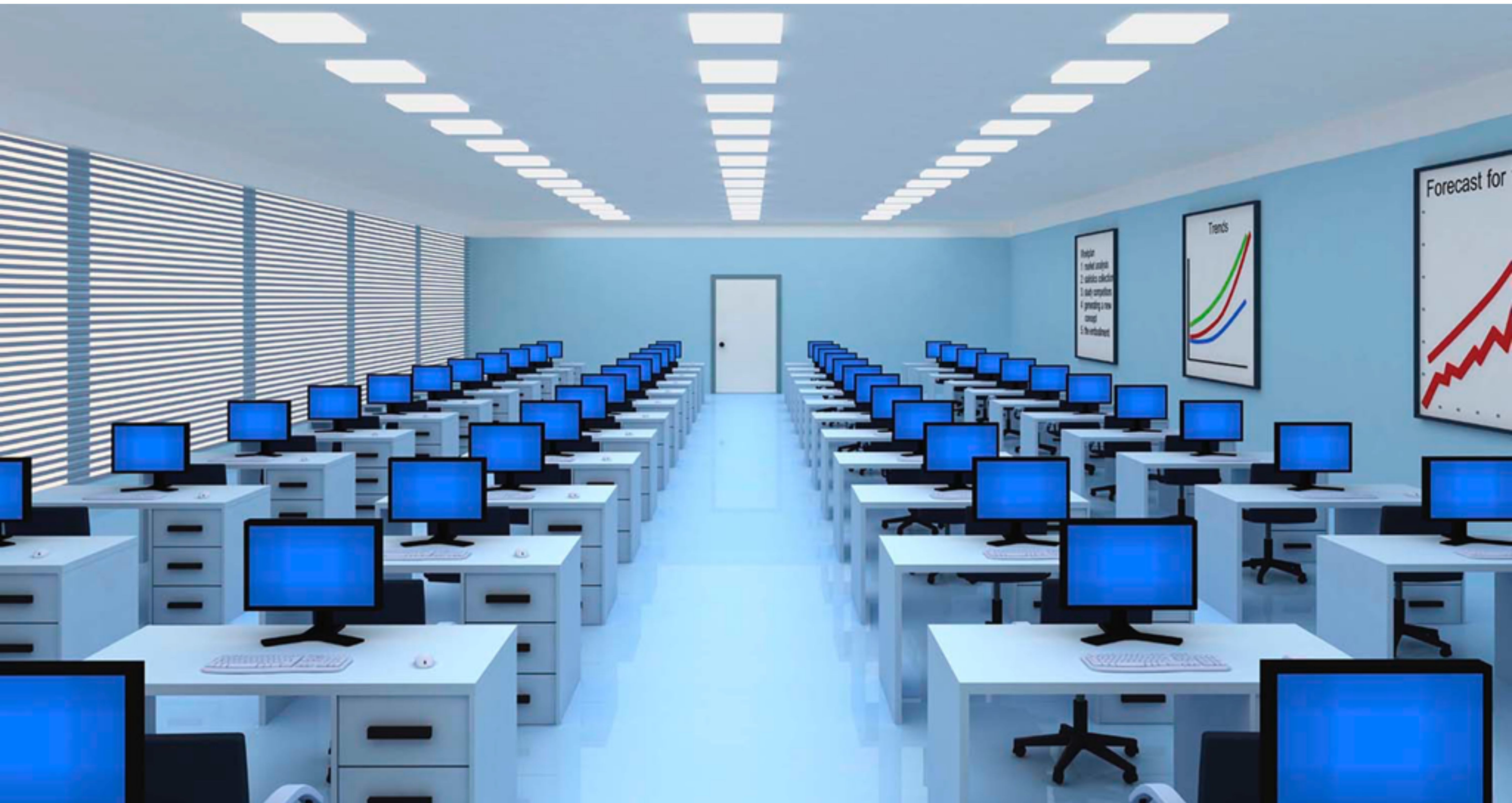
Graphical > Tangible?



Graphical > Tangible?

- Dynamicity, Flexibility
- Price

Graphical > Tangible?

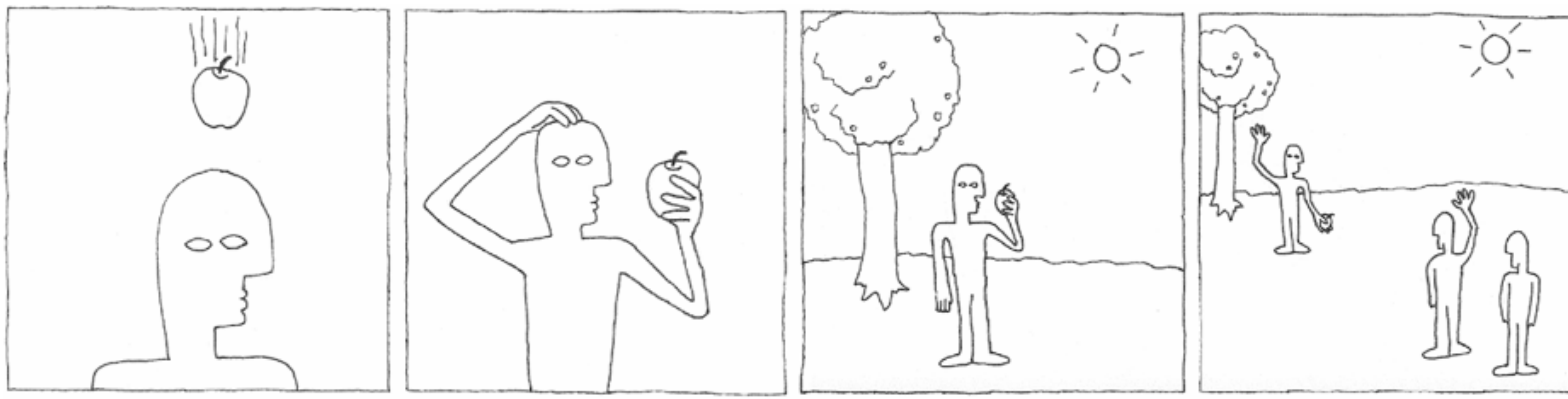
- Reality based interaction
  - Compromise with software when it brings benefit

http://dl.acm.org/citation.cfm?doid=1357054.1357089

Reality Based Interaction

- Interface design
  - build on 4 themes (= human capabilities) from the “real” world
  - compromise with 6 tradeoffs in order to reach design goal

Reality Based Interaction



Naïve Physics | Body Awareness & Skills | Environment Awareness & Skills | Social Awareness & Skills

Reality Based Interaction


Naïve Physics

E.g., gravity, friction, velocity

Example of interfaces using users' knowledge of naive physics?

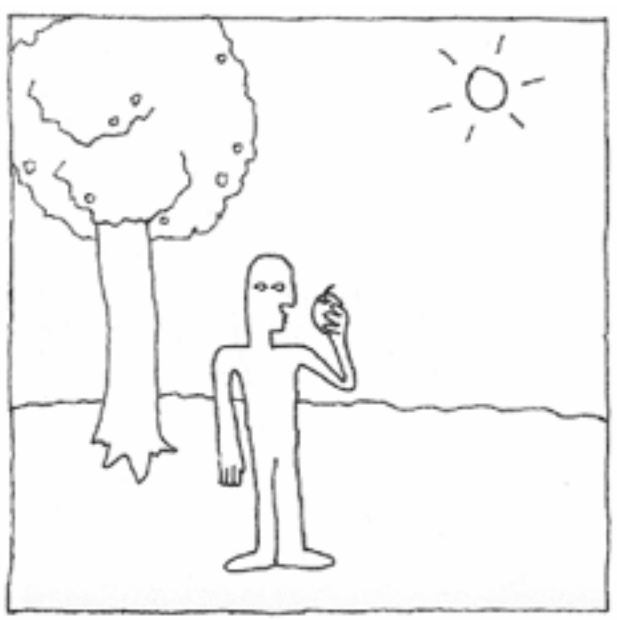
Reality Based Interaction

Body Awareness & Skills

E.g., relative position of body parts, range of motion, skills to coordinate movements (to walk, kick a ball)

Example of interfaces using users' body awareness and skills?

Reality Based Interaction


Environment Awareness & Skills

E.g., horizon gives a sense of directional information, lighting and shadow provide depth cues

Example of interfaces using users' environment awareness and skills?

Reality Based Interaction

Social Awareness & Skills

E.g., verbal and non-verbal communication, exchange objects, ability for collaboration

Example of interfaces using users' social awareness and skills?

Reality Based Interaction: Six tradeoffs

Expressive power
ability to perform a variety of tasks within the application domain

Efficiency
ability to perform a task rapidly

Versatility
ability to perform many tasks from different application domains

Ergonomics
ability to perform a task without physical injury or fatigue

Accessibility
ability to perform a task when handicapped

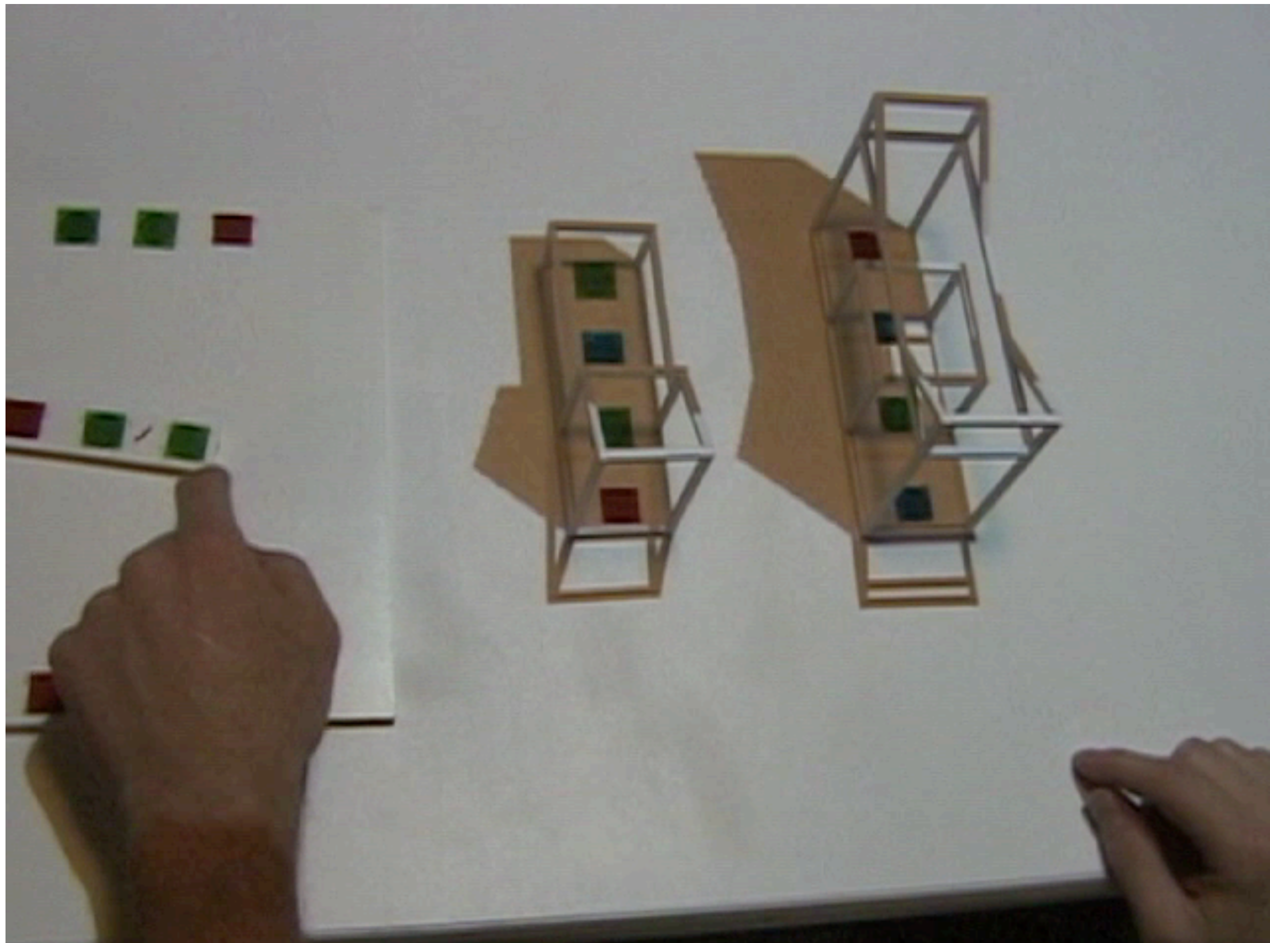
Practicality
(designers) ability to produce the system

Reality Based Interaction

Case study: URP

What themes does URP use?

- Naive Physics
- Body
- Environment
- Social Awareness



Reality Based Interaction

What does URP sacrifice for which benefit?

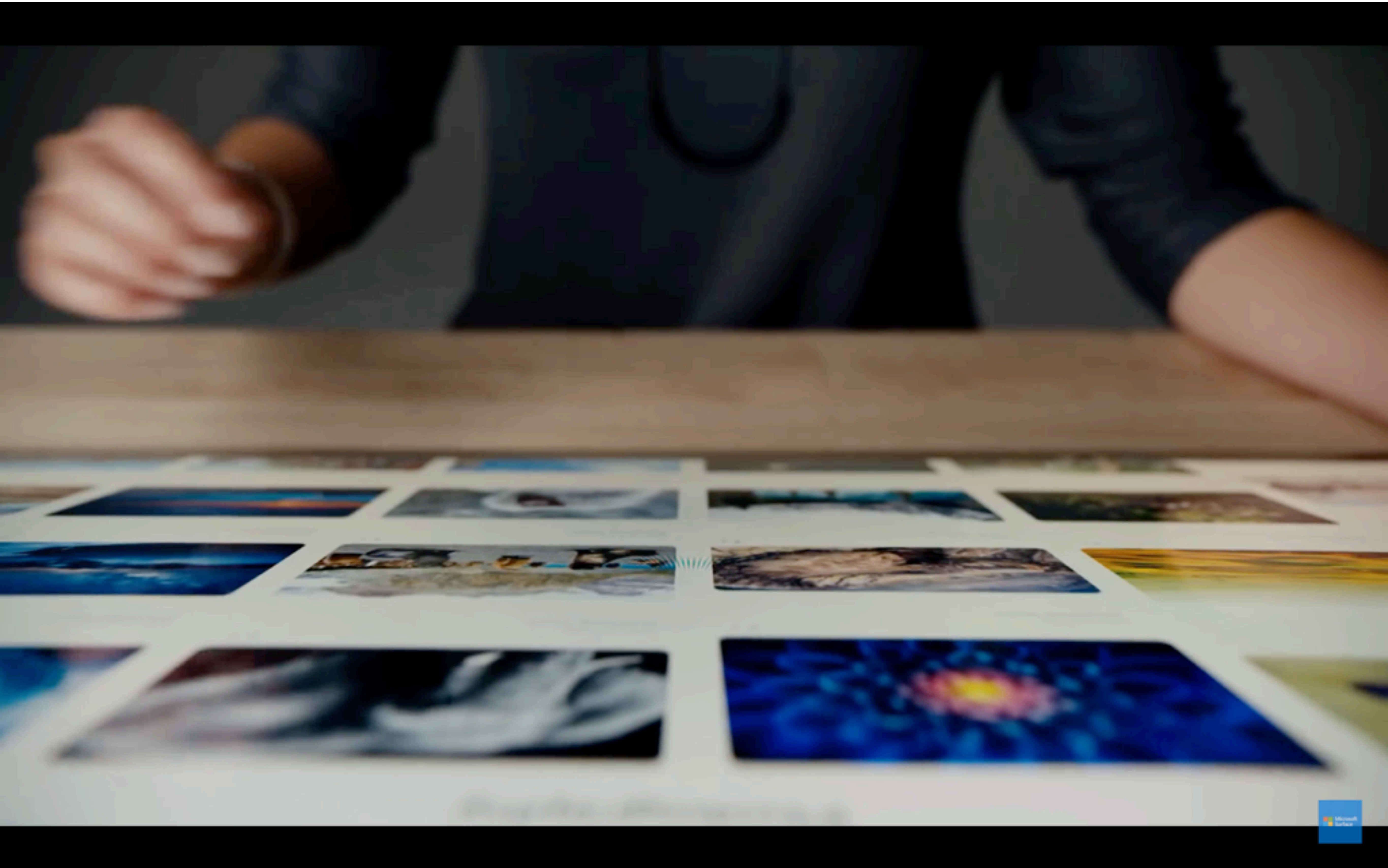
- Expressive power
- Efficiency
- Versatility
- Ergonomics
- Accessibility
- Practicality

Graphical > Tangible?

- Software mouse+touch GUI took over
- Tangible might be coming back
  E.g., induction hub
  with removable magnetic tangible knob



E.g., Microsoft Surface Studio (2016)



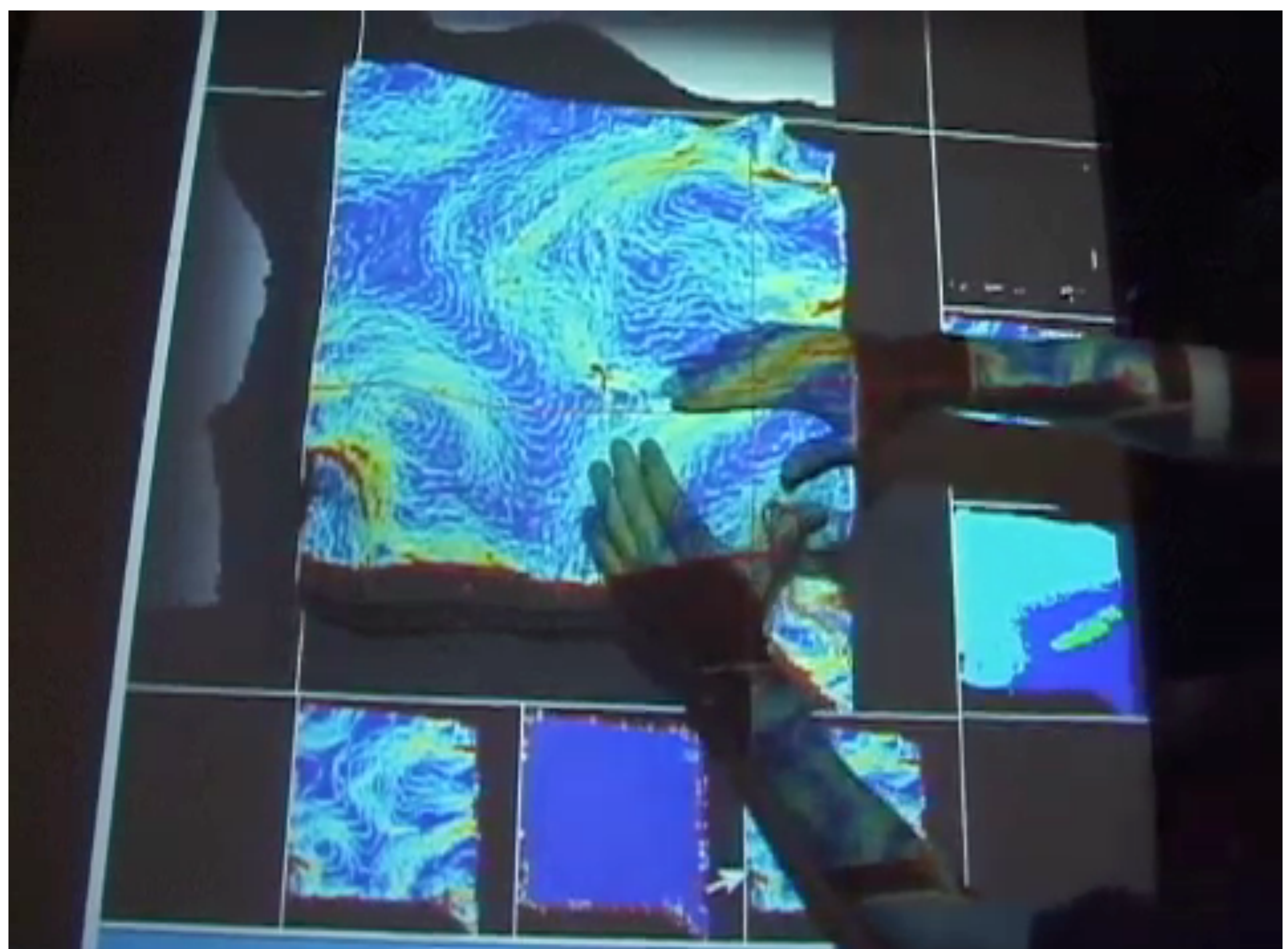
Graphical > Tangible?

- New and Open research areas
  that bring tangibles closer to software

How can we benefit again from Tangibility?

