INFORMATION VISUALIZATION

8 Oct 2015

ERIC PAULOS
www.paulos.net

UNIVERSITY OF CALIFORNIA Berkeley

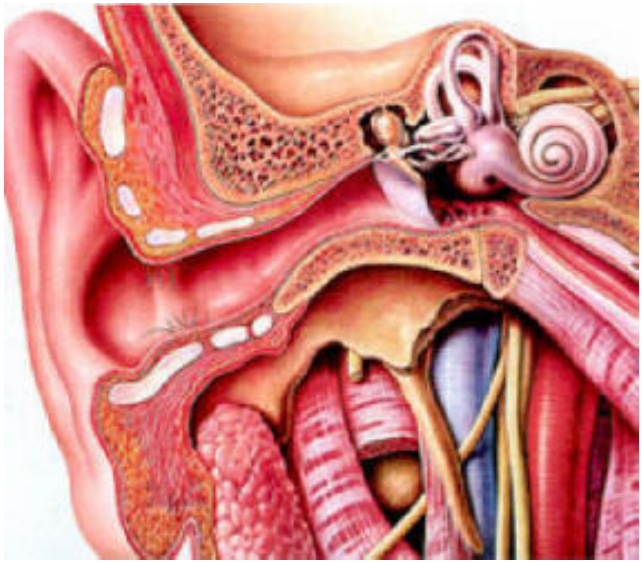
WHAT IS VISUALIZATION?

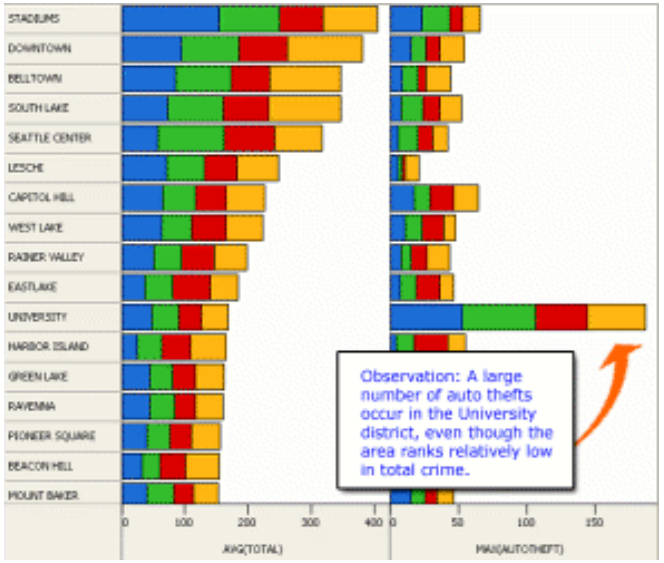
Definition [www.oed.com]

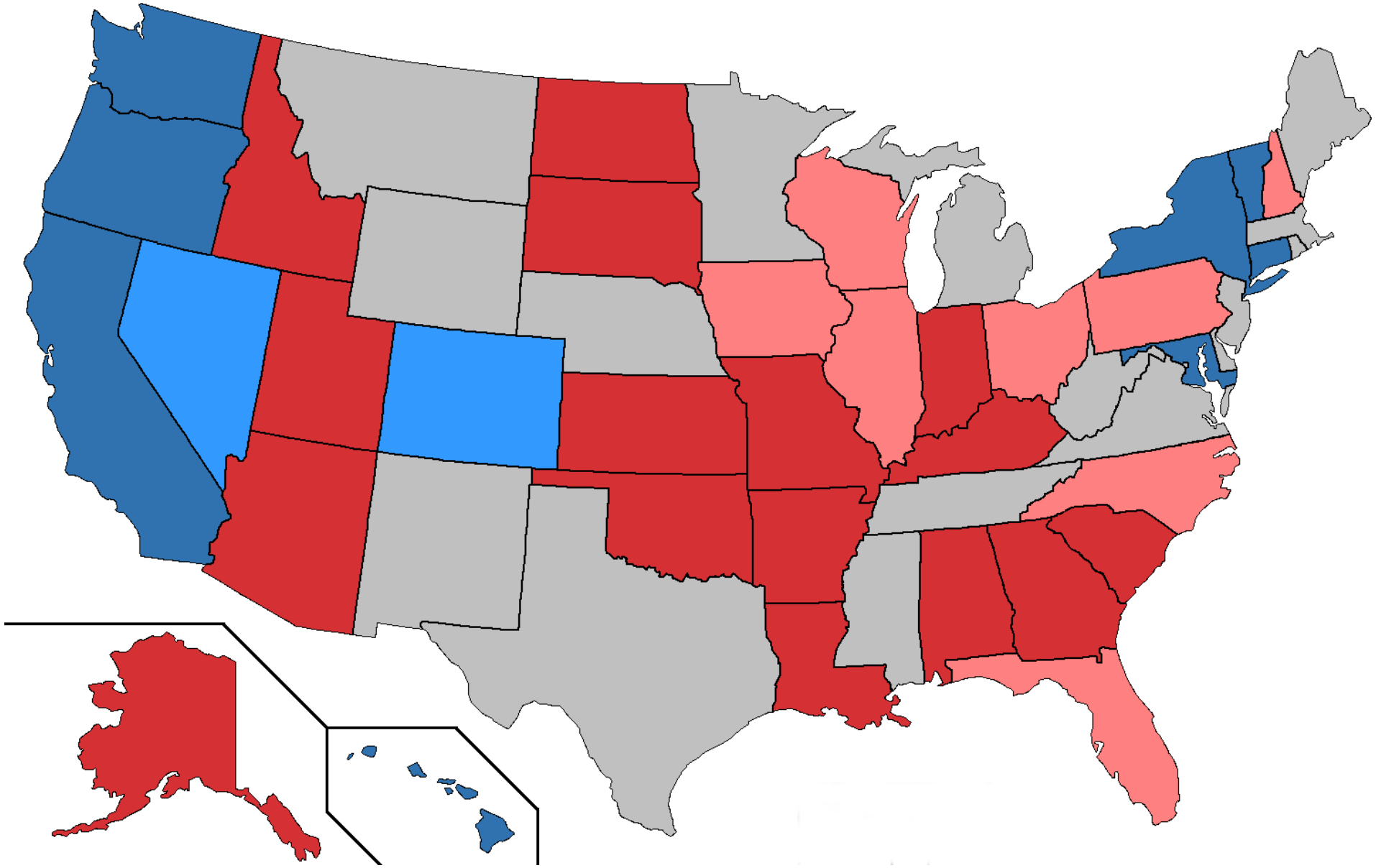
1. The action or fact of visualizing; the power or process of forming a mental picture or vision of something not actually present to the sight; a picture thus formed.

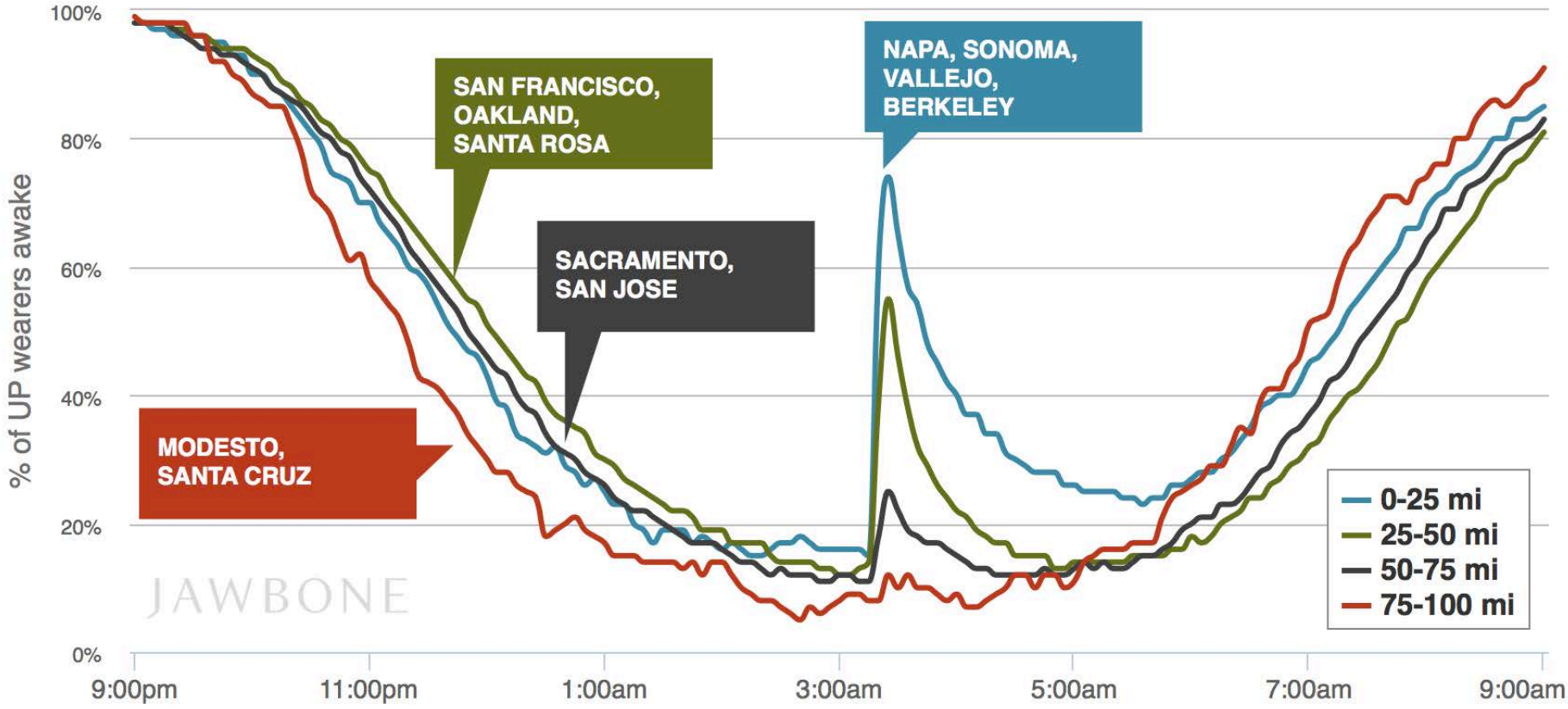
2. The action or process of rendering visible.

EXAMPLES




STADIUMS
DOWNTOWN
BELLTOWN
SOUTH LAKE
SEATTLE CENTER
LESCHE
CAPETOL HILL
WEST LAKE
RAINER VALLEY
EASTLAKE
UNIVERSITY
HARBOR ISLAND
GREEN LAKE
RAVENNA
PIONEER SQUARE
BEACON HILL
MOUNT BAKER
0
100
200
300
400
AVG(TOTAL)
0
50
100
150
MAX(AUTOTHEFT)
Observation: A large number of auto thefts occur in the University district, even though the area ranks relatively low in total crime.




100%
80%
60%
40%
20%
0%
% of UP wearers awake
9:00pm
11:00pm
1:00am
3:00am
5:00am
7:00am
9:00am
SAN FRANCISCO, OAKLAND, SANTA ROSA
SACRAMENTO, SAN JOSE
NAPA, SONOMA, VALLEJO, BERKELEY
MODESTO, SANTA CRUZ
JAWBONE
0-25 mi
25-50 mi
50-75 mi
75-100 mi

WHY DO WE CREATE VISUALIZATIONS?

THREE PRIMARY FUNCTIONS

Record information

- Photographs, blueprints, ...

Support reasoning about information (analyze)

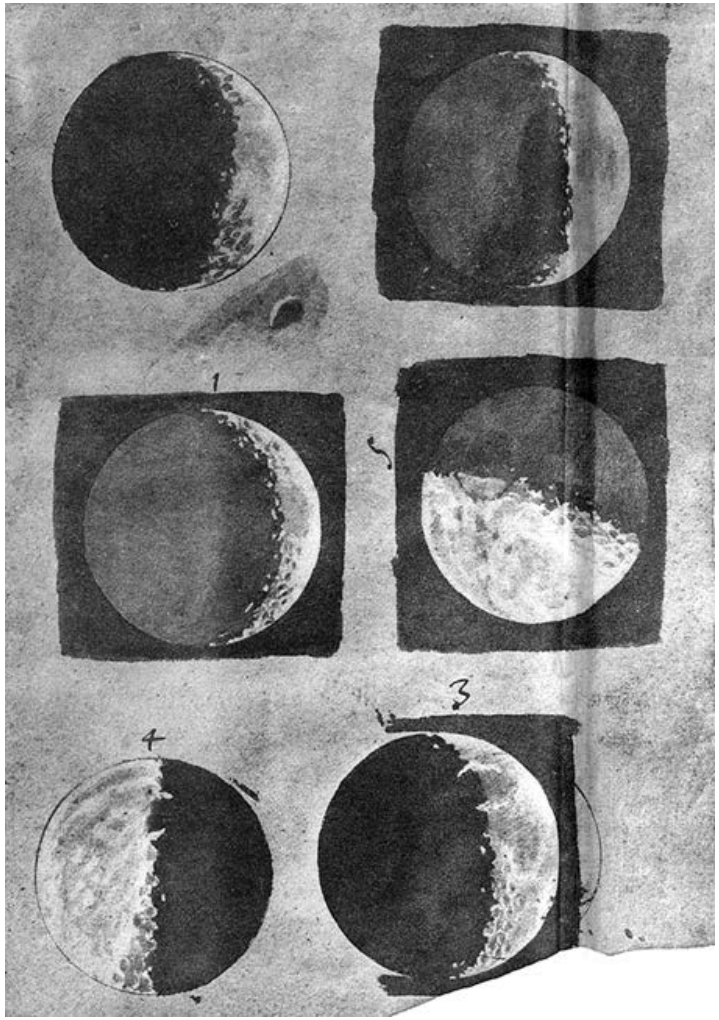
- Process and calculate
- Reason about data
- Feedback and interaction

Convey information to others (present)

- Share and persuade
- Collaborate and revise
- Emphasize important aspects of data

