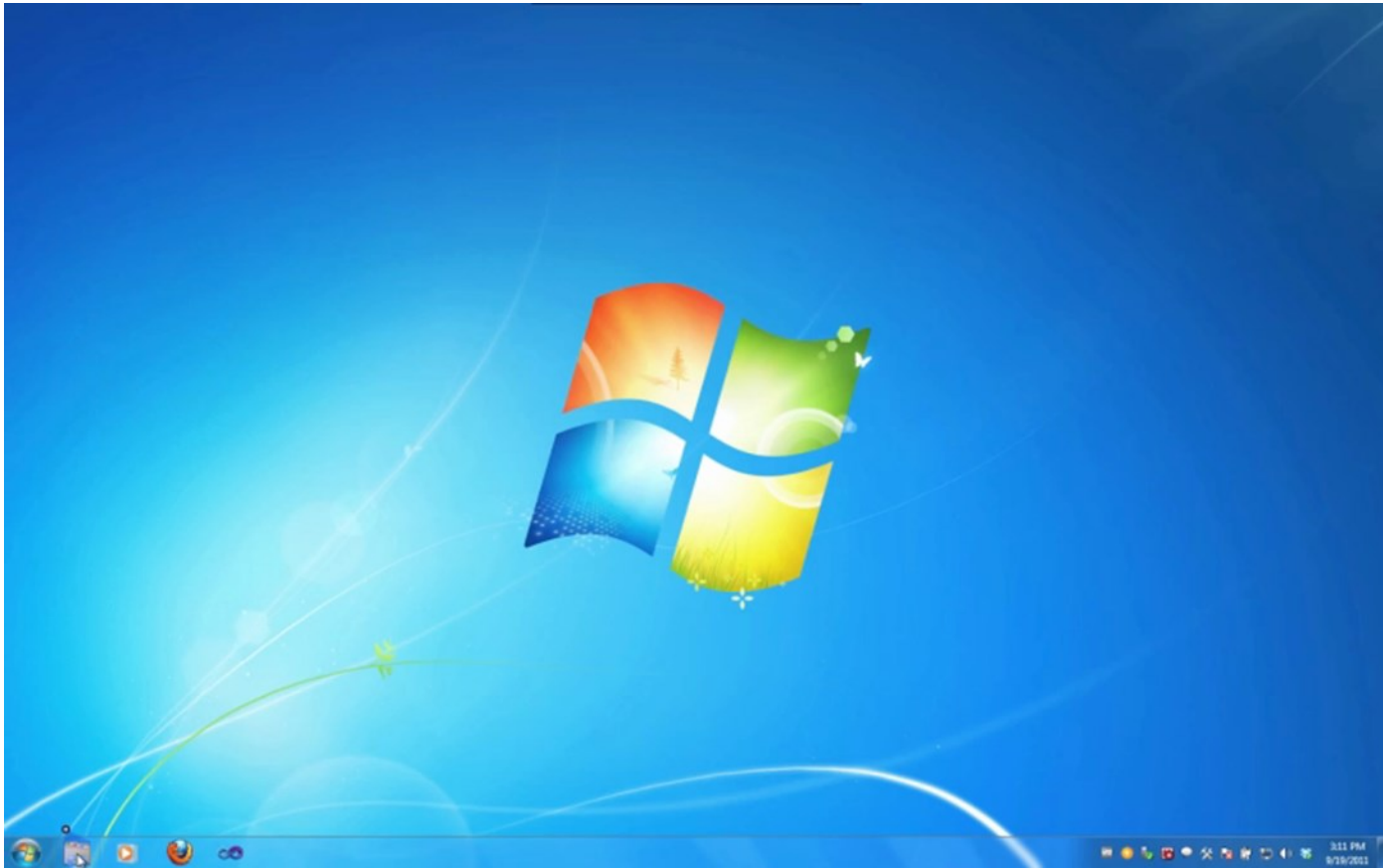
Grossman and Balakrishnan, 2005

Bubble Cursor



Grossman and Balakrishnan, 2005

Bubble Cursor with Prefab



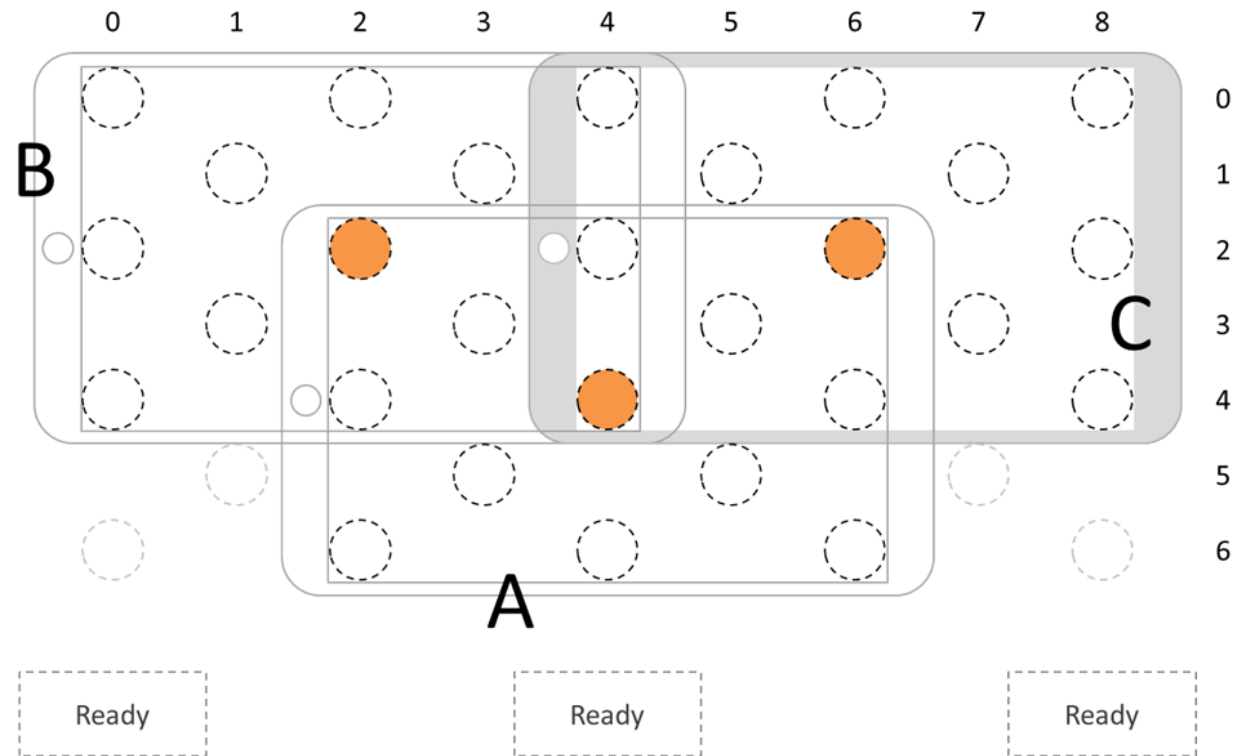
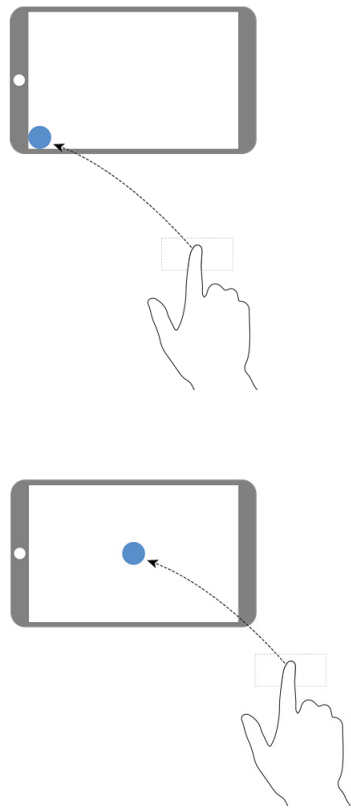
Dixon et al, 2012