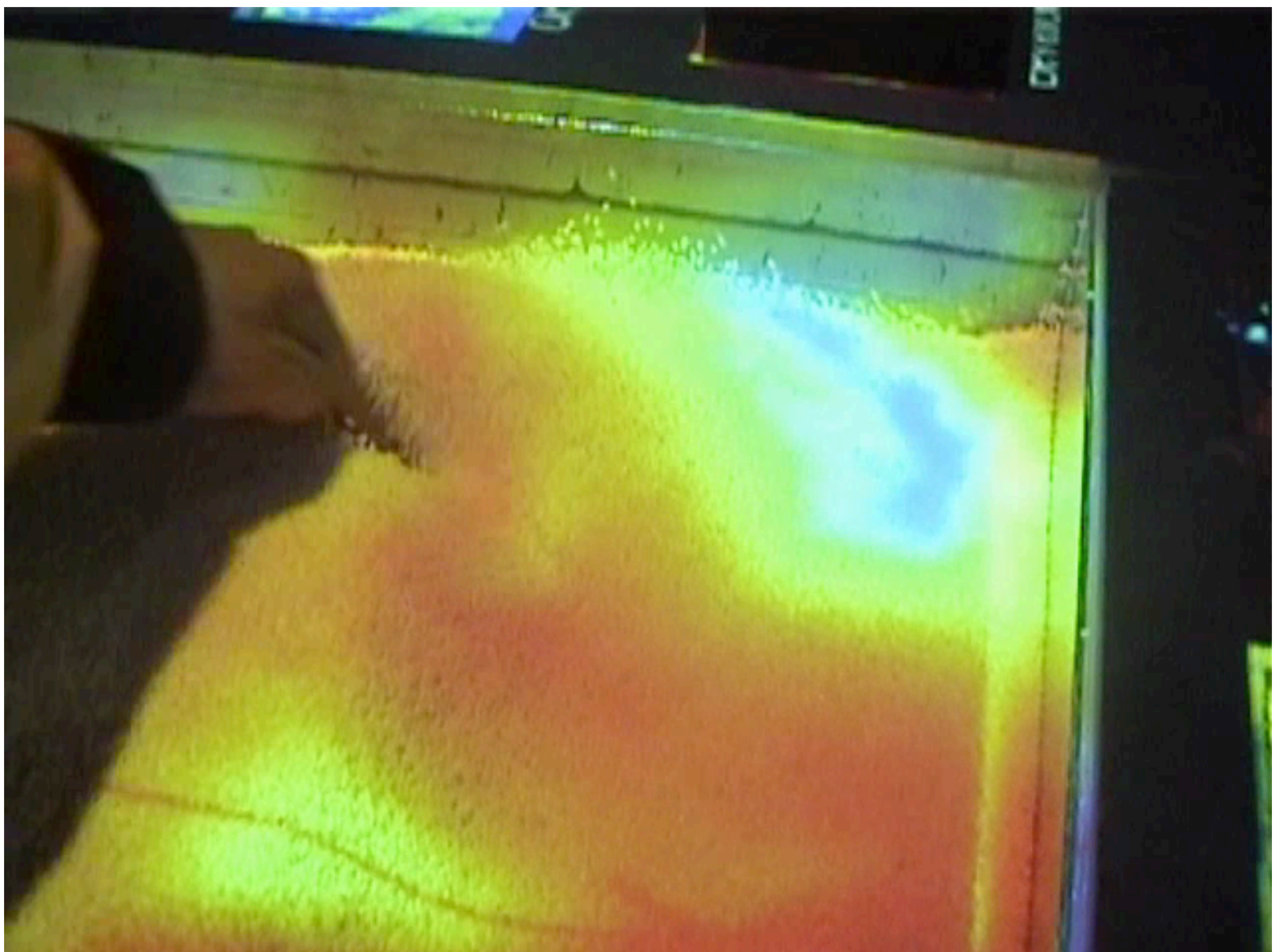
Dynamicity & Flexibility: Shape

Illuminating Clay



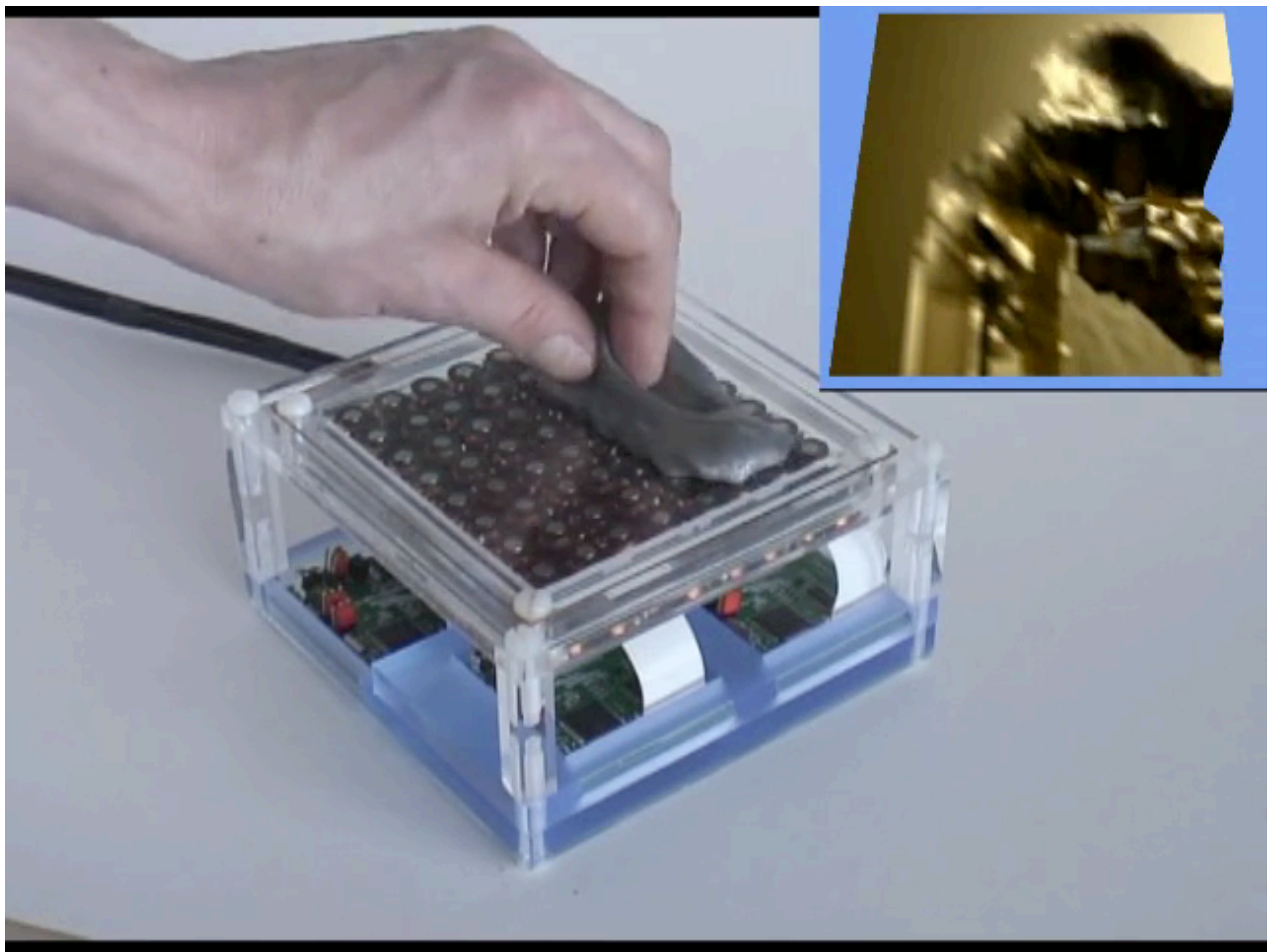
Dynamicity & Flexibility: Shape

SandScape



Dynamicity & Flexibility: Shape

A Reconfigurable Ferromagnetic Input Device



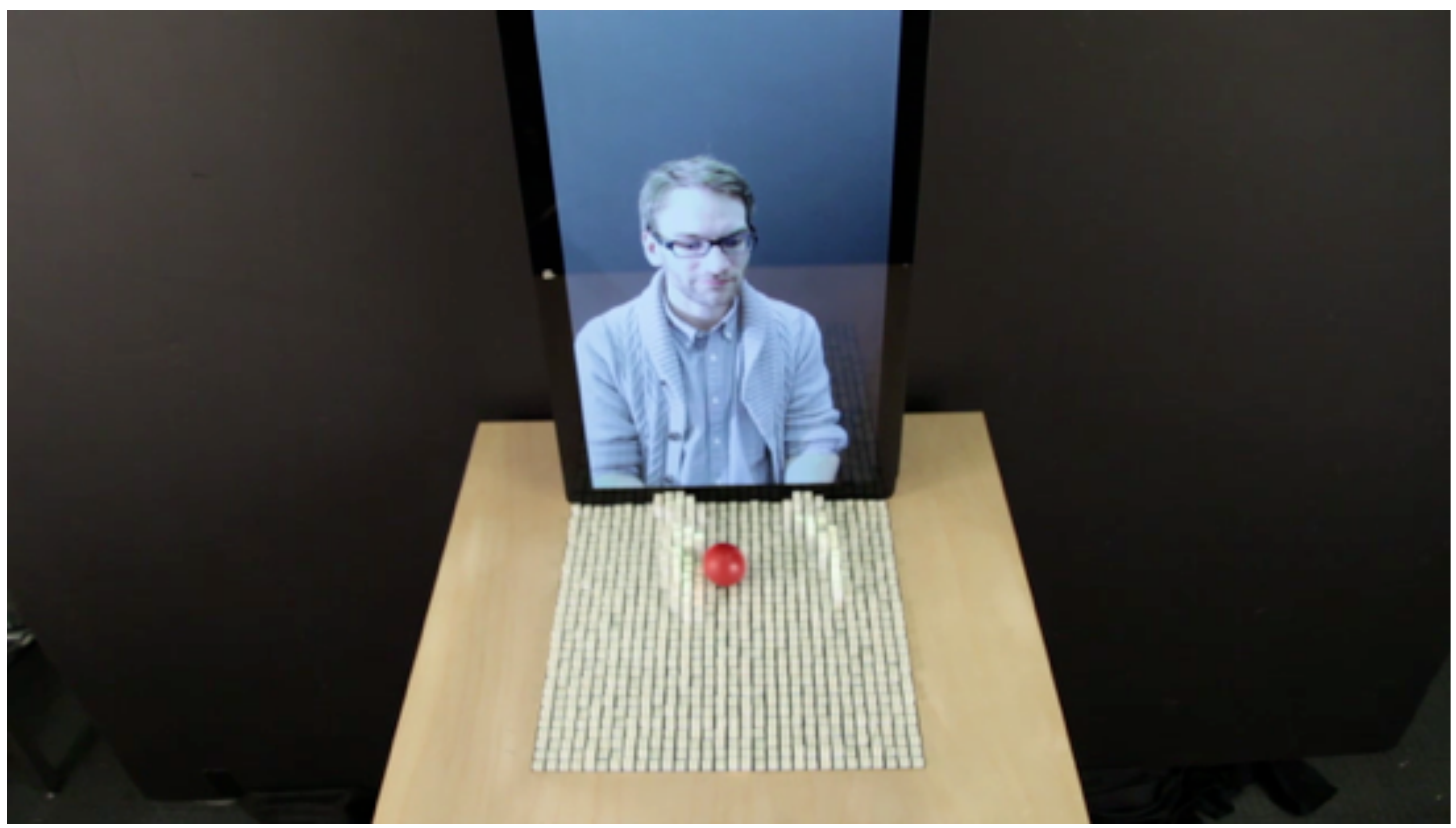
Dynamicity & Flexibility: Shape

Dynamically changeable buttons:
http://www.youtube.com/watch?v=Smai_Z_galE

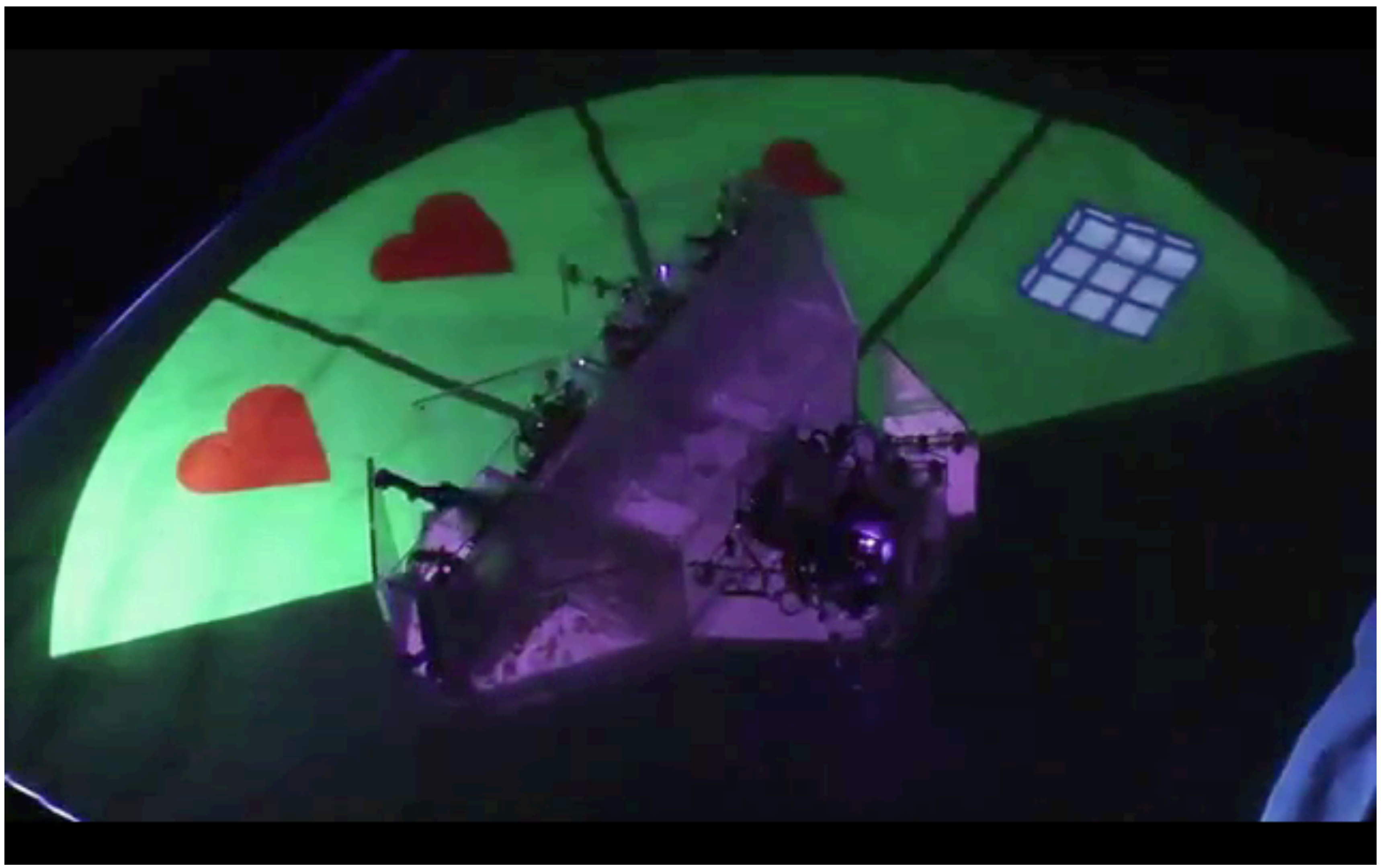
Dynamicity & Flexibility: Shape

Shutters with shape memory alloy

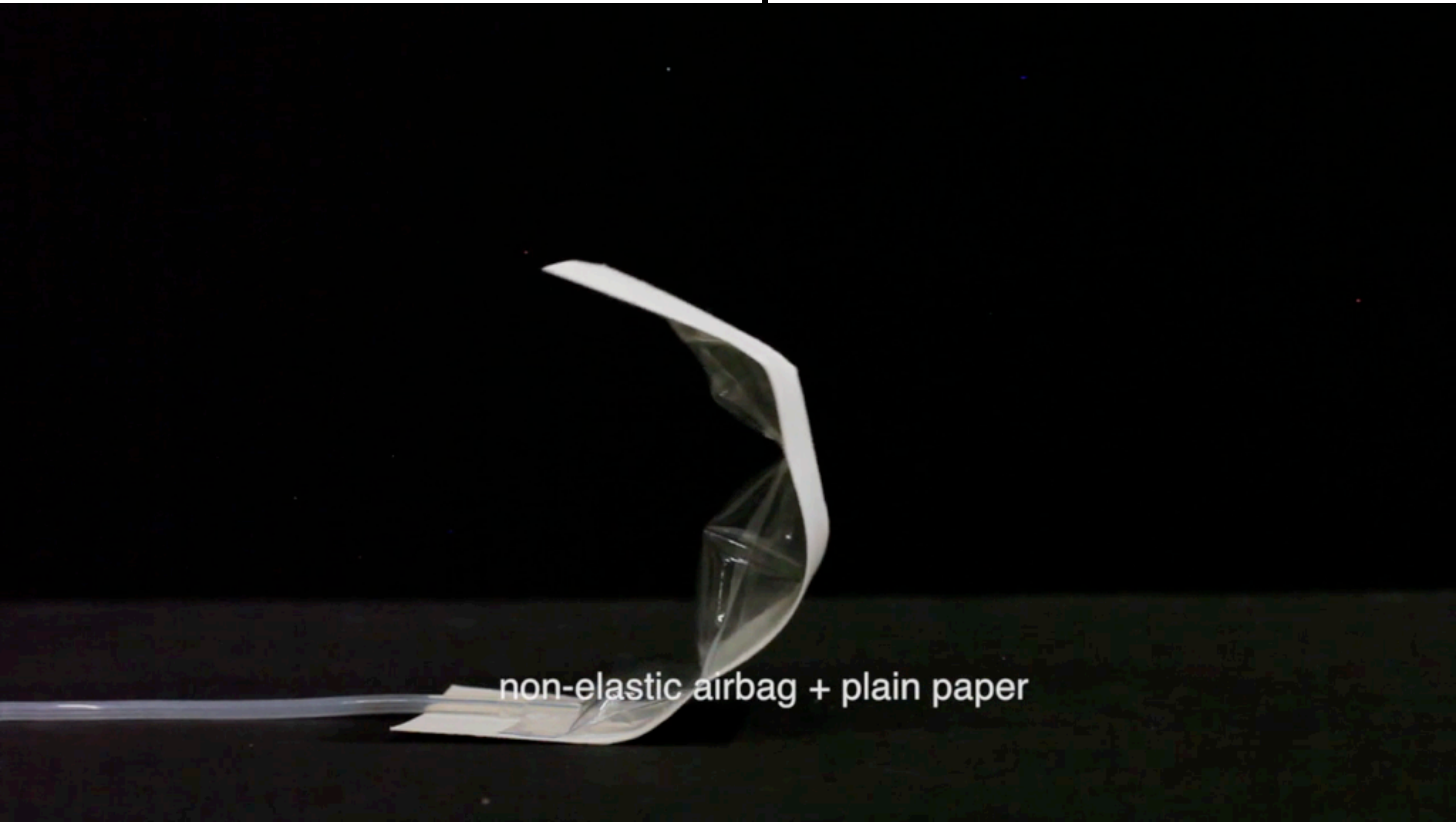
Dynamicity & Flexibility: Shape



Dynamicity & Flexibility: Shape



Dynamicity & Flexibility: Shape



Dynamicity & Flexibility: Shape

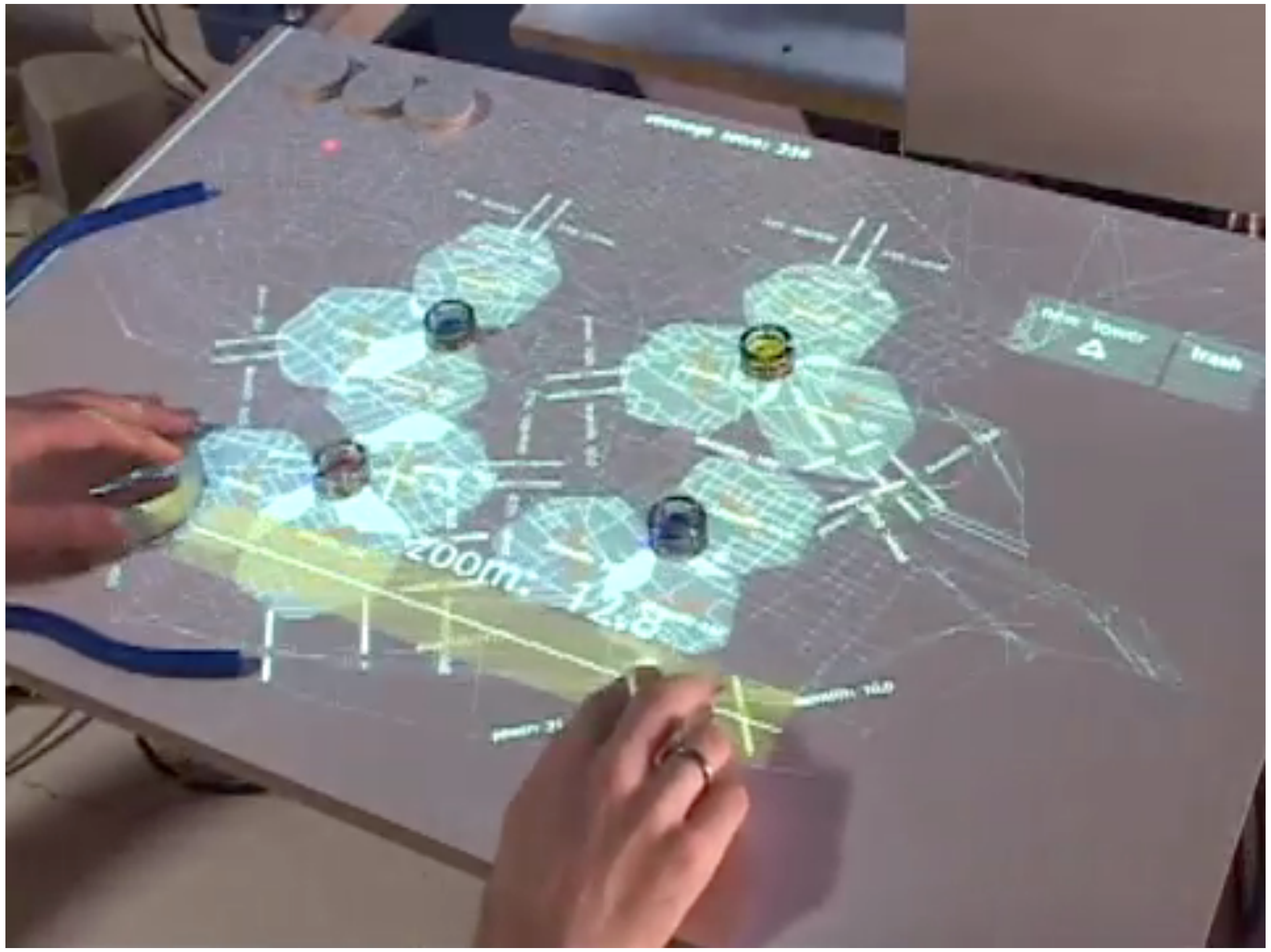
Dynamicity & Flexibility: Shape

Dynamicity & Flexibility: Shape with nanoscopic cells

Dynamicity & Flexibility: 2D location

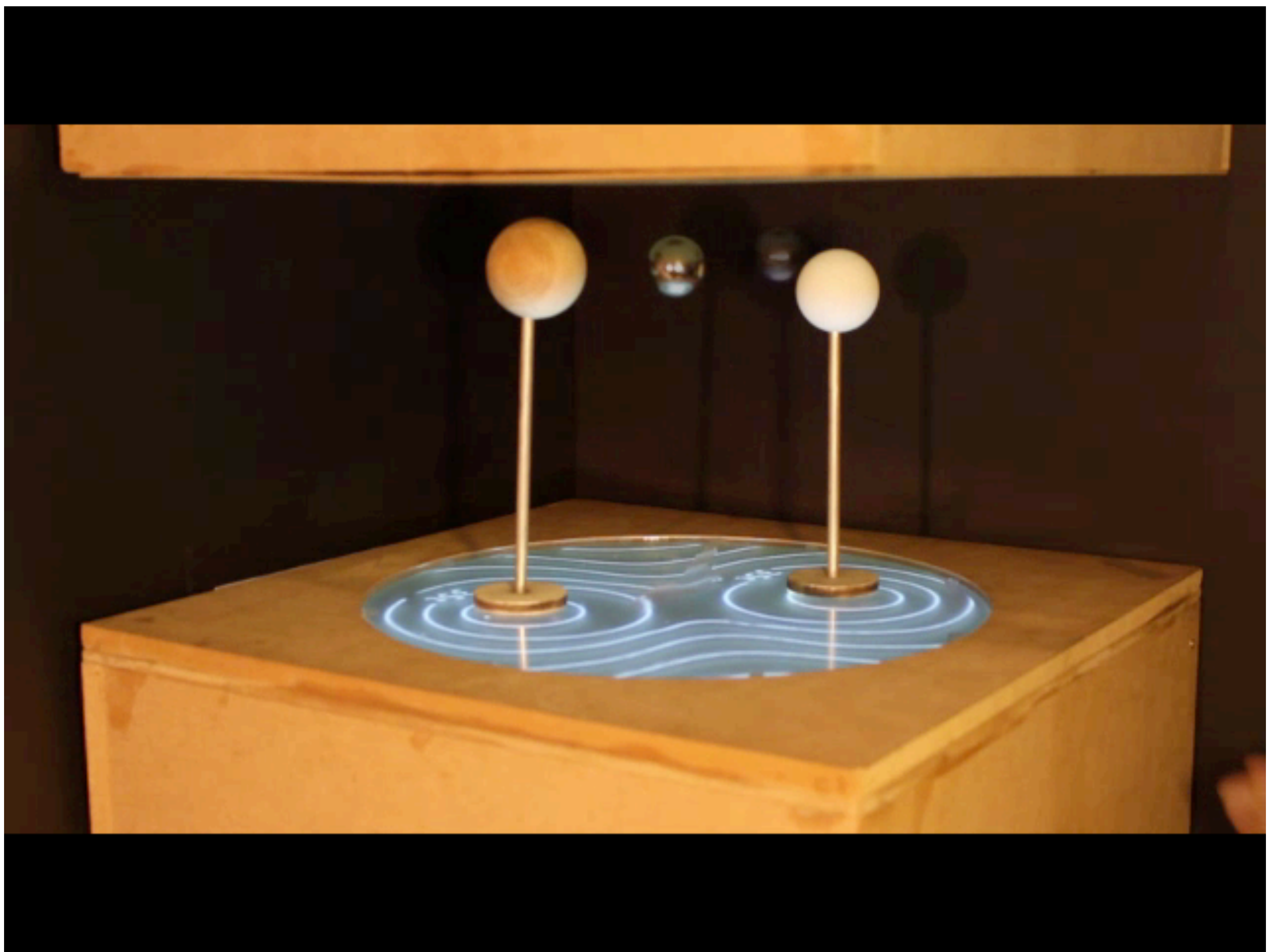
Actuated workBench

PICO



Dynamicity & Flexibility: 3D location

(magnetic)

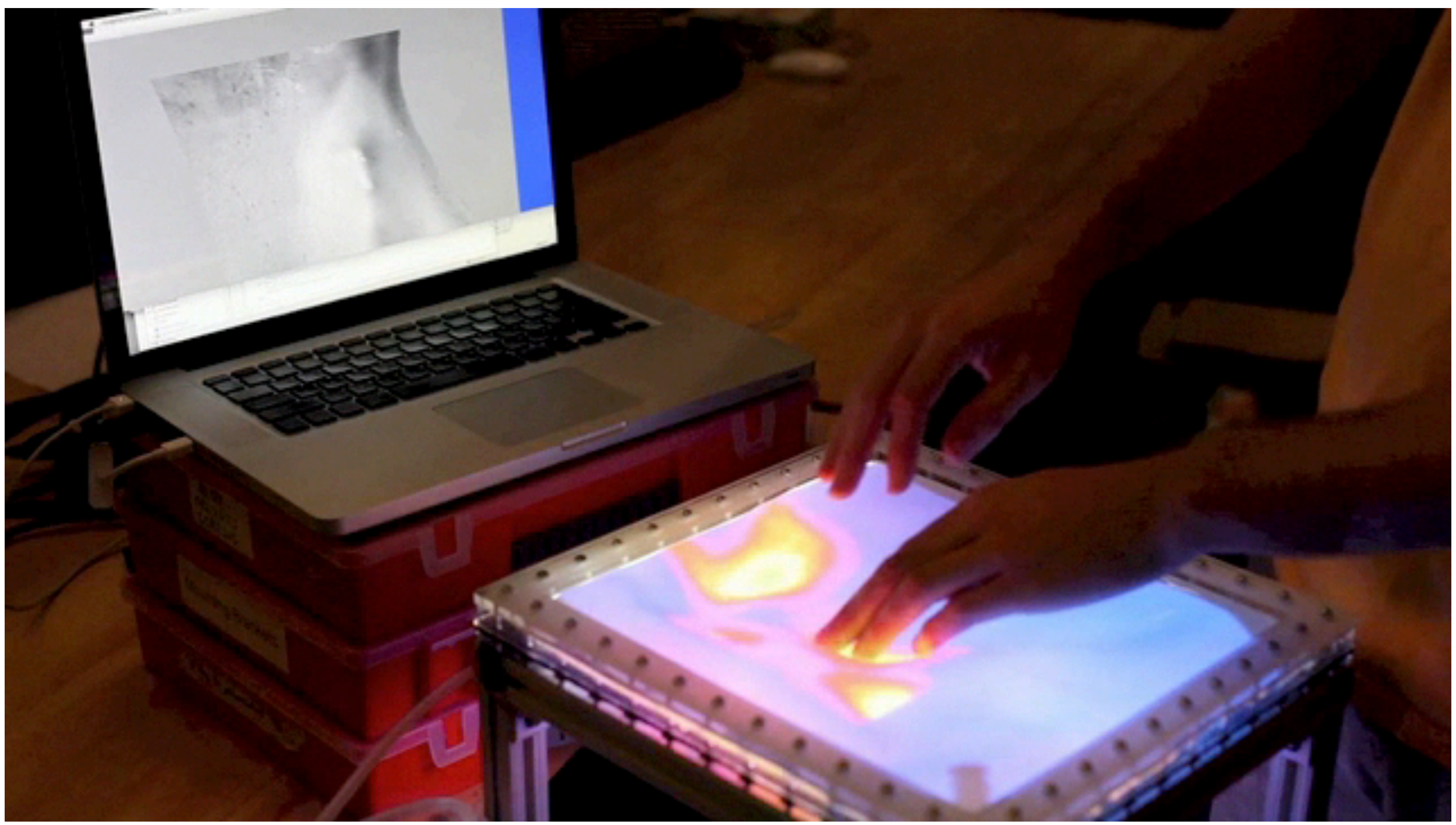


Dynamicity & Flexibility: 3D location

(ultrasonic)

https://www.youtube.com/watch?v=g_EM1y4MKSc

Dynamicity & Flexibility: Stiffness



Dynamicity & Flexibility: Stiffness

3D Printing Pneumatic Device Controls
with Variable Activation Force Capabilities

https://youtu.be/-4gFYvhkz0Y

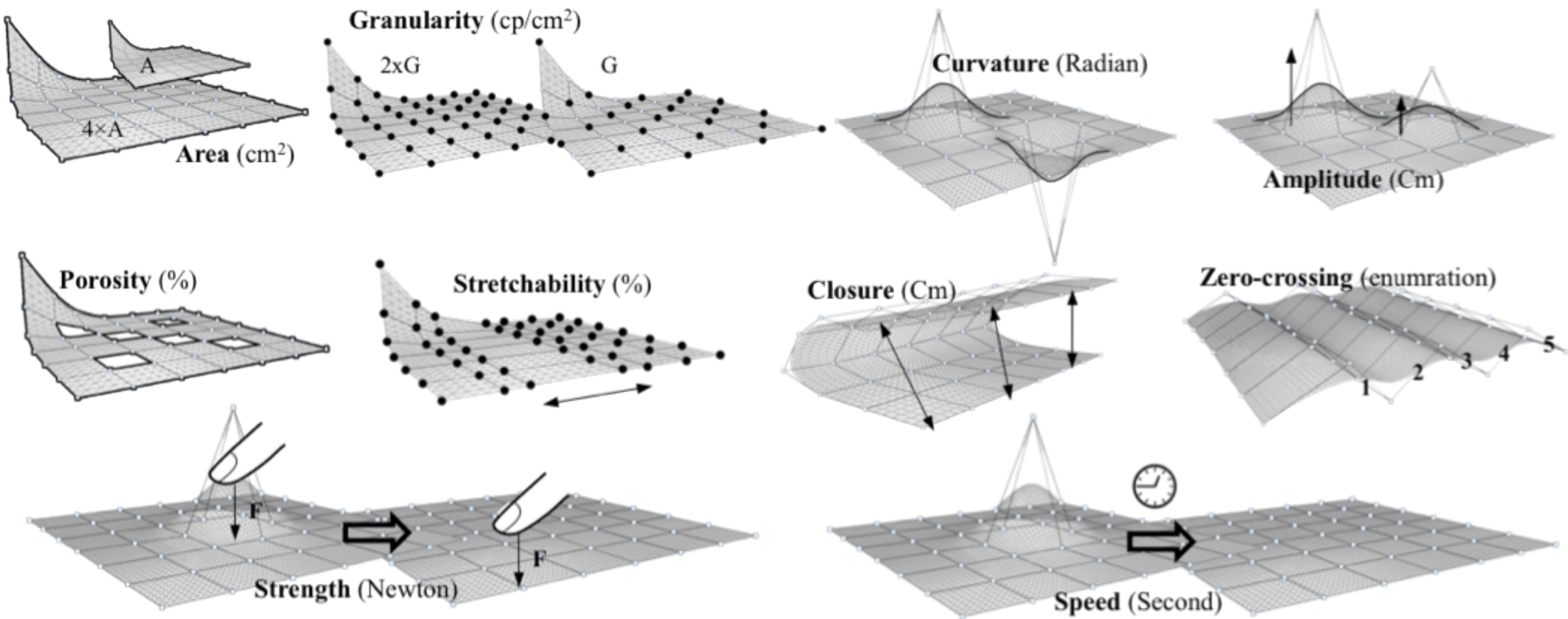
Dynamicity & Flexibility: Weight

Many possibilities

- How to make sense of it?
  → Taxonomies and Design spaces

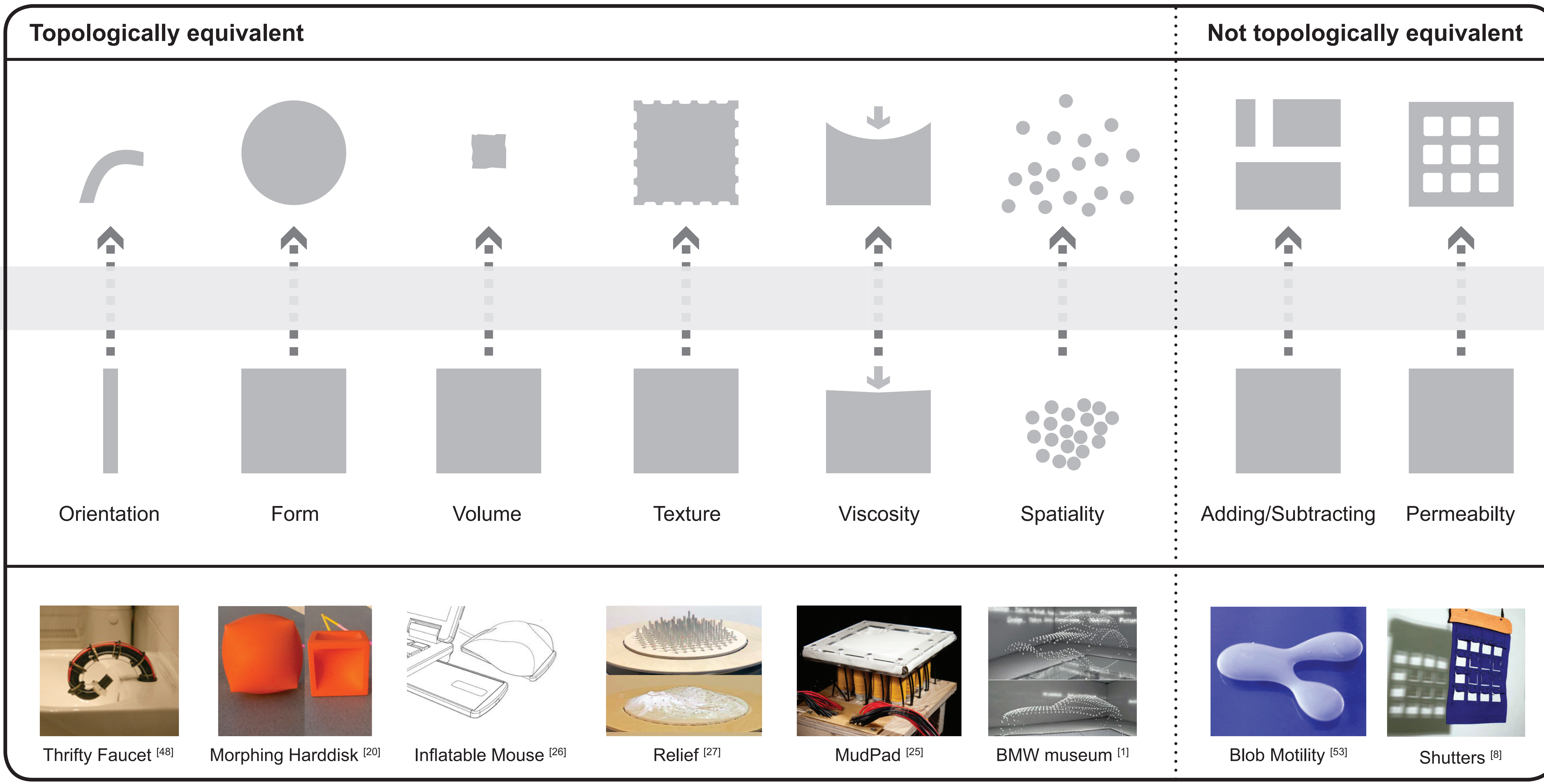
1. Morphees
2. Rasmussen
3. Sturdee
4. Emergeables

Morphees



Granularity (cp/cm²)
A
4×A
Area (cm²)
2xG
G
Curvature (Radian)
Amplitude (Cm)
Porosity (%)
Stretchability (%)
Closure (Cm)
Zero-crossing (enumration)
1
2
3
4
5
F
F
Strength (Newton)
Speed (Second)