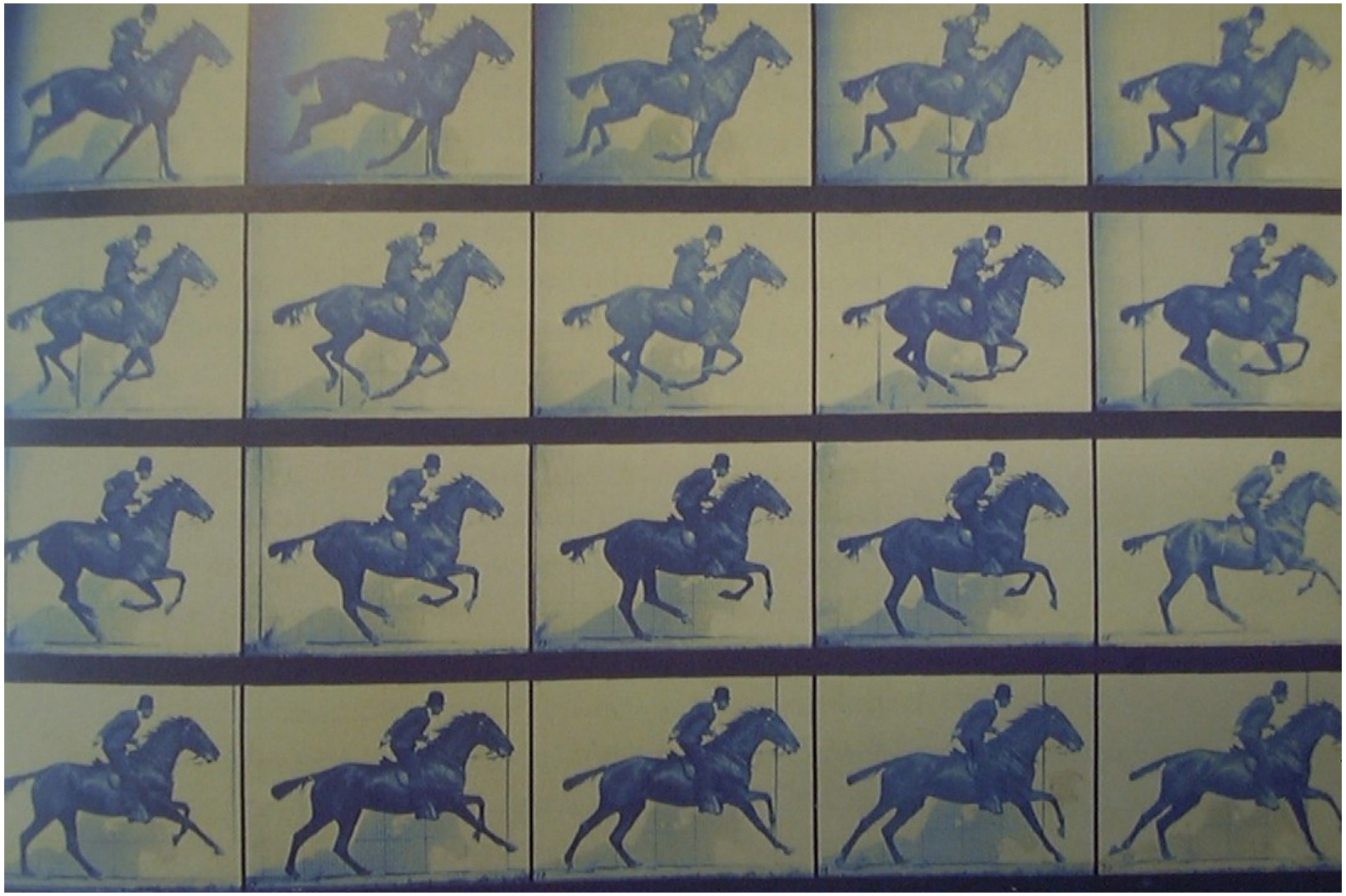
RECORD INFORMATION

DRAWING: PHASES OF THE MOON



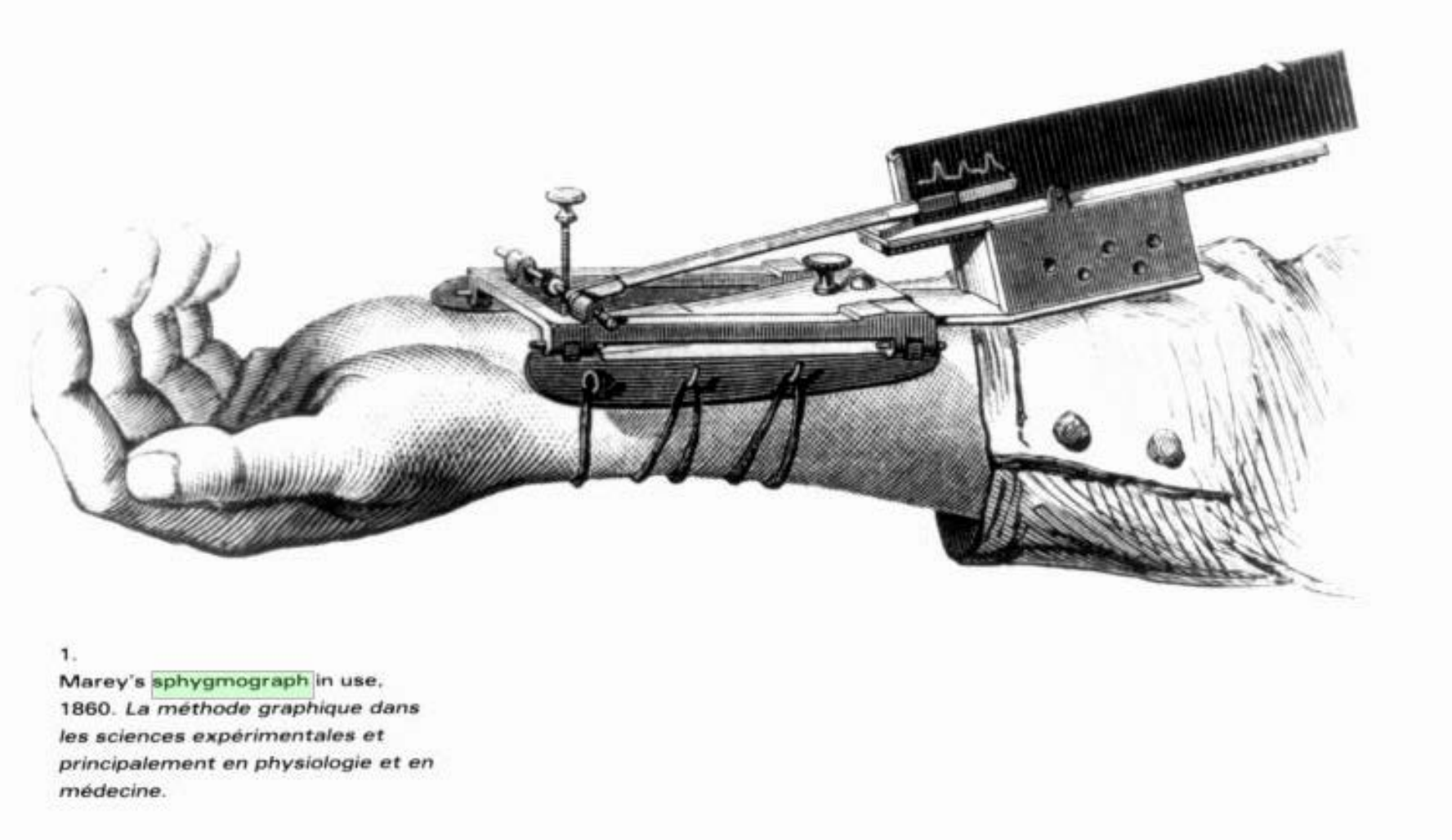
Galileo's drawings of the phases of the moon from 1616
http://galileo.rice.edu/sci/observations/moon.html

ANSWER QUESTION



Gallop, Bay Horse “Daisy” [Muybridge 1884-86]

OTHER RECORDING INSTRUMENTS



1.
Marey's sphygmograph in use, 1860. *La méthode graphique dans les sciences expérimentales et principalement en physiologie et en médecine.*

Marey's sphygmograph [from Braun 83]

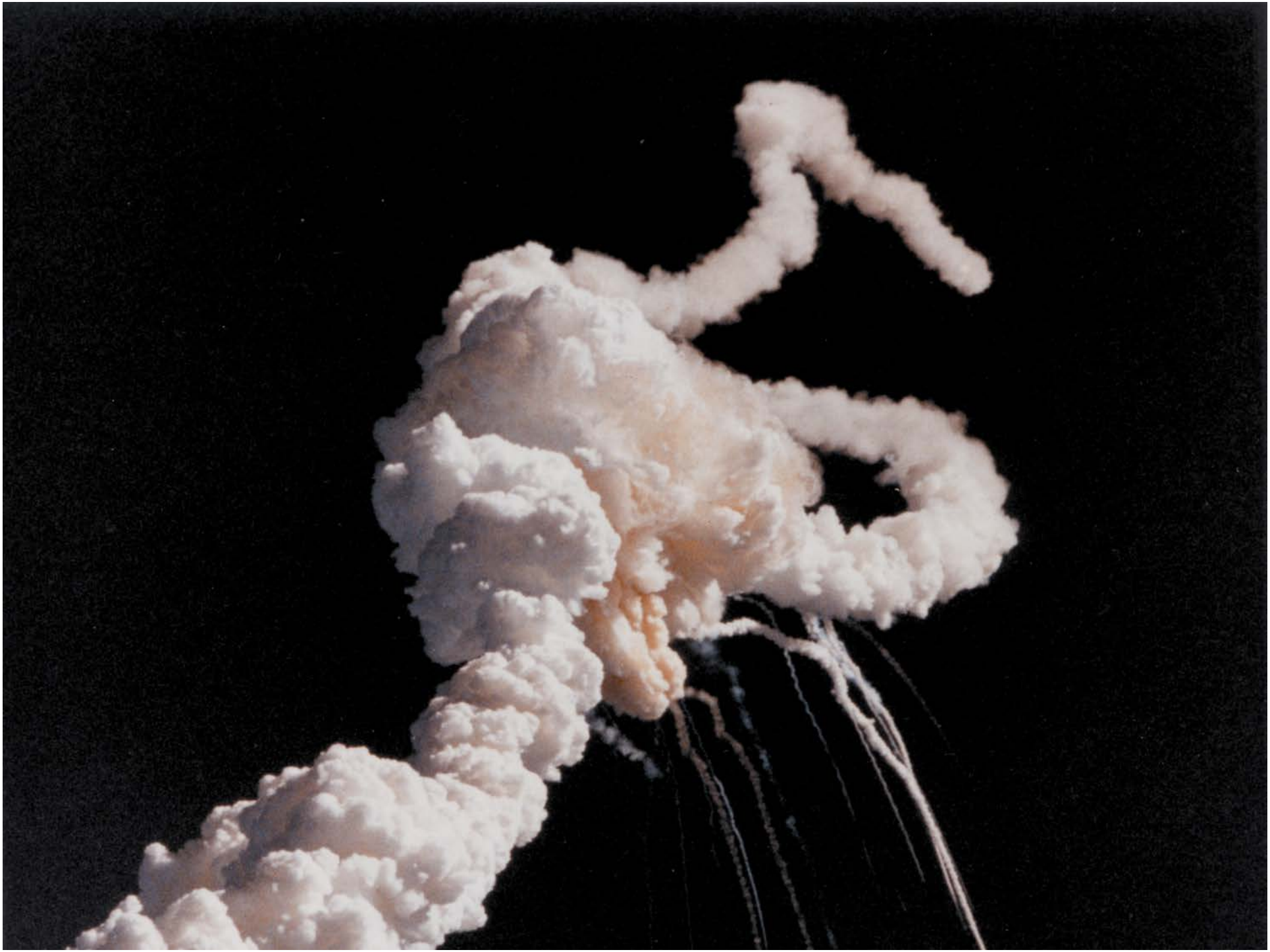
SUPPORT REASONING

DATA IN CONTEXT: CHOLERA OUTBREAK

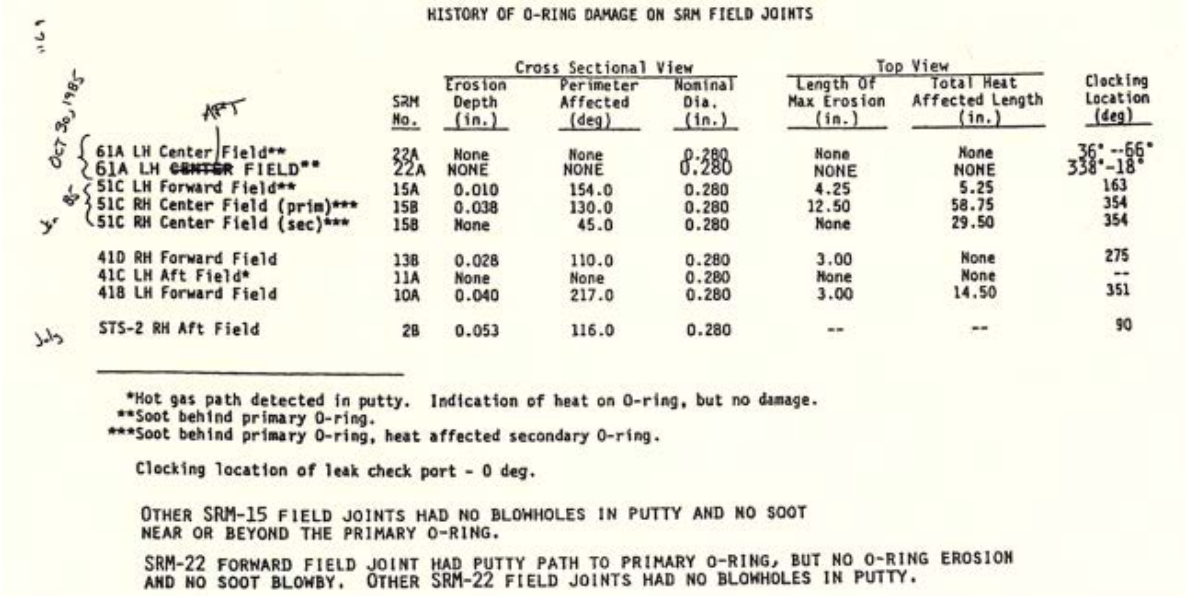
In 1864 John Snow plotted the position of each cholera case on a map. [from Tufte 83]

DATA IN CONTEXT: CHOLERA OUTBREAK

Used map to hypothesize that pump on Broad St. was the cause. [from Tufte 83]



MAKE A DECISION: CHALLENGER



HISTORY OF O-RING DAMAGE ON SRM FIELD JOINTS

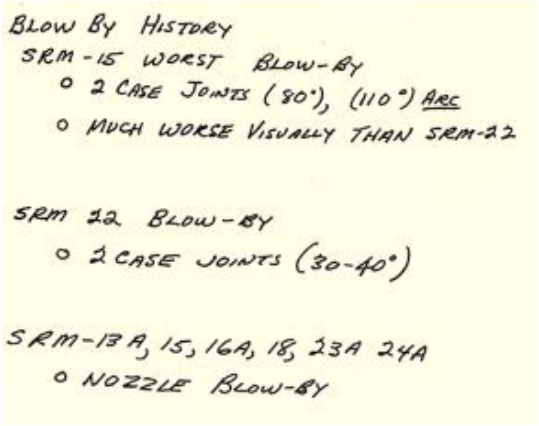
	SRM No.	Cross Sectional View: Erosion Depth (in.)	Cross Sectional View: Perimeter Affected (deg)	Cross Sectional View: Nominal Dia. (in.)	Top View: Length Of Max Erosion (in.)	Top View: Total Heat Affected Length (in.)	Clocking Location (deg)
61A LH Center Field**	22A	None	None	0.280	None	None	36°--66°
61A LH ~~CENTER~~ FIELD**	22A	NONE	NONE	0.280	NONE	NONE	338°-18°
51C LH Forward Field**	15A	0.010	154.0	0.280	4.25	5.25	163
51C RH Center Field (prim)***	15B	0.038	130.0	0.280	12.50	58.75	354
51C RH Center Field (sec)***	15B	None	45.0	0.280	None	29.50	354
41D RH Forward Field	13B	0.028	110.0	0.280	3.00	None	275
41C LH Aft Field*	11A	None	None	0.280	None	None	--
41B LH Forward Field	10A	0.040	217.0	0.280	3.00	14.50	351
STS-2 RH Aft Field	2B	0.053	116.0	0.280	--	--	90

*Hot gas path detected in putty. Indication of heat on O-ring, but no damage.
**Soot behind primary O-ring.
***Soot behind primary O-ring, heat affected secondary O-ring.

Clocking location of leak check port - 0 deg.

OTHER SRM-15 FIELD JOINTS HAD NO BLOWHOLES IN PUTTY AND NO SOOT NEAR OR BEYOND THE PRIMARY O-RING.

SRM-22 FORWARD FIELD JOINT HAD PUTTY PATH TO PRIMARY O-RING, BUT NO O-RING EROSION AND NO SOOT BLOWBY. OTHER SRM-22 FIELD JOINTS HAD NO BLOWHOLES IN PUTTY.

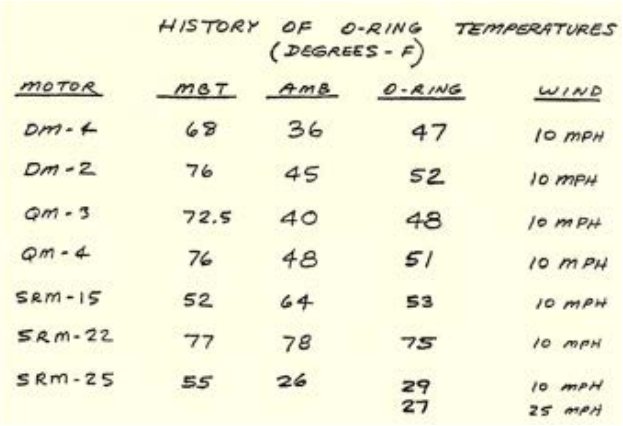


BLOW BY HISTORY

SRM-15 WORST BLOW-BY
- 2 CASE JOINTS (80°), (110°) ARC
- MUCH WORSE VISUALLY THAN SRM-22

SRM 22 BLOW-BY
- 2 CASE JOINTS (30-40°)

SRM-13A, 15, 16A, 18, 23A 24A
- NOZZLE BLOW-BY

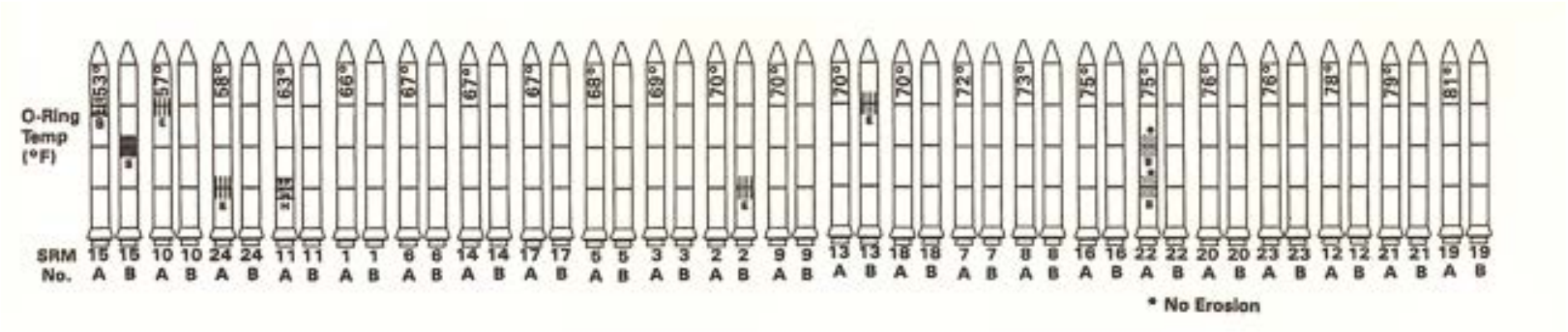


HISTORY OF O-RING TEMPERATURES (DEGREES - F)