Bubble Cursor with Prefab



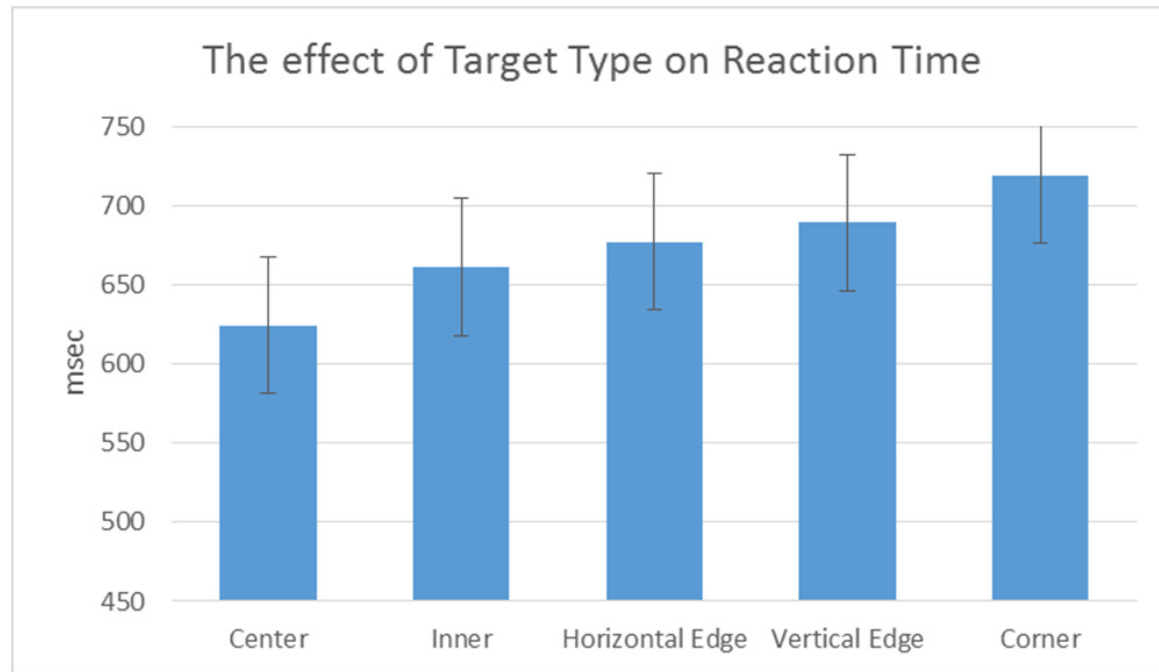
Dixon et al, 2012

Fitts's Law, Edge Targets, and Touch



Fitts's Law, Edge Targets, and Touch

Avrahami finds edge targets are actually slower with touch devices, at same physical location



Are people border cautious?

Fitts's Law Related Techniques

Put targets closer together

Make targets bigger

Make cursor bigger

Area cursors

Bubble cursor

Use impenetrable edges

Fitts's Law Related Techniques

Gravity Fields

Pointer gets close, gets “sucked in” to target

Sticky Icons

When within target, pointer “sticks”

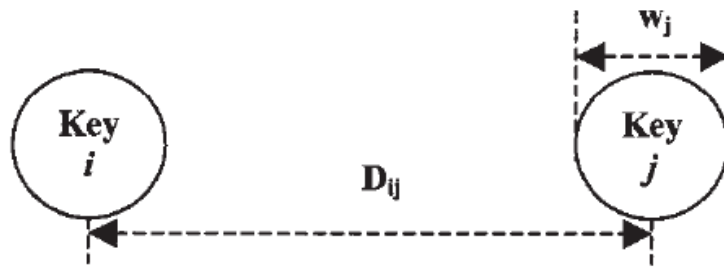
Constrained Motion

Snapping, holding Shift to limit degrees of movement

Target Prediction

Determine likely target, move it nearer or expand it

Fitts's Law and Keyboard Layout



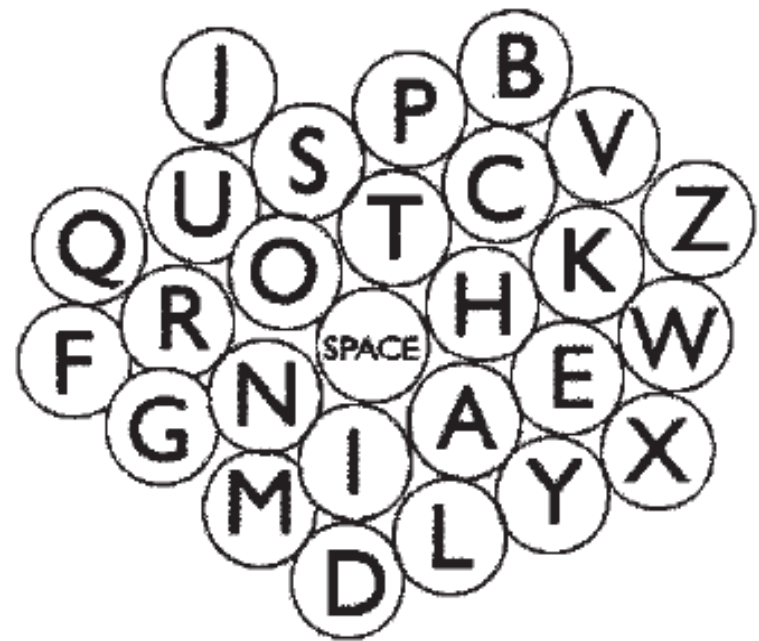
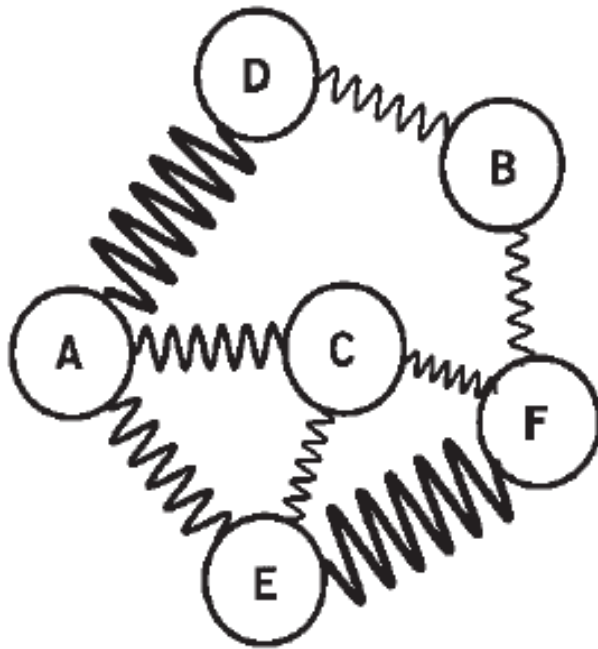
Zhai et. al (2002) pose stylus keyboard layout as an optimization of all key pairs, weighted by language frequency