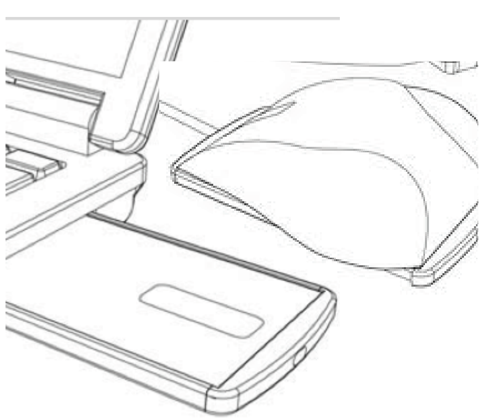
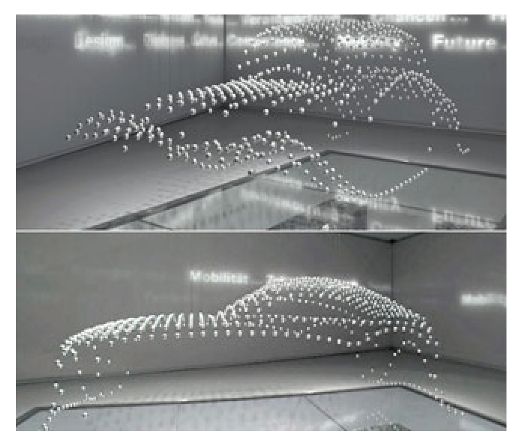
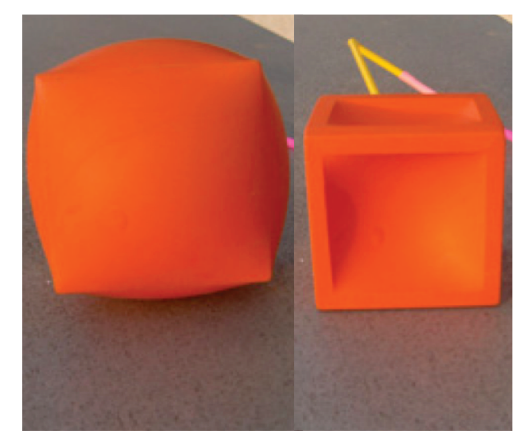
Rasmussen



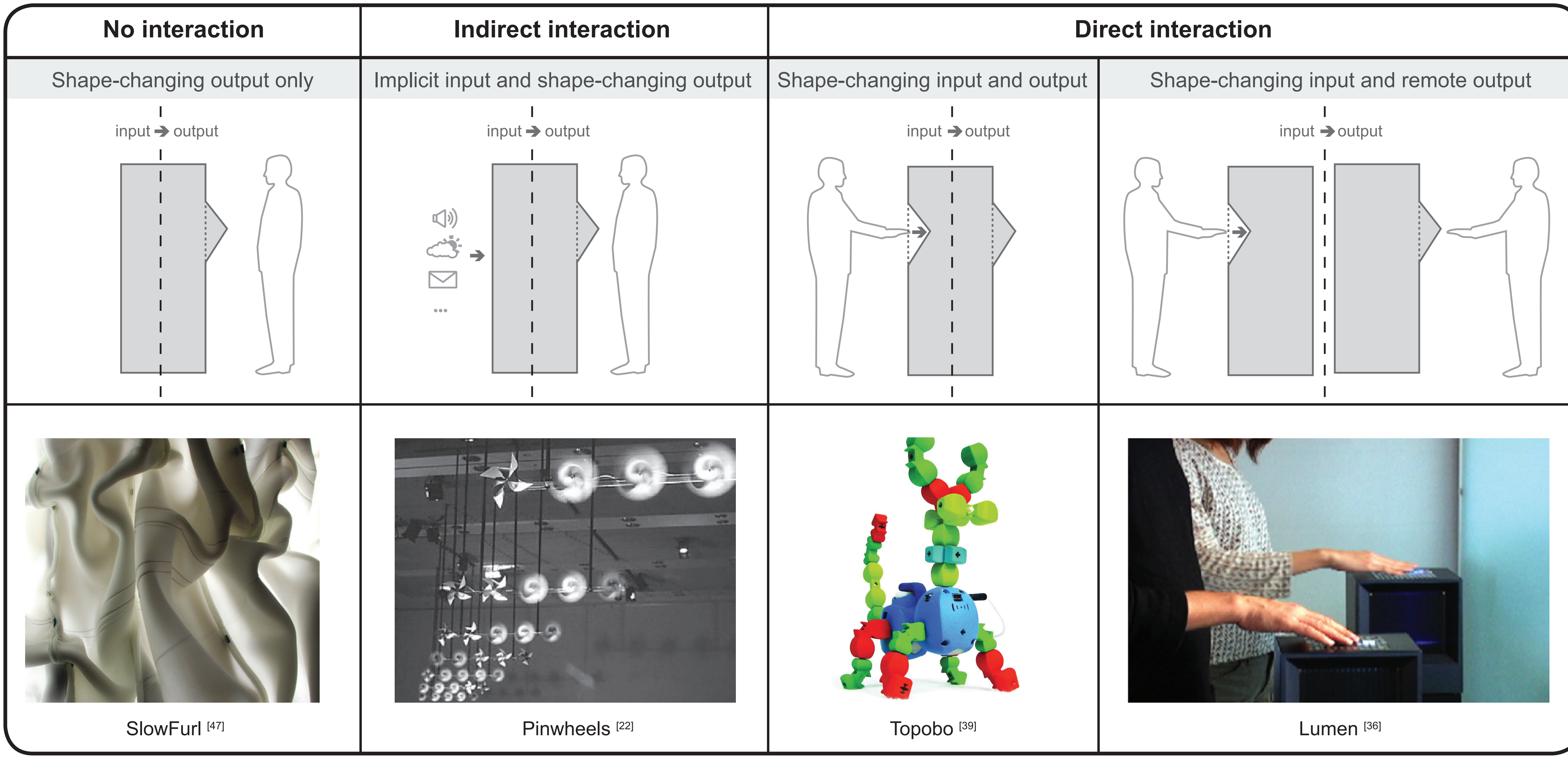
Topologically equivalent
Not topologically equivalent
Orientation
Form
Volume
Texture
Viscosity
Spatiality
Adding/Subtracting
Permeabilty
Thrifty Faucet [48]
Morphing Harddisk [20]
Inflatable Mouse [26]
Relief [27]
MudPad [25]
BMW museum [1]
Blob Motility [53]
Shutters [8]

Rasmussen

Kinetic parameters

Velocity	Path	Direction	Space
speed *acceleration* *tempo* *twitter* *frequency*	*linear/curved* *continuous/intermittent* *smooth/jerky* *pattern/random*	*up/down* *right/left* *forward/backwards*	*scale* *form* *kinesphere*
 Inflatable Mouse [26]	 Muscle Tower 2 [31]	 BMW museum [1]	 Morphing Harddisk [20]

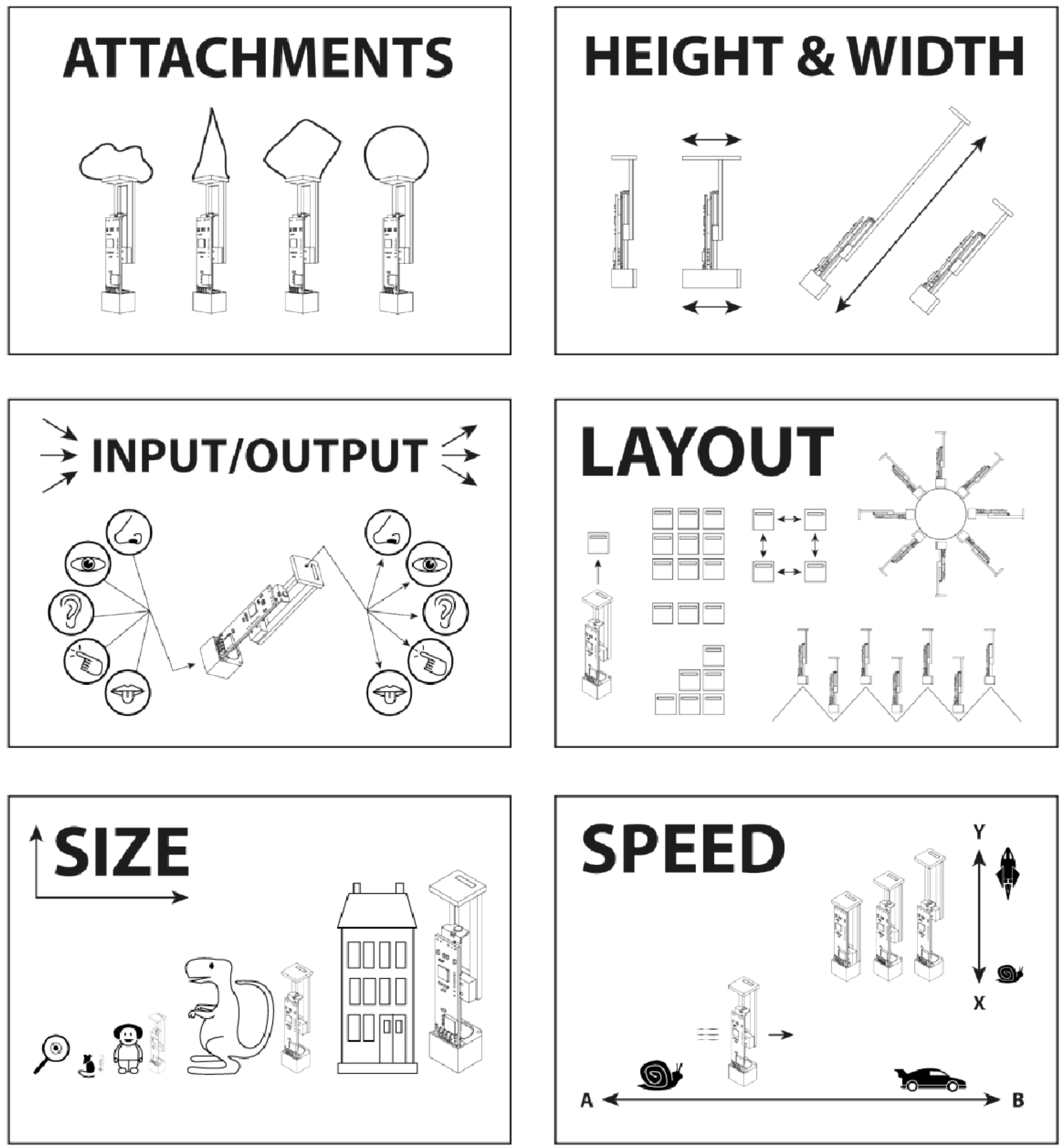
Rasmussen


No interaction
Indirect interaction
Direct interaction
Shape-changing output only
Implicit input and shape-changing output
Shape-changing input and output
Shape-changing input and remote output
input → output
input → output
input → output
input → output
...
SlowFurl [47]
Pinwheels [22]
Topobo [39]
Lumen [36]

Sturdee

http://www.shapeclip.com/video.html

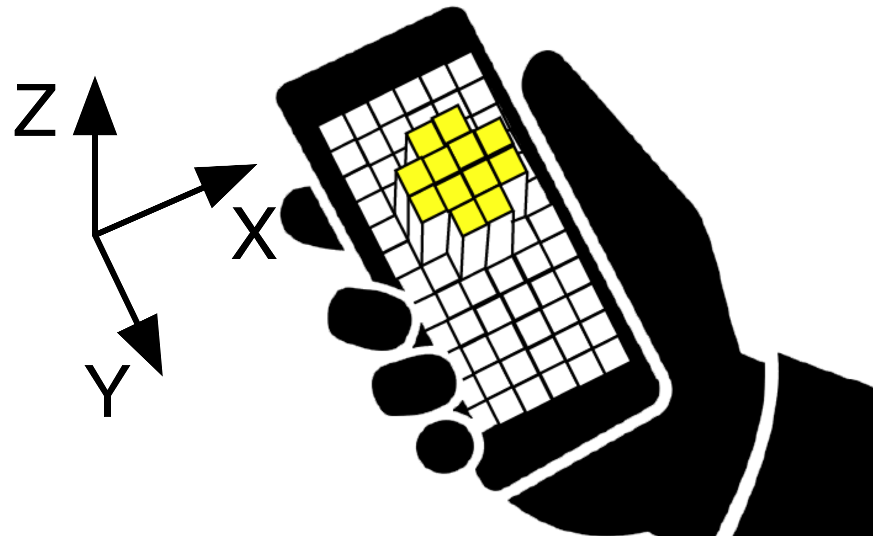
Sturdee


ATTACHMENTS
HEIGHT & WIDTH
INPUT/OUTPUT
LAYOUT
SIZE
SPEED
Y
X
A
B

Emergeables

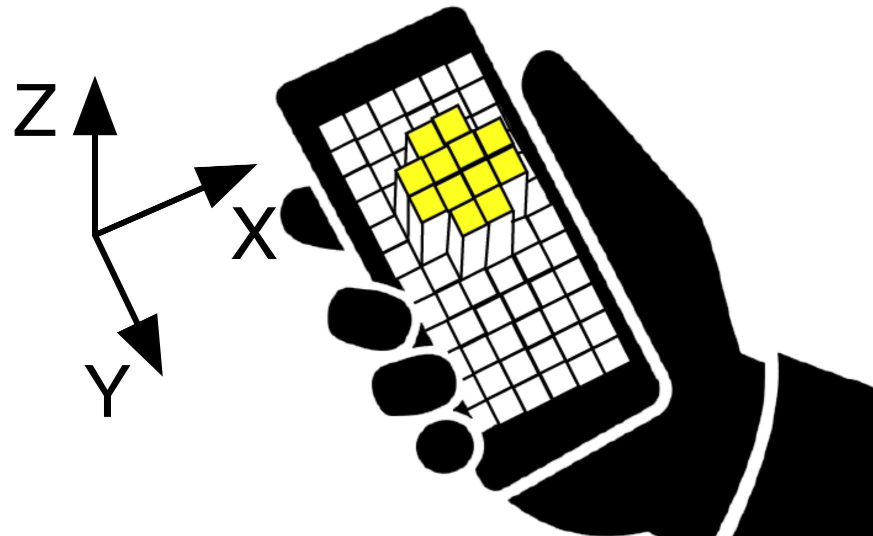
https://www.youtube.com/watch?v=YeE9hSdUdRQ

Emergeables



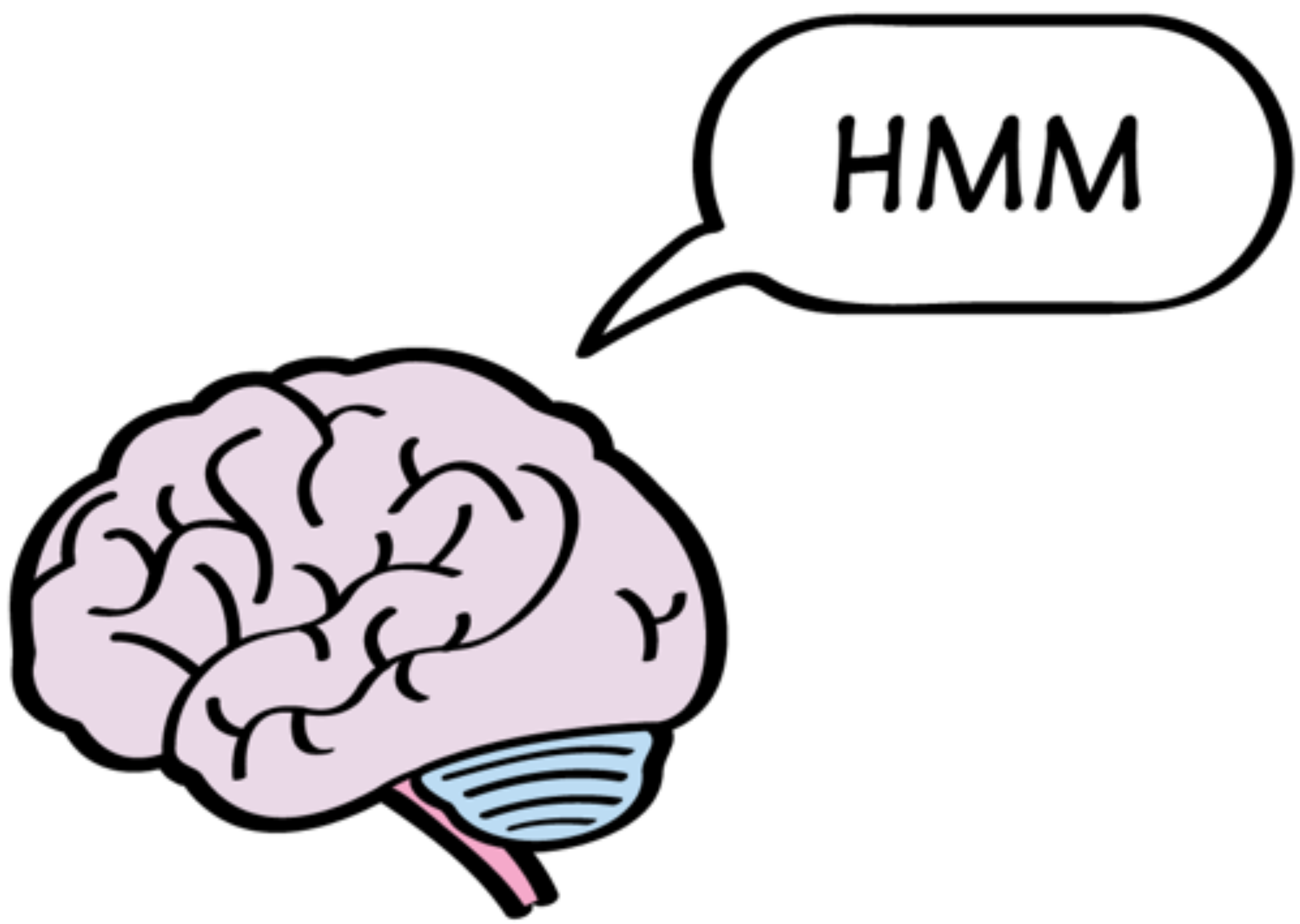
			Resolution of sensels
			Low — High
Tangible manipulation of sensels	Translation	X	
		Y	
		Z	
	Rotation	X	
		Y	
		Z	

Emergeables



<table>
<tr><td colspan="3"></td><td>Resolution of sensels</td></tr>
<tr><td colspan="3"></td><td>Low High</td></tr>
<tr><td rowspan="6">Tangible manipulation of sensels</td><td rowspan="3">Translation</td><td>X</td><td rowspan="6">How to extend?</td></tr>
<tr><td>Y</td></tr>
<tr><td>Z</td></tr>
<tr><td rowspan="3">Rotation</td><td>X</td></tr>
<tr><td>Y</td></tr>
<tr><td>Z</td></tr>
</table>

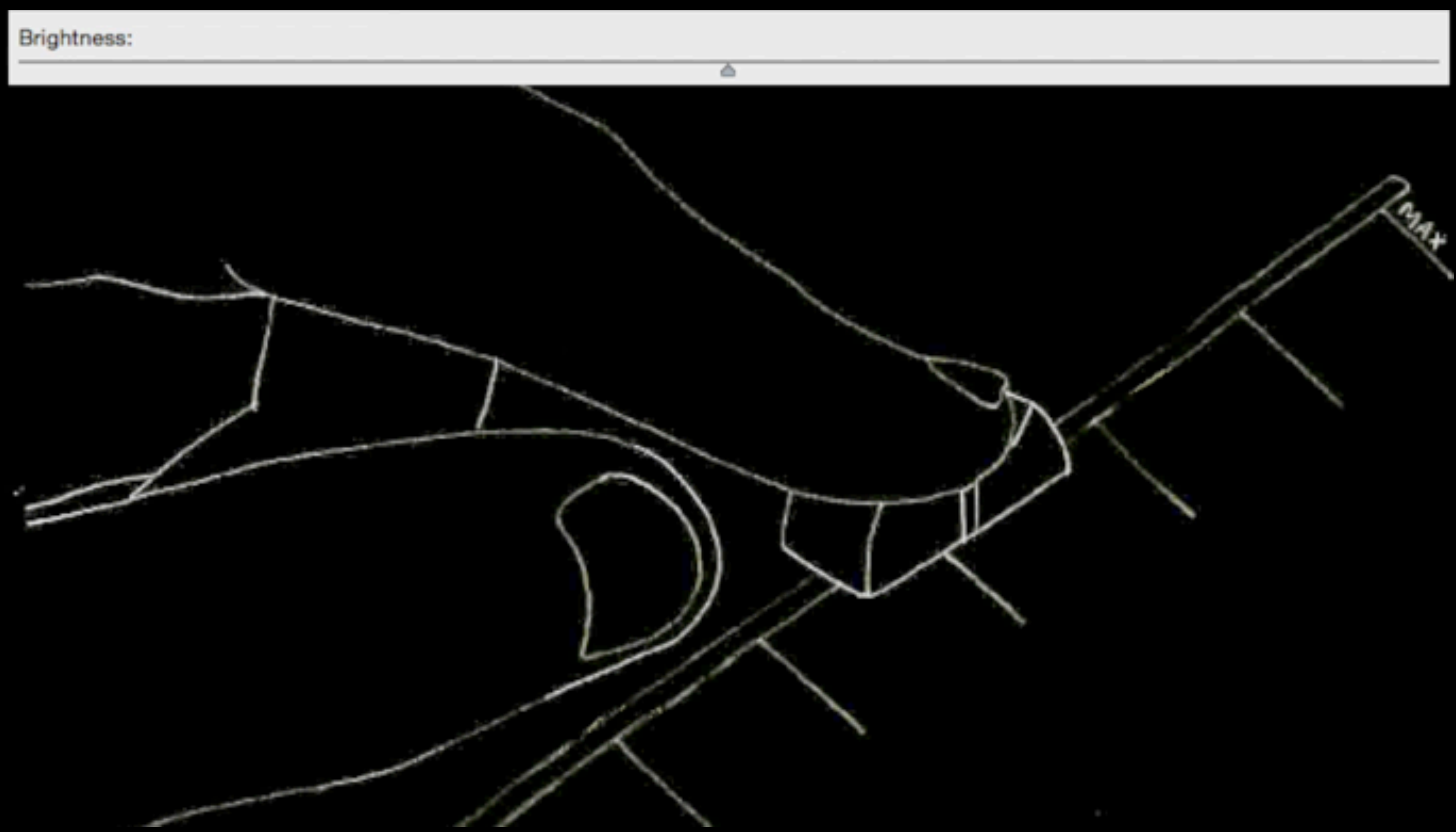
Dynamicity & Flexibility: What is is good for?



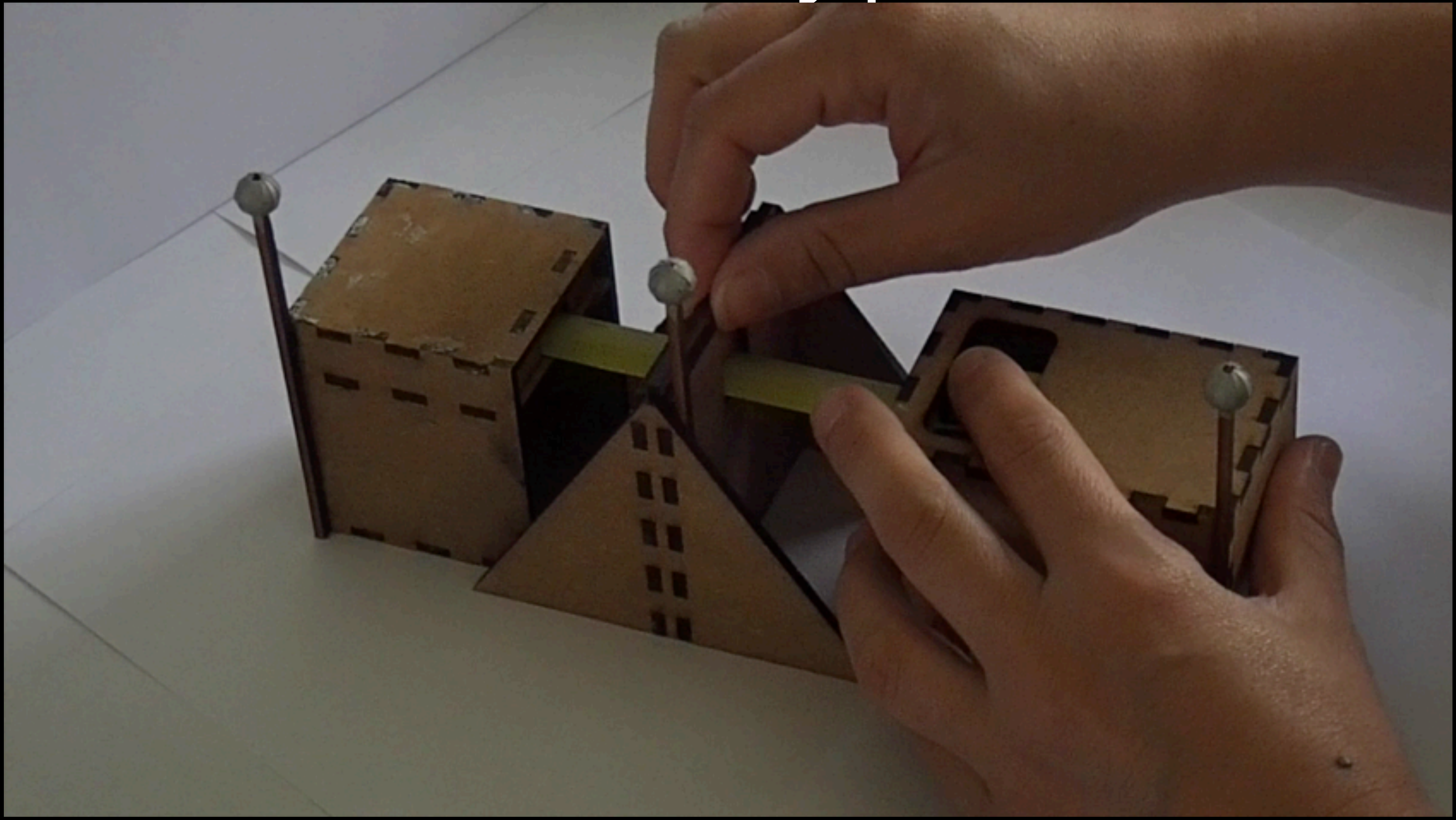
Dynamicity & Flexibility: What is is good for?

- Balancing footprint and performance
- Notifications
- Switching between controls and flat screen
- etc.

For balancing footprint and performance



Prototype



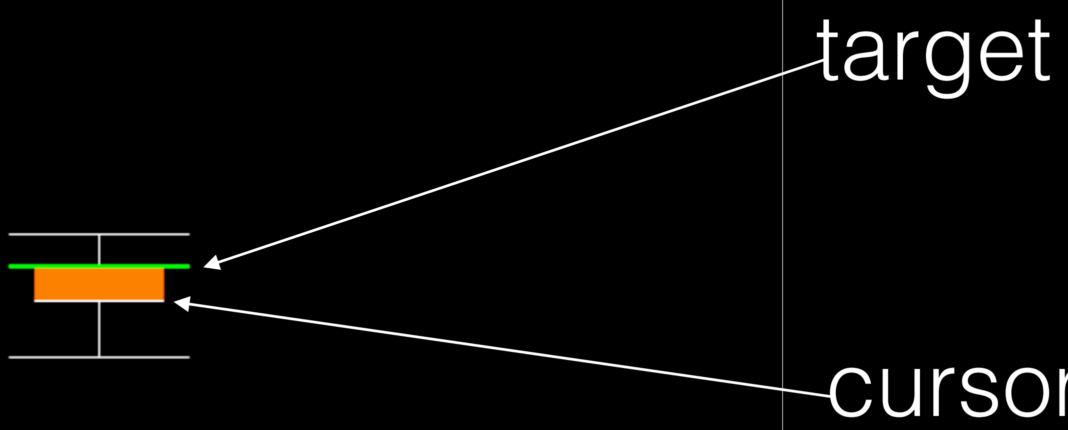
Prototype

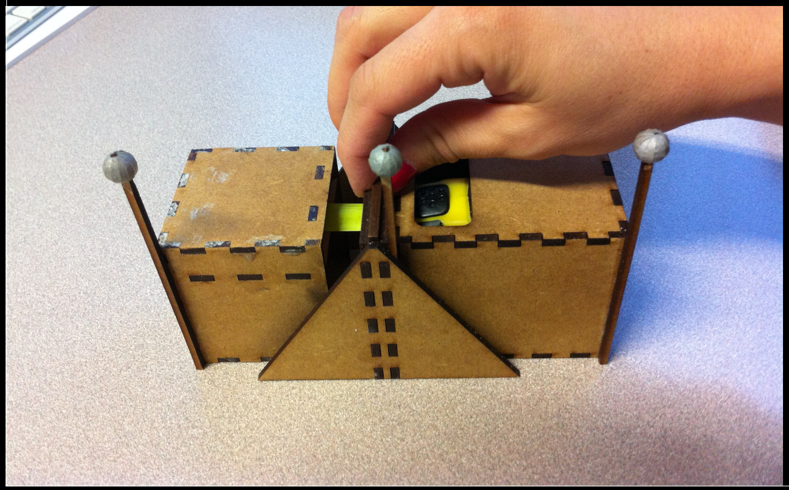
resolution: 2822 dpi

Benefit of Multiple Sizes: Experiment 1

How much more efficient are users
with a large slider than a small slider?