MOTOR	MBT	AMB	O-RING	WIND
DM-4	68	36	47	10 MPH
DM-2	76	45	52	10 MPH
QM-3	72.5	40	48	10 MPH
QM-4	76	48	51	10 MPH
SRM-15	52	64	53	10 MPH
SRM-22	77	78	75	10 MPH
SRM-25	55	26	29 27	10 MPH 25 MPH

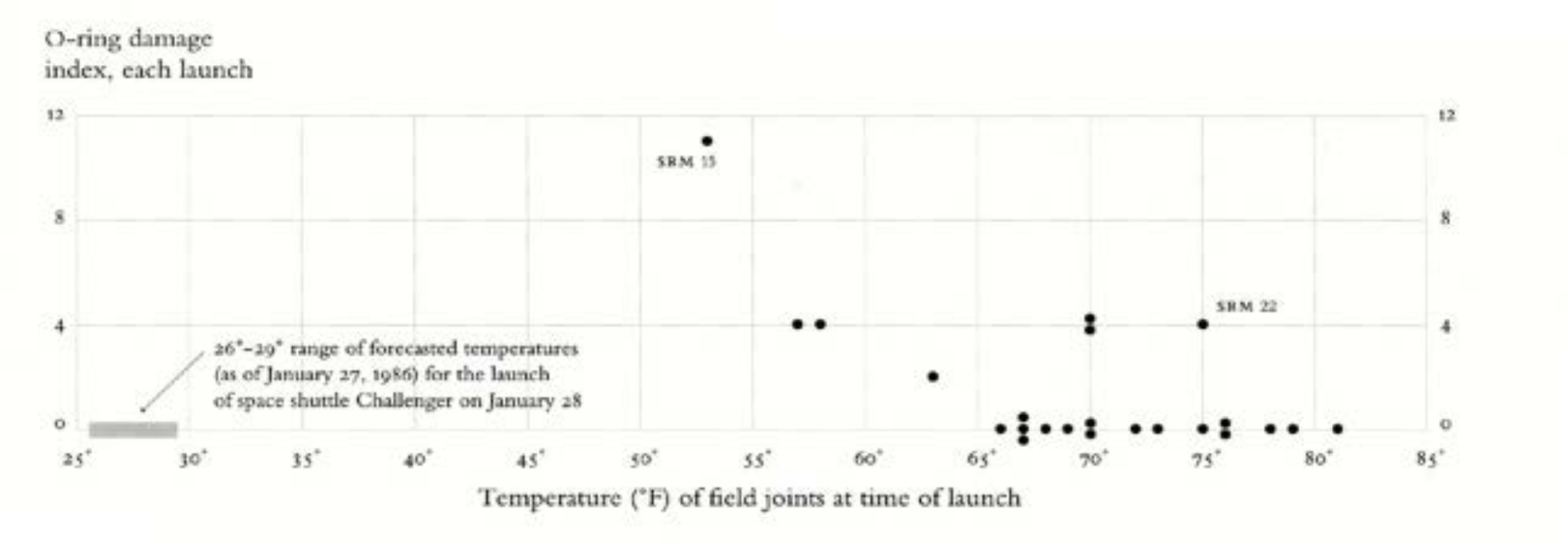
2 of 13 pages of material faxed to NASA by Morton Thiokol [from Tufte 1997]

MAKE A DECISION: CHALLENGER



Visualizations by booster rocket manufacturer of damage to O-rings [Tufte 97]

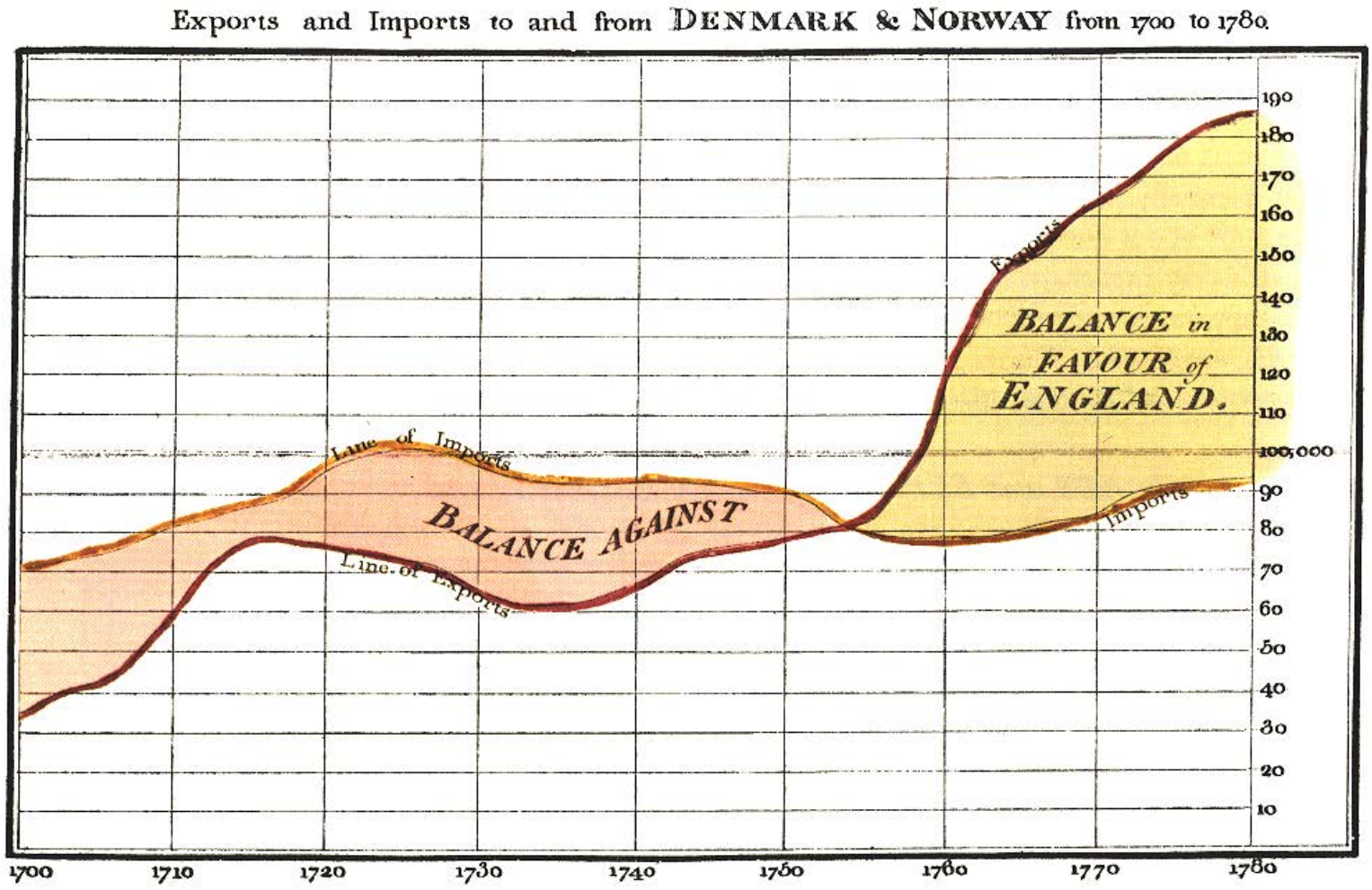
MAKE A DECISION: CHALLENGER



Visualizations drawn by Tufte show how low temperatures damage O-rings [Tufte 97]

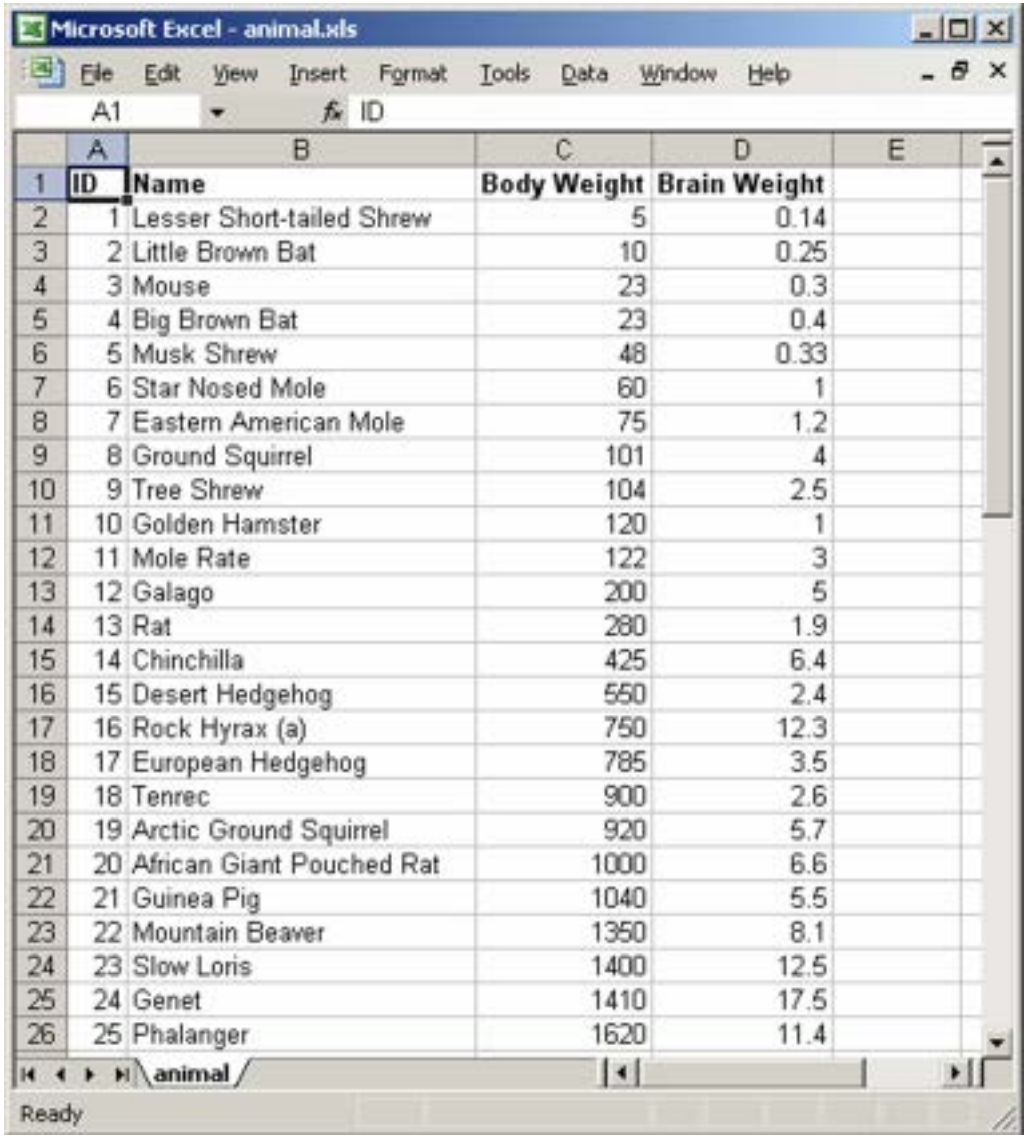
CONVEY INFORMATION TO OTHERS

PRESENT ARGUMENT: EXPORTS & IMPORTS



William Playfair 1786

TELL STORY: MOST POWERFUL BRAIN?



Microsoft Excel - animal.xls

File Edit View Insert Format Tools Data Window Help

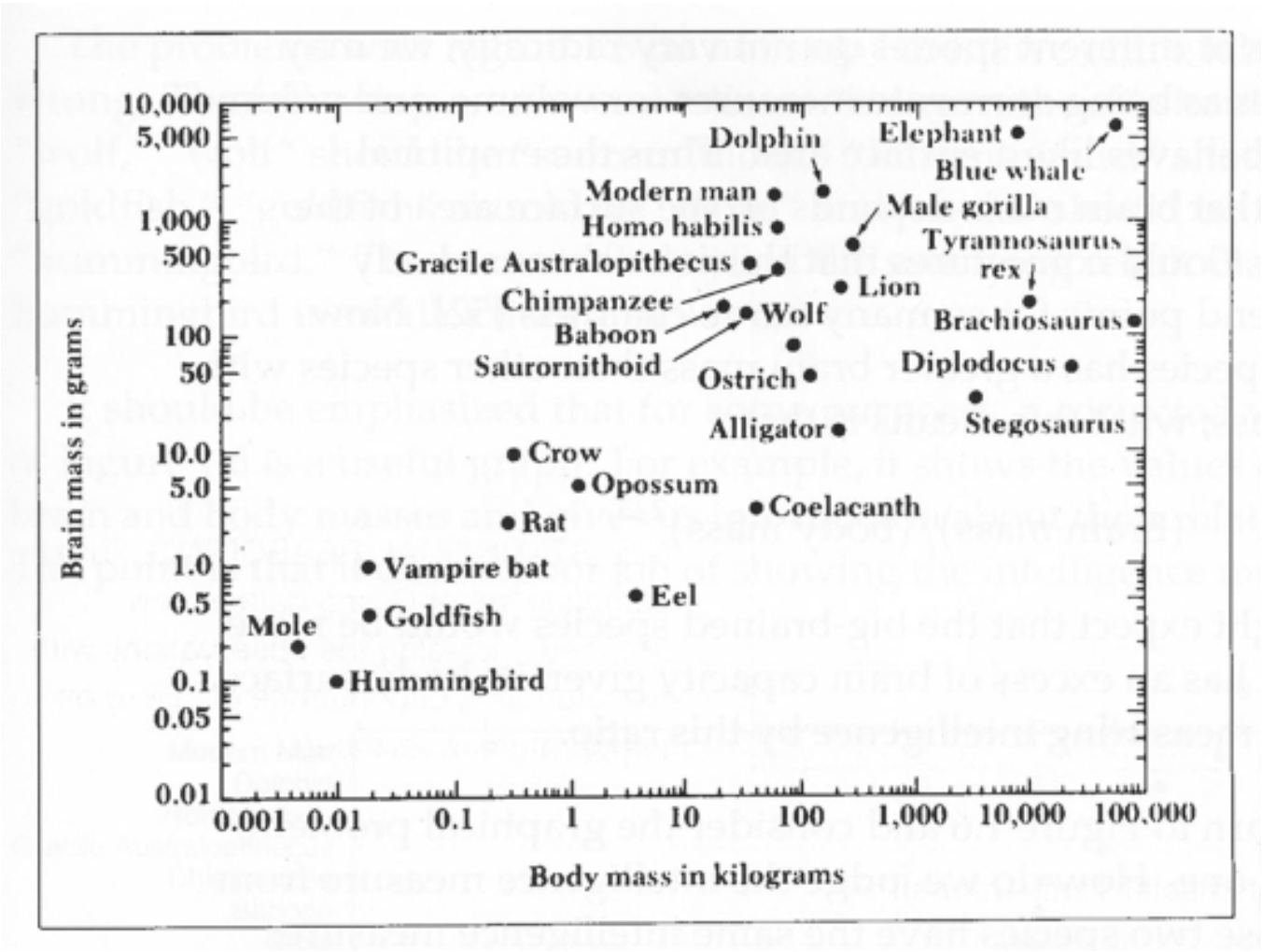
A1 ID

	A	B	C	D	E
1	ID	Name	Body Weight	Brain Weight	
2	1	Lesser Short-tailed Shrew	5	0.14	
3	2	Little Brown Bat	10	0.25	
4	3	Mouse	23	0.3	
5	4	Big Brown Bat	23	0.4	
6	5	Musk Shrew	48	0.33	
7	6	Star Nosed Mole	60	1	
8	7	Eastern American Mole	75	1.2	
9	8	Ground Squirrel	101	4	
10	9	Tree Shrew	104	2.5	
11	10	Golden Hamster	120	1	
12	11	Mole Rate	122	3	
13	12	Galago	200	5	
14	13	Rat	280	1.9	
15	14	Chinchilla	425	6.4	
16	15	Desert Hedgehog	550	2.4	
17	16	Rock Hyrax (a)	750	12.3	
18	17	European Hedgehog	785	3.5	
19	18	Tenrec	900	2.6	
20	19	Arctic Ground Squirrel	920	5.7	
21	20	African Giant Pouched Rat	1000	6.6	
22	21	Guinea Pig	1040	5.5	
23	22	Mountain Beaver	1350	8.1	
24	23	Slow Loris	1400	12.5	
25	24	Genet	1410	17.5	
26	25	Phalanger	1620	11.4	