$$MT = a + b \log_2 \left(\frac{D_{ij}}{W_j} + 1 \right),$$

$$t = \sum_{i=1}^{27} \sum_{j=1}^{27} \frac{P_{ij}}{IP} \left[\log_2 \left(\frac{D_{ij}}{W_j} + 1 \right) \right],$$

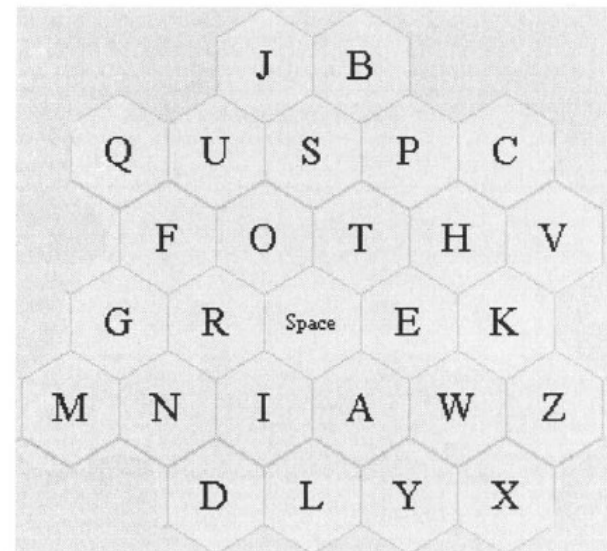
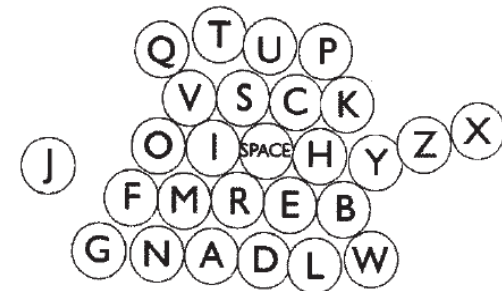
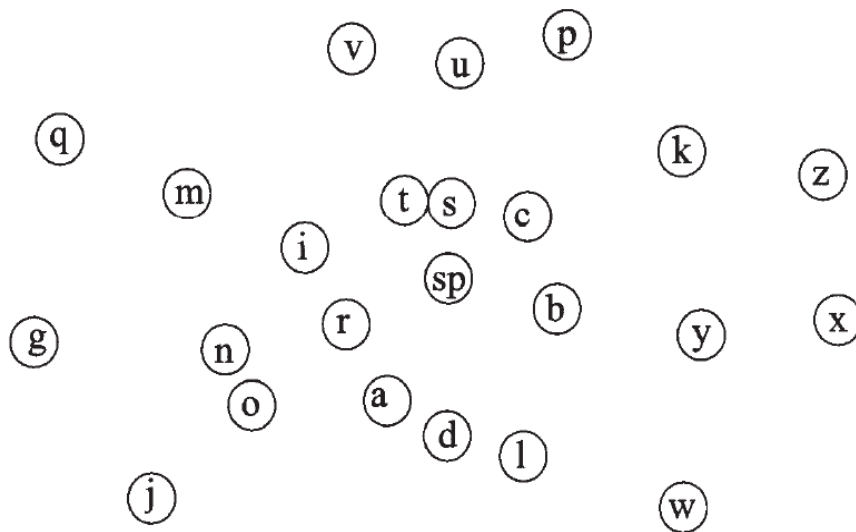
Hooke's Keyboard

Optimizes a system of springs



Metropolis Keyboard

Random walk minimizing scoring function



Considering Multiple Space Keys

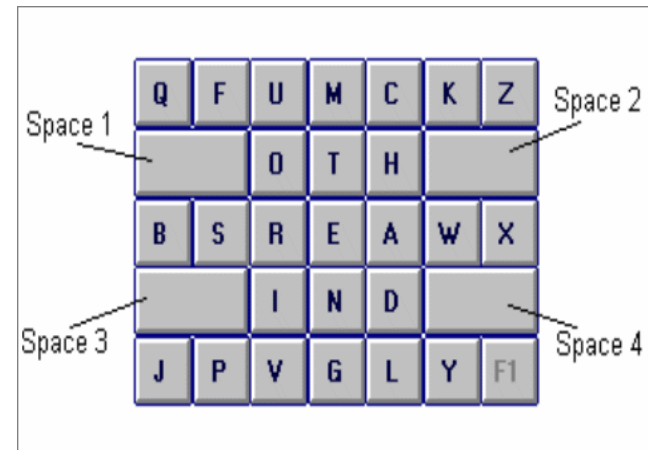
FITALY Keyboard

Textware Solutions

Z	V	C	H	W	K
F	I	T	A	L	Y
		N	E		
G	D	O	R	S	B
Q	J	U	M	P	X

OPTI Keyboard

MacKenzie and Zhang 1999



Considering Multiple Space Keys

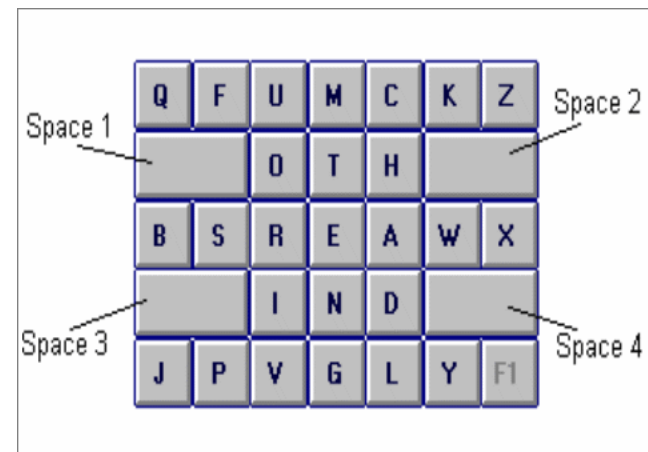
FITALY Keyboard

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Z	V	C	H	W	K
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OPTI Keyboard