Task: **pointing** with a tangible slider at a target displayed on a distant screen





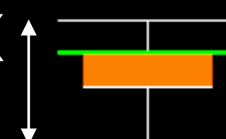
block 1/2

42 targets left

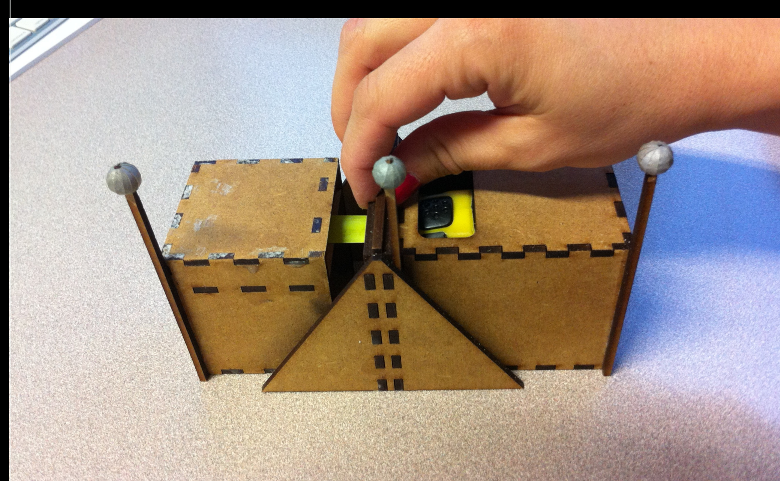
User cursor Sensor Location: 1 / 2.0

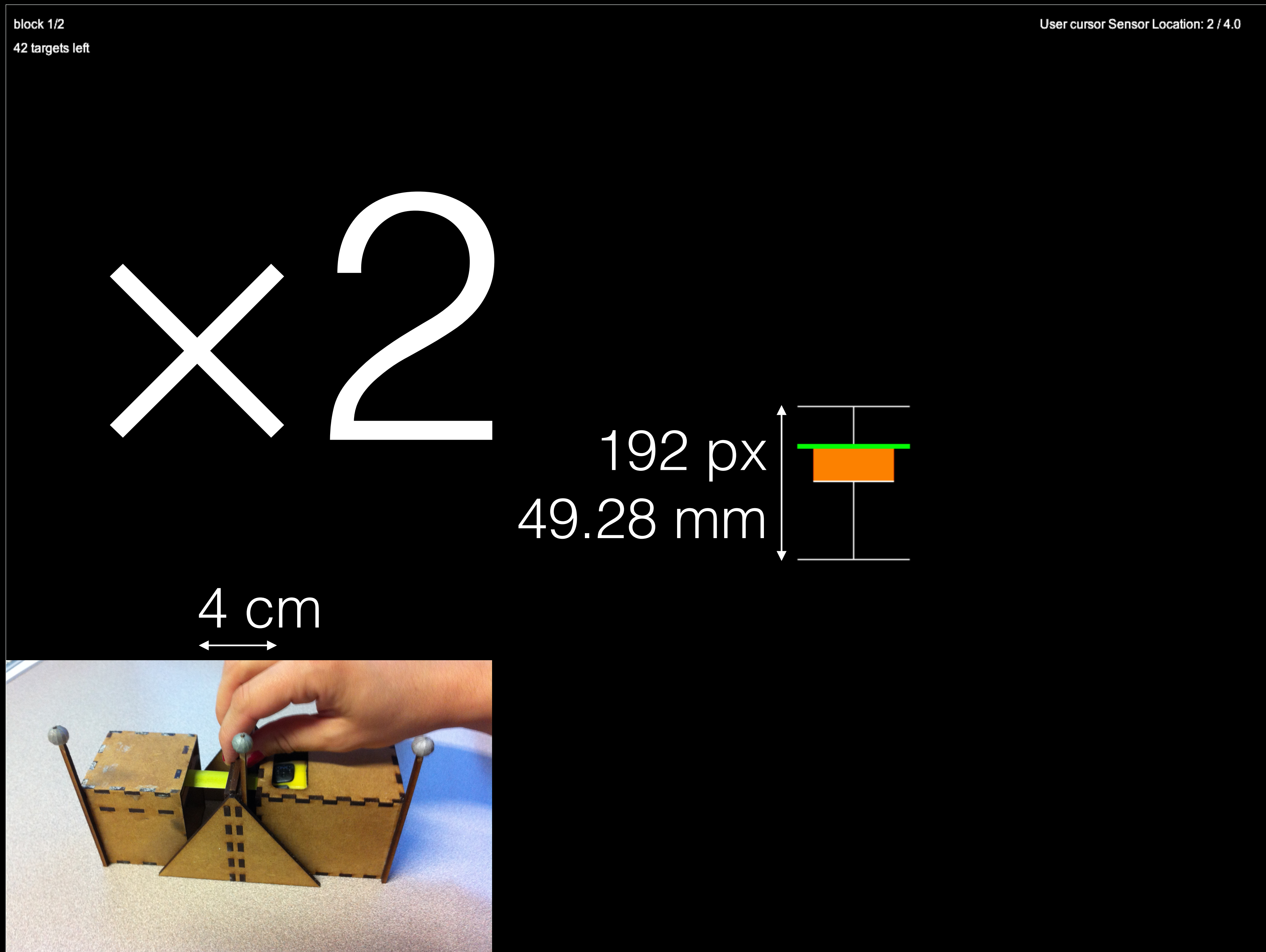
96 px

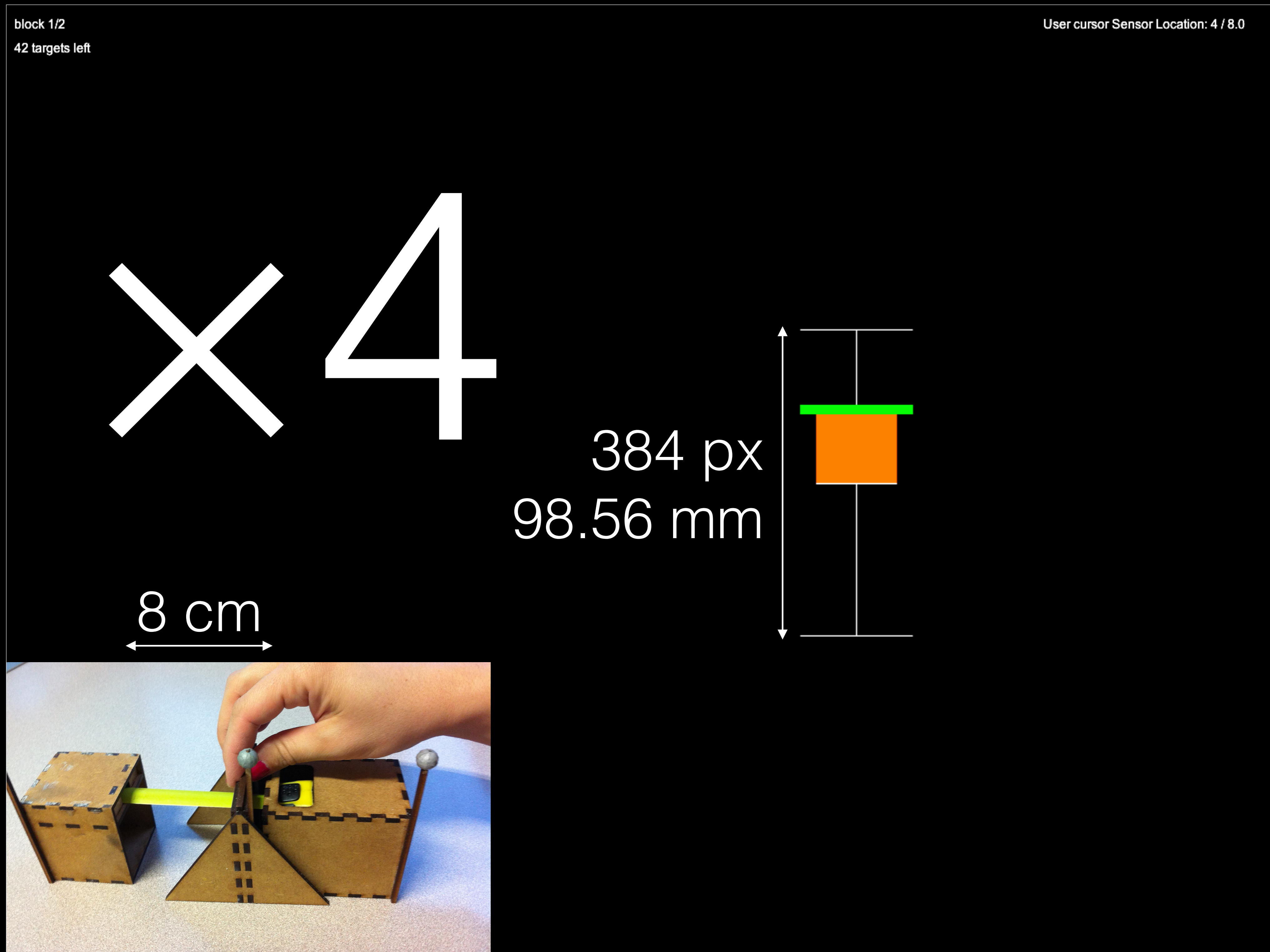
24.64 mm



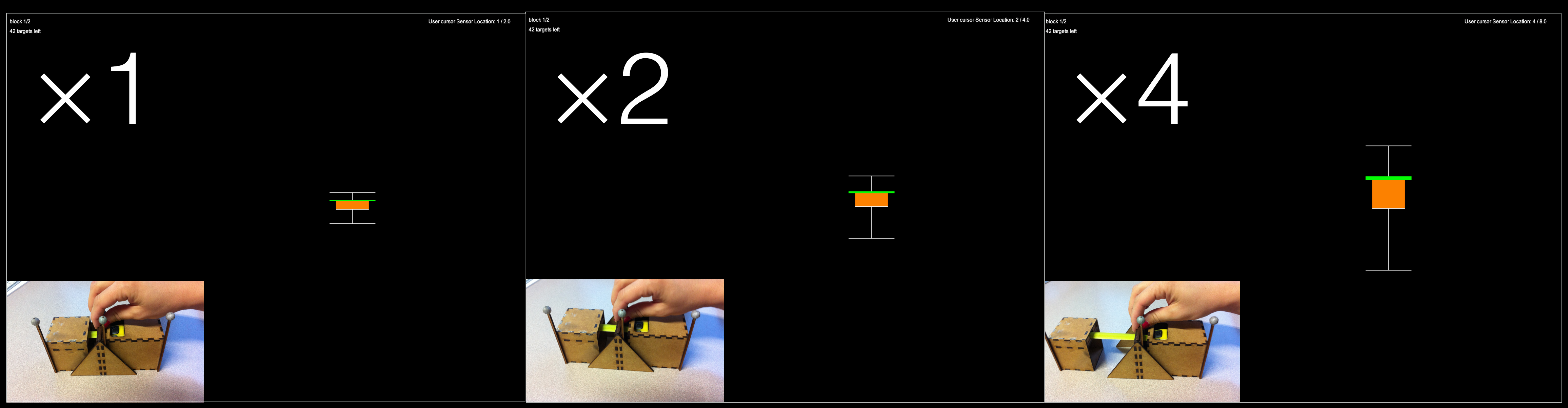
2 cm




block 1/2
42 targets left
User cursor Sensor Location: 2 / 4.0
×2
192 px
49.28 mm
4 cm

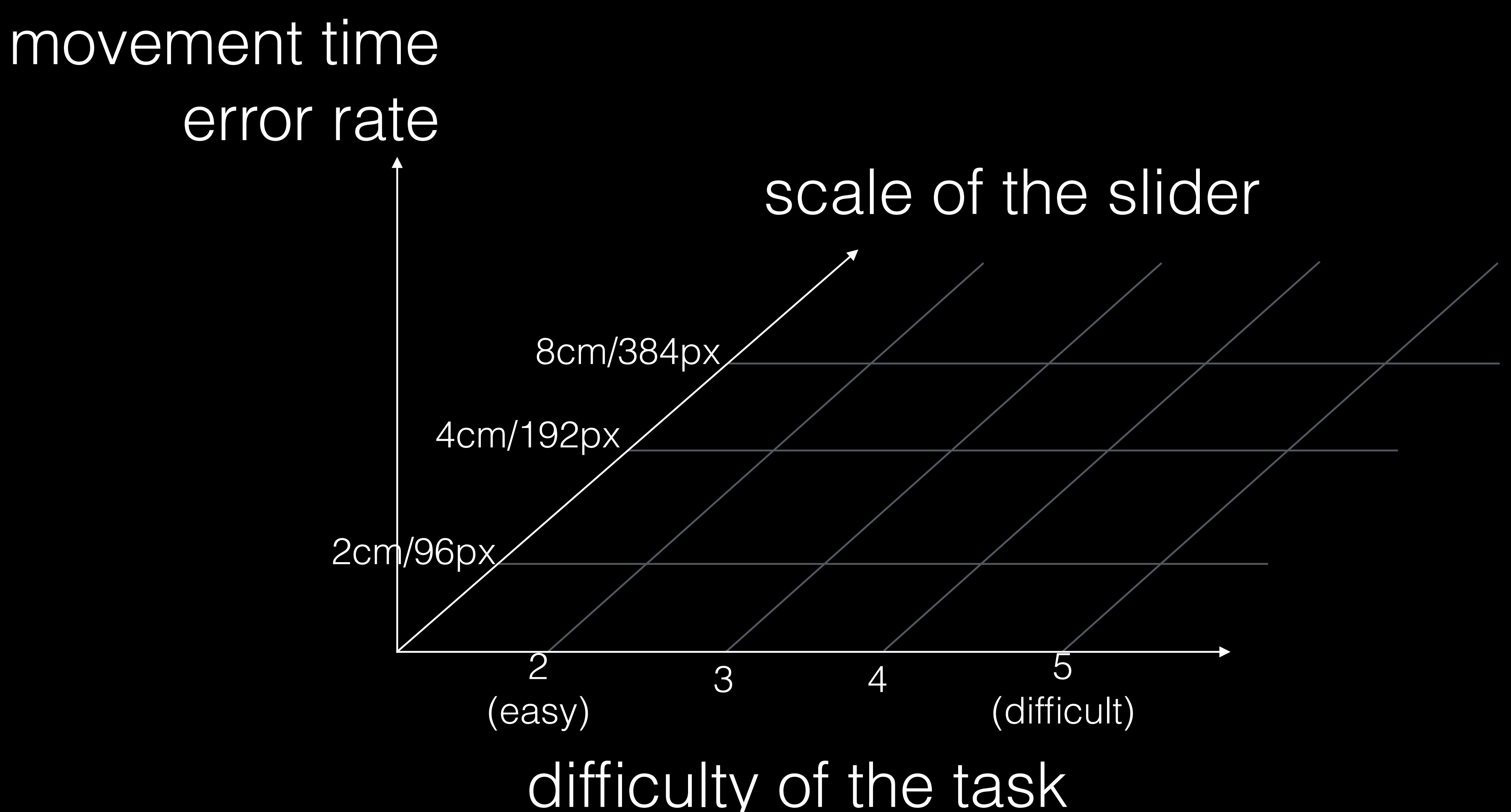

block 1/2
42 targets left
User cursor Sensor Location: 4 / 8.0
×4
384 px
98.56 mm
8 cm

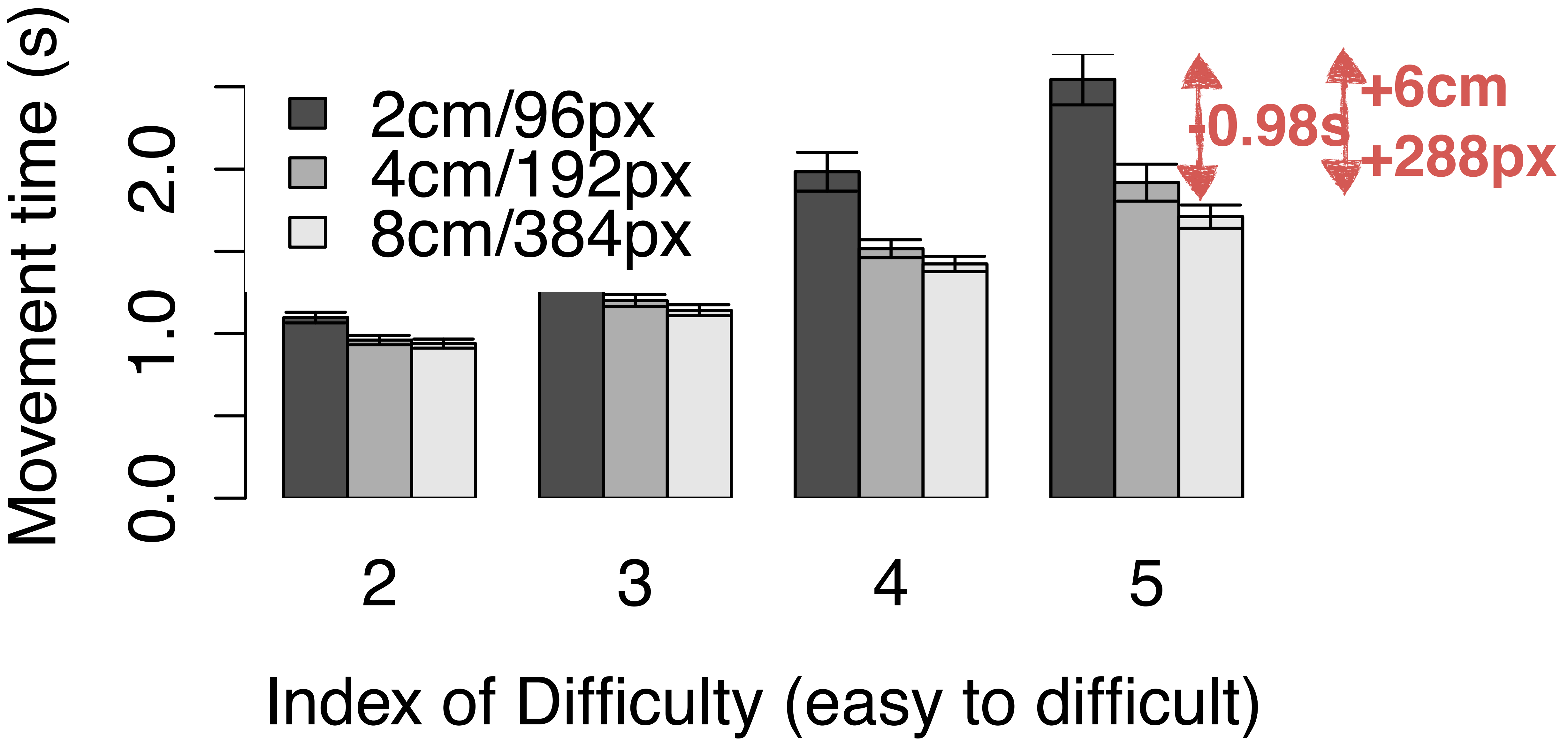
Constant
Control-Display gain



2/96 = 4/192 = 8/384

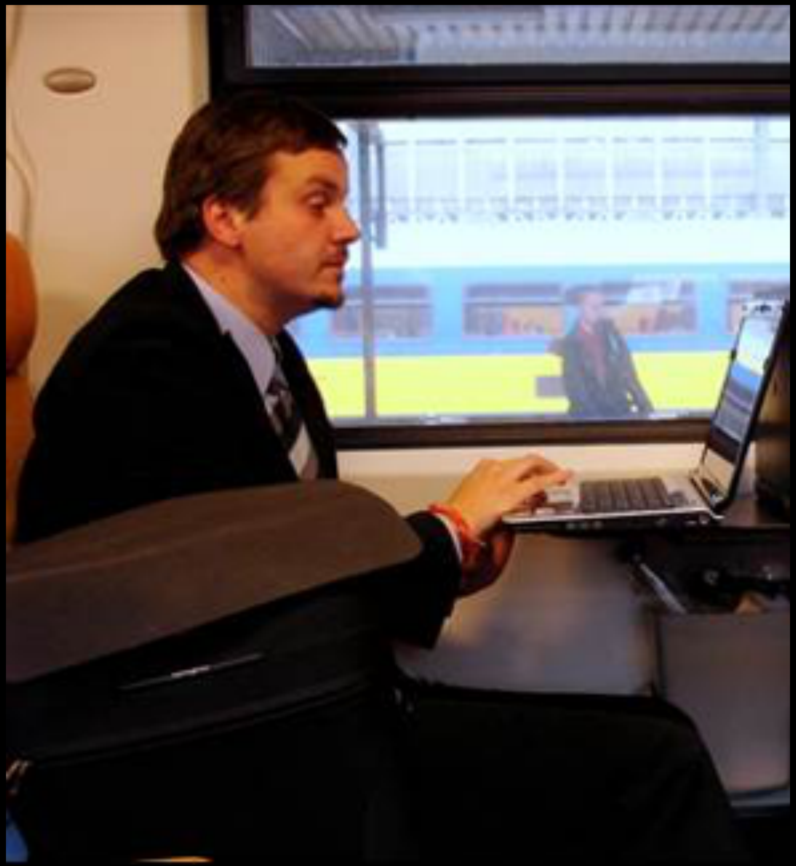
Benefit of Multiple Sizes: Experiment 1





Movement time (s)
0.0
1.0
2.0
2cm/96px
4cm/192px
8cm/384px
+0.98s
+6cm
+288px
2
3
4
5
Index of Difficulty (easy to difficult)

Zoomed in is better



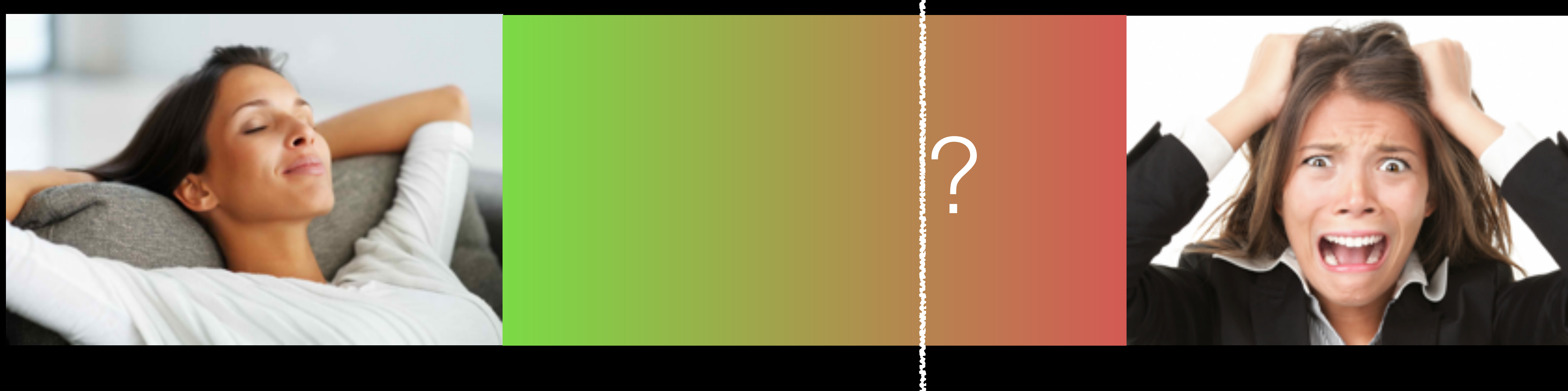
not possible when workspace is restricted

Drawback of resizing: Experiment 2

Impact of resizing on performance

Drawback of resizing: Experiment 2

Need to measure
the limit of usability



Task 1: **pursuing**

cursor
pursuit error
moving target

Task 1: **pursuing** moving target when difficulty changes

Small slider (2cm/96px)

difficult

↕1 px

↕2 px

↕4 px

size of target changes

easy

Task 1: **pursuing** moving target when difficulty changes

difficult

easy

Small slider (2cm/96px)

↕1 px

↕2 px

↕4 px

size of target changes

Resizable slider

resize so that size of target is constant

↕4 px

Task 1: **pursuing** moving target when difficulty changes

difficult ↑ easy

Small slider (2cm/96px)

↕1 px

↕2 px

↕4 px

size of target changes

Resizable slider

resize so that size of target is constant

↕4 px

Large slider (8cm/384px)

size of target changes

↕4 px

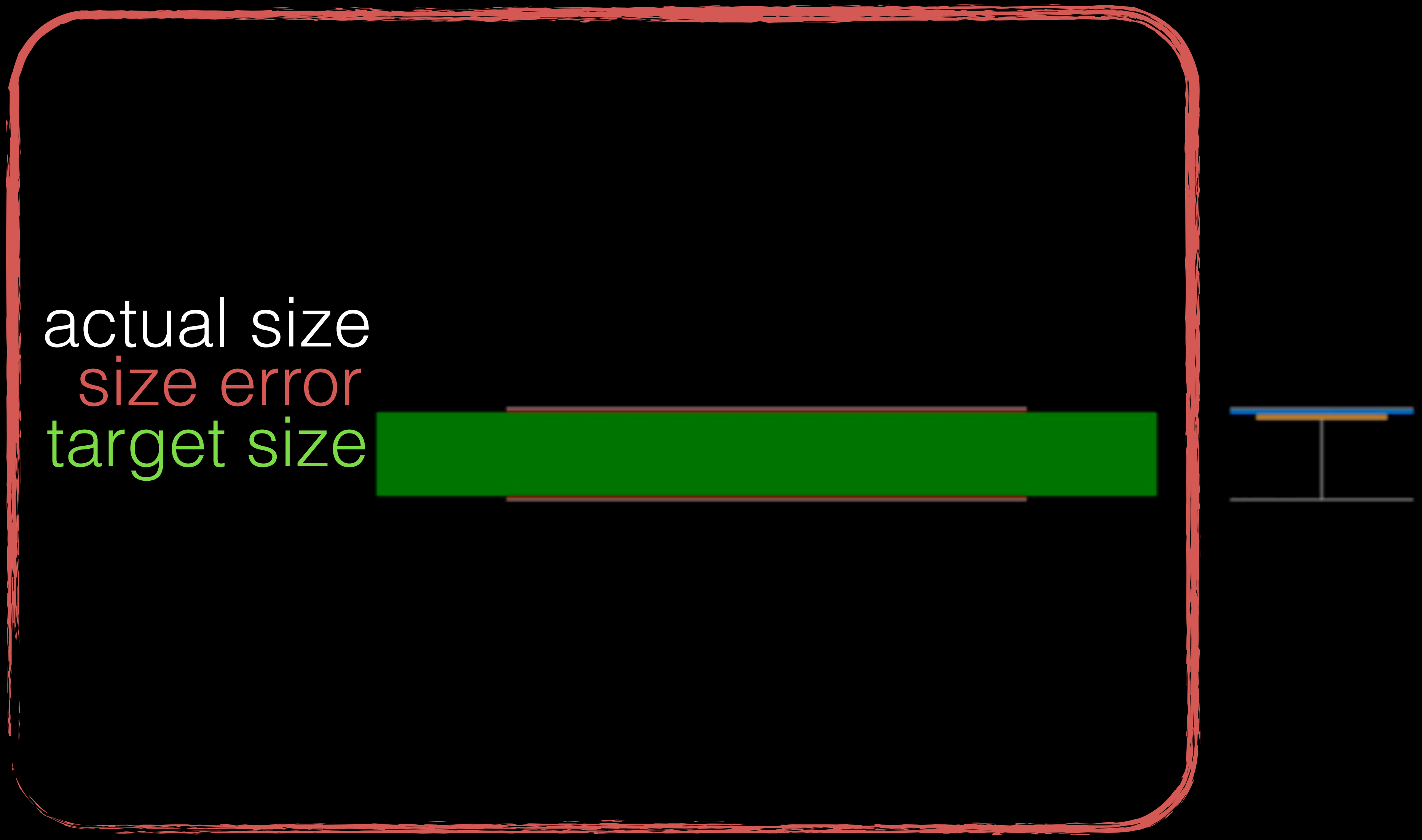
↕8 px

↕16 px

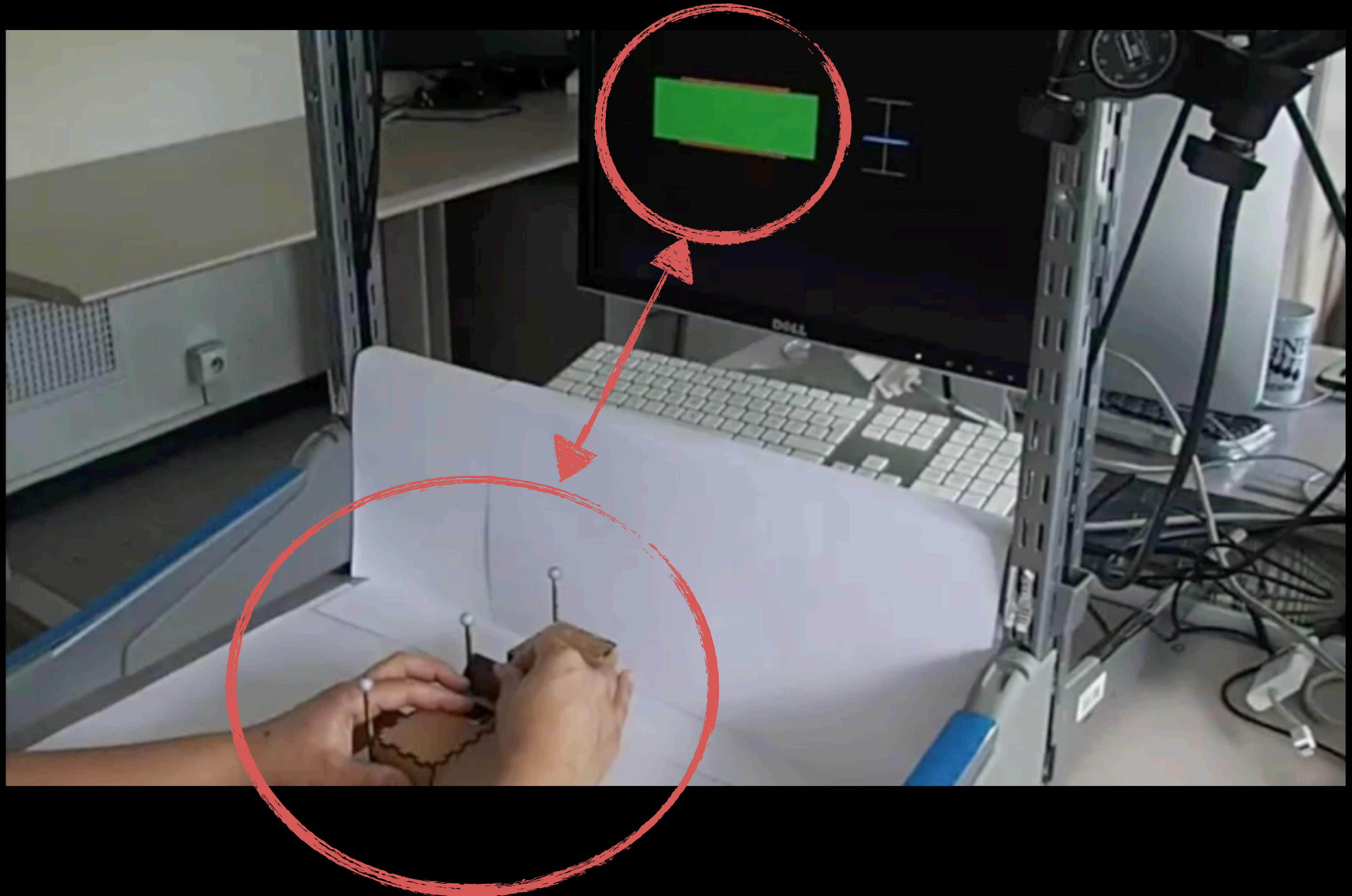
Task 1: **pursuing** moving target when difficulty changes