animal

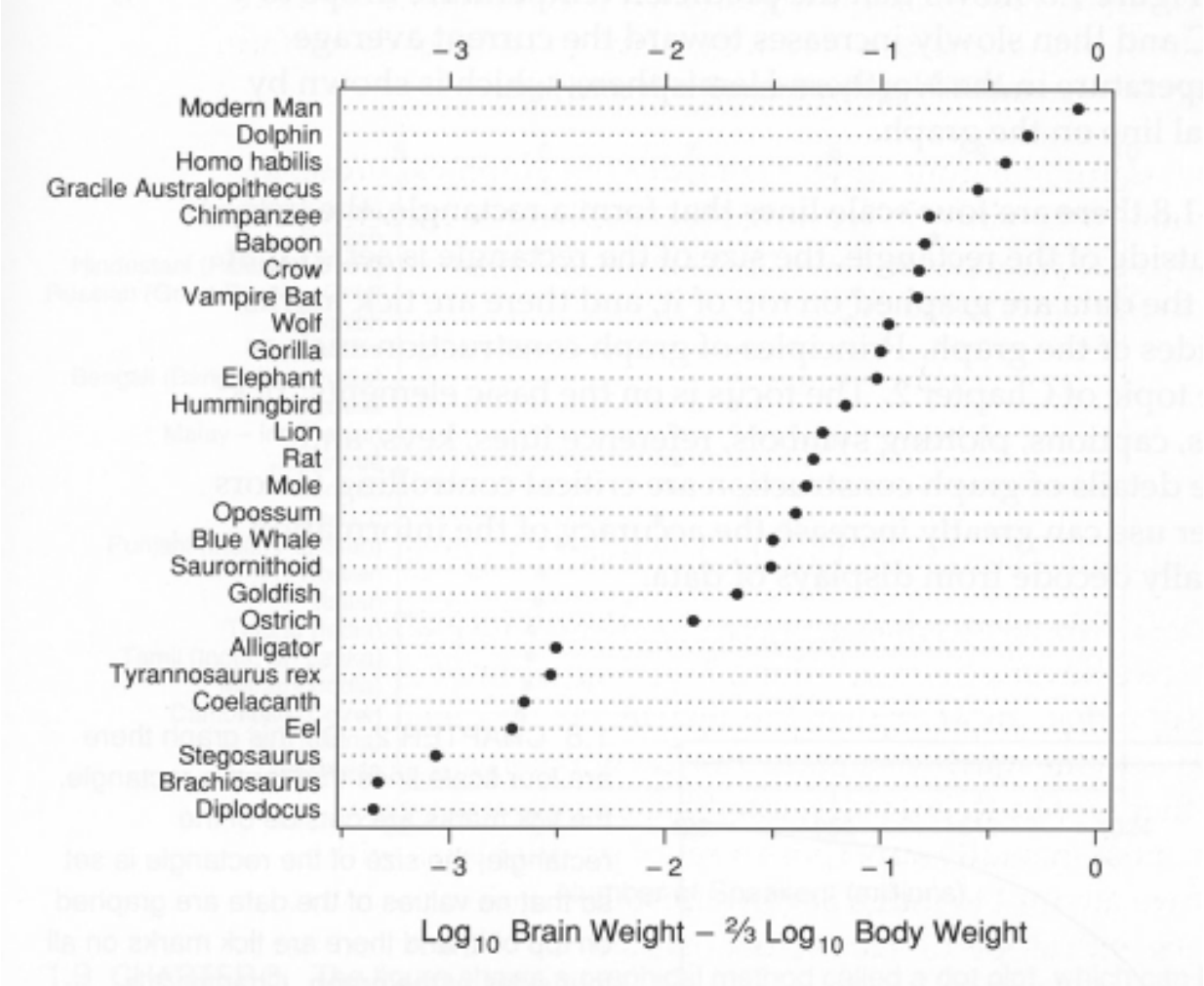
Ready

TELL STORY: MOST POWERFUL BRAIN?



The Dragons of Eden [Carl Sagan]

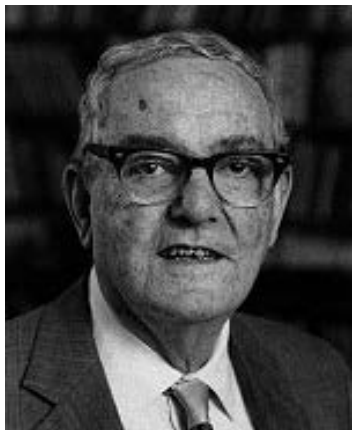
TELL STORY: MOST POWERFUL BRAIN?



The Elements of Grasping Data [Cleveland]

ATTENTION

"What information consumes is rather obvious: it consumes the **attention** of its recipients. Hence a wealth of information creates a poverty of attention, and a need to allocate that attention efficiently among the overabundance of information sources that might consume it."



~Herb Simon
as quoted by Hal Varian
Scientific American
September 1995

[slide from PARC UIR group]

DATA

DATA TYPES

Physical type (model)

Characterized by storage format

Characterized by machine operations

Example:

bool, short, int32, float, double, string, ...

Abstract type

Provide (conceptual) descriptions of the data

May be characterized by methods/attributes

May be organized into a hierarchy

Example:

nominal, ordinal, quantitative, ...,

plants, animals, metazoans, ...

NOMINAL, ORDINAL & QUANTITATIVE

N - Nominal (labels)

Fruits: Apples, oranges, ...

O - Ordered

Quality of meat: Grade A, AA, AAA

Q - Quantitative

Real numbers

Ordered, with measurable distances, or amounts

Dates: Jan, 19, 2006; Location: (LAT 33.98, LONG -118.45)

Physical measurement: Length, Mass, Temp, ...

S. S. Stevens, On the theory of scales of measurements, 1946

FROM DATA MODEL TO DATA TYPE

Data model

32.5, 54.0, -17.3, ...

floats

Conceptual model

Temperature

Data type

Burned vs. Not burned (N)

Hot, warm, cold (O)

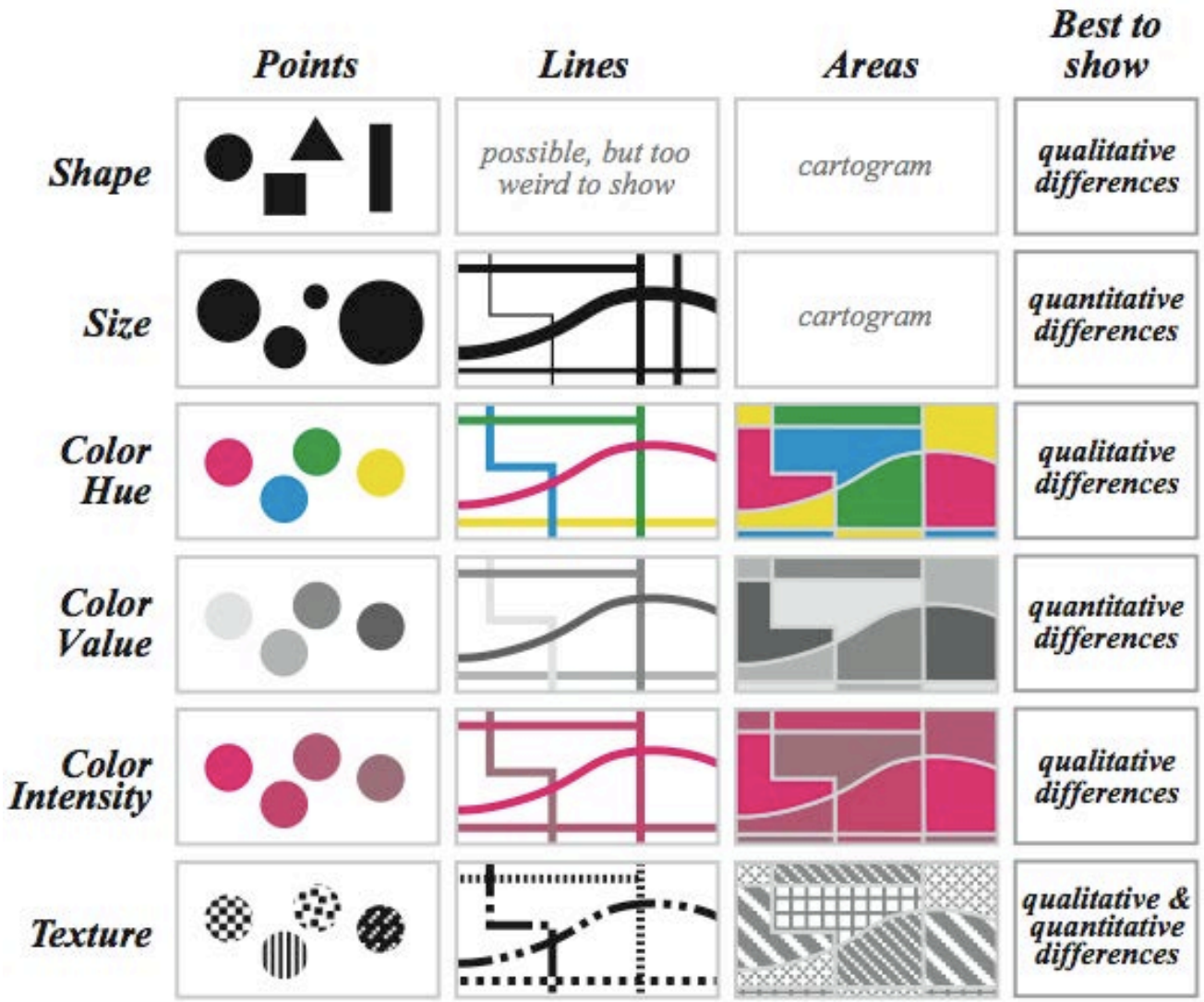
Continuous range of values (Q)

[based on slide from Munzner]

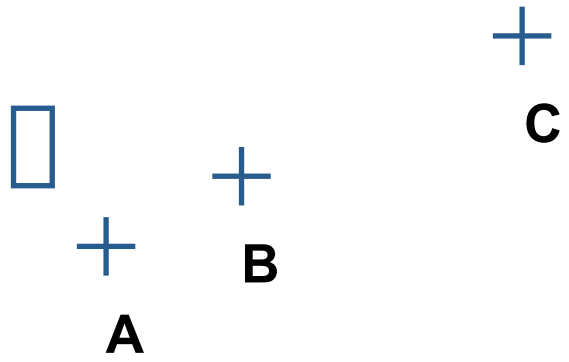
IMAGE

Jacques Bertin

VISUAL VARIABLES



INFORMATION IN POSITION



1. A, B, C are distinguishable
2. B is between A and C.
3. BC is twice as long as AB.

4. ∴ Encode quantitative variables (Q)

INFORMATION IN COLOR AND VALUE

Value is perceived as ordered

∴ Encode ordinal variables (O)

∴ Encode continuous variables (Q) [not as well] – can't tell distance

Hue is normally perceived as unordered

∴ Encode nominal variables (N) using color

BERTINS' "LEVELS OF ORGANIZATION"

Position	N	O	Q
Size	N	O	Q
Value	N	O	Q
Texture	N	O	
Color	N		
Orientation	N		
Shape	N		

N Nominal
O Ordinal
Q Quantitative

ESTIMATING MAGNITUDE

DETECTING BRIGHTNESS

Which is brighter?

DETECTING BRIGHTNESS

(128, 128, 128)

(144, 144, 144)

Which is brighter?

JUST NOTICEABLE DIFFERENCES

JND (Weber's Law)

$$\Delta S = k \frac{\Delta I}{I}$$

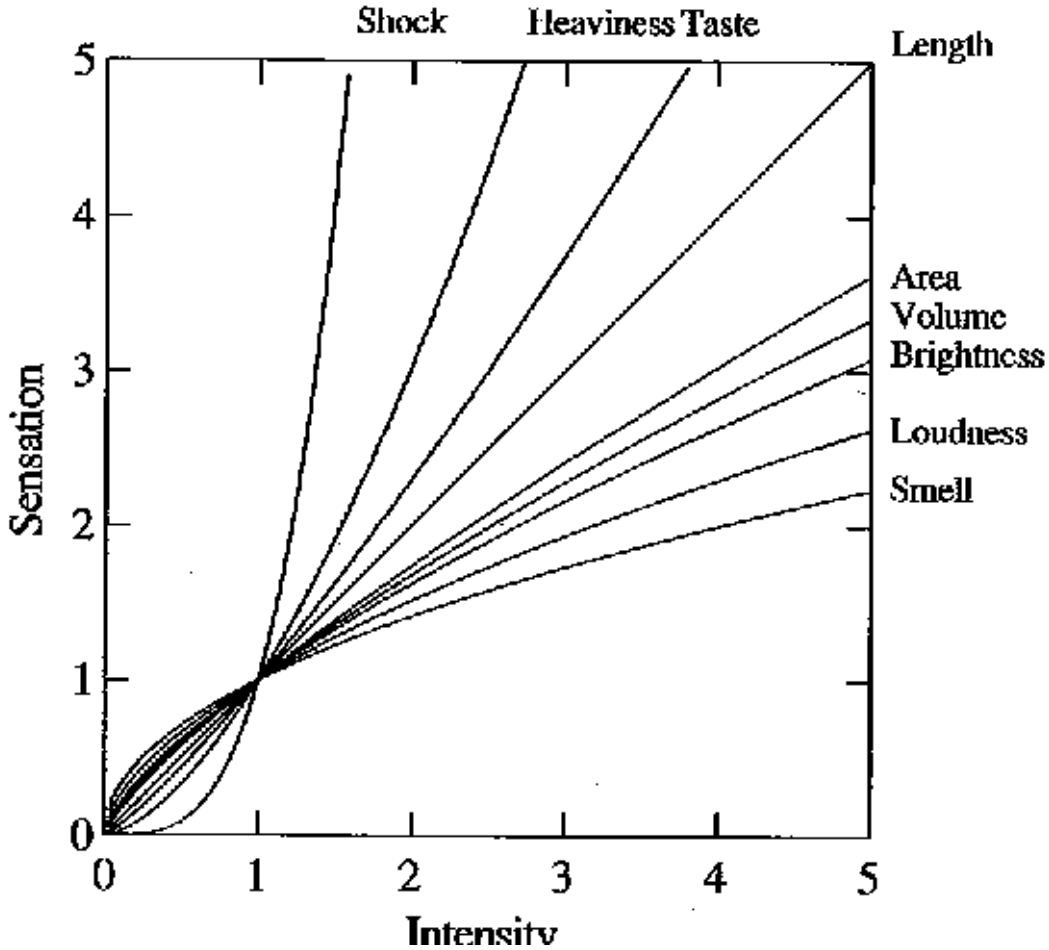
Ratios more important than magnitude

Most continuous variations perceived in discrete steps

STEVEN'S POWER LAW

$$S = I^p$$

p < 1 : underestimate
p > 1 : overestimate



[graph from Wilkinson 99, based on Stevens 61]

EXPONENTS OF POWER LAW

Sensation	Exponent
Loudness	0.6
Brightness	0.33
Smell	0.55 (Coffee) - 0.6 (Heptane)
Taste	0.6 (Saccharine) -1.3 (Salt)
Temperature	1.0 (Cold) – 1.6 (Warm)
Vibration	0.6 (250 Hz) – 0.95 (60 Hz)
Duration	1.1
Pressure	1.1
Heaviness	1.45
Electic Shock	3.5

[Psychophysics of Sensory Function, Stevens 61]