MacKenzie and Zhang 1999

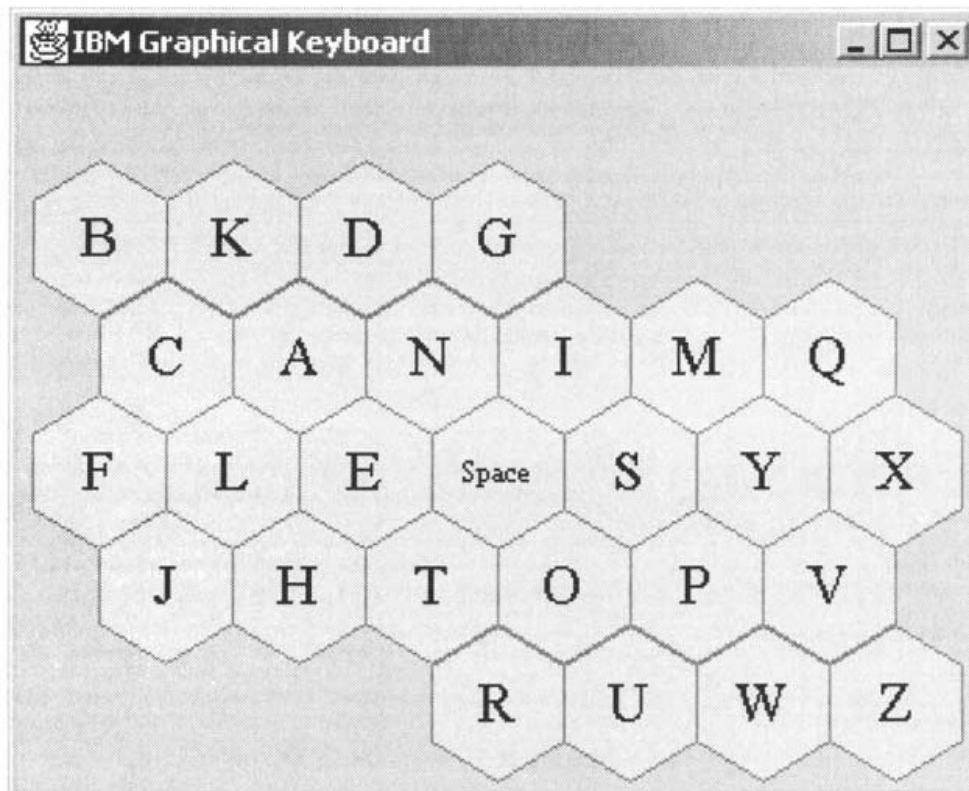


Correct choice of space key becomes important

Requires planning head to be optimal

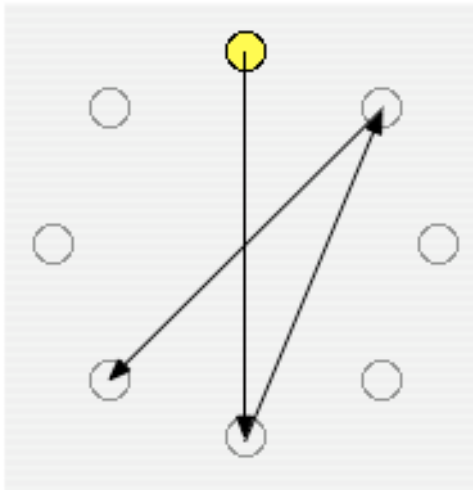
ATOMIK Keyboard

Optimized keyboard, adjusted for early letters in upper left and later letters in lower right