	Small slider (2cm/96px)	**Resizable slider**	**Large slider (8cm/384px)**
difficult	↕1 px	resize so that size of target is constant	size of target changes
	↕2 px		
	↕4 px	↕4 px	↕4 px
	size of target changes		↕8 px
easy			↕16 px

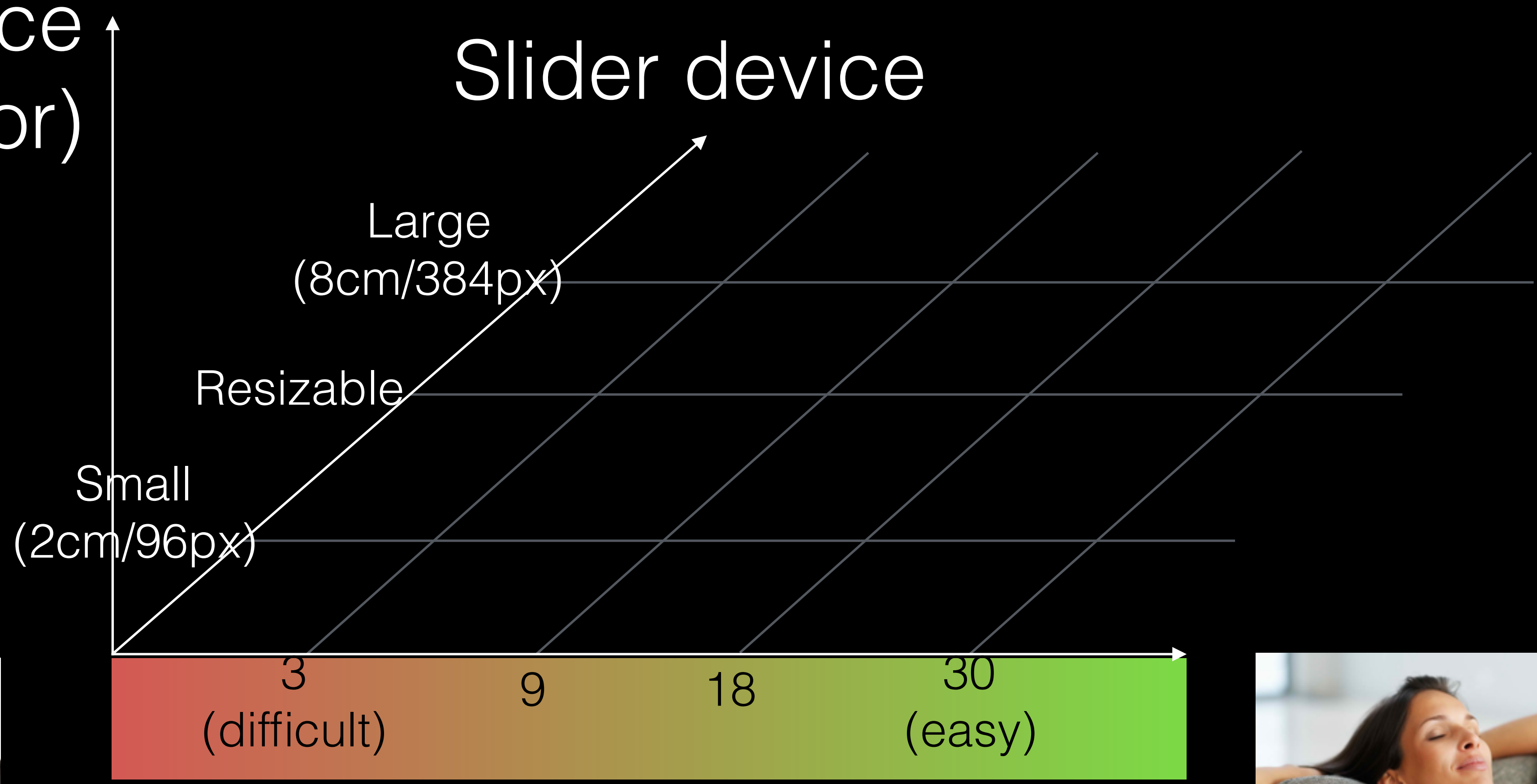
Task 2: **resizing**

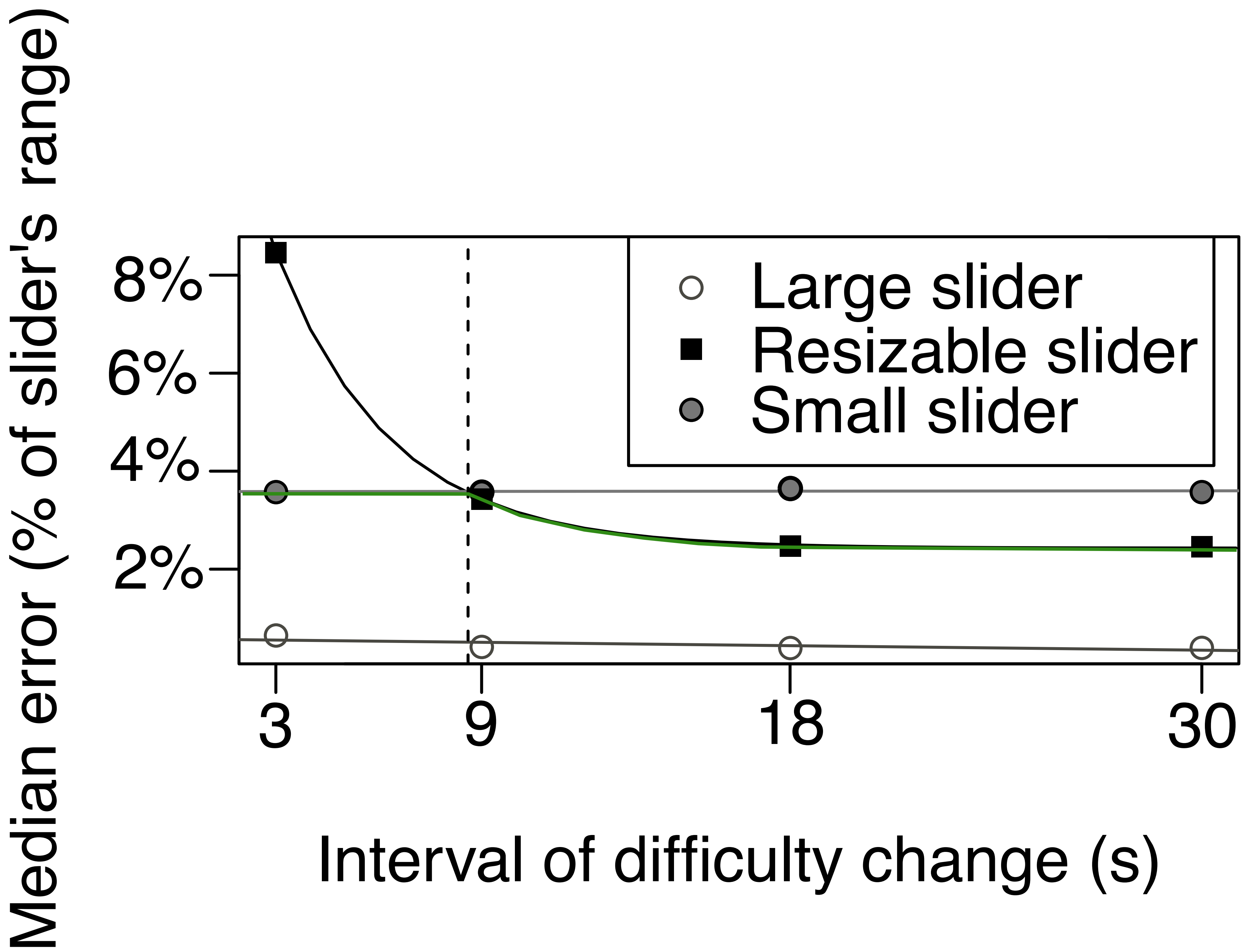


Task 2: **resizing**



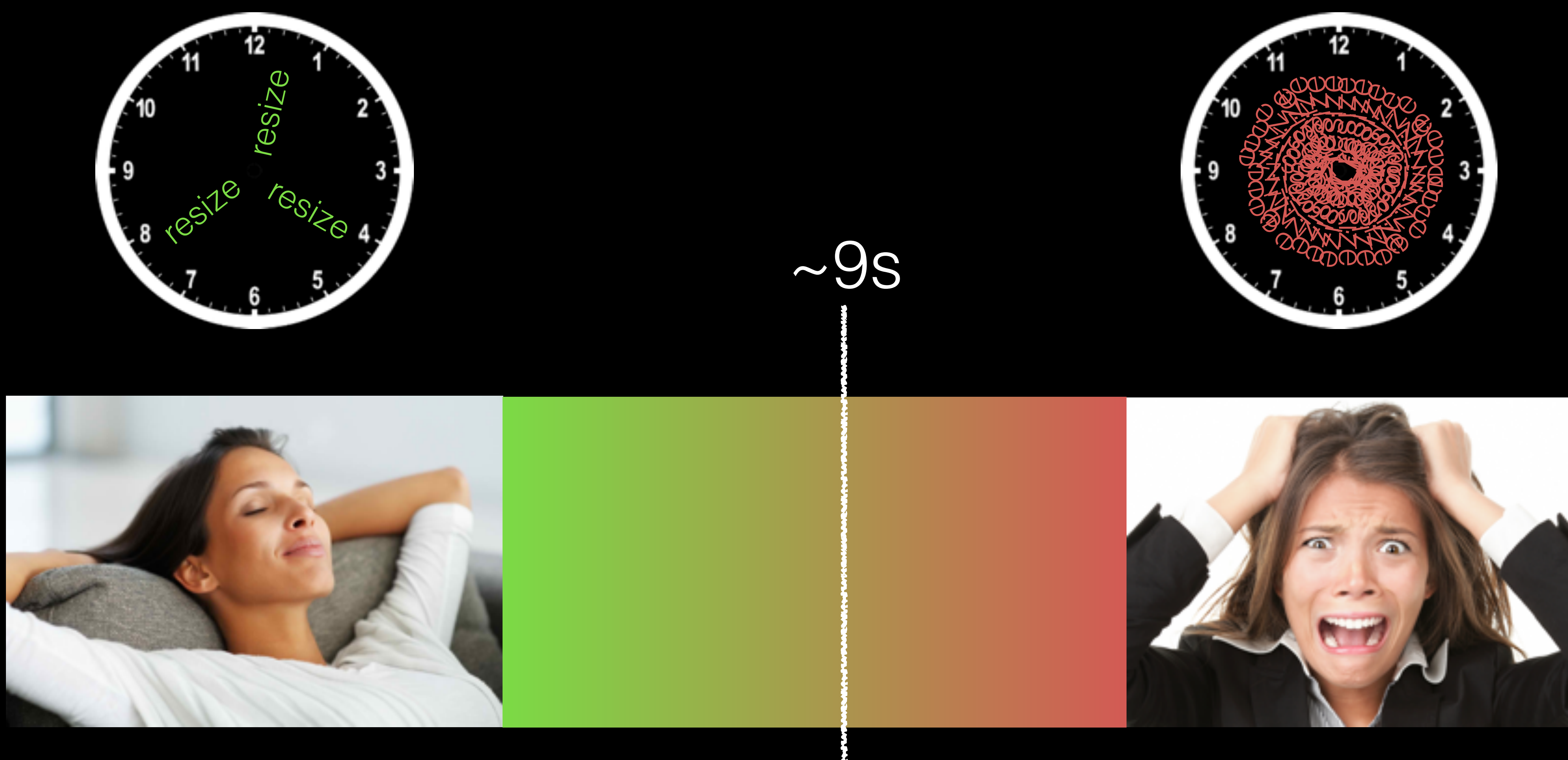
Drawback of resizing: Experiment



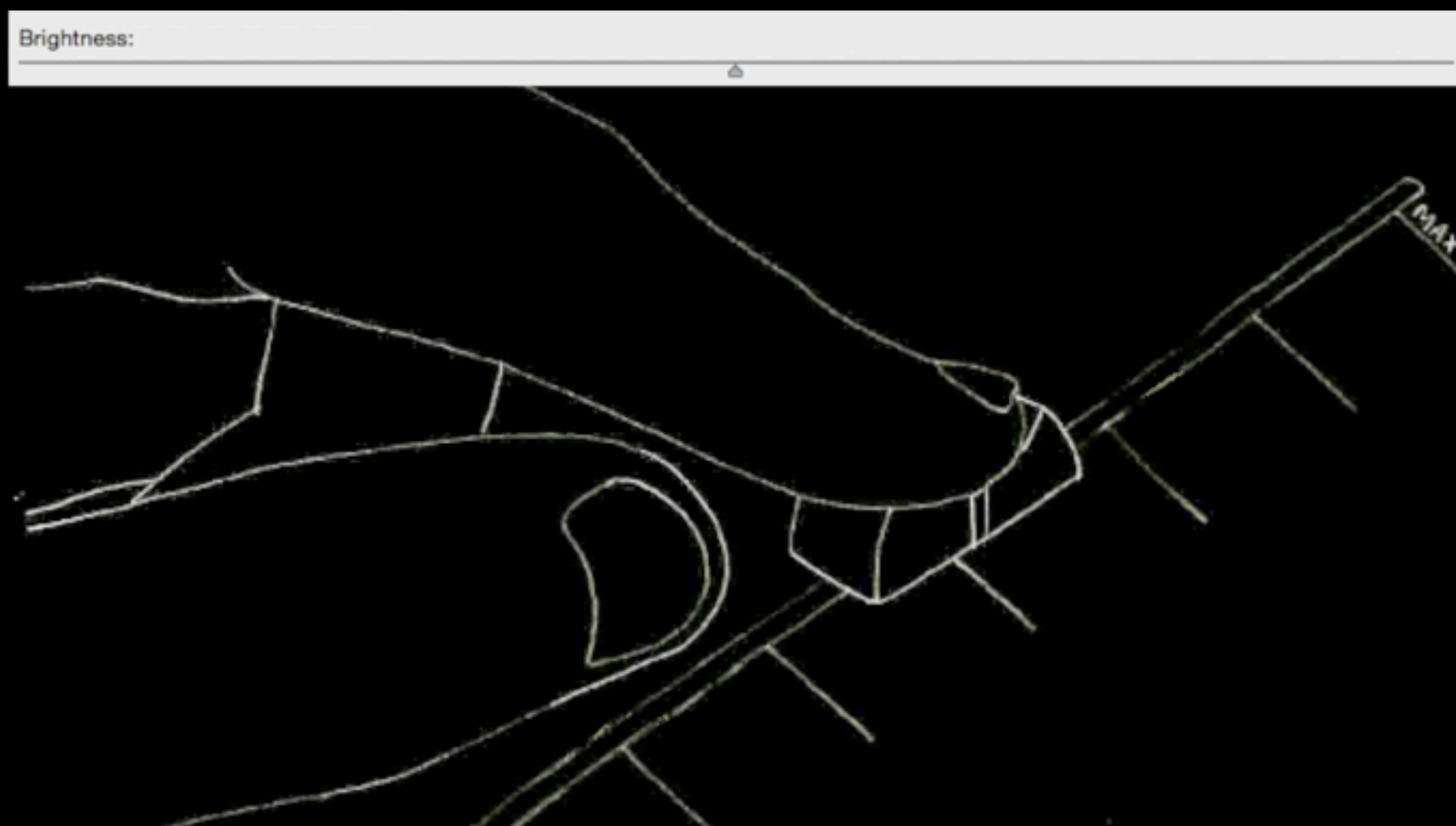


if no room available, resize only if less often than every ~9 seconds

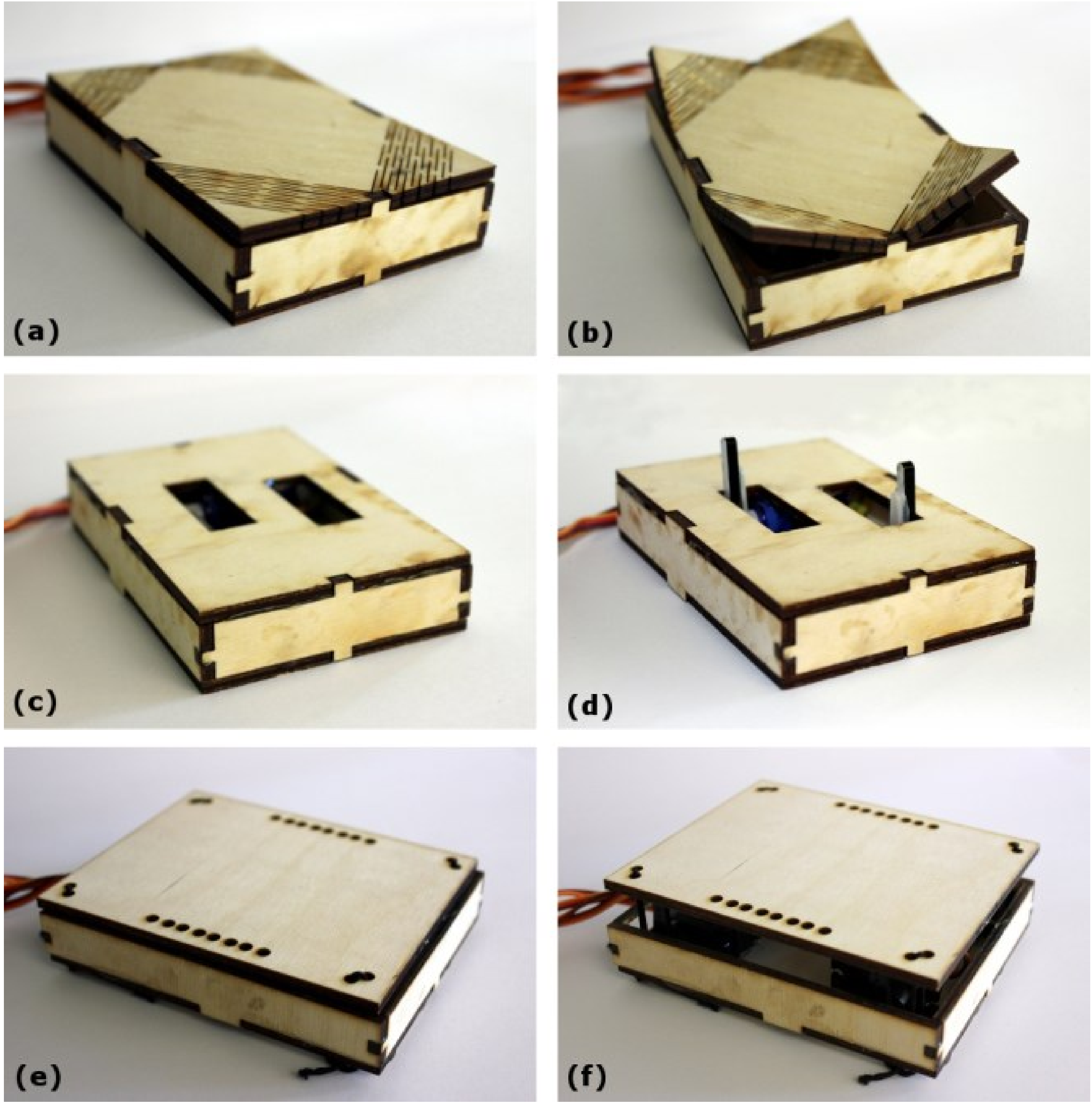
Resizing brings benefits
If less often than every ~9 seconds



For balancing footprint and performance

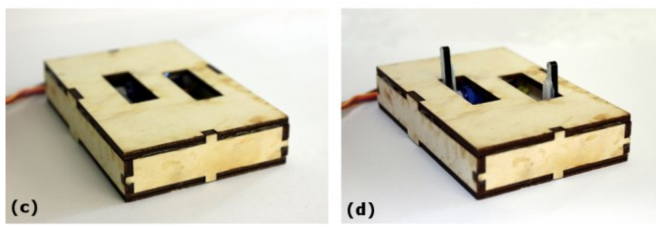


For notifications

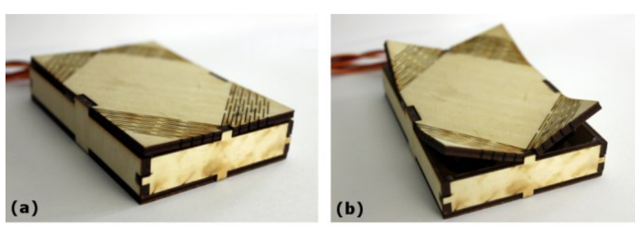


For notifications

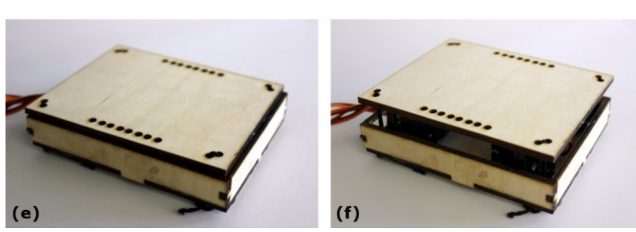
Protrusion



Corner bending

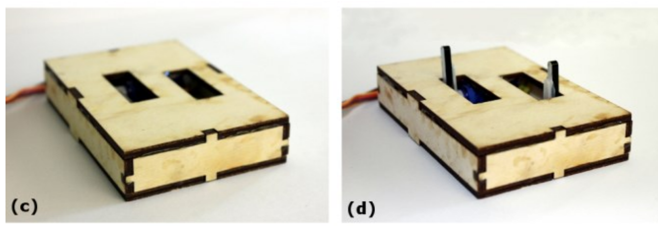


Volume



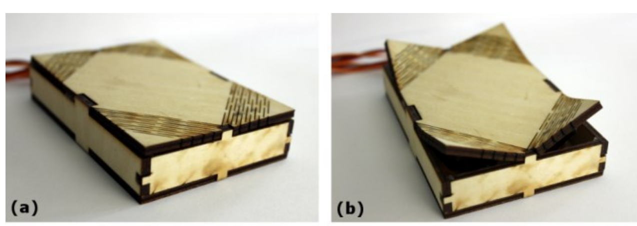
For notifications

Protrusion



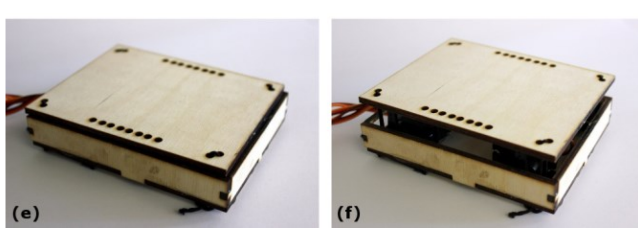
- Height (10mm or **15mm**)
- Type (static, slow pulse, or **fast pulse**)

Corner bending



- Number of corners (1–**4**)
- Height (8mm or **12mm**)
- Type (static, slow pulse, **fast pulse**)

Volume



- Mode (**full expansion** or tapering)
- Height (5mm or **10mm**)
- Type (static, slow pulse, **fast pulse**)

For notifications

- Type
  - Static: Moves immediately to its final position (taking 200ms)
  - Slow pulse: repeats
    - Moves to the position (200ms),
    - Pause for 500ms,
    - Return to the rest position (200ms)
    - Pause for a further 500ms
  - Fast pulse: **Continually move between positions**

For notifications

- Vibrotactile feedback
  - Samsung Galaxy S3
  - Default vibration mode (1.6s pulse/pause cycle)

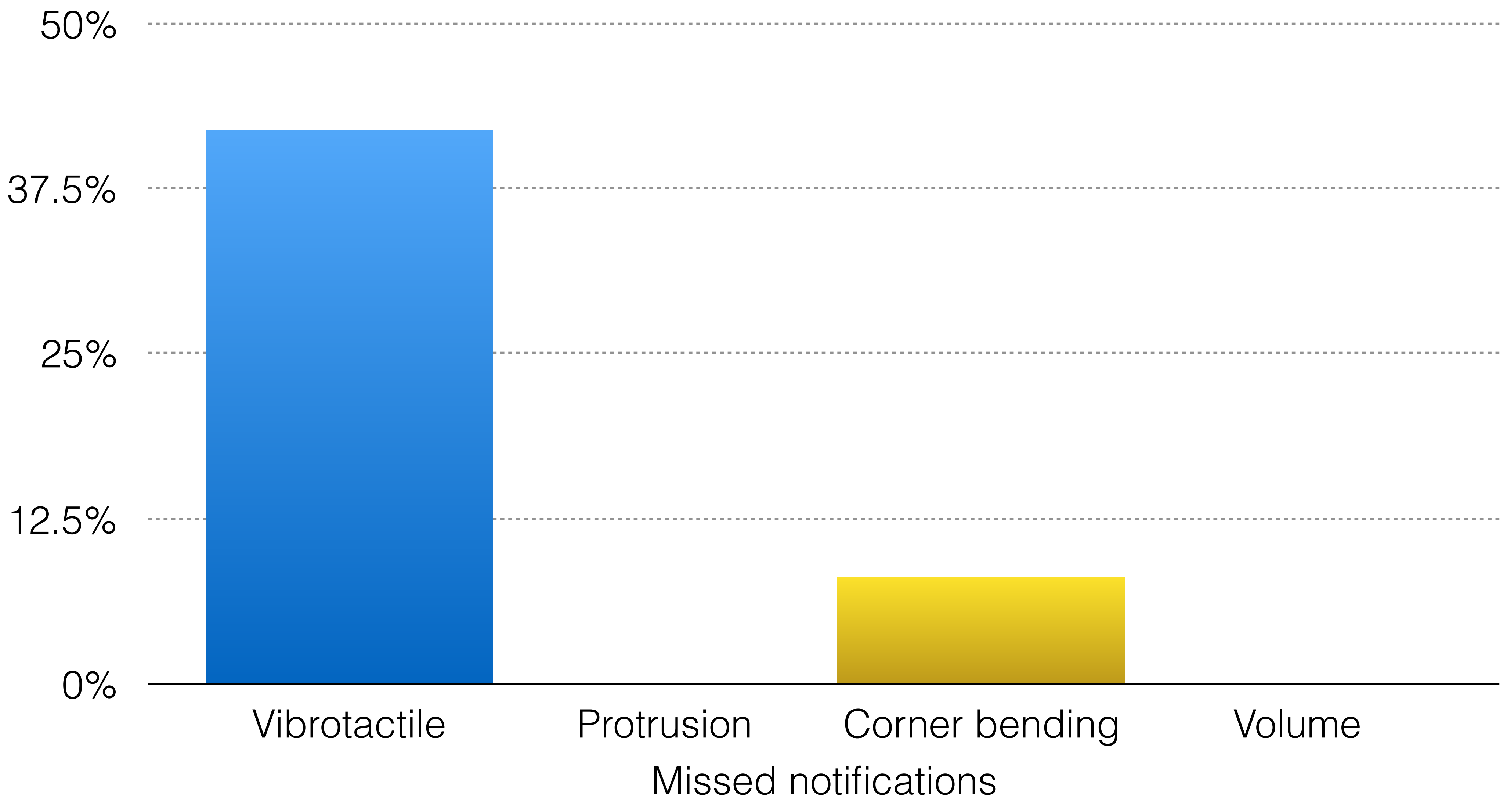
For notifications

- Measures
  - Recognition time
  - Missed notifications

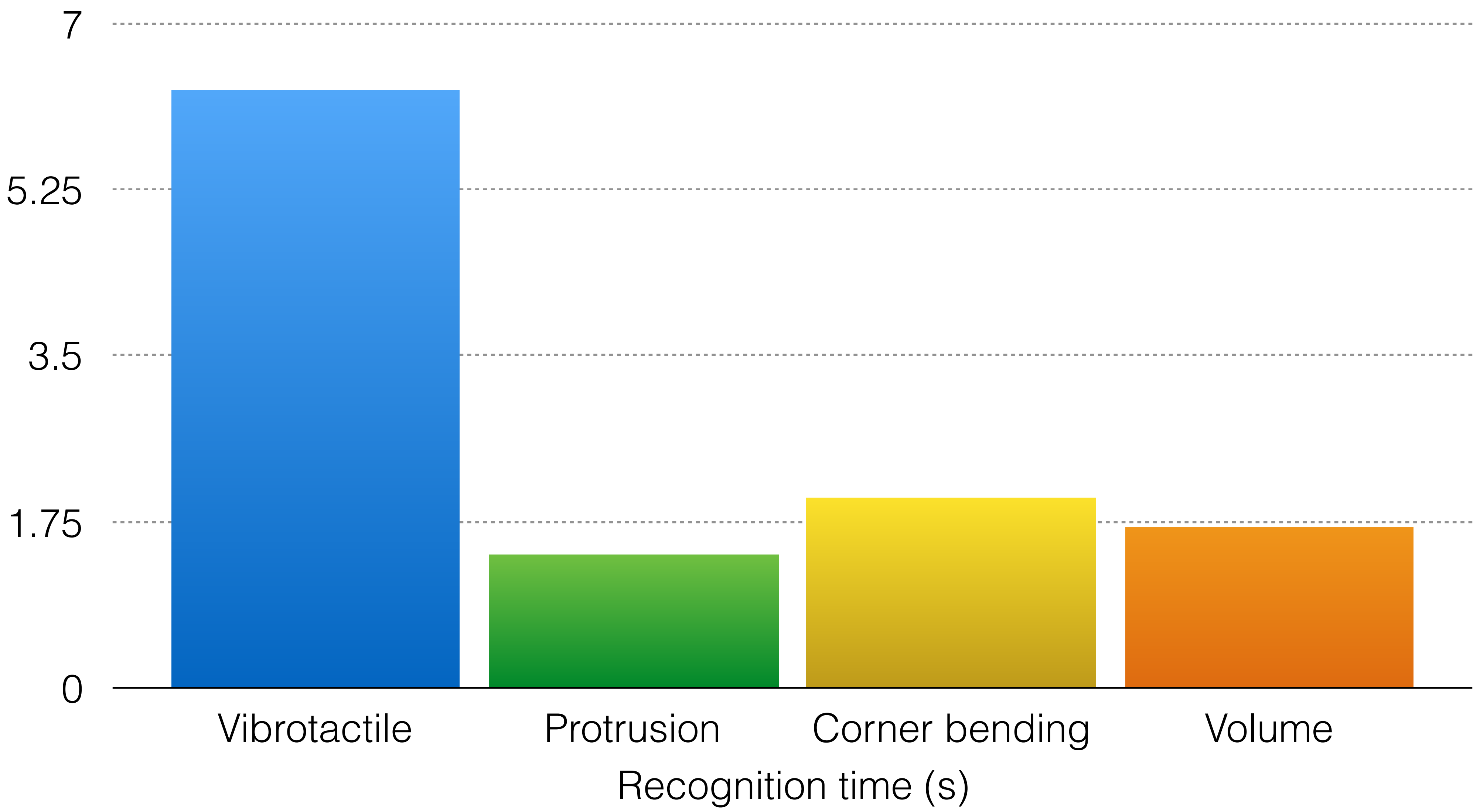
For notifications

- Task
  - Participants walk
    - with device in pocket, facing body
    - with headphones playing white noise
  - 5 notifications, lasting each 20s (~ phone call)
  - Participant presses a physical button held in their dominant hand
    when they feel the device move