SUMMARY

We create visualizations to

Record information

Support reasoning about the information

Convey information to others

Choose the right mark for your data

Position good for N, O, Q, but Hue best only for N

With careful design it is possible to display many dimensions at once

THE VALUE OF PROTOTYPING

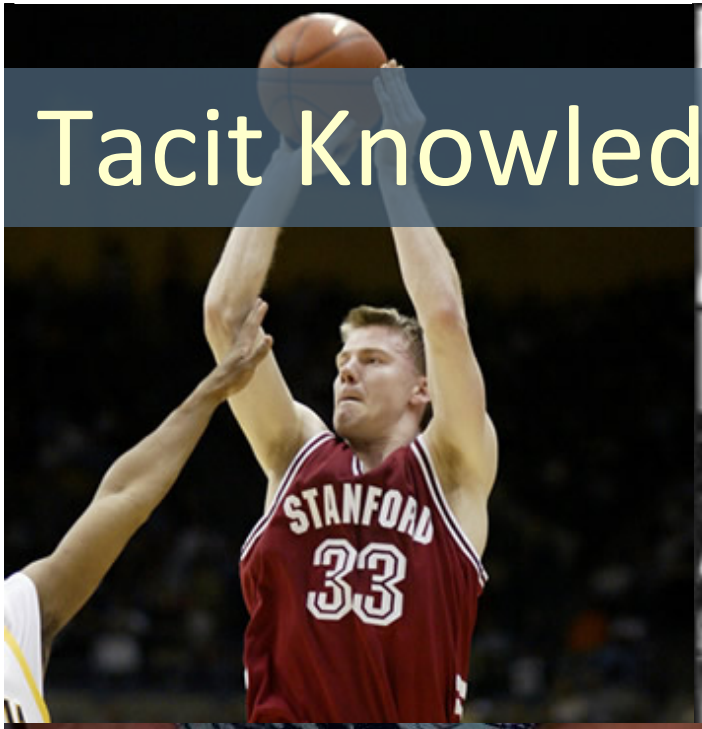
BENEFITS OF PROTOTYPING

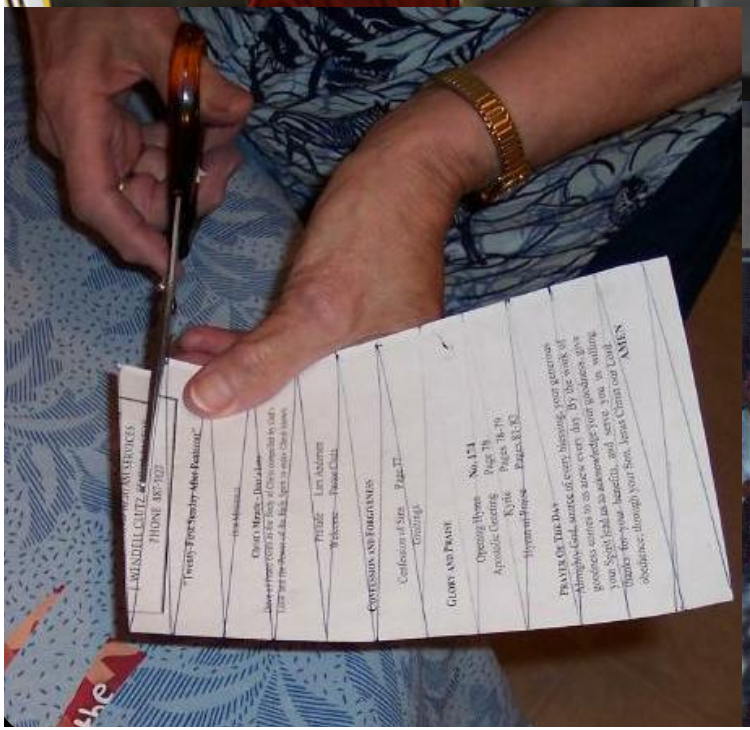
We know more than we can tell

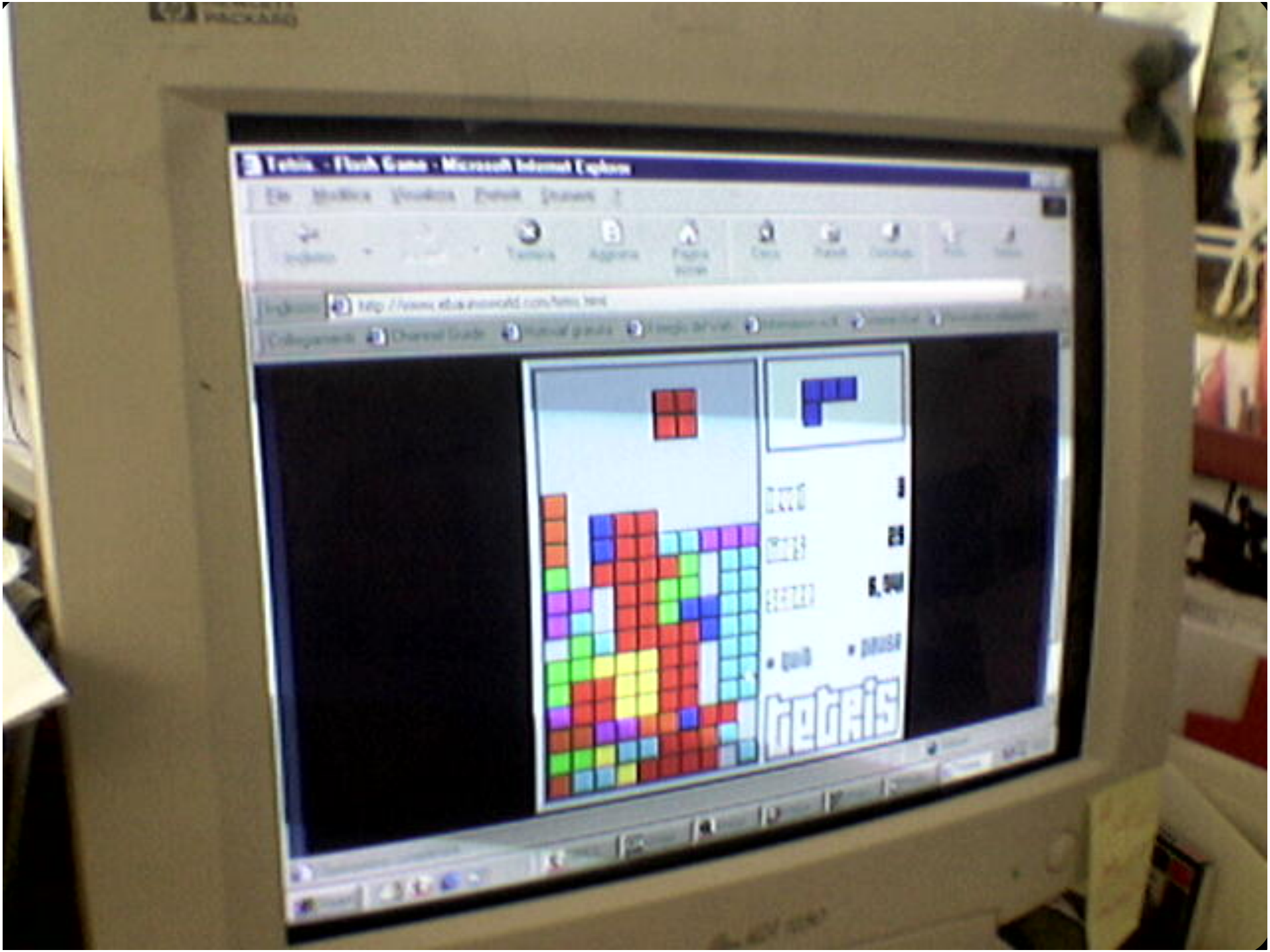
Actions in the world outperform mental operations

The value of surprise

Tacit Knowledge

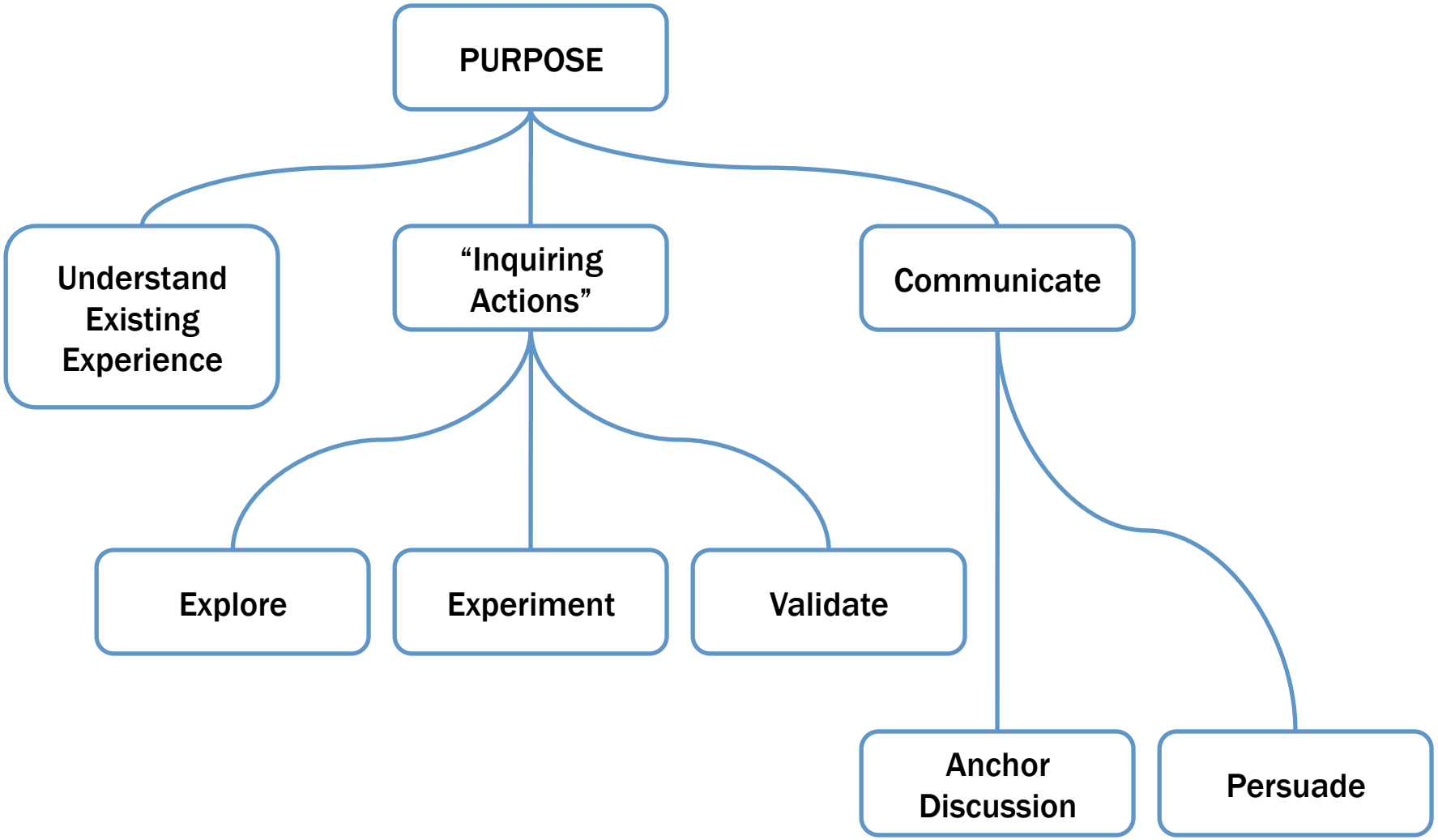


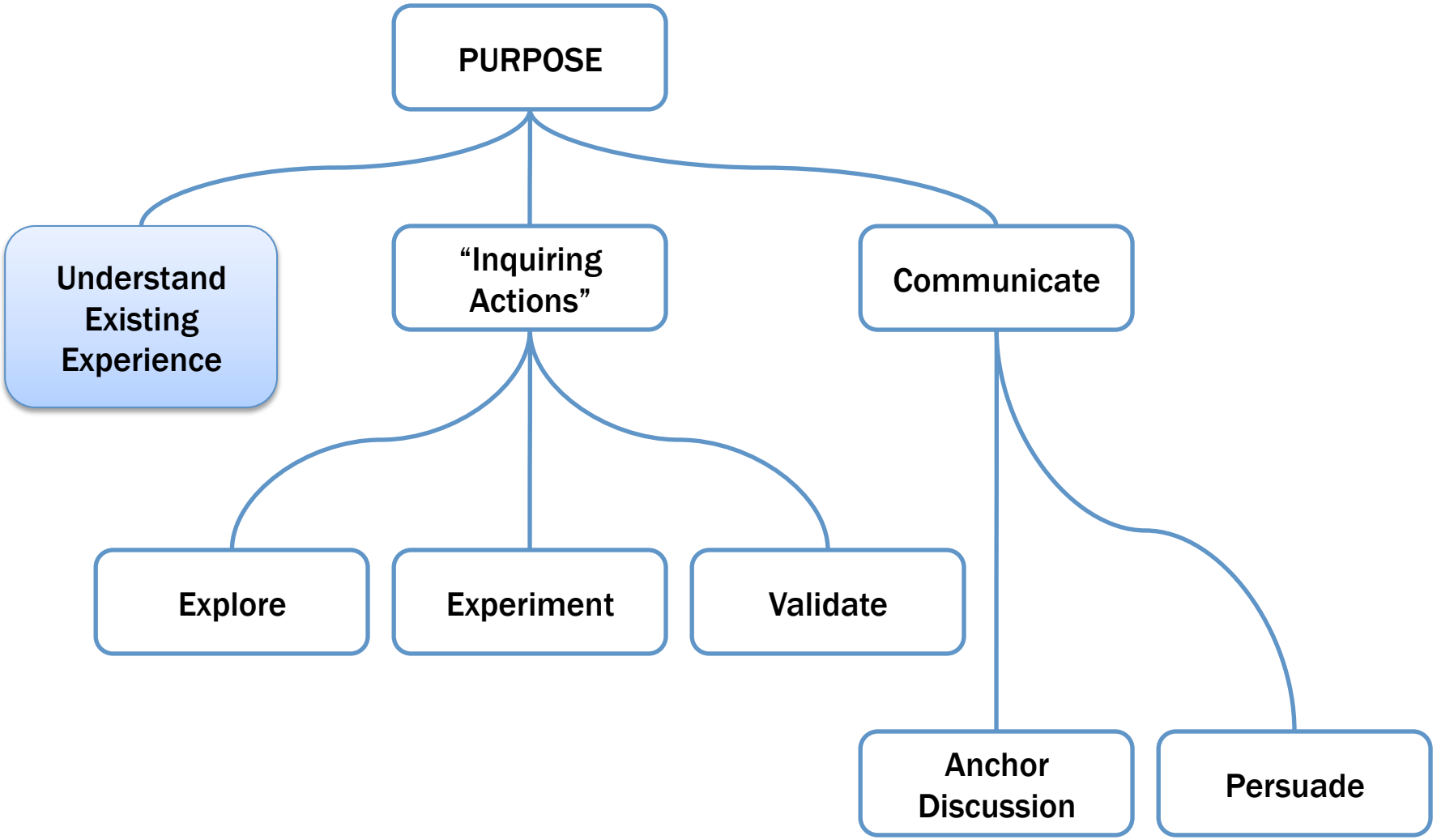



tetris

THE PURPOSE OF PROTOTYPING

What questions do prototypes answer?
When and how should they be constructed?


PURPOSE
Understand Existing Experience
“Inquiring Actions”
Communicate
Explore
Experiment
Validate
Anchor Discussion
Persuade