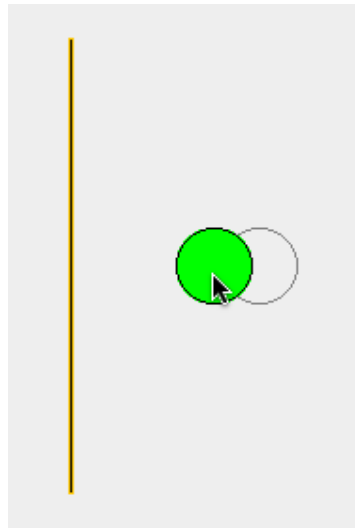


Using Motor Ability in Design

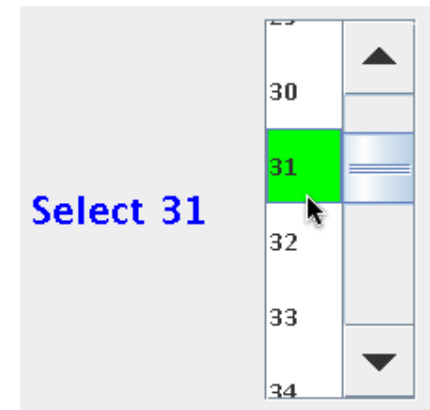
Pointing



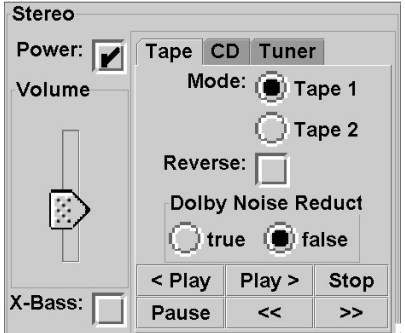
Dragging



List Selection

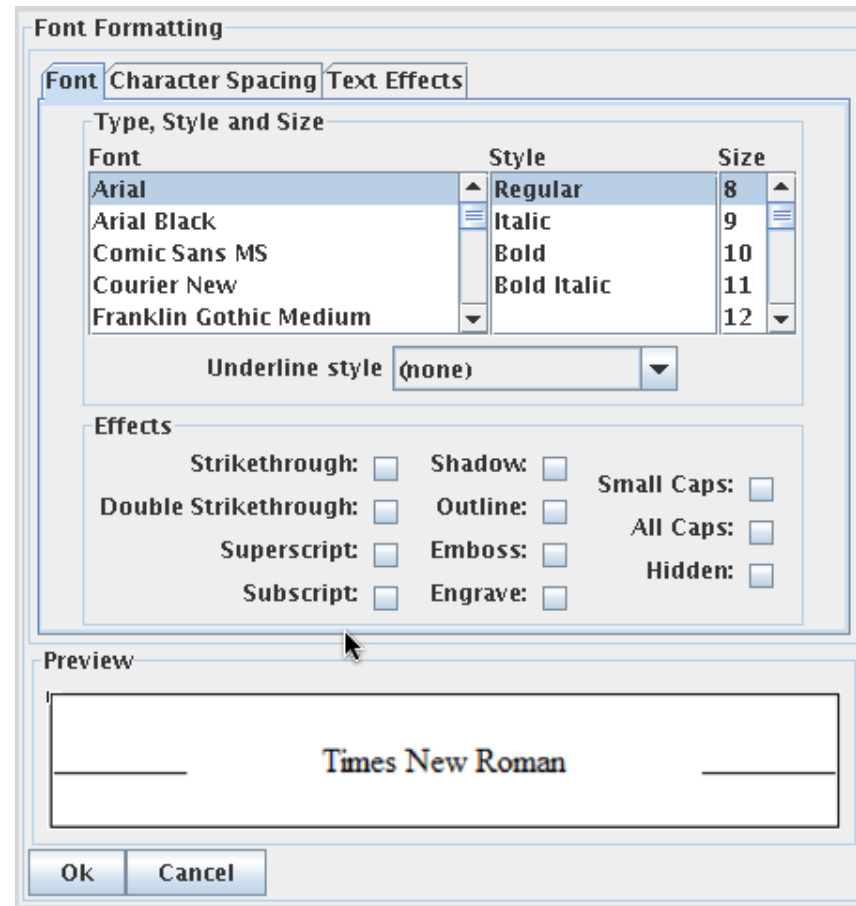


Interface Generation As Optimization

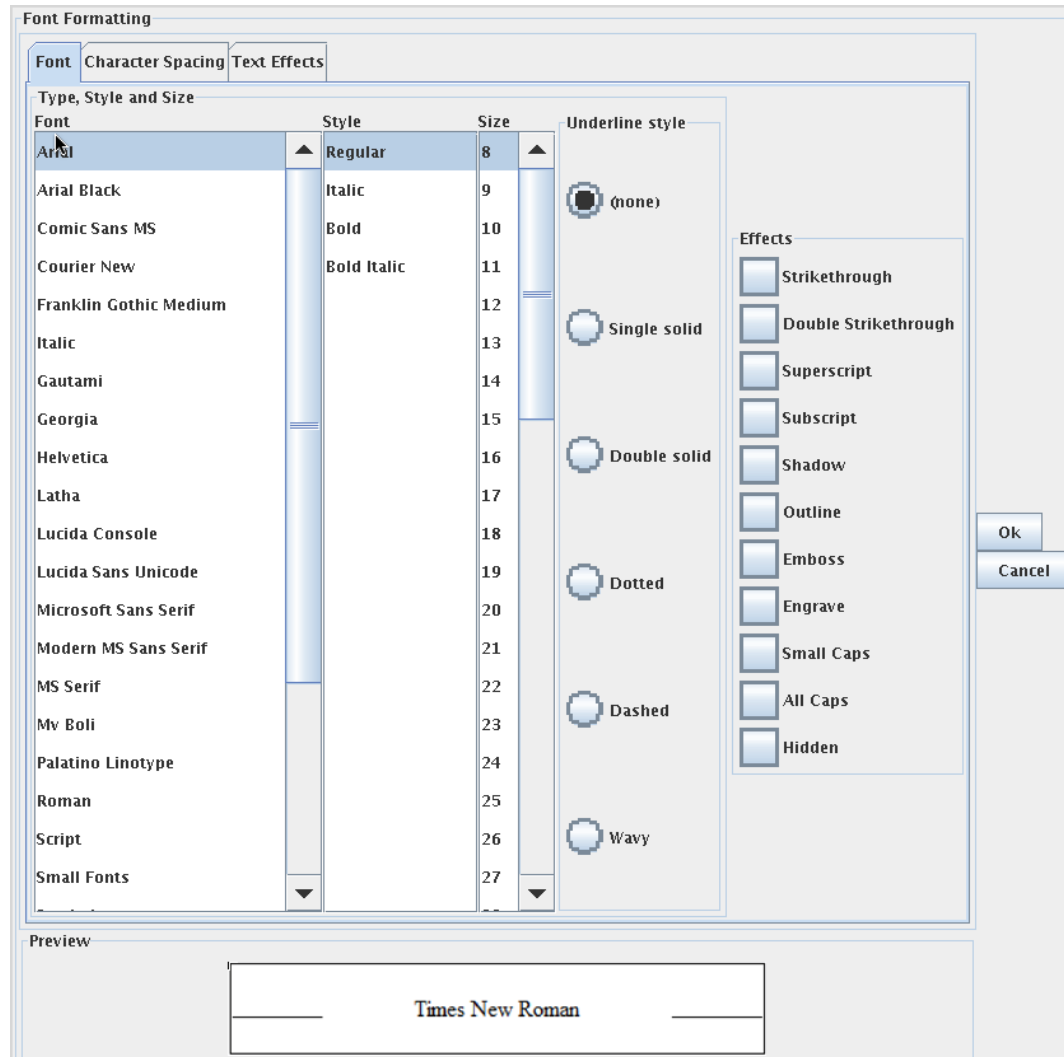
\$ () = Estimated task completion time

The image shows a vintage-style audio player interface. It features a 'Stereo' label at the top left. Below it are 'Power' and 'Volume' controls. The 'Power' control has a checked checkbox. The 'Volume' control is a vertical slider with a speaker icon. Below the volume slider is an 'X-Bass' checkbox, which is unchecked. To the right of the volume slider are three tabs: 'Tape', 'CD', and 'Tuner'. The 'Tape' tab is selected. Under the 'Tape' tab, there is a 'Mode' section with two radio buttons: 'Tape 1' (selected) and 'Tape 2'. Below the mode section is a 'Reverse' checkbox, which is unchecked. Further down is a 'Dolby Noise Reduct' section with two radio buttons: 'true' (selected) and 'false'. At the bottom of the interface are six buttons arranged in two rows: '< Play', 'Play >', and 'Stop' in the top row; 'Pause', '<<', and '>>' in the bottom row.