For notifications



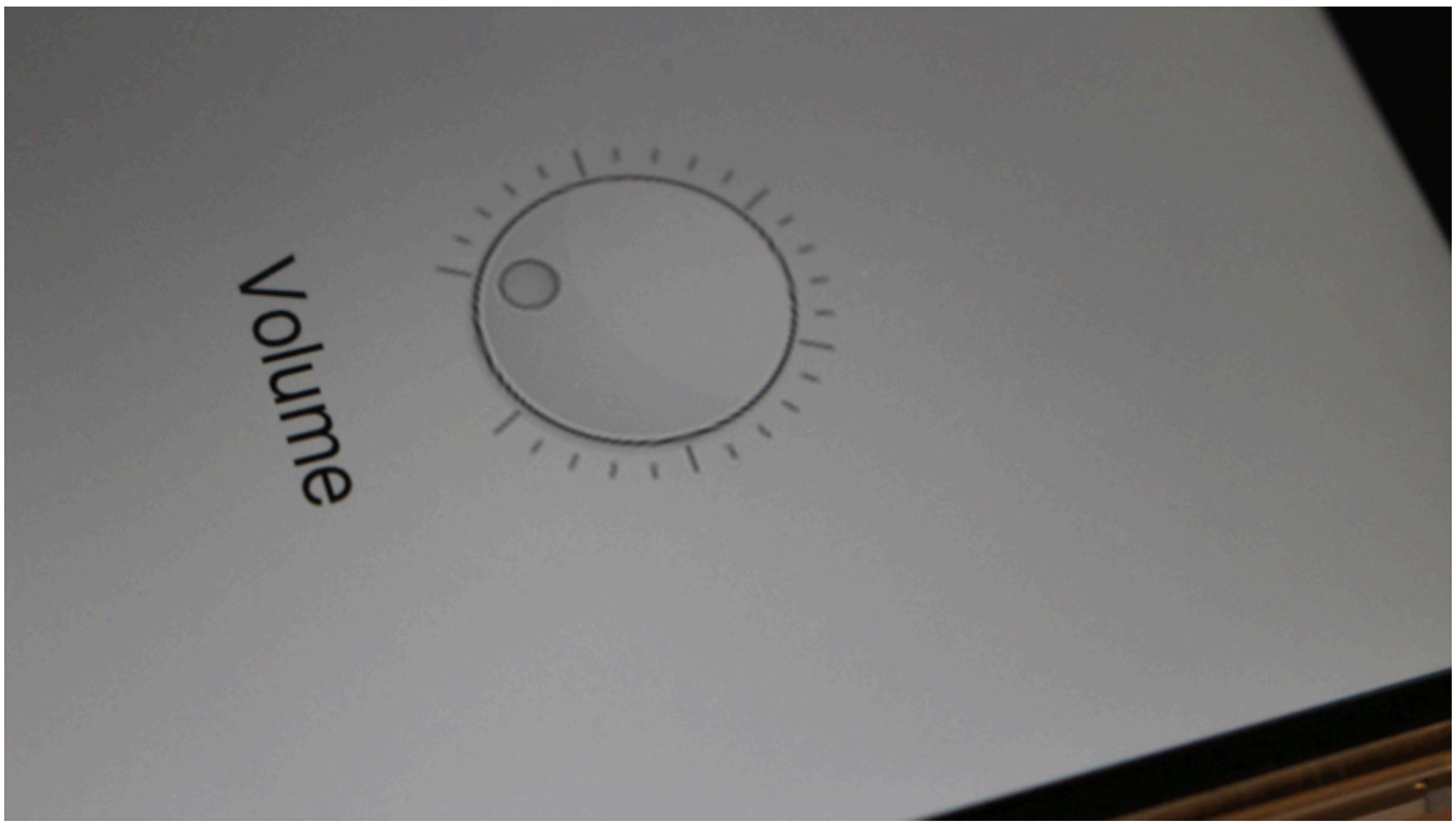
For notifications



For notifications

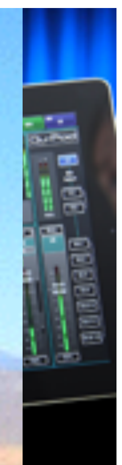
- Limitations of this study?