PURPOSE
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“Inquiring Actions”
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Anchor Discussion
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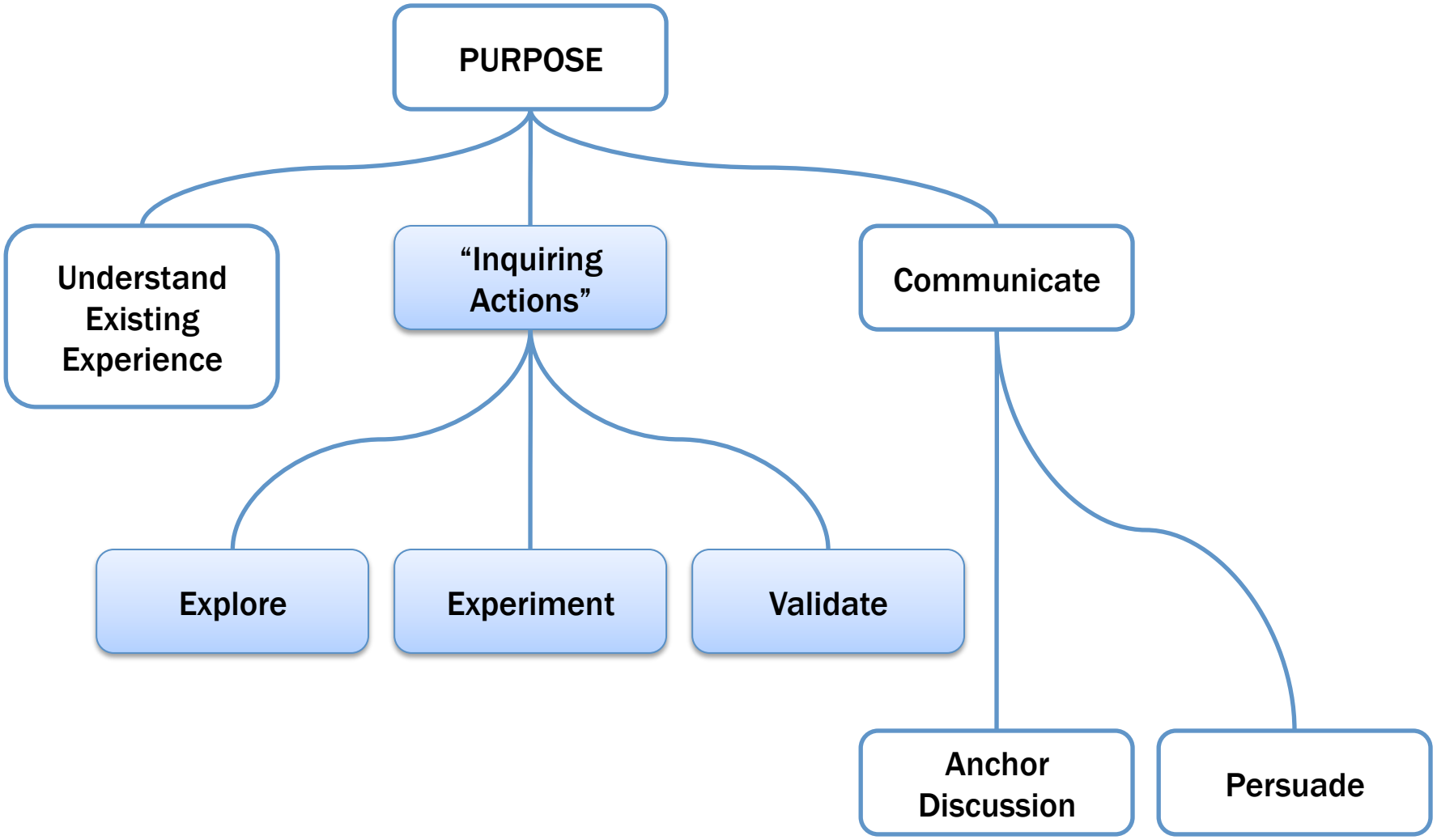
Figure 2: Experiencing a train journey.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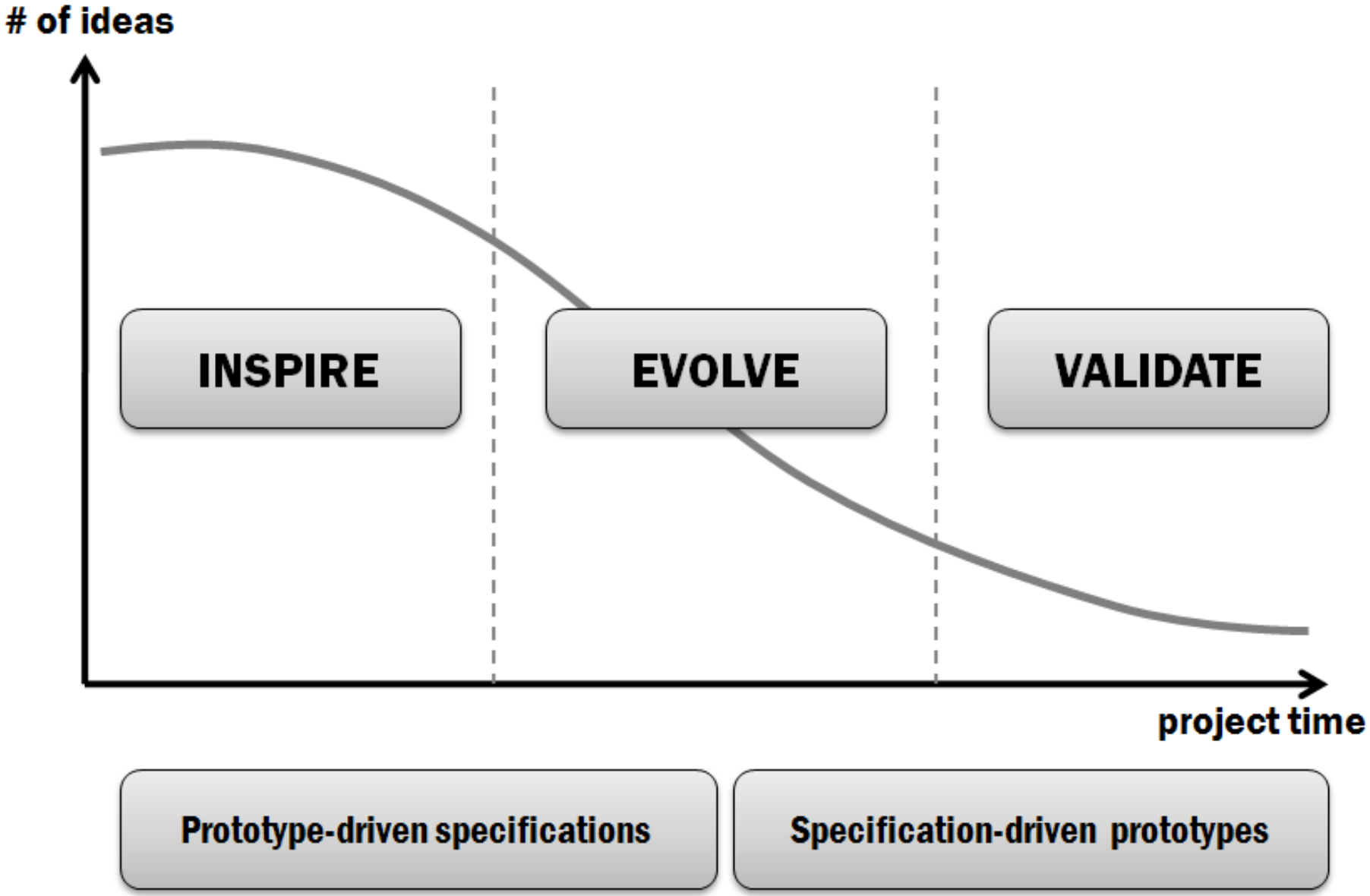
Three Stages of Prototyping (IDEO)