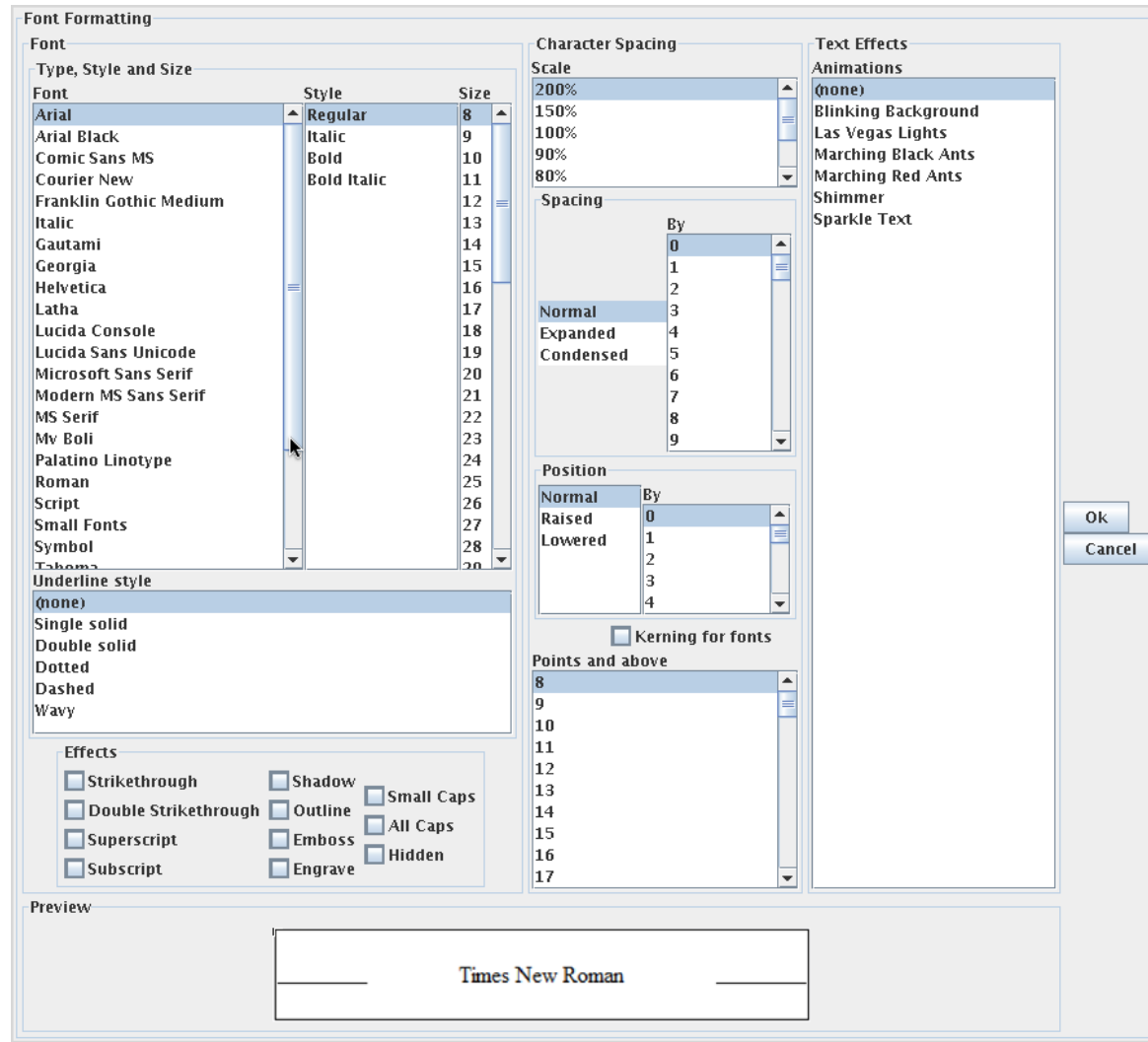
Manufacturer Interface



Person with Cerebral Palsy



Person with Muscular Dystrophy



Interface Generation As Optimization

In a study with 11 participants with diverse motor impairments:

Consistently faster using generated interfaces (26%)

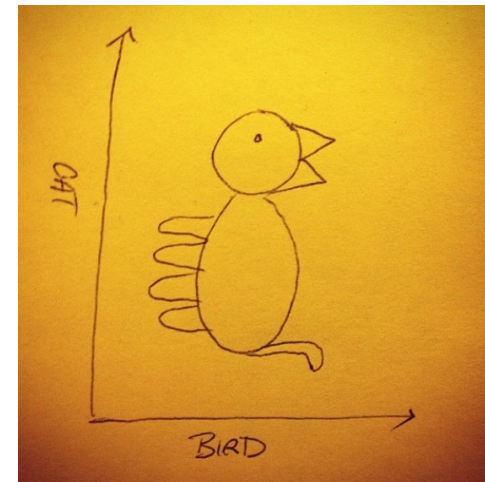
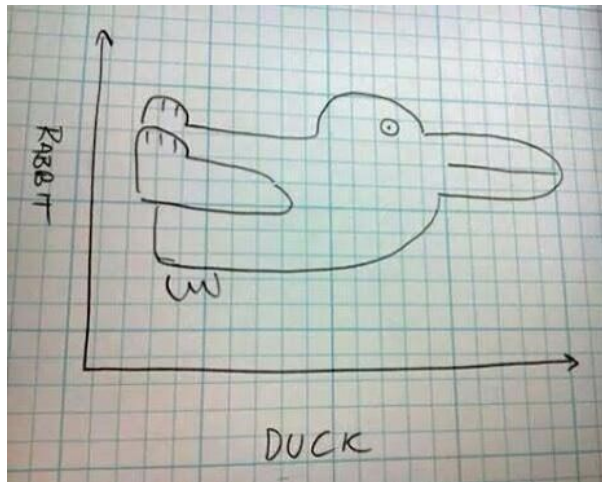
Fewer errors using generated interfaces (73% fewer)

Strongly preferred generated interfaces

Gestalt Psychology

Described loosely in the context of this lecture and associated work, not a real definition

Perception is neither bottom-up nor top-down, rather both inform the other as a whole



Gestalt Psychology

You can still see the dog...