Switching between tangible controls and touchscreen



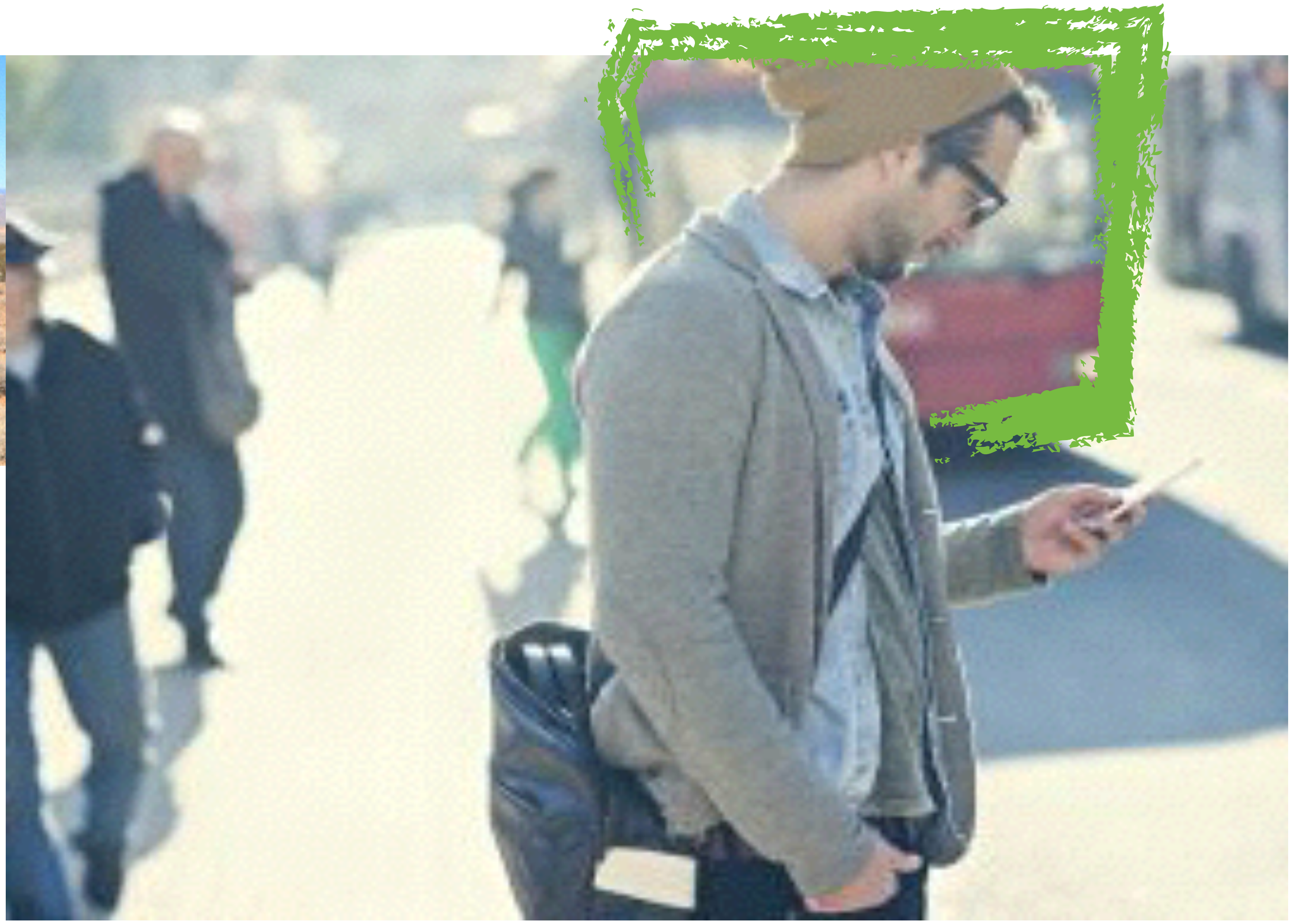
Mobile UIs lack tangibility

Mobile UIs lack tangibility

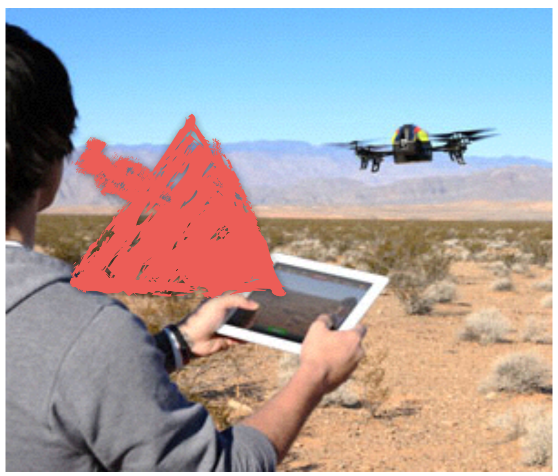




Mobile UIs lack tangibility

Mobile UIs lack tangibility



Mobile UIs lack tangibility

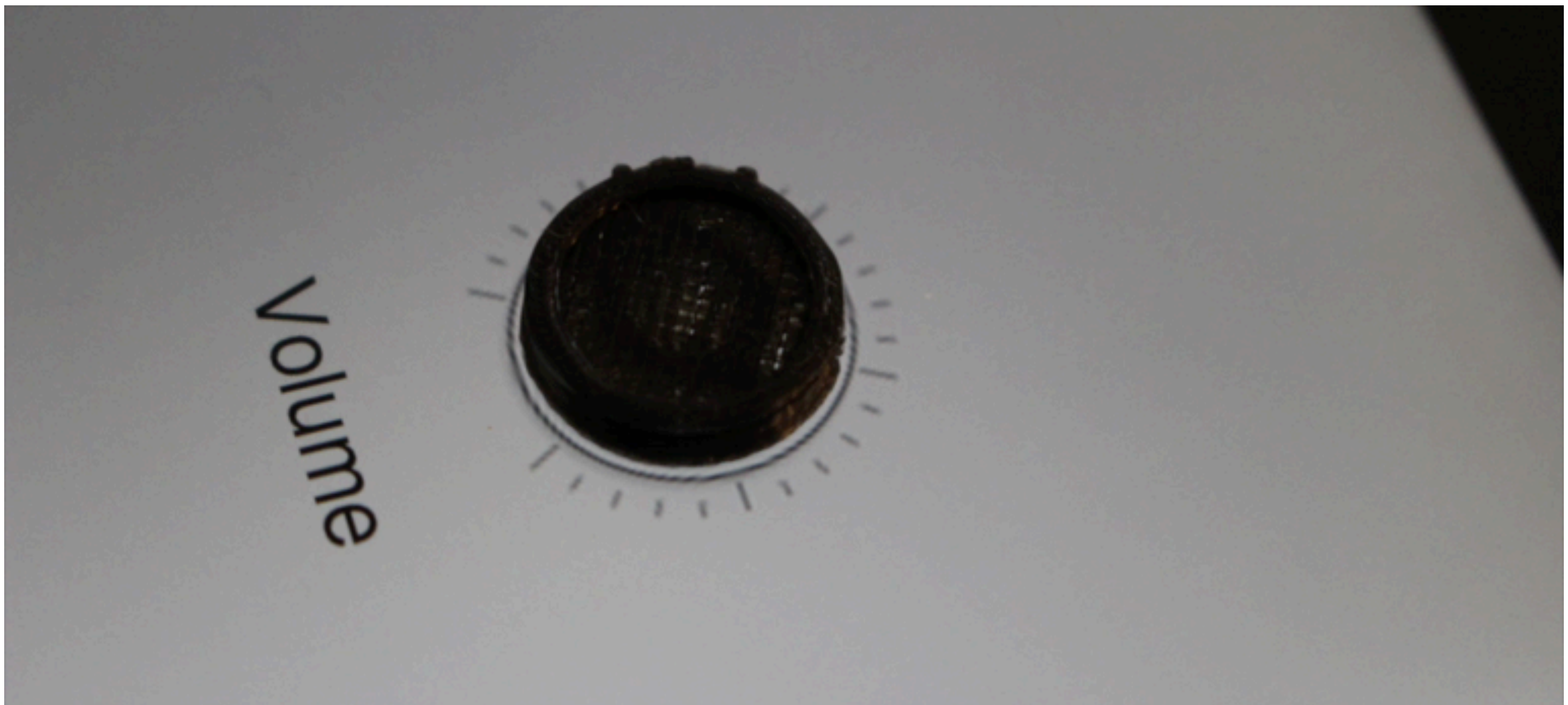


Preference

Performance

Safety

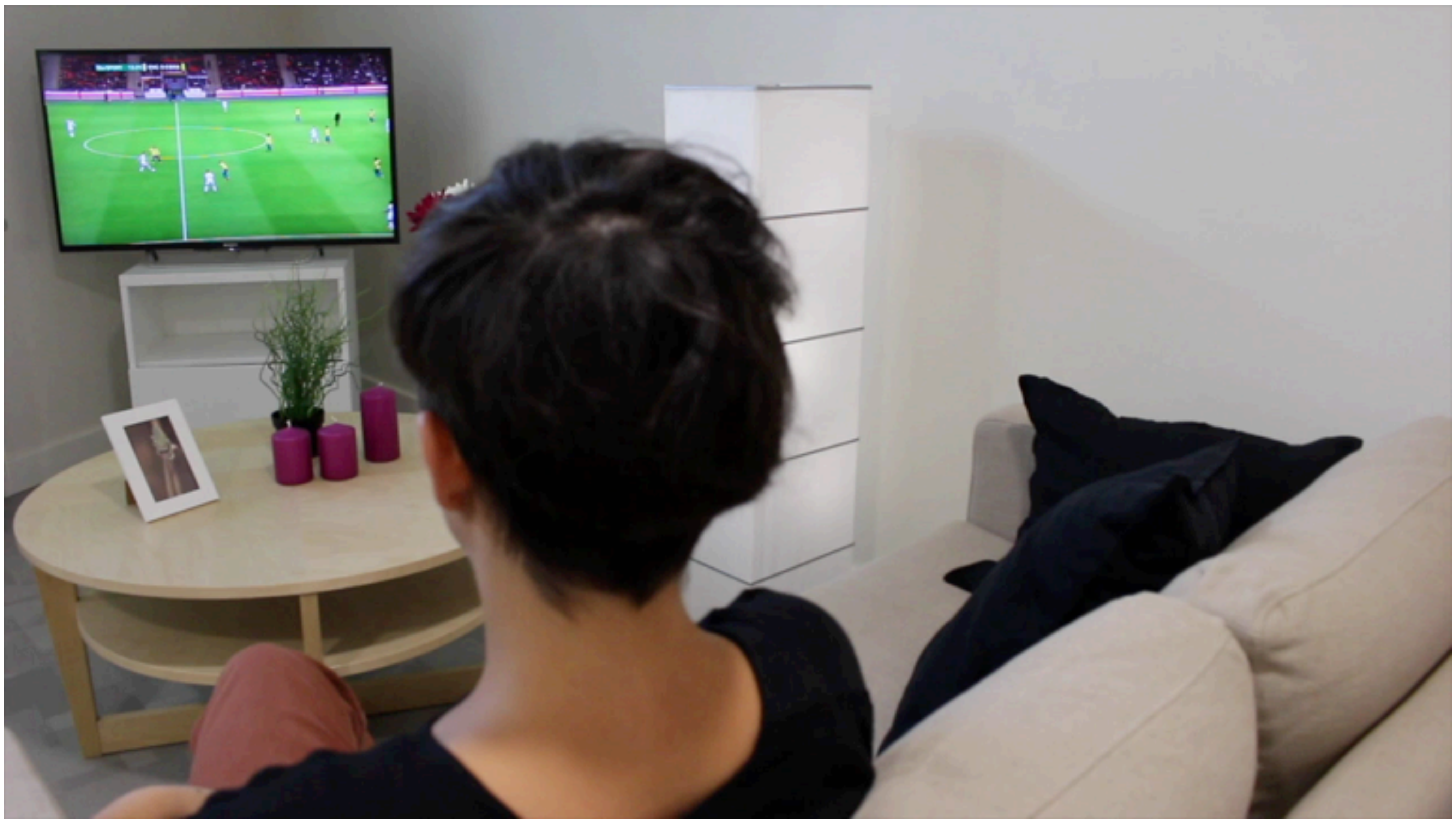
Emergeables



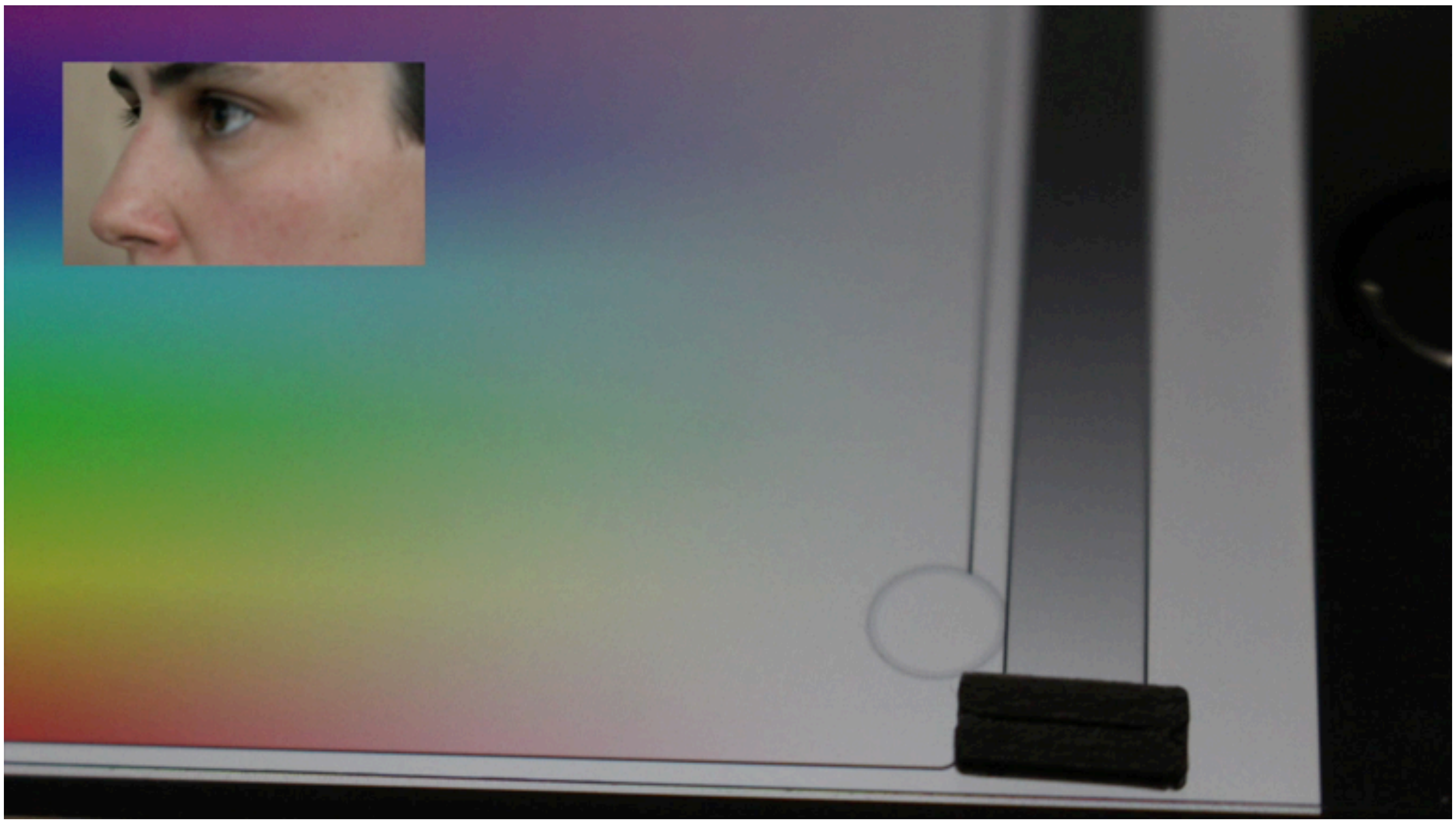
Emergeables

Emergeables

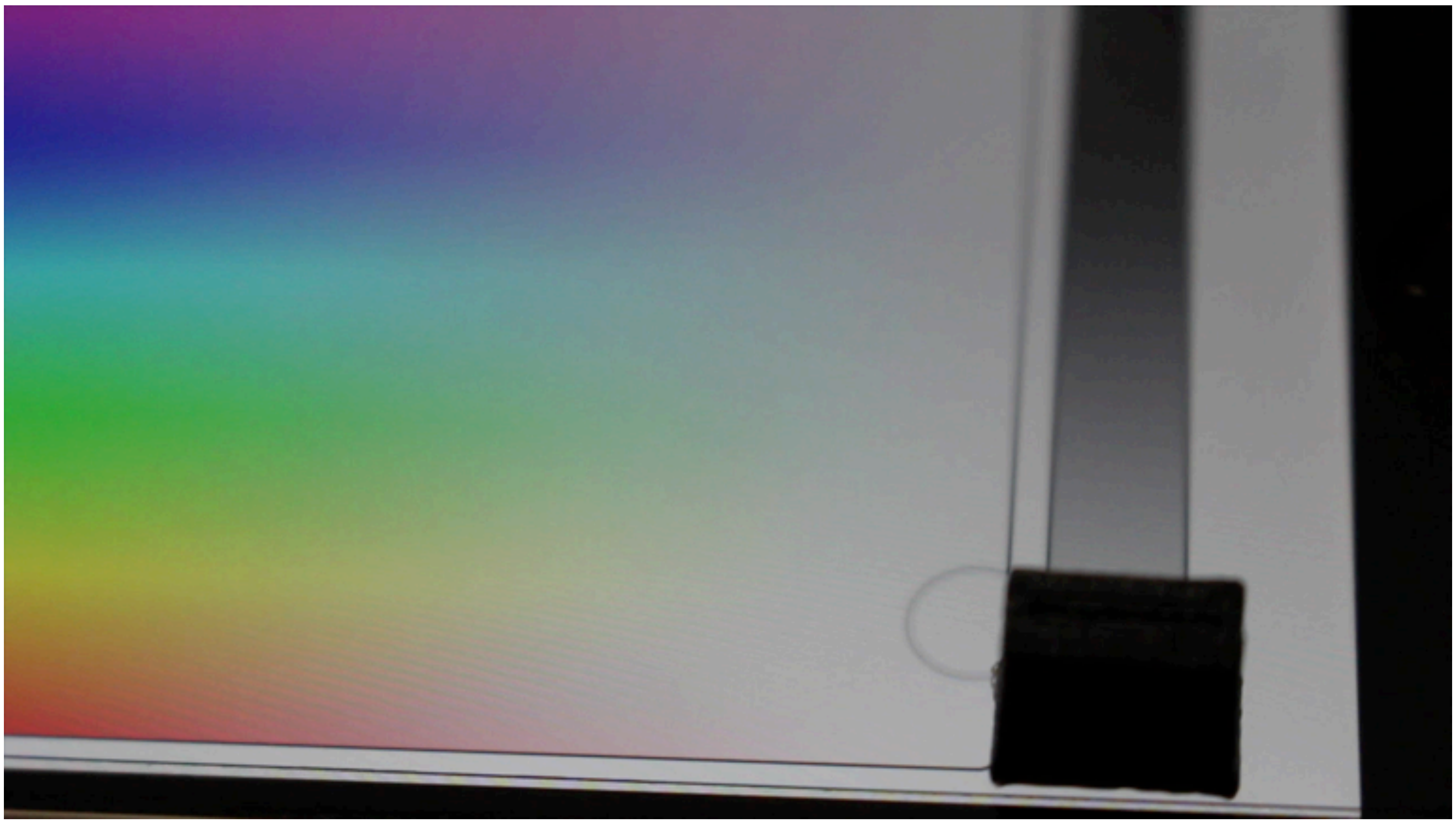
Emergeables



Emergeables



Emergeables



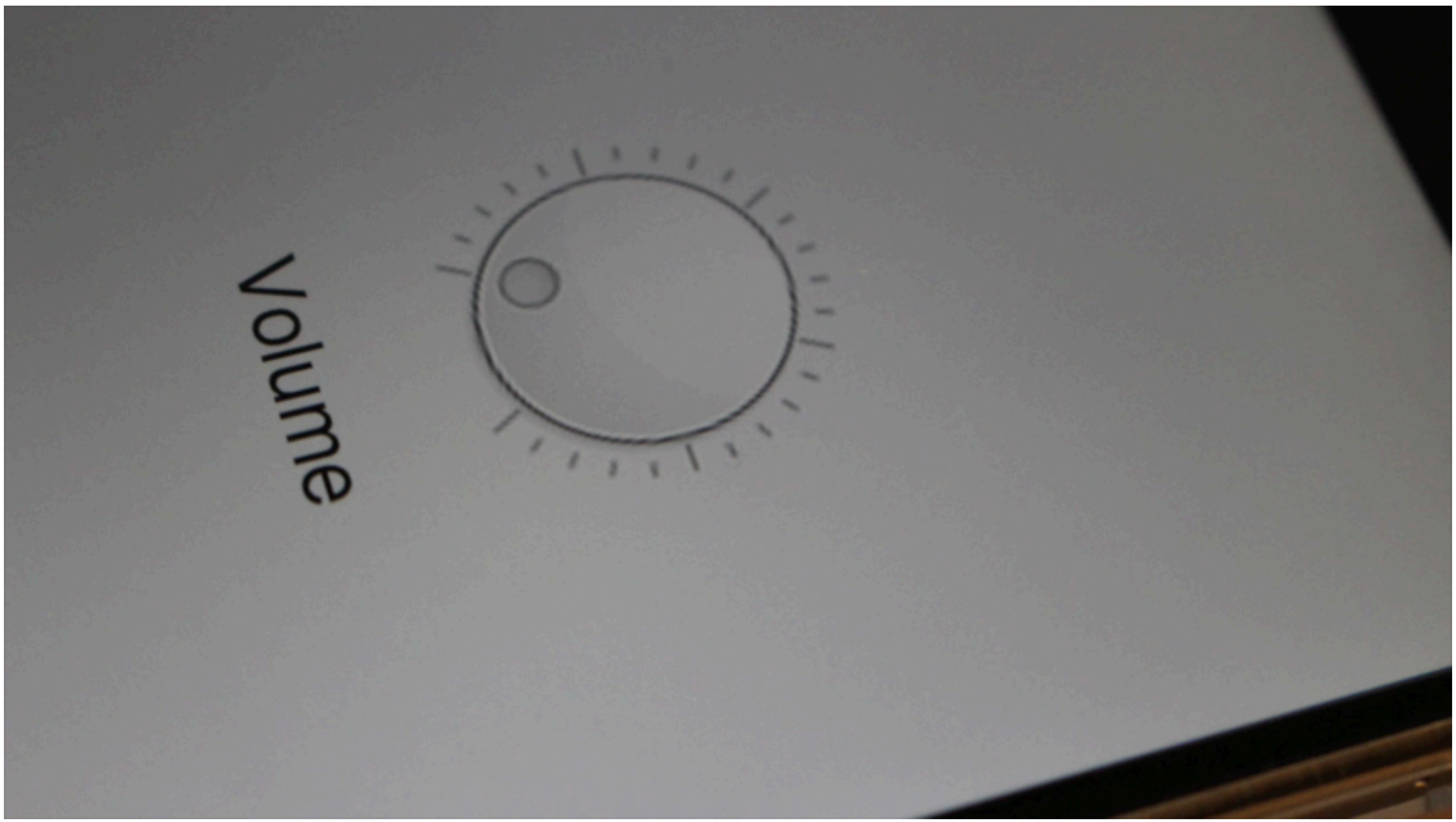
Emergeables

Emergeables

**During half-time
and advertisements**

Emergeables

Emergeables



Emergeables

Emergeables

Benefits of Emergeables vs. new interaction

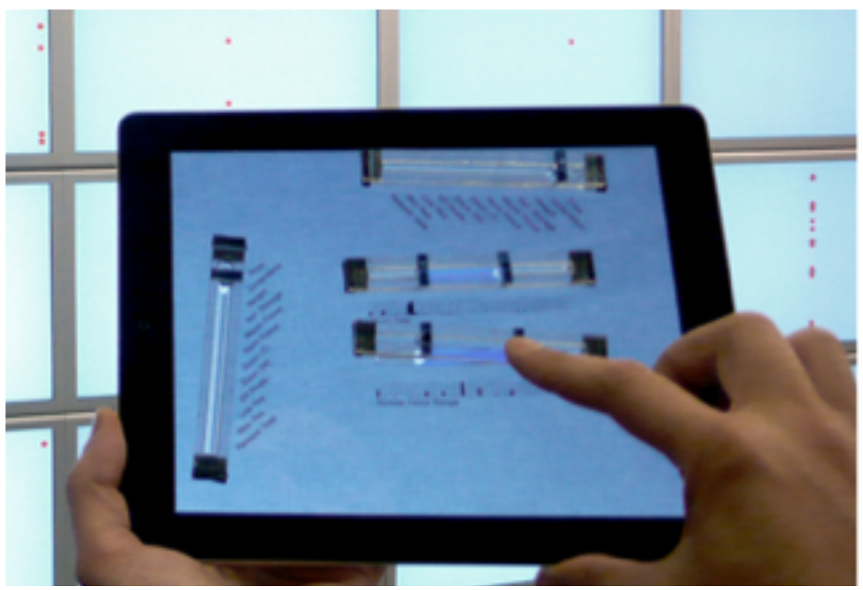
Karrer *et al.*, 2011

Serrano *et al.*, 2014

Ramakers *et al.*, 2014

known tangible controls

Benefits of Emergeables vs. additional controls

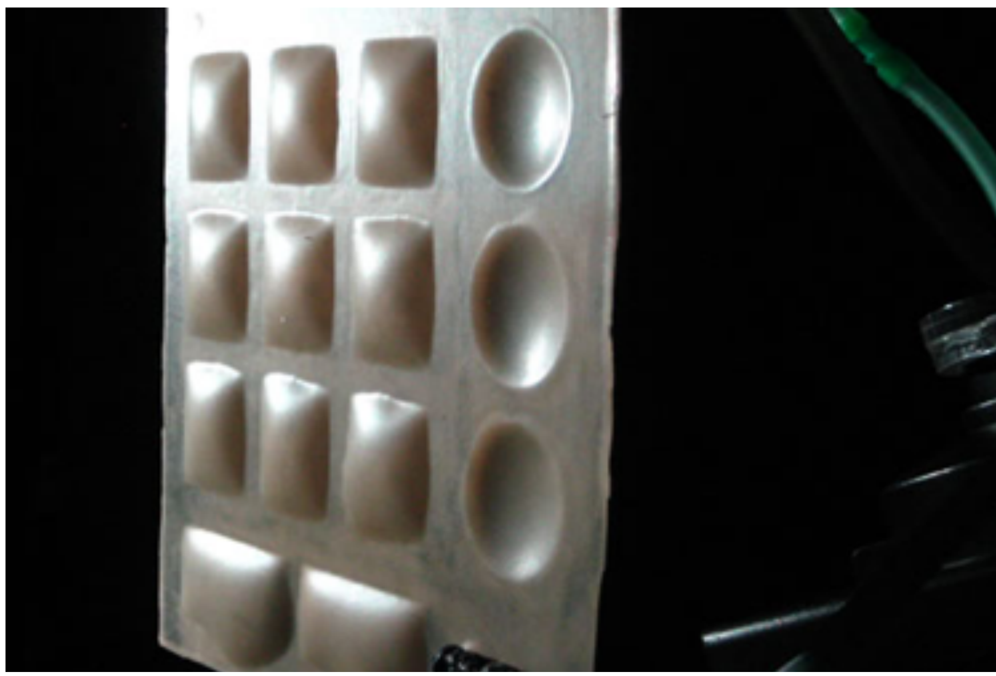


Jansen *et al.* 2012

Florian Born, 2013

no additional configuration

Benefits of Emergeables vs. discrete control



Harrison and Hudson, 2009

http://tactustechnology.com

continuous control

Benefits of Emergeables for eyes-free mobile tasks

+ known tangible controls

+ no additional configuration task

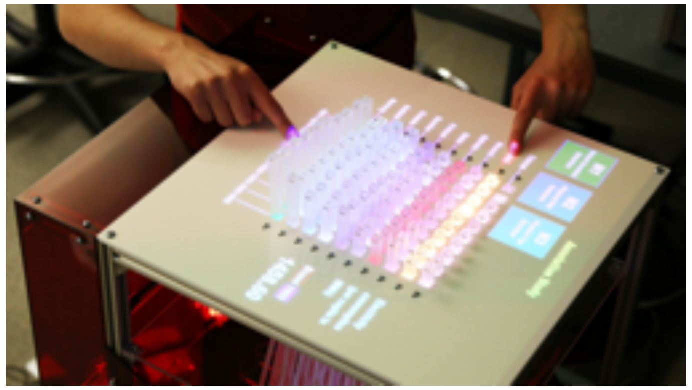
+ continuous control

Difficulty: technology

Technology:
current approach

Poupyrev *et al.*, 2004

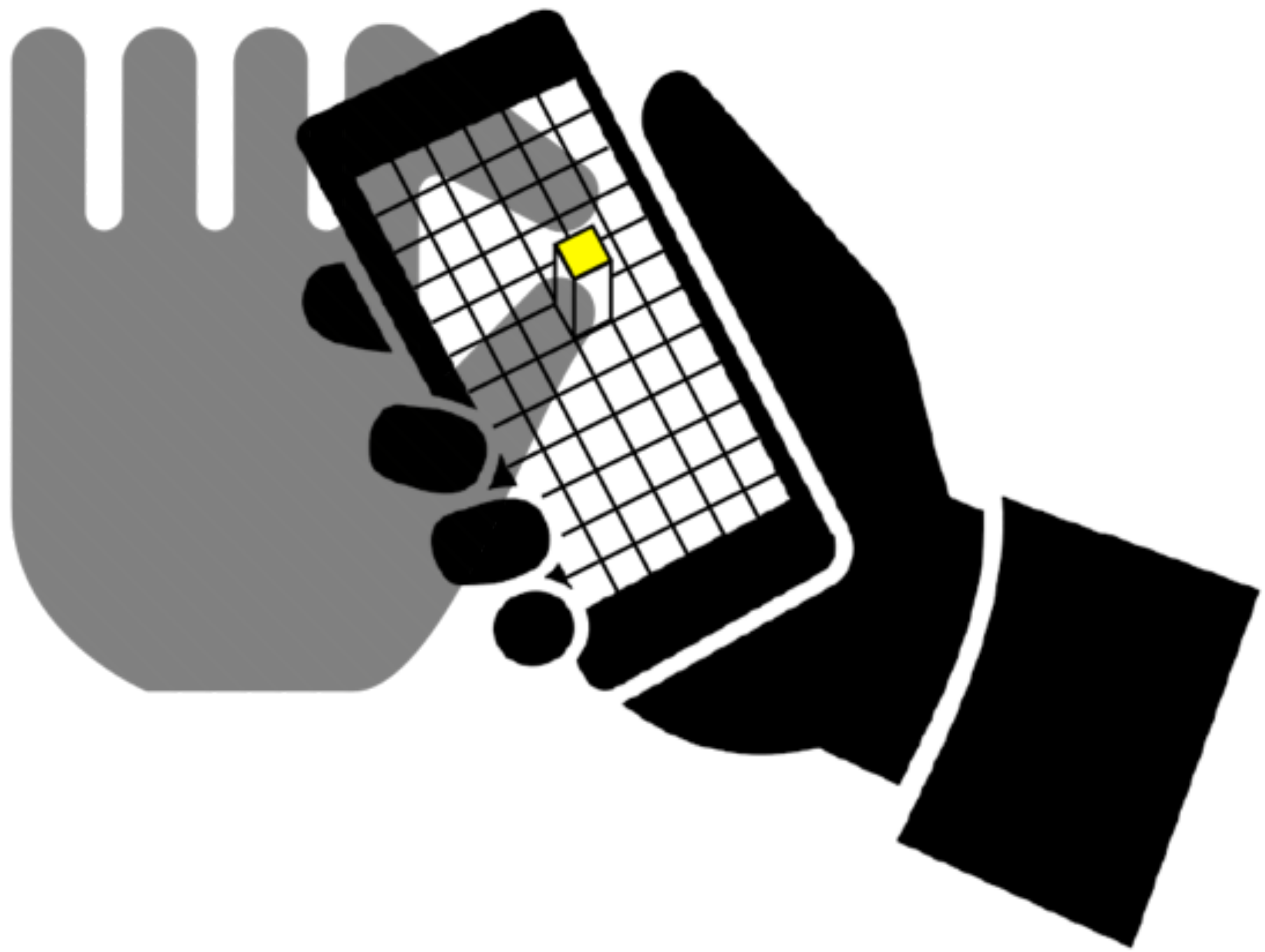
Follmer *et al.*,
2013



Taher *et al.*, 2015

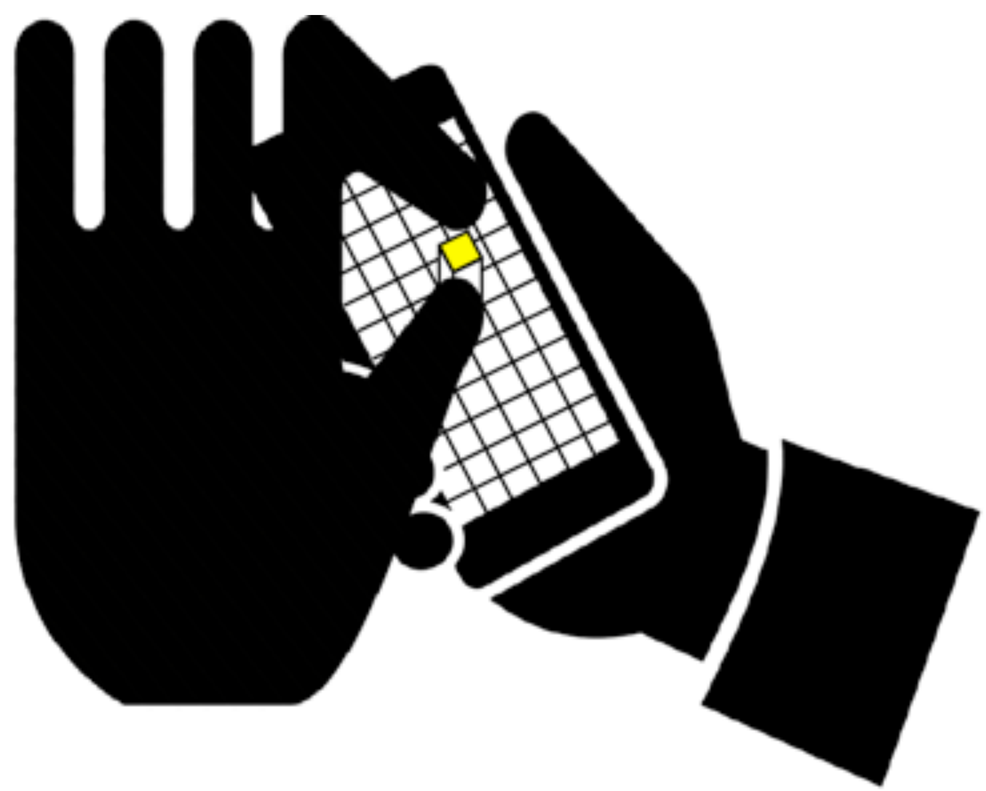
Our approach

Manipulation

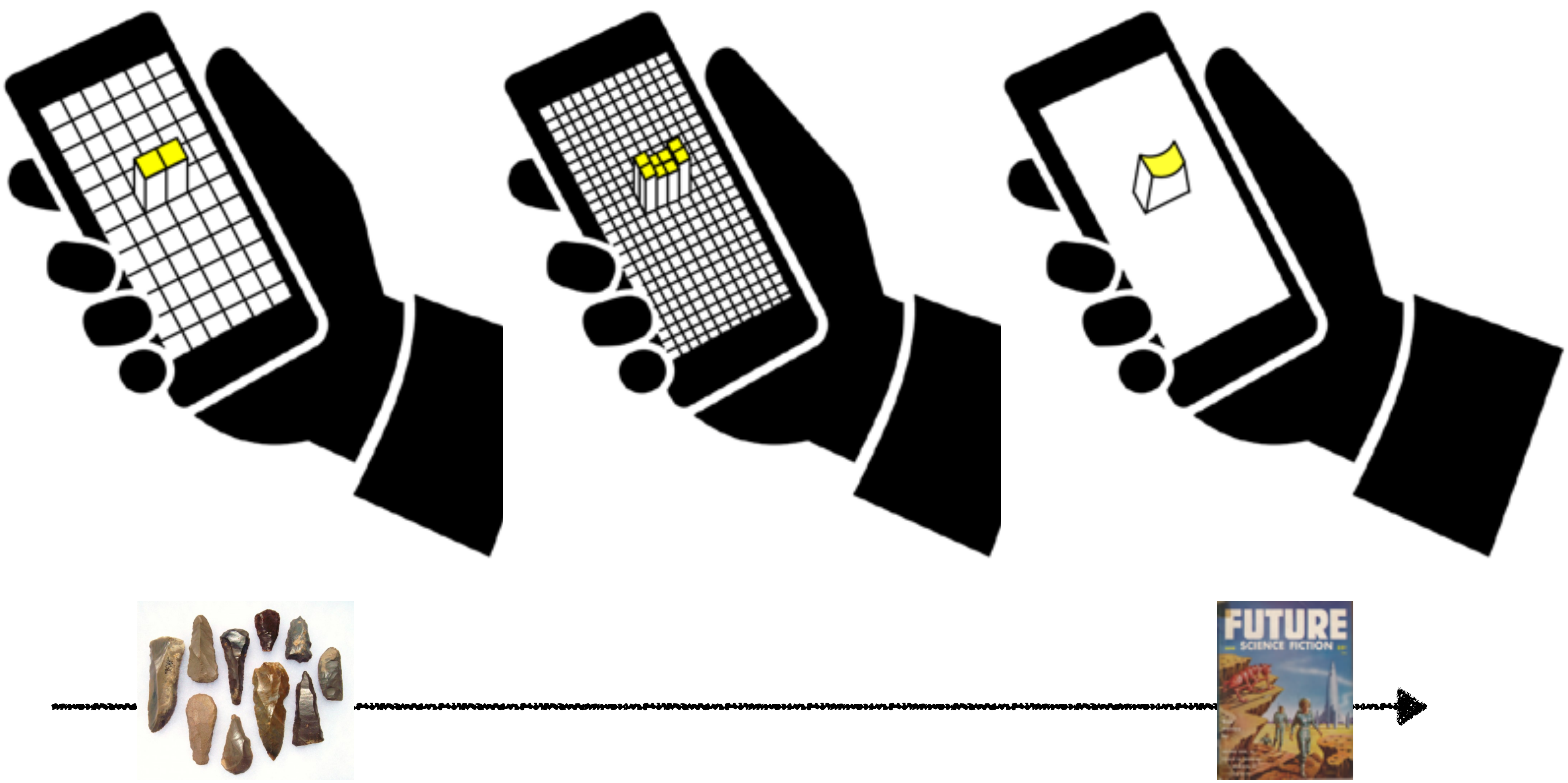


Manipulation: Translation

Manipulation: Rotation

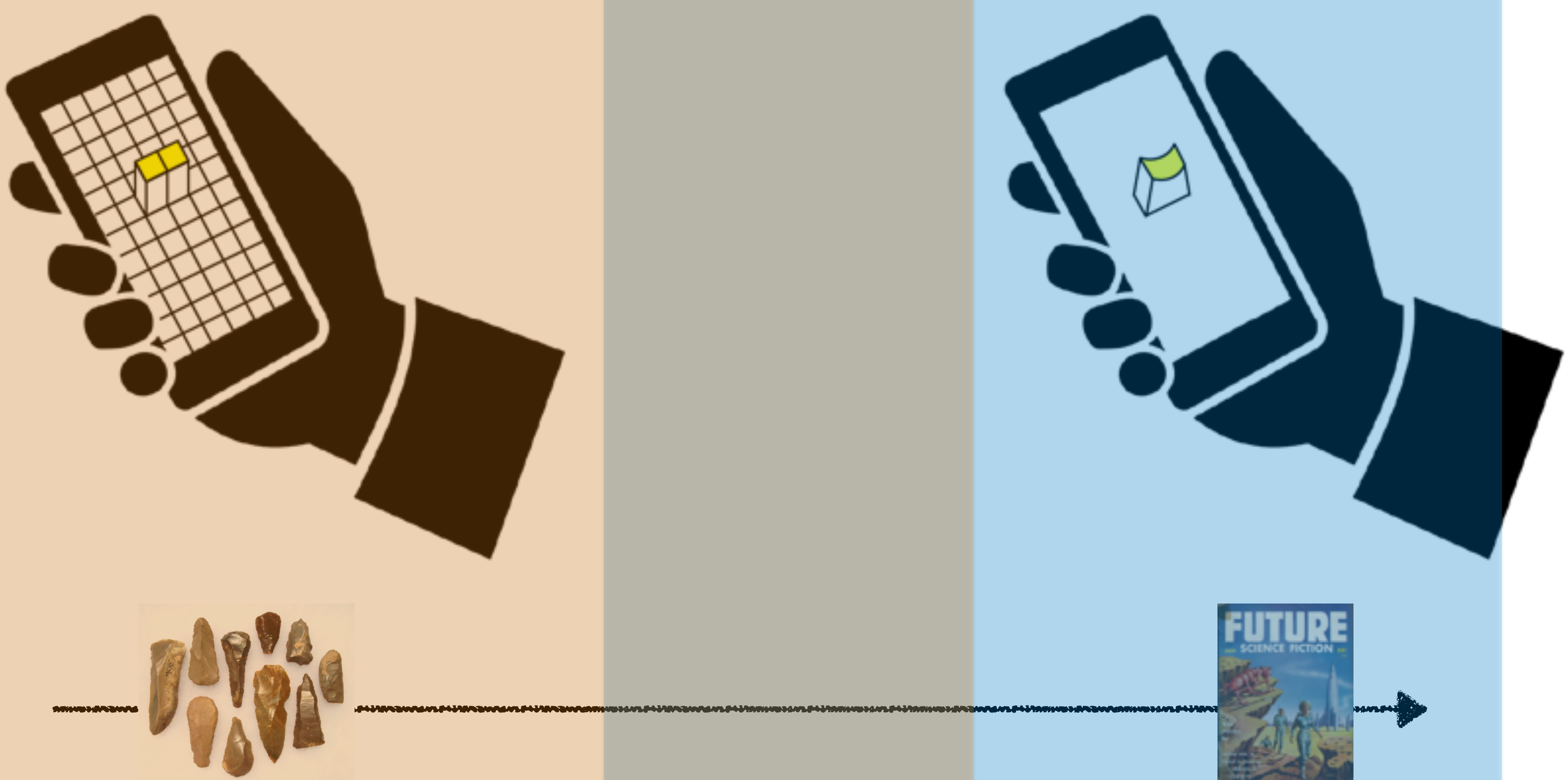


Resolution

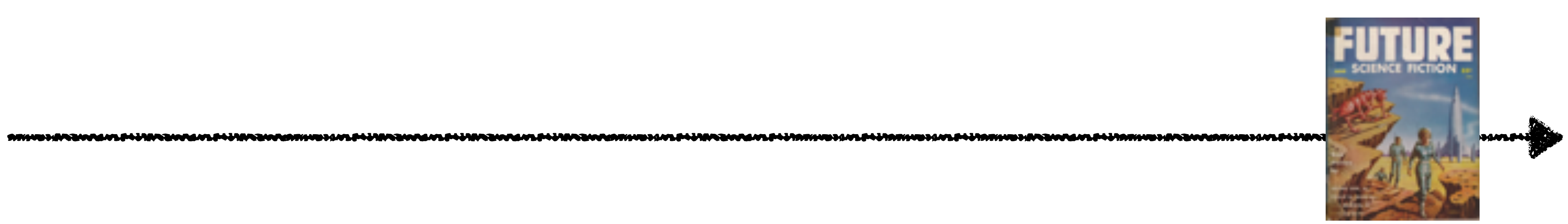


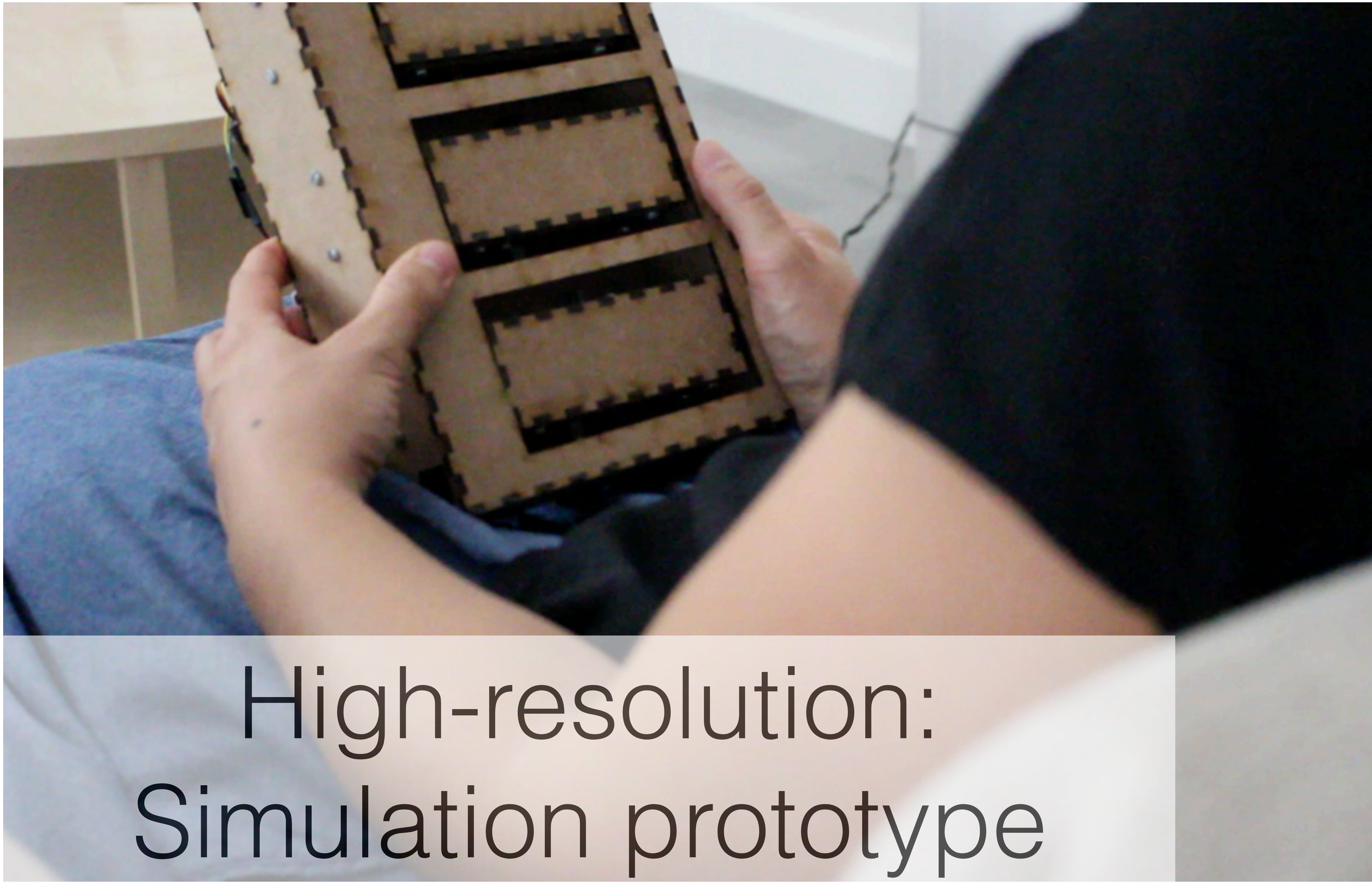
Is it worth the effort?

How far are we today?