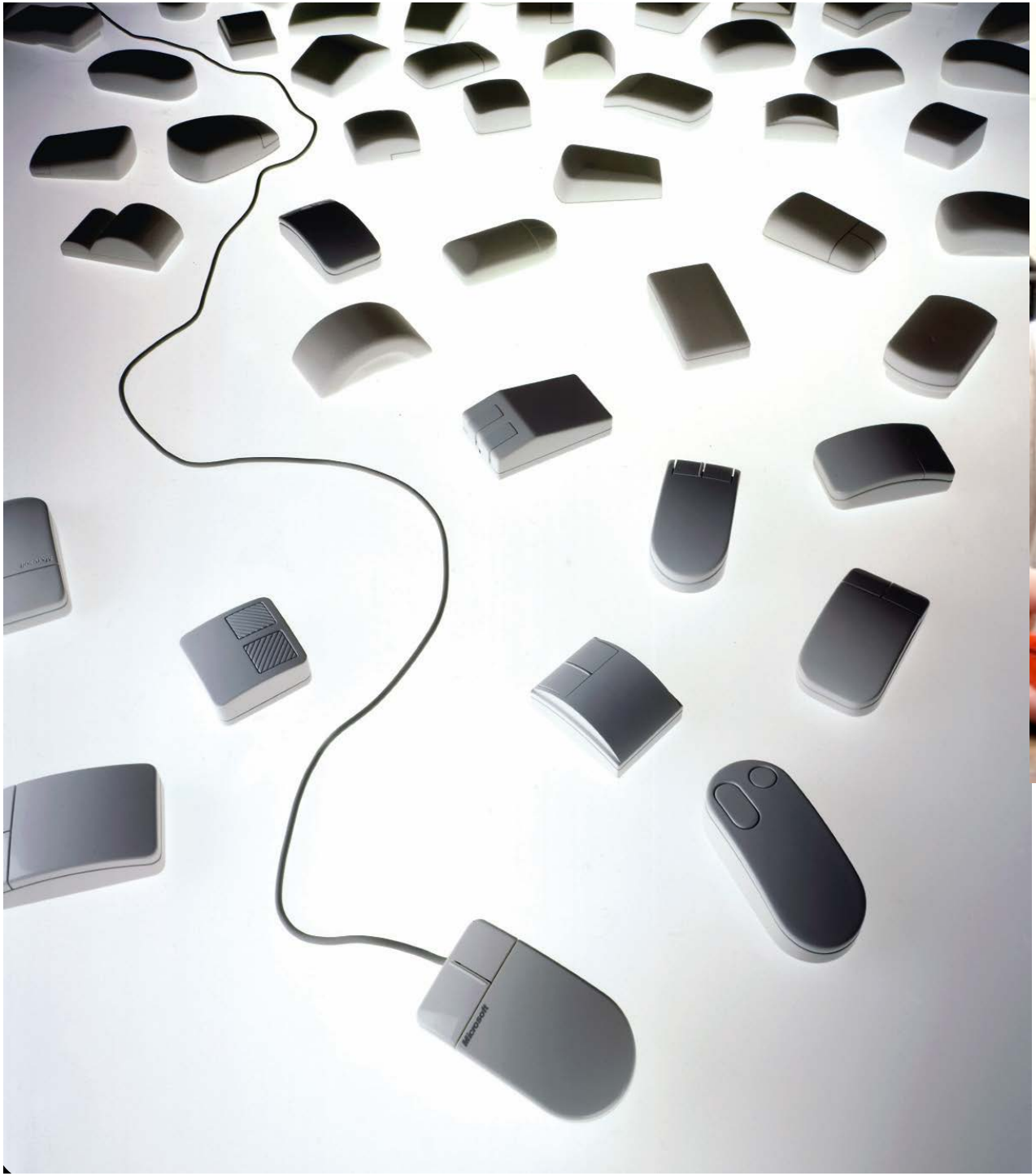

Apple Proto 0897
AllThingsD.com


iPod
Apple Proto 1015

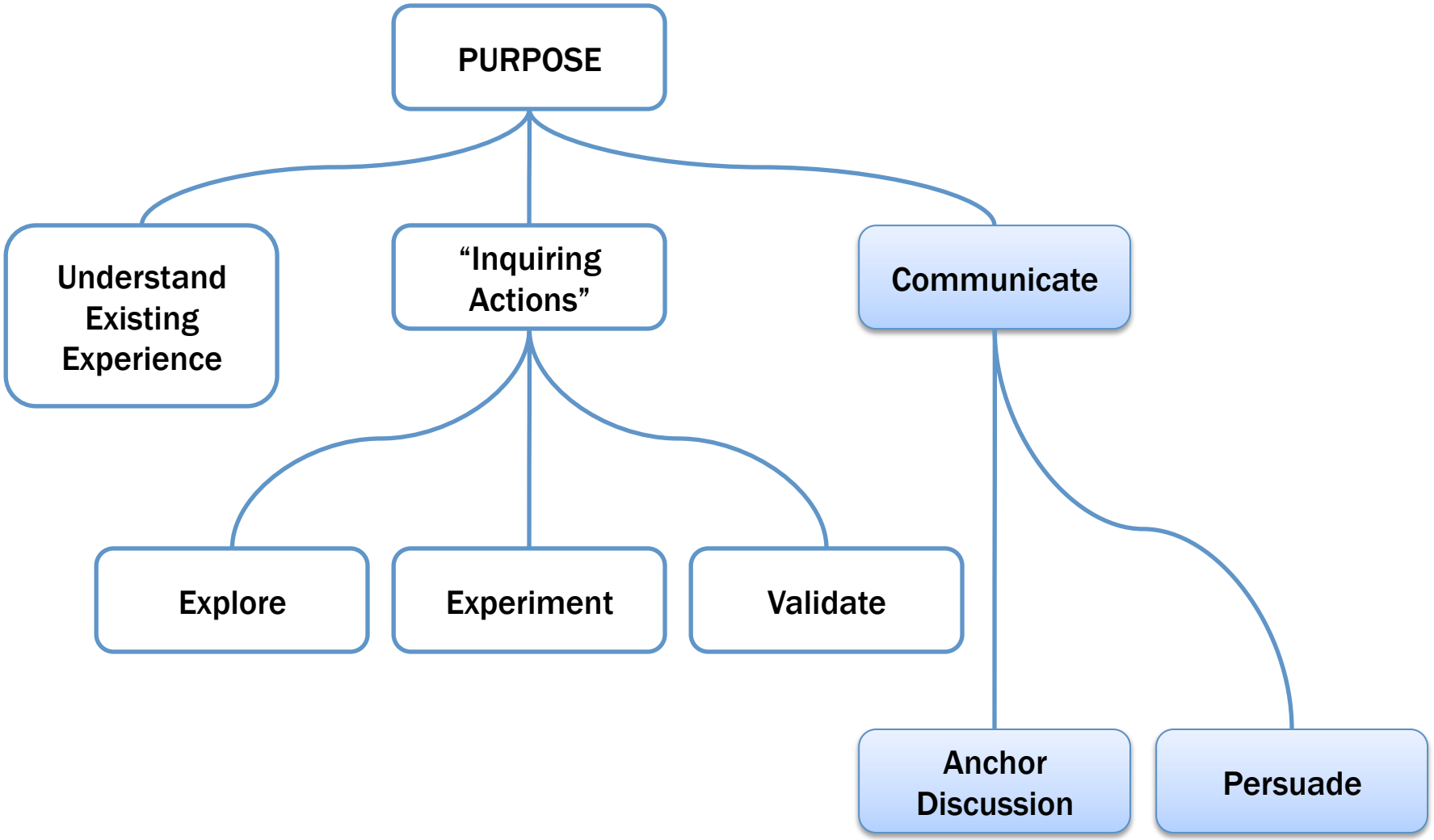

Apple Proto 0956


tm62-w1-111705


31
Apple Proto 0515



Prototypes for the
Microsoft mouse
From Moggridge,
Designing Interactions, Ch2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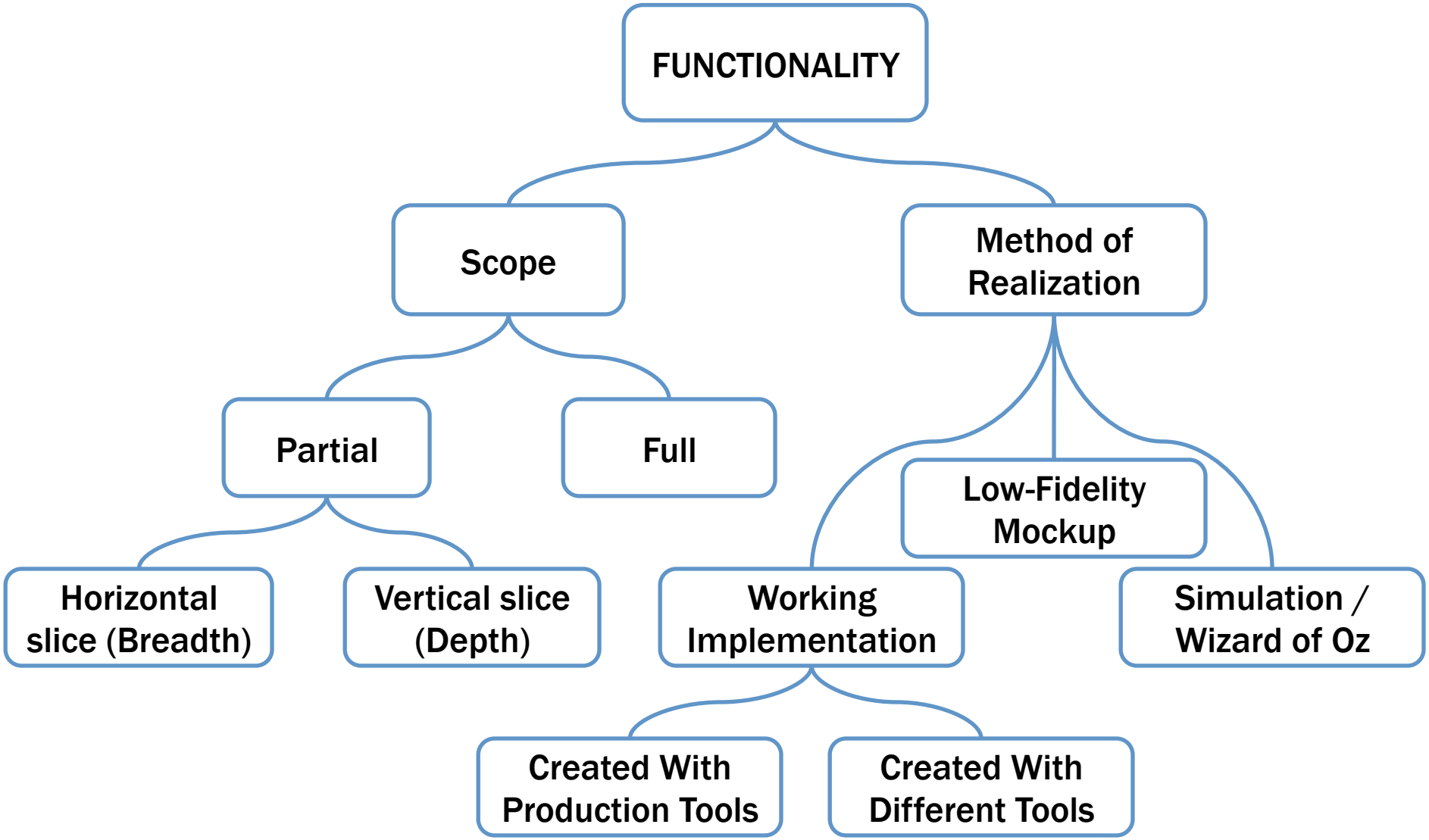
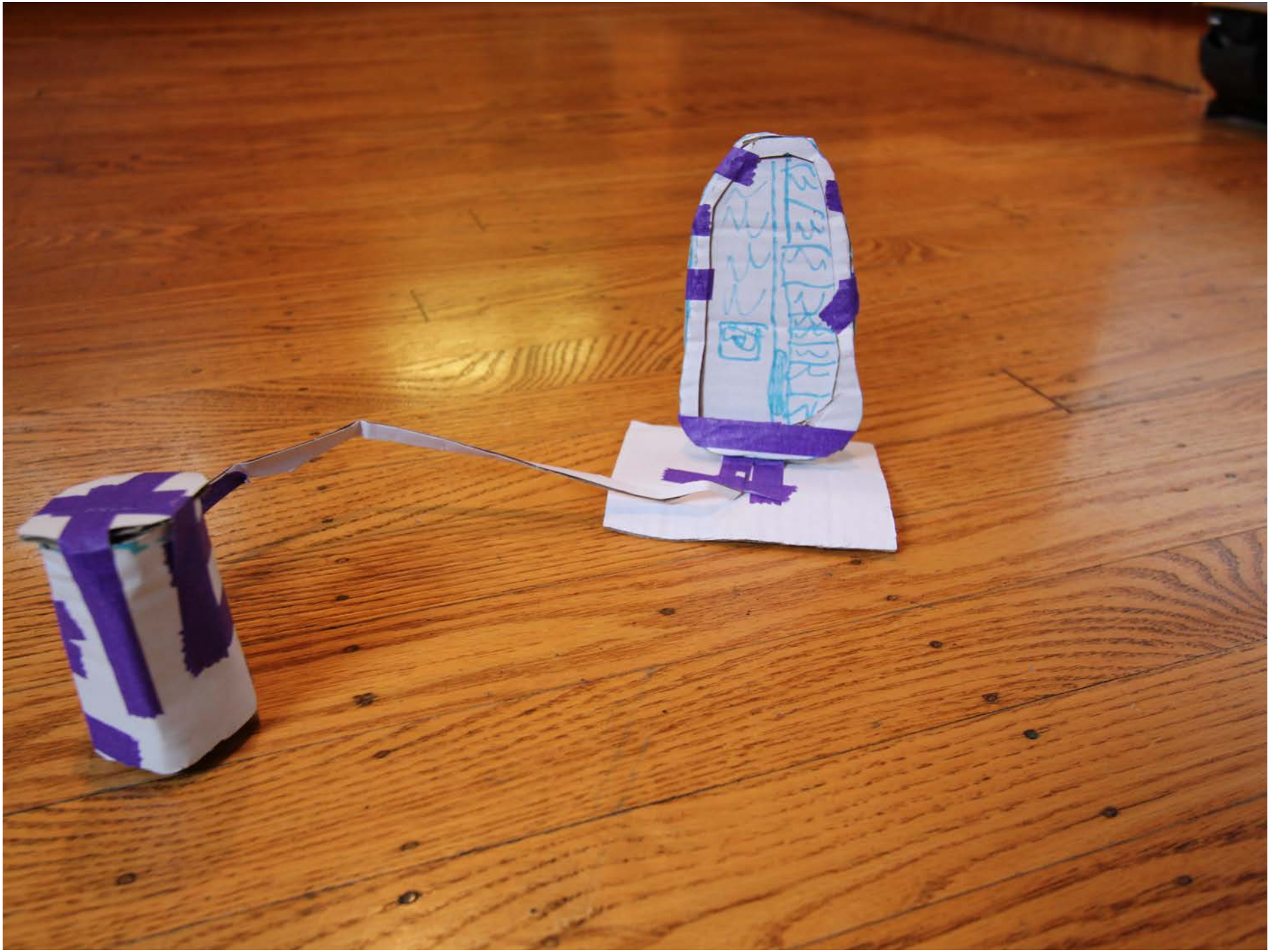
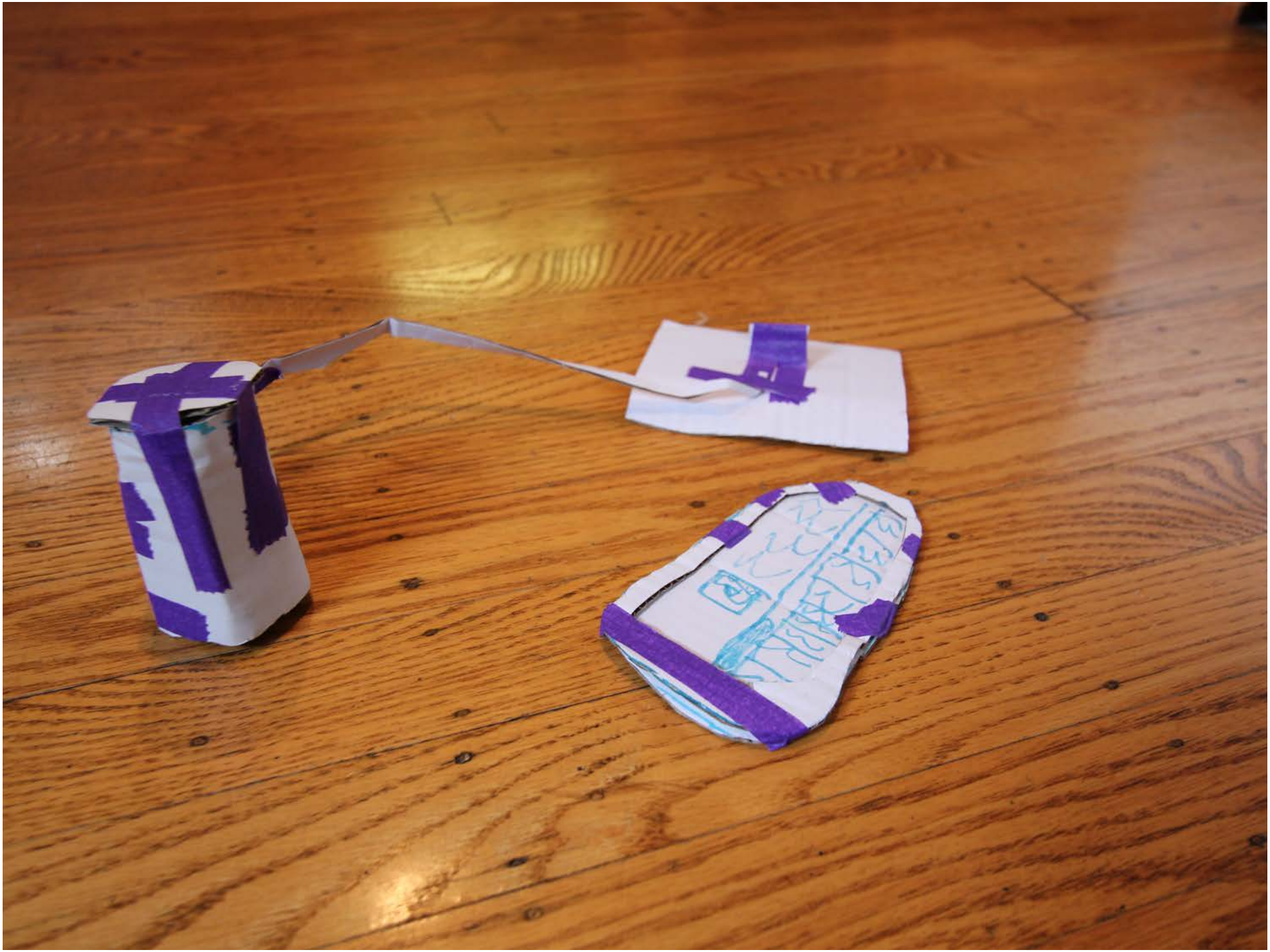
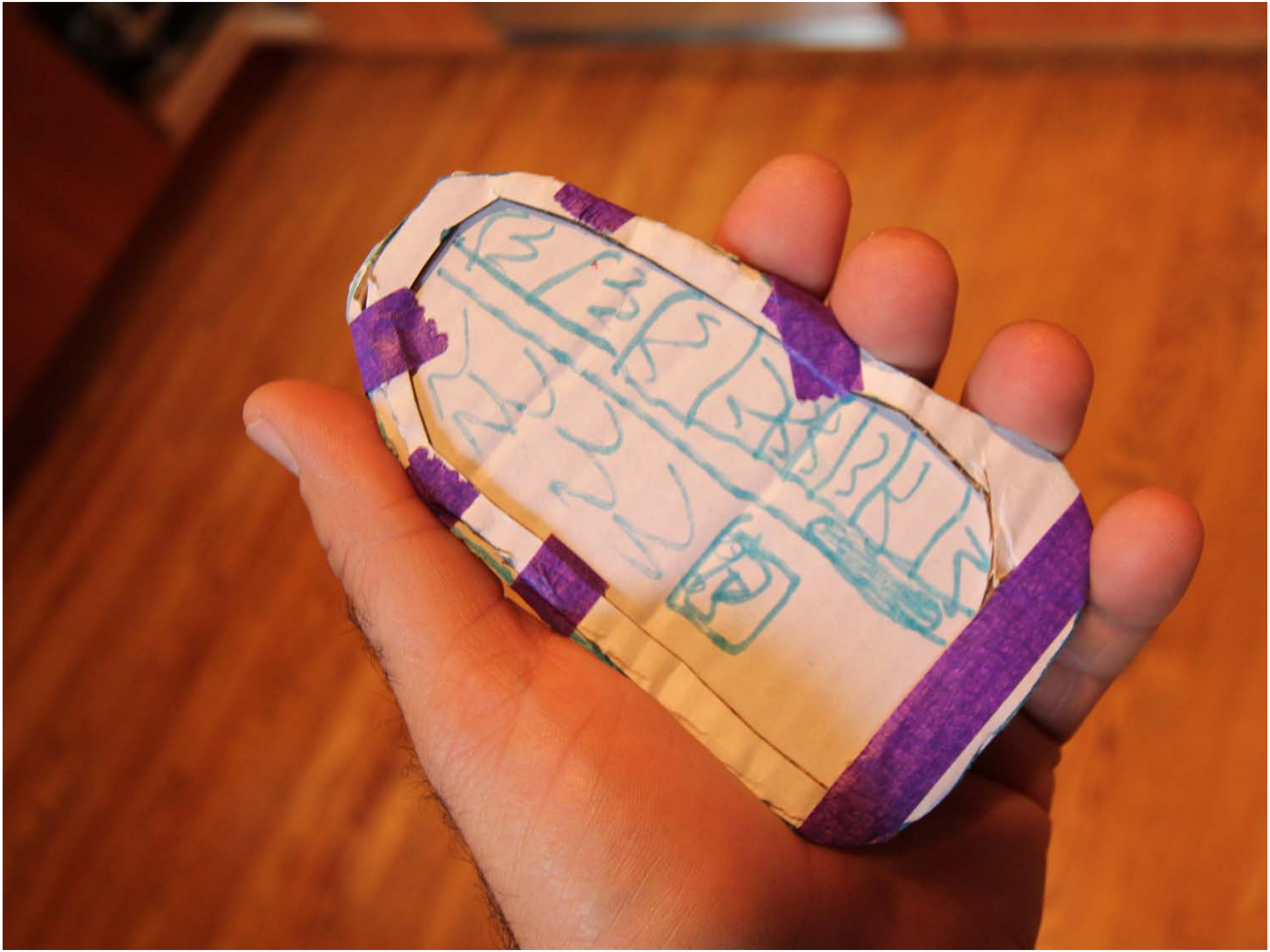

FUNCTIONALITY
Scope
Method of Realization
Partial
Full
Low-Fidelity Mockup
Horizontal slice (Breadth)
Vertical slice (Depth)
Working Implementation
Simulation / Wizard of Oz
Created With Production Tools
Created With Different Tools

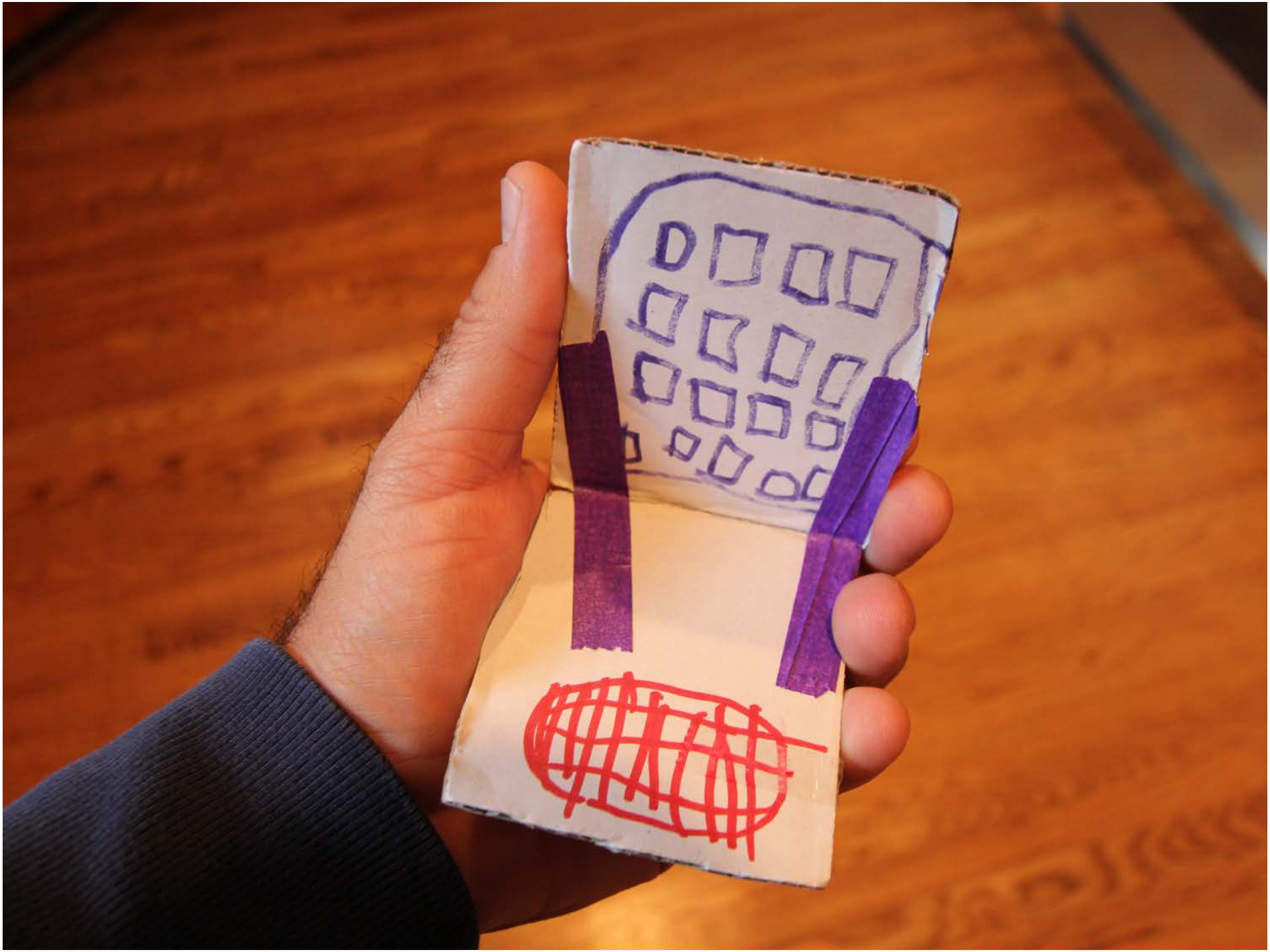
PAPER PROTOTYPING

Towards Wizard of Oz Studies









MATERIALS

Large, heavy, white paper (11 x 17)