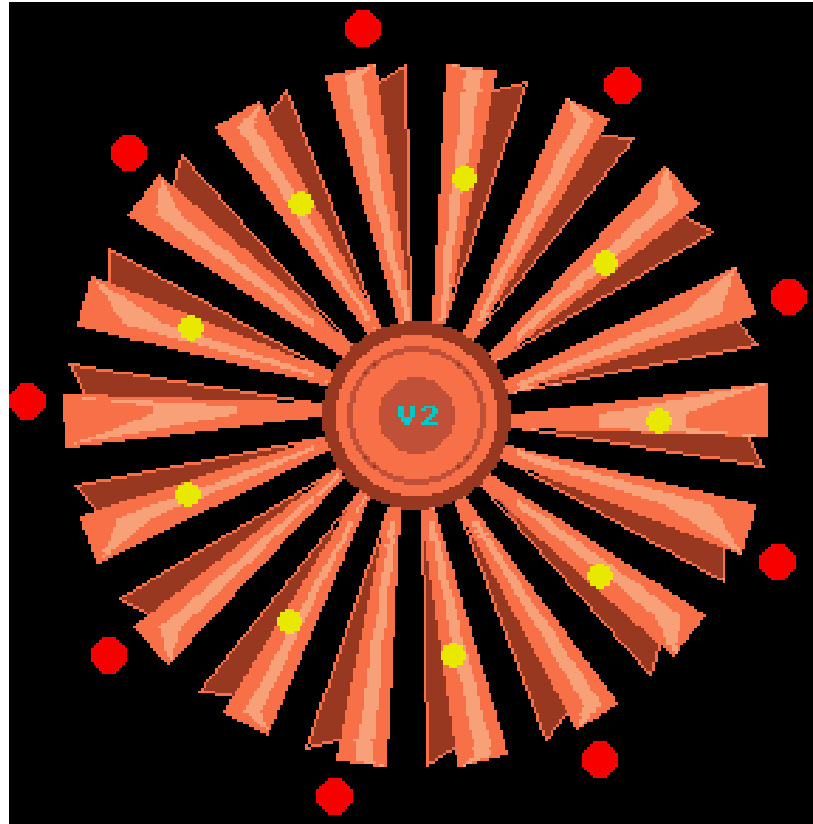


Gestalt Psychology

You can still see the dog...

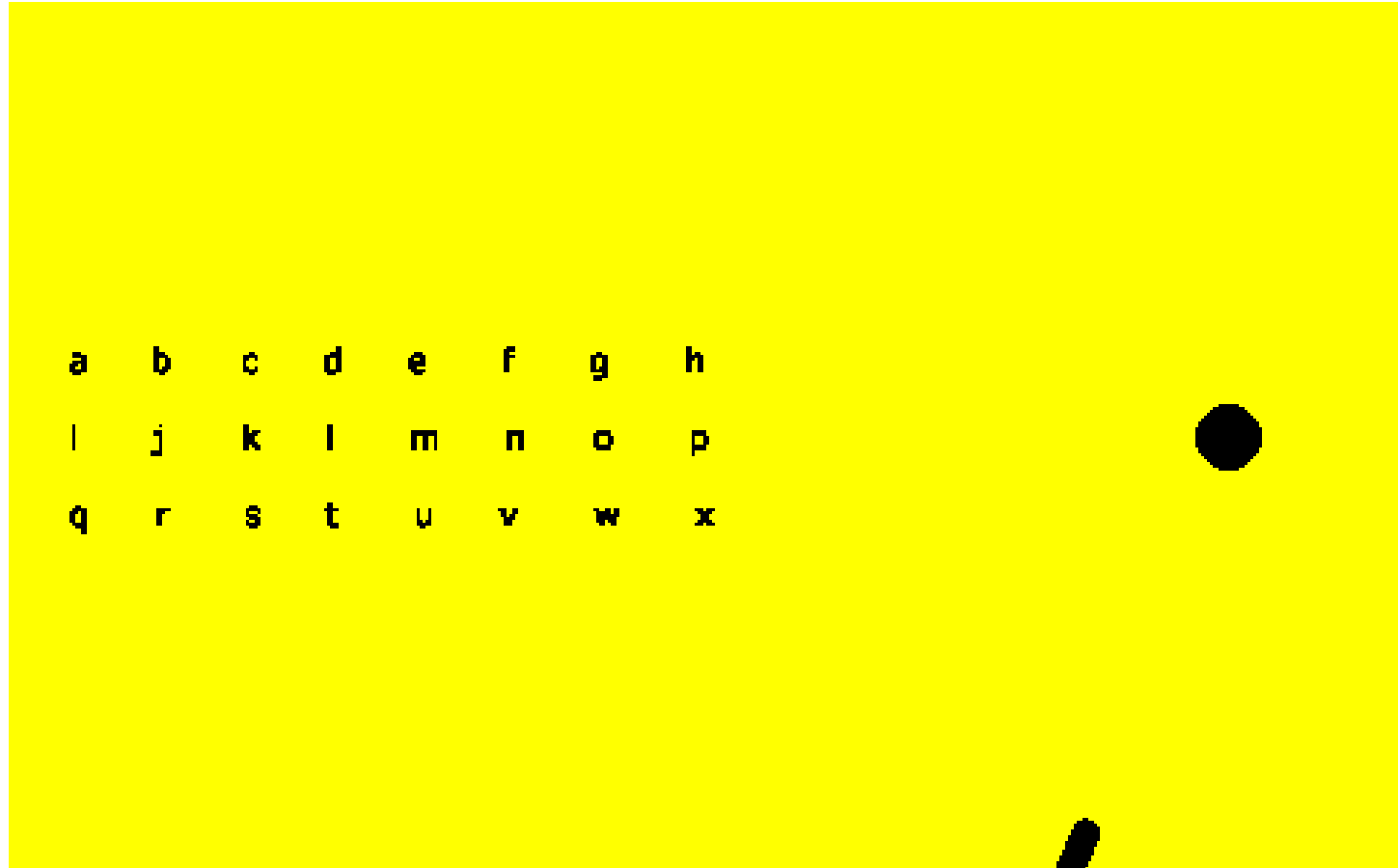


Spinning Wheel



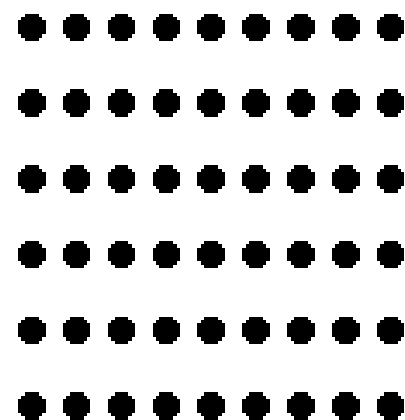
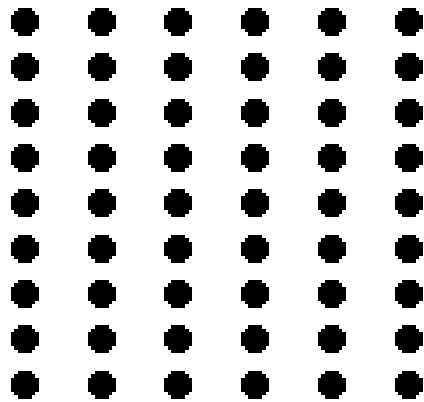
Follow the red dots vs
follow the yellow dots

Blind Spot Interpolation



Proximity

Objects close to each other form a group



Proximity

Using Lies in Research

By Nate Bolt • March 8, 2011

While it might be an uncomfortable topic, uncovering the lies behind a product or interface can be one of the most effective ways to turn ailing projects around.

[Read More](#)

Considerations for Mobile Design (Part 2): Dimensions

By David Leggett • March 1, 2011

In part two of this series, David helps readers adapt their design regimes to the (typically) small screens of mobile devices. Using responsive design, our experiences adapt to a variety of conditions.