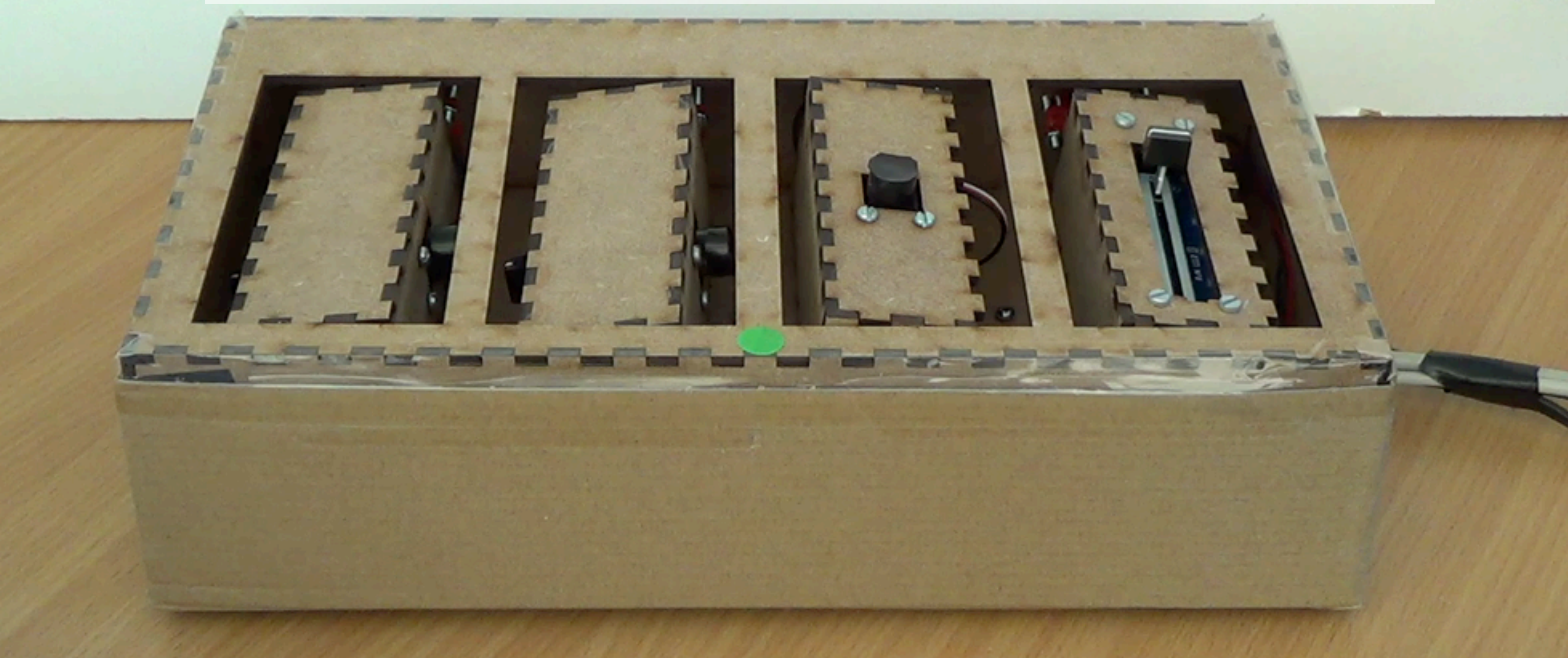


Prototype simulating high-resolution: tailored for experiment

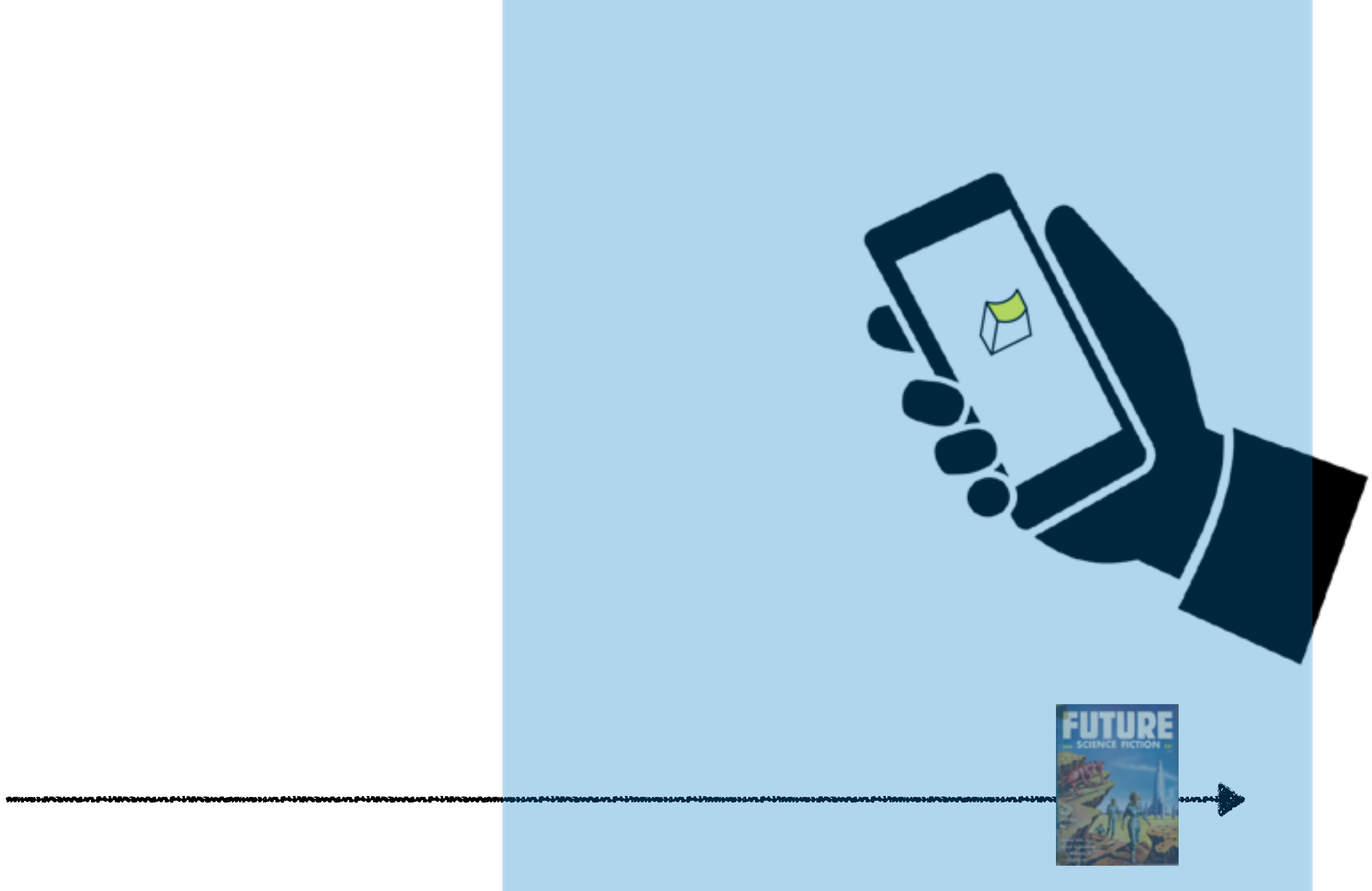



High-resolution:
Simulation prototype

High-resolution: Simulation prototype



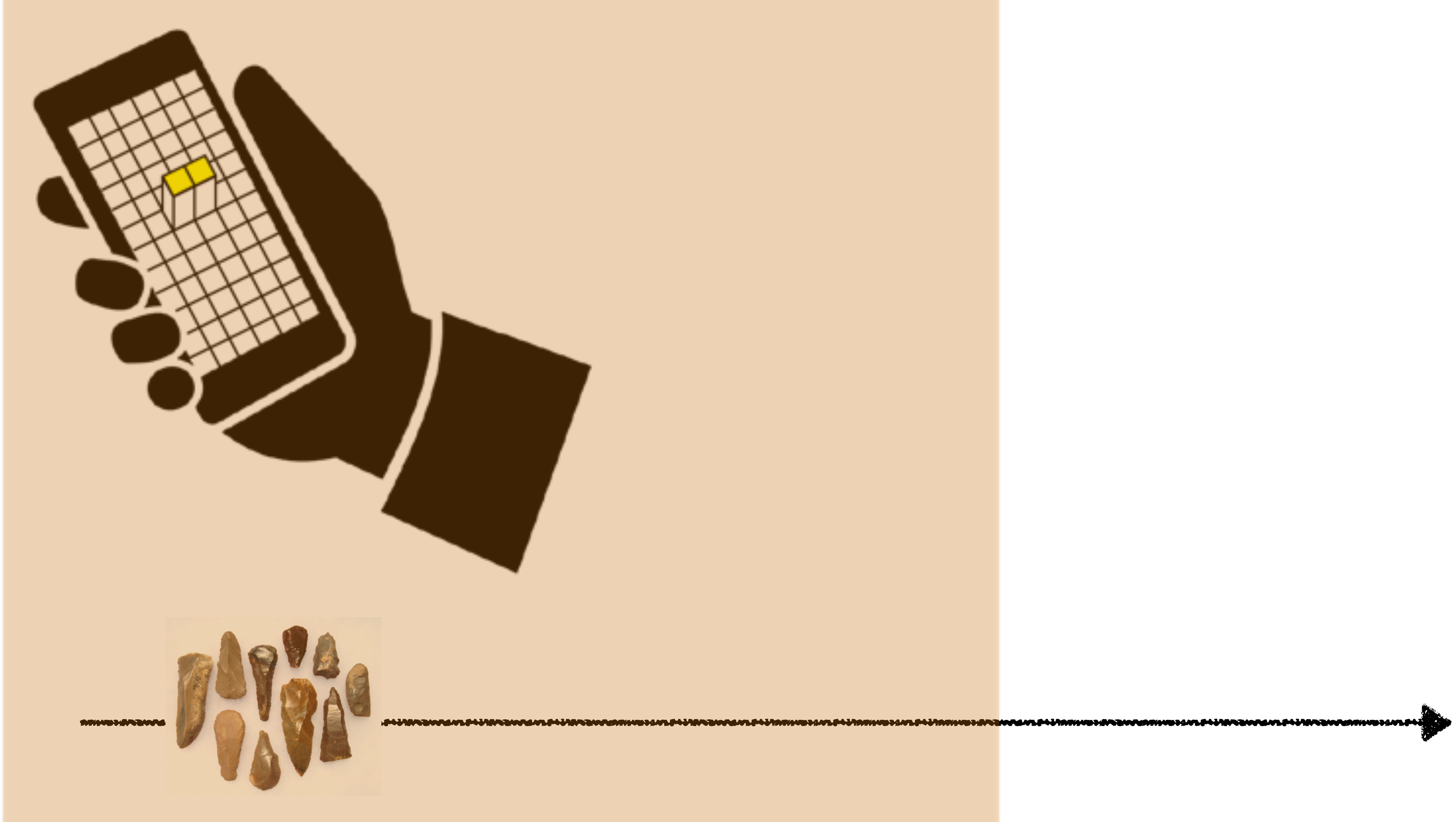
Is it worth the effort?



Is it worth the effort?

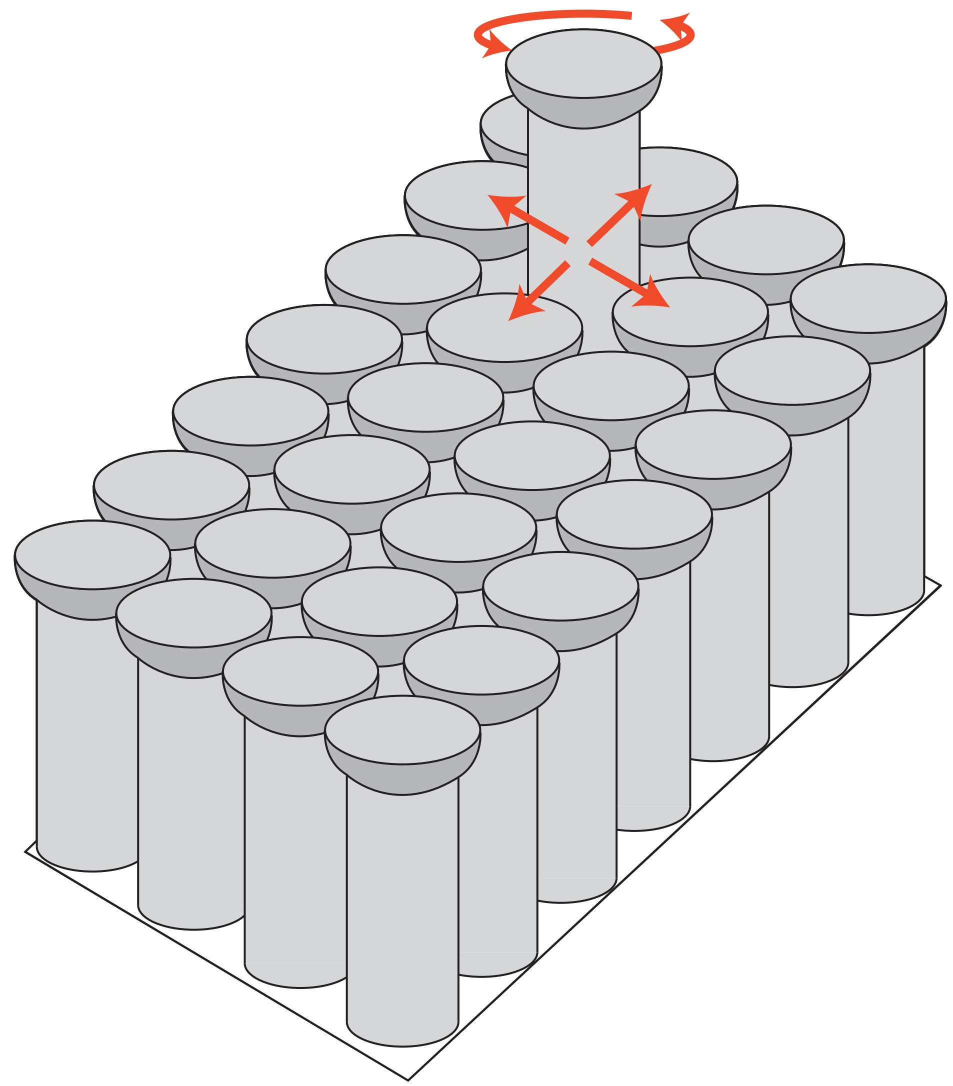
How far are we today?

How far are we today?



Low-resolution prototype

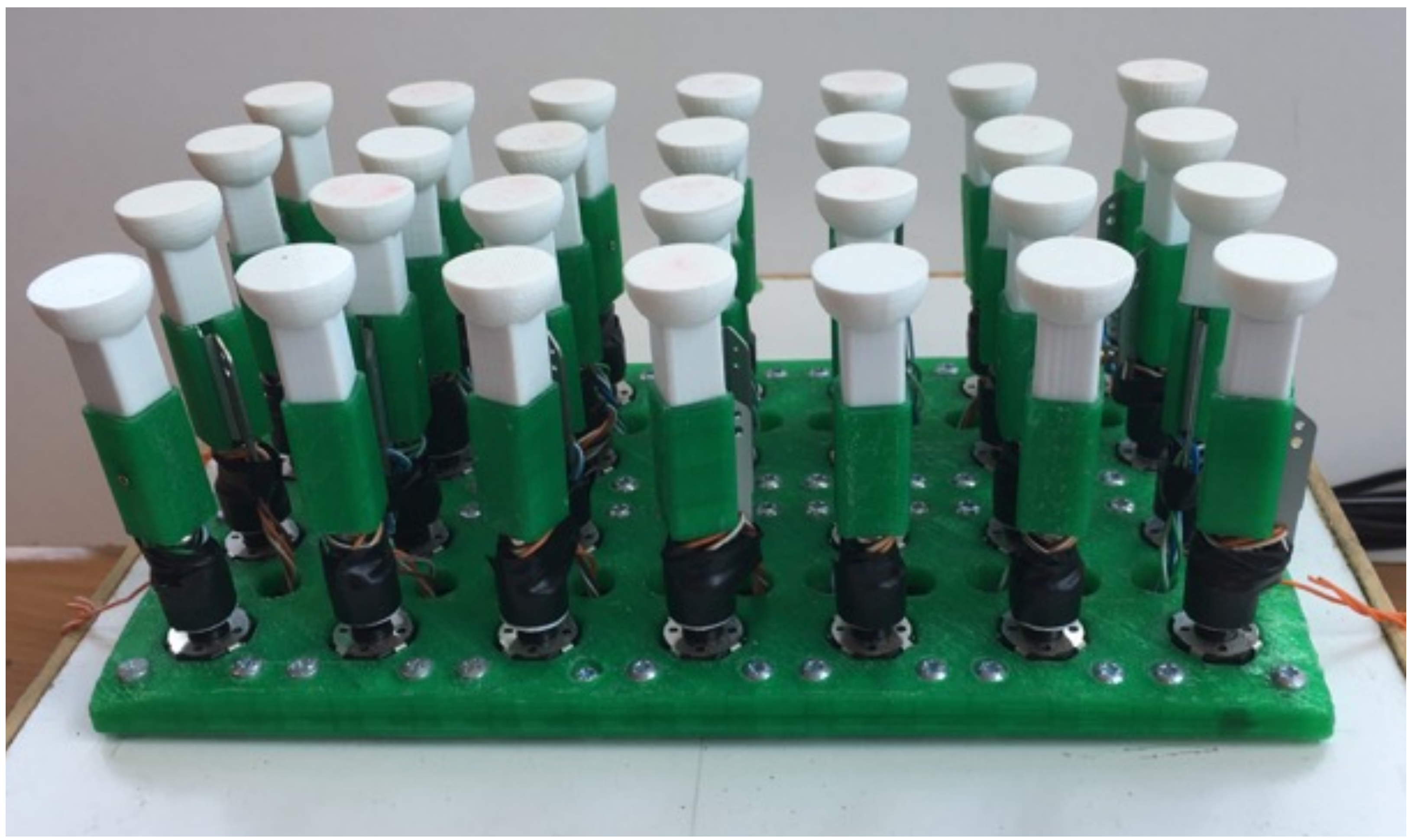
Design



Components

Components

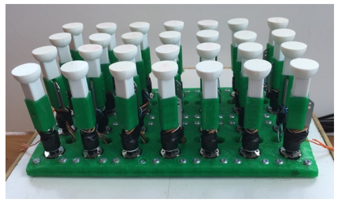
Prototype



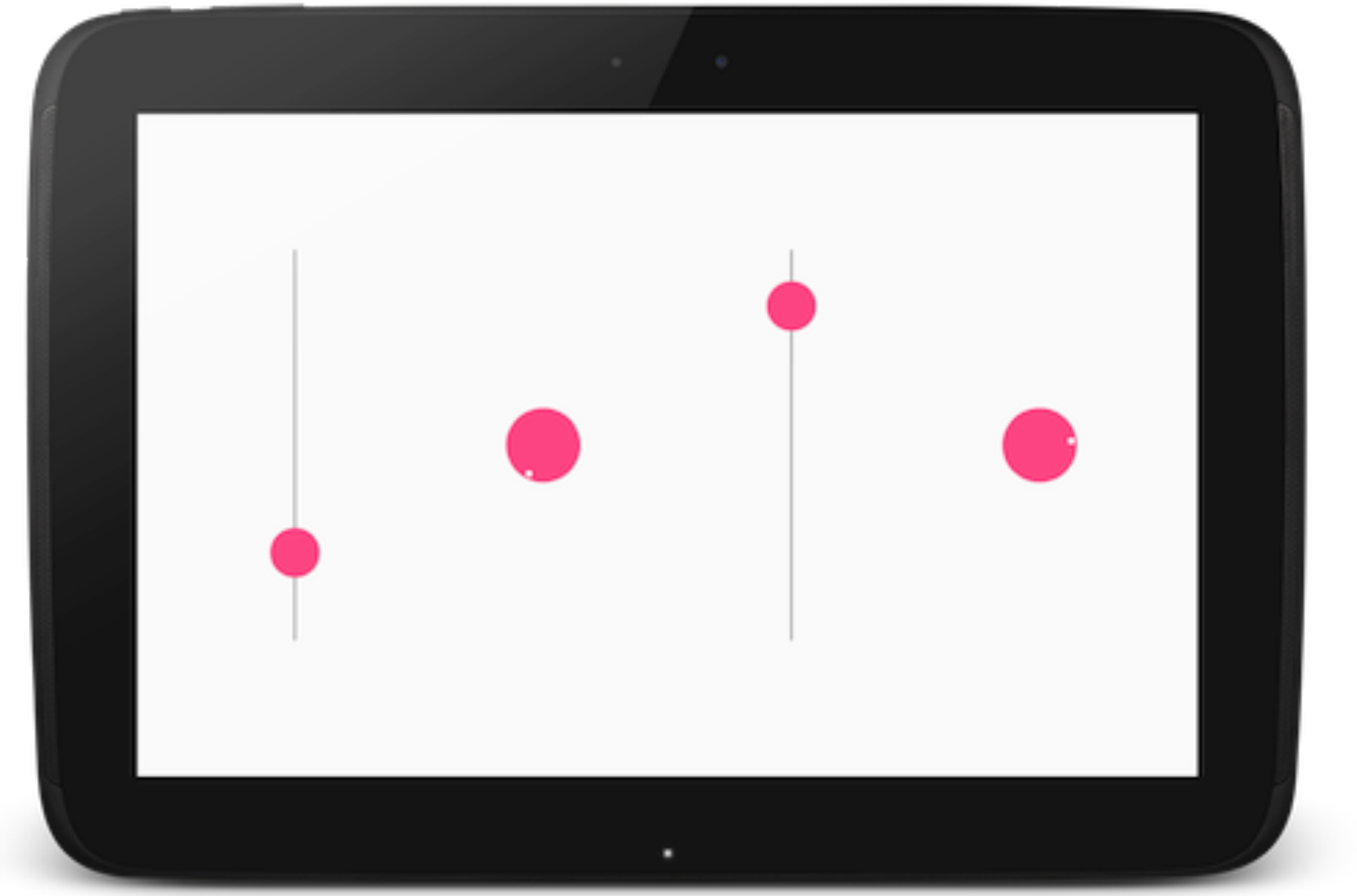
Controls

Experiment

Experiment

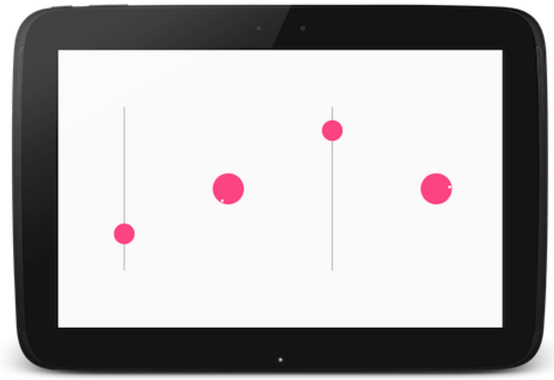
- Within-subjects design
- Three interfaces:
  - High-resolution prototype 
  - Low-resolution prototype 
  - Graphical comparison interfa 

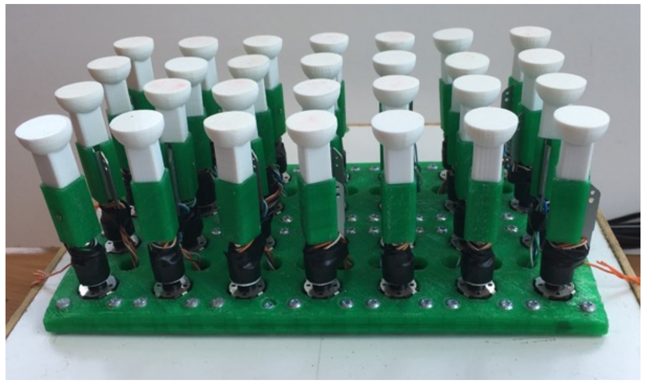
Experiment

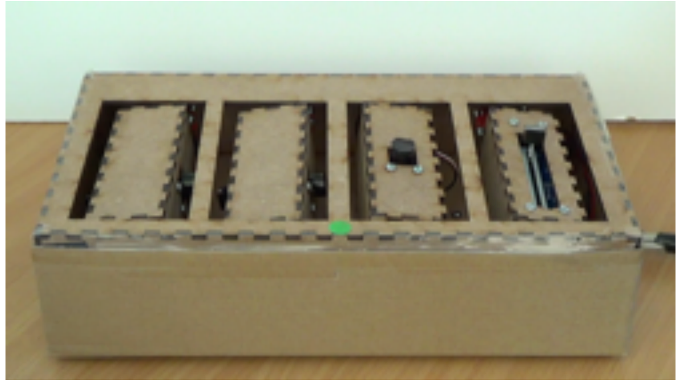


Experiment

Resolution

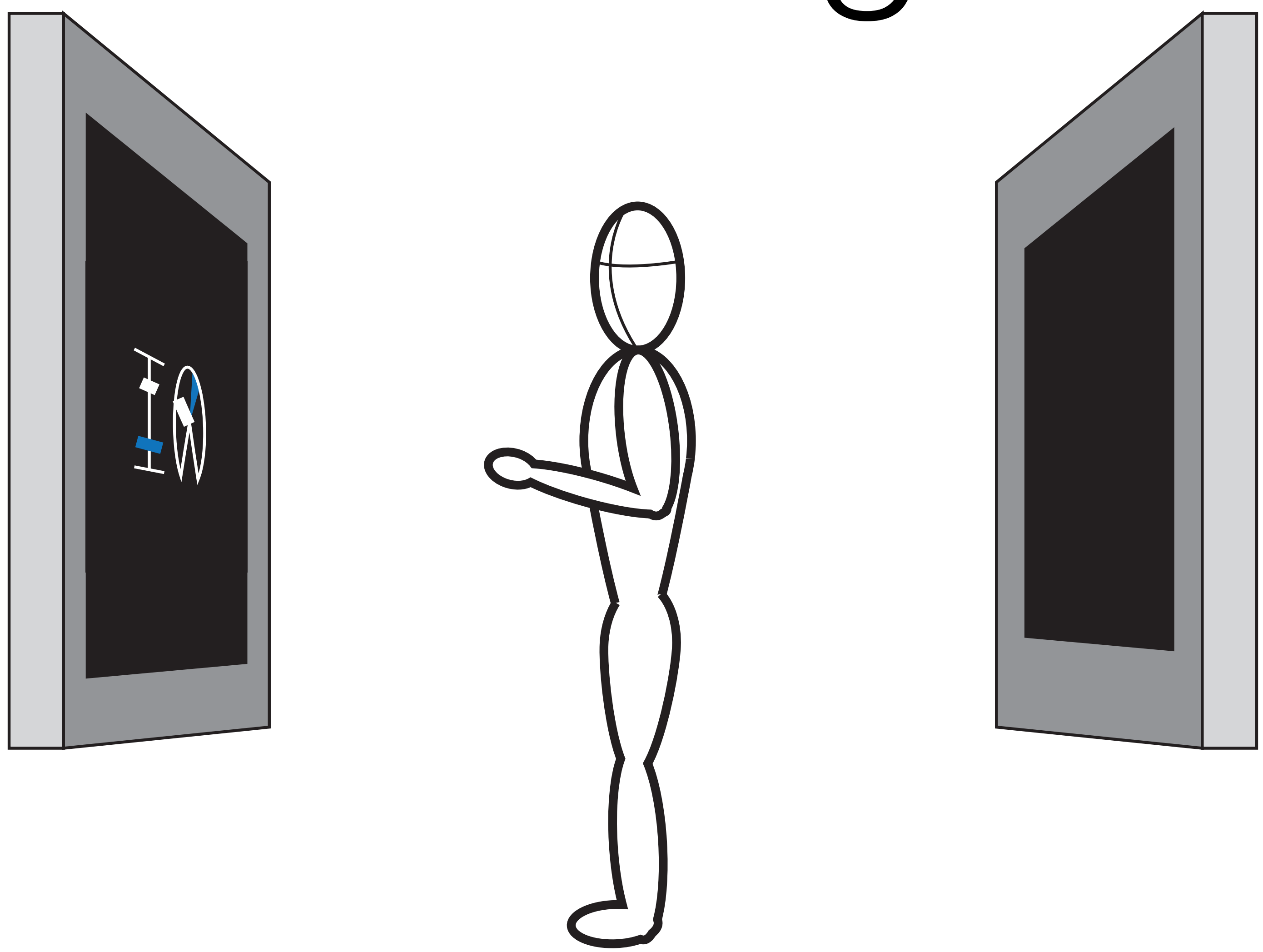




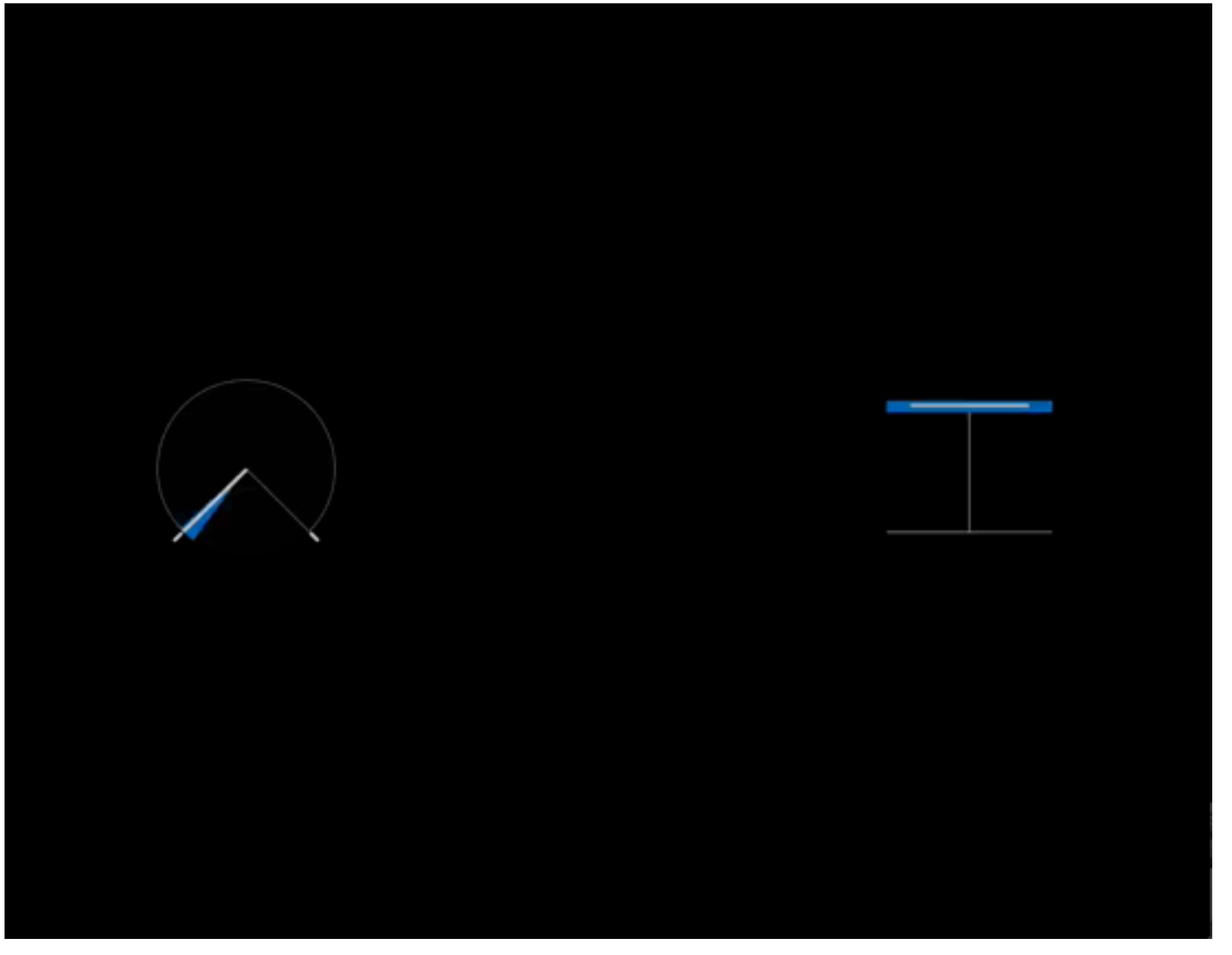


Widget

Setting



Pursuit Tasks

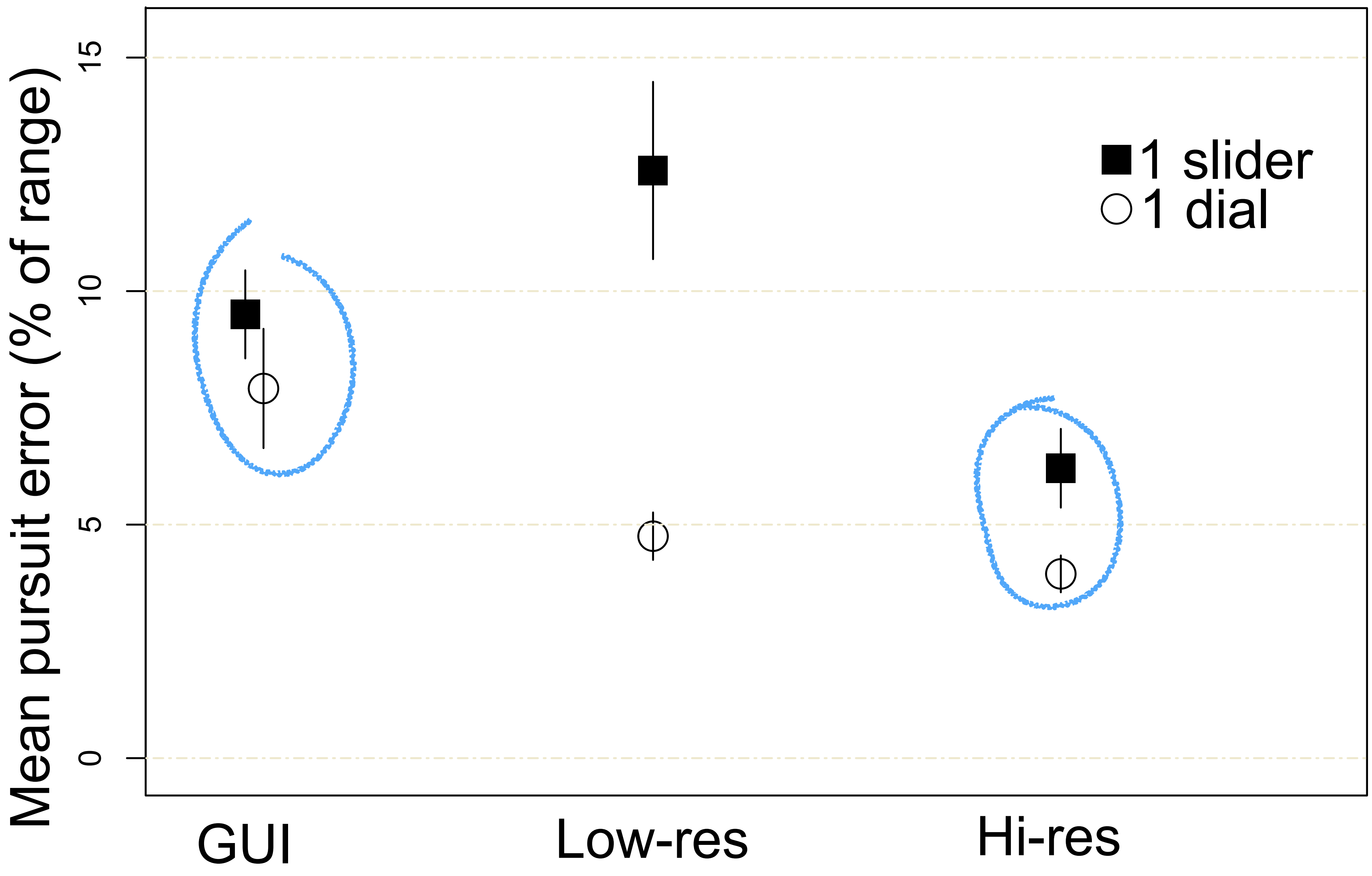


Measures