5x8 in. index cards

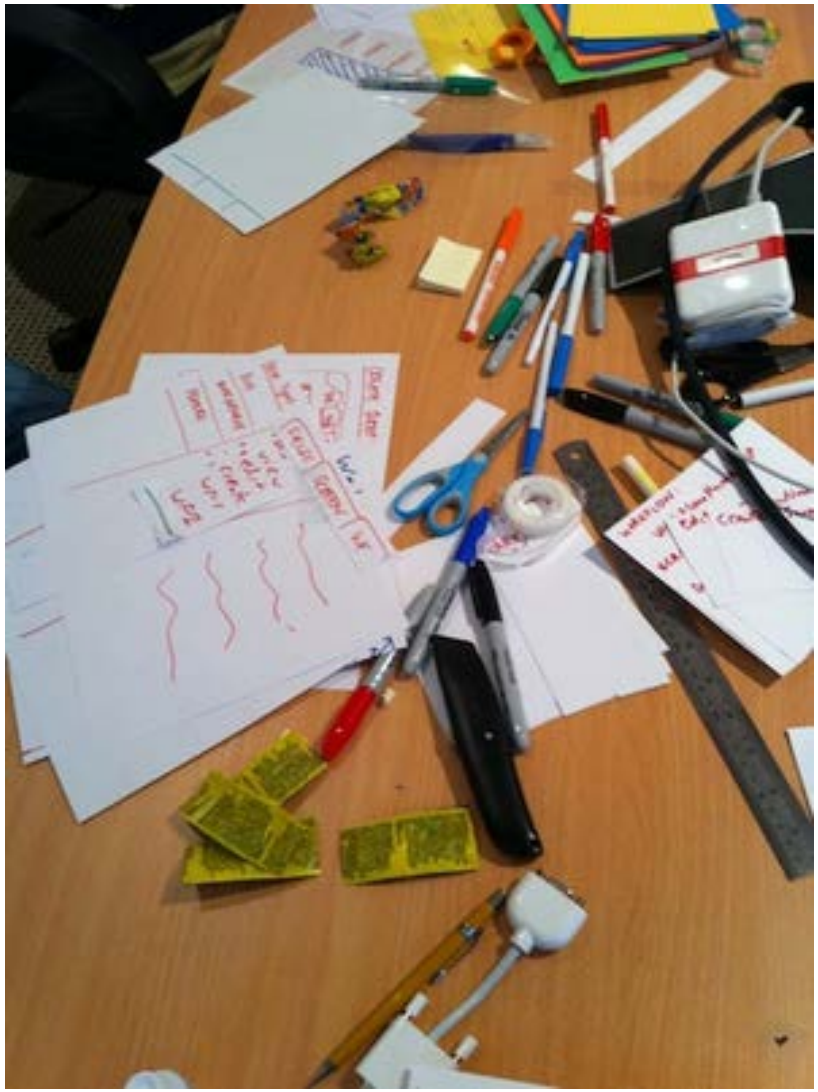
Post-it notes

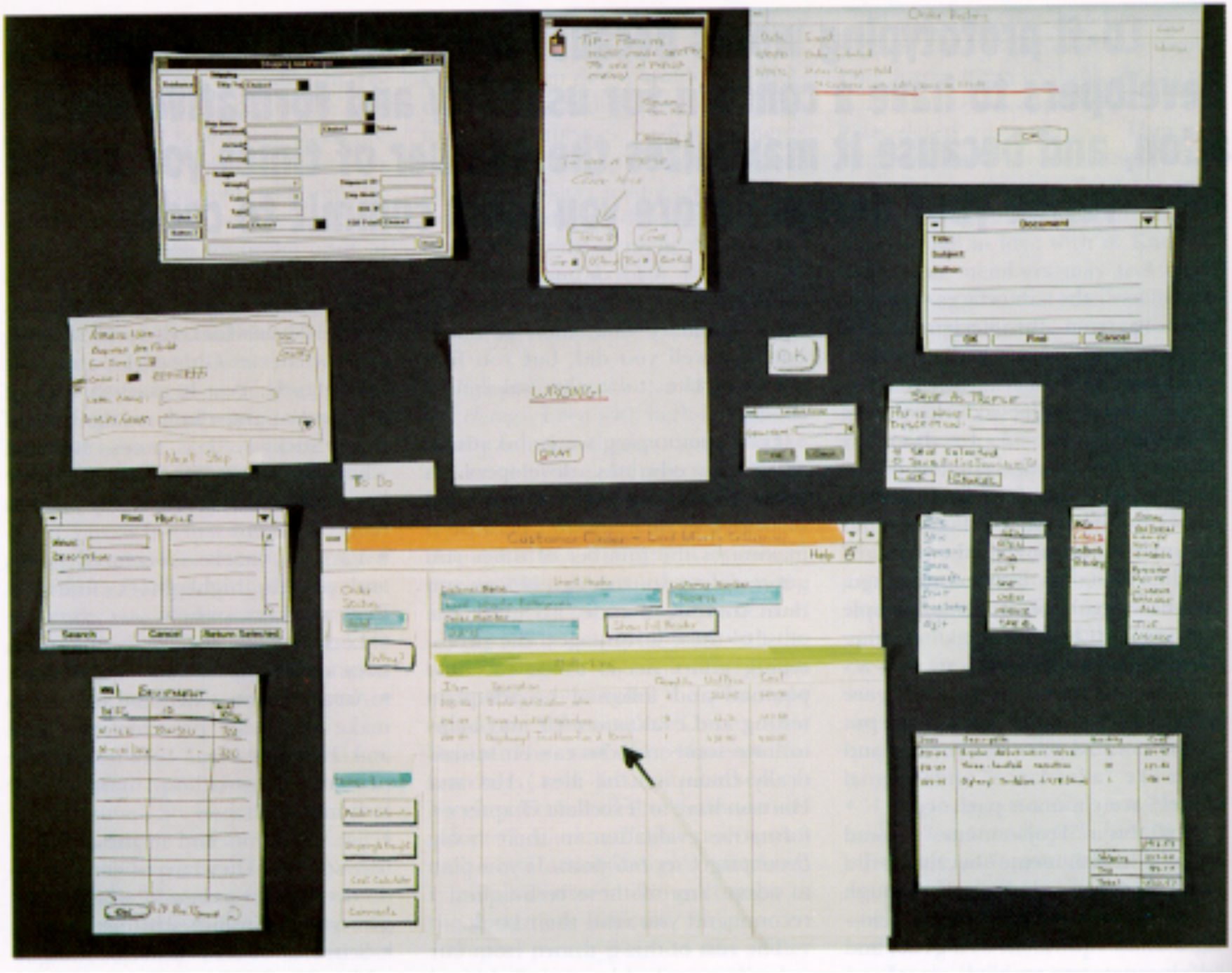
Tape, stick glue, correction tape

Pens & markers (colors & sizes)

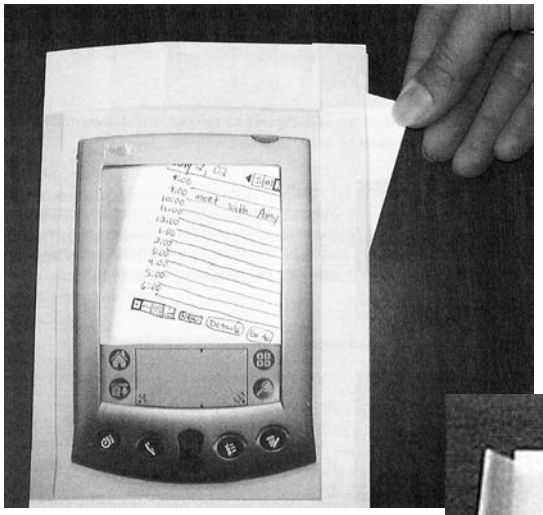
Transparencies (including colored)

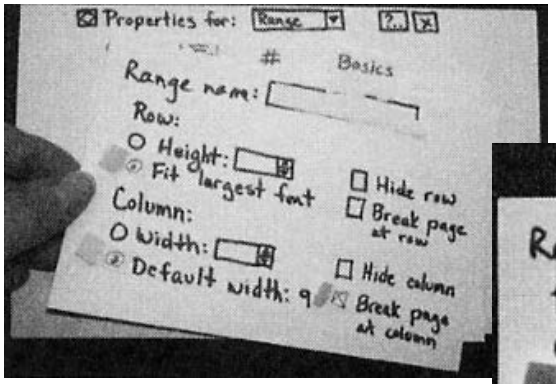
Scissors, X-acto knives, etc.

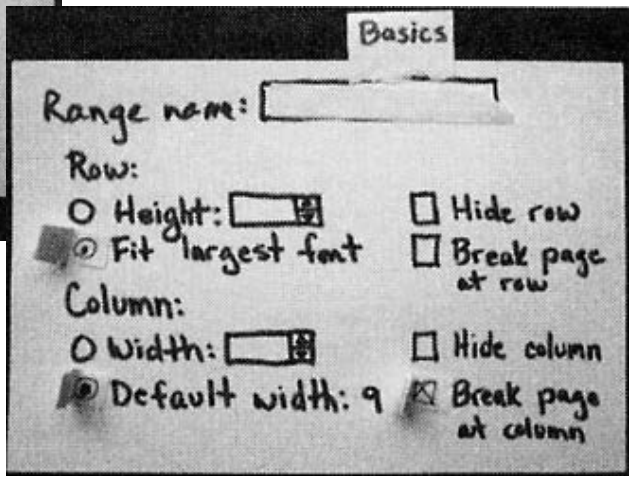


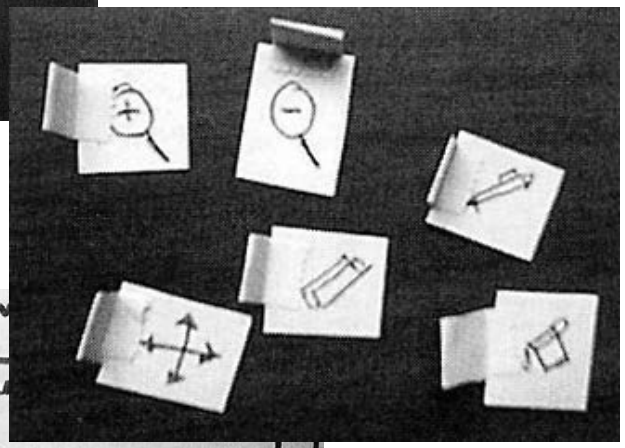

Document
Title:
Subject:
Author:
OK
Find
Cancel
WRONG!
OK
To Do
Next Step
Search
Cancel
Return Selected
Help

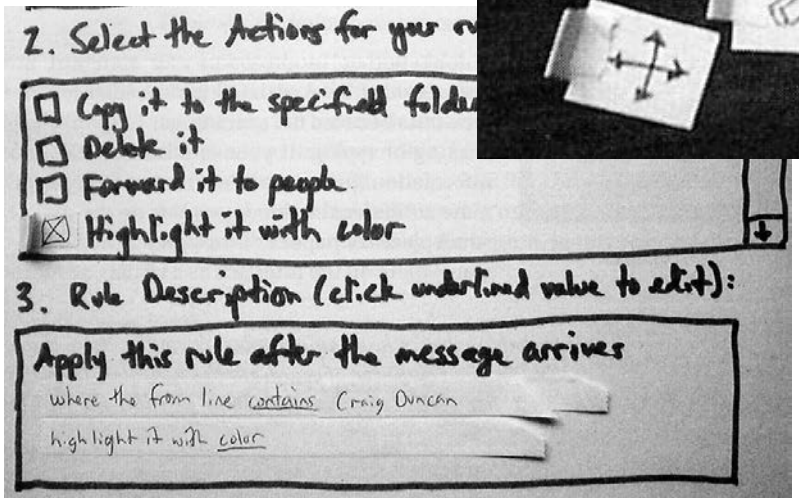
INTERFACE ELEMENTS

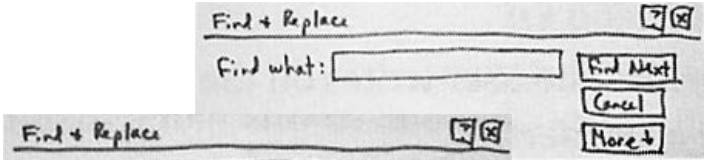


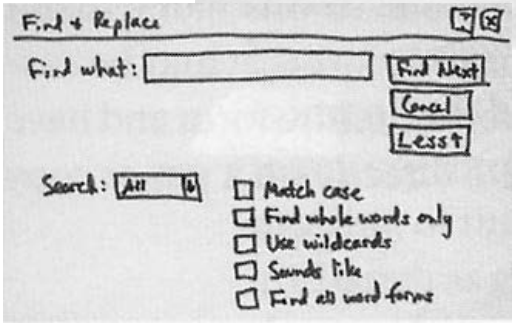




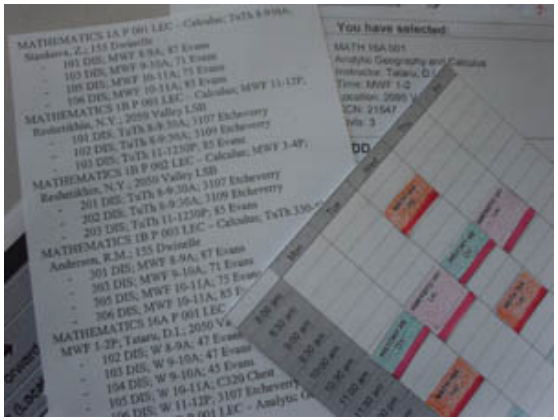








WIZARD OF OZ TESTING



A Wizard of Oz experiment is a research experiment in which subjects interact with a computer system that subjects believe to be autonomous, but which is actually being operated or partially operated by an unseen or seen human being.

CONSTRUCTING THE PROTOTYPE

Set a deadline

Don't think too long - build it!

Draw a window frame on large paper

Draw at a large size, but use correct aspect ratio

Put different screen regions on cards

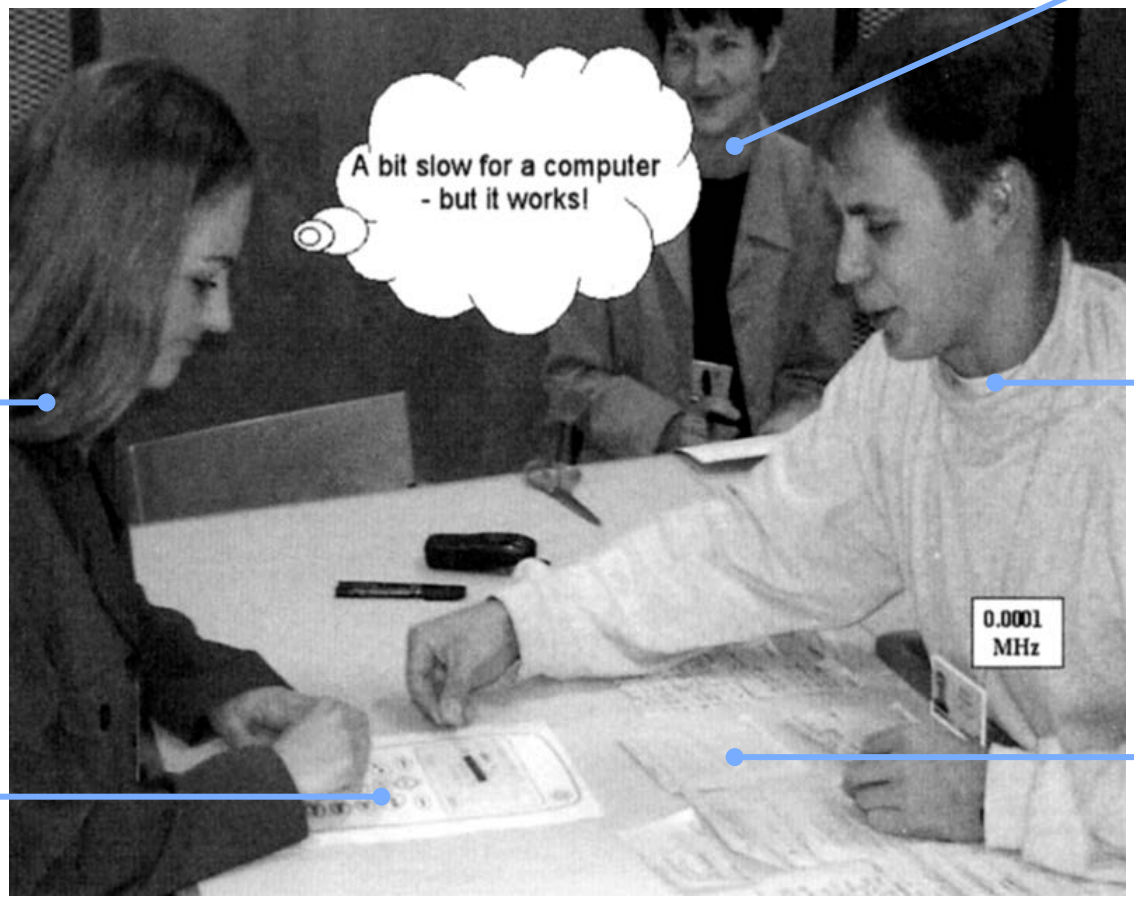
Anything that moves, changes, appears/disappears

Use greeking to indicate text if necessary

Ready response for any user action

e.g., Have those pull-down menus already made

Use photocopier to make many versions



Observer
(or video camera)

User

"Computer"

Interface

Interface elements

CONDUCTING A TEST

Three or Four testers (preferable)

Greeter - Puts users at ease & gets data

Facilitator - only team member who speaks

Gives instructions & encourages thoughts, opinions

Computer - knows application logic & controls it

Always simulates the response, w/o explanation

Observer(s) - Take notes & recommendations

Typical session should be approximately 1 hour

Preparation, the test, debriefing

CONDUCTING A TEST (CONT.)

Greet

Get forms filled, assure confidentiality, etc.

Test

Facilitator explains how test will work

Performs a simple task

Facilitator hands written tasks to the user

Must be clear & detailed

Facilitator keeps getting "output" from participant

"What are you thinking right now?", "Think aloud"

Observers record what happens

Avoid strong reactions:, frowning, laughing, impatience – biases the test

Designers should not lead participants

Let users figure things out themselves as much as possible

Only answer questions if user remains stuck for a long time

CONDUCTING A TEST (CONT.)

Debrief

Fill out post-evaluation questionnaire

Ask questions about parts you saw problems on

Gather impressions

Thank participants

PREPARING FOR A TEST

Select your participants

Understand background of intended users
Use a questionnaire to get the people you need
Don't use friends or family

Prepare scenarios that are

Typical of the product during actual use
Make prototype support these (small, yet broad)

Practice running the computer to avoid "bugs"

You need every menu and dialog for the tasks
All widgets the user might press
Remember "help" and "cancel" buttons

WOZ is different from pre-built/canned functionality

WIZARD OF OZ TIPS

Rehearse your actions

Make a flowchart which is hidden from the user

Make list of legal words for a speech interface

Stay “in role”

You are a computer, and have no common sense, or ability to understand spoken English.

Facilitator can remind user of the rules/think-aloud approach if the user gets stuck

RECORD CRITICAL INCIDENTS

Critical incidents are any unusual/interesting events

Most of them are usability problems.

They may also be moments when the user

- Got stuck
- Suddenly understood something
- Said “that’s cool” etc.

USING THE RESULTS

Update task analysis and rethink design

Rate severity & ease of fixing problems

Fix both severe problems & make the easy fixes

Will thinking aloud give the right answers?

Not always

If you ask a question, people will always give an answer, even it is has nothing to do with the facts

Try to avoid leading questions