[Read More](#)

A Simple, Usable Review

By Paul Seys • February 24, 2011

In this detailed review, Paul Seys describes an up-and-coming UX title that's jam-packed with lessons for designers both new and established. Follow along to learn how author Giles Colborne's teaches his readers the essence of great design.

[Read More](#)

Proximity

1. Tell us about yourself...

My Name

Gender

Birthday

I live in

Postal Code

2. Select an ID and password

Yahoo! ID and Email @

Password Password Strength

Re-type Password

3. In case you forget your ID or password...

Alternate Email

1.Security Question

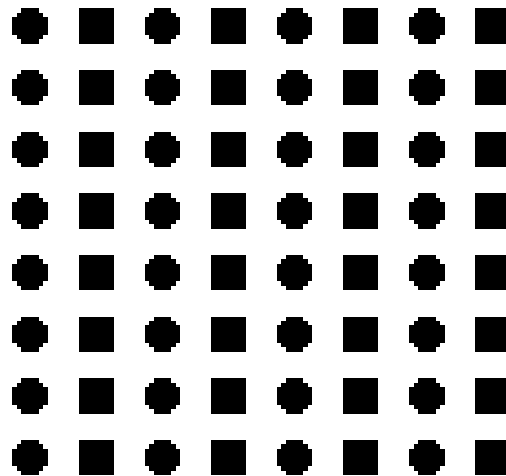
Your Answer

2.Security Question

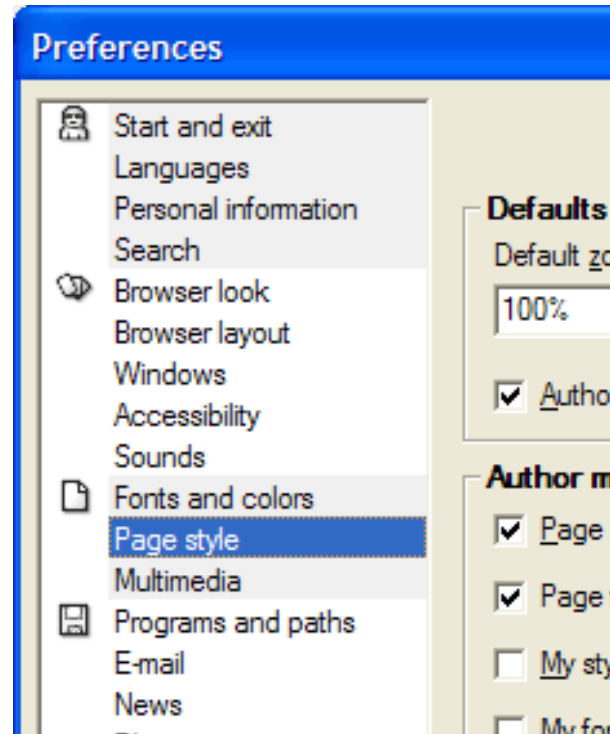
Your Answer

Similarity

Objects that are similar form a group



Similarity



Proximity and Similarity



Proximity and Similarity

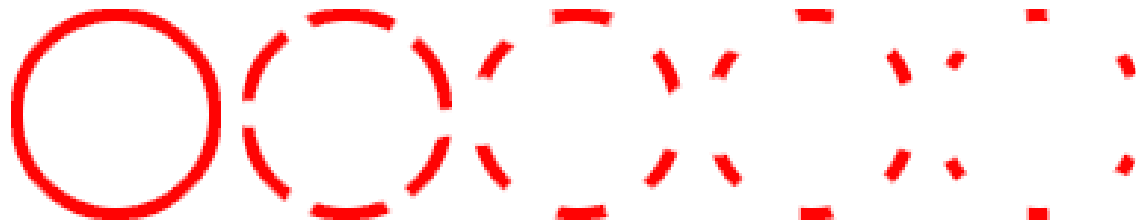


After discovering that one of these accesses a menu, people will expect they all access a menu. They are the same.

Closure

Even incomplete objects are perceived as whole

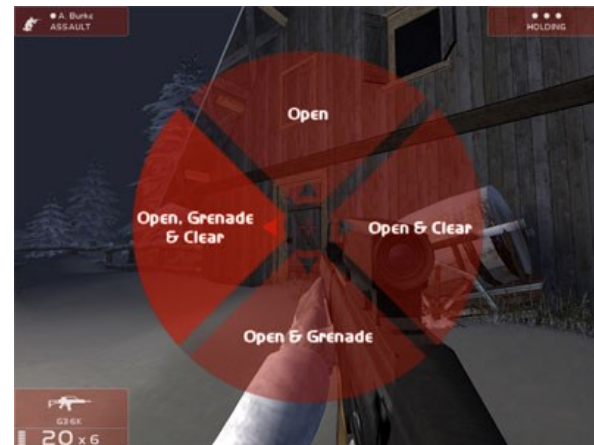
Increases regularity of stimuli



Closure



The Sims



Rainbow 6

Symmetry

Objects are perceived as symmetrical and forming around a center point



C S C

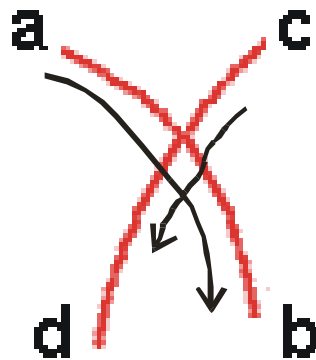
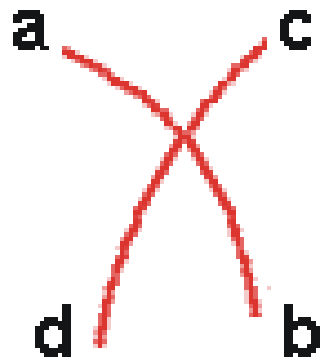
If you fight
symmetry,
be sure you
have a reason

Continuity

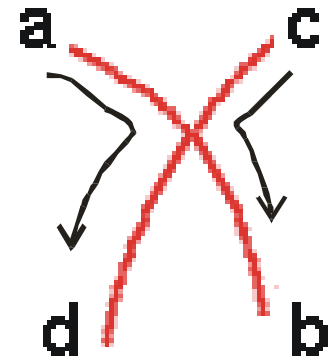
Objects are perceived as grouped when they align

Remain distinct even with overlap

Preferred over abrupt directional changes



what most
people see



not this

Continuity



Models from Different Perspectives

Some example models of human performance

Visual System

Model Human Processor

Fitts's Law

Gestalt Principles

Biological Model

Higher-Level Model

Model by Analogy

Predict Interpretation

CSE 440: Introduction to HCI

User Interface Design, Prototyping, and Evaluation

Lecture 06:
Human Performance

James Fogarty
Daniel Epstein
Brad Jacobson
King Xia



Tuesday/Thursday
10:30 to 11:50
MOR 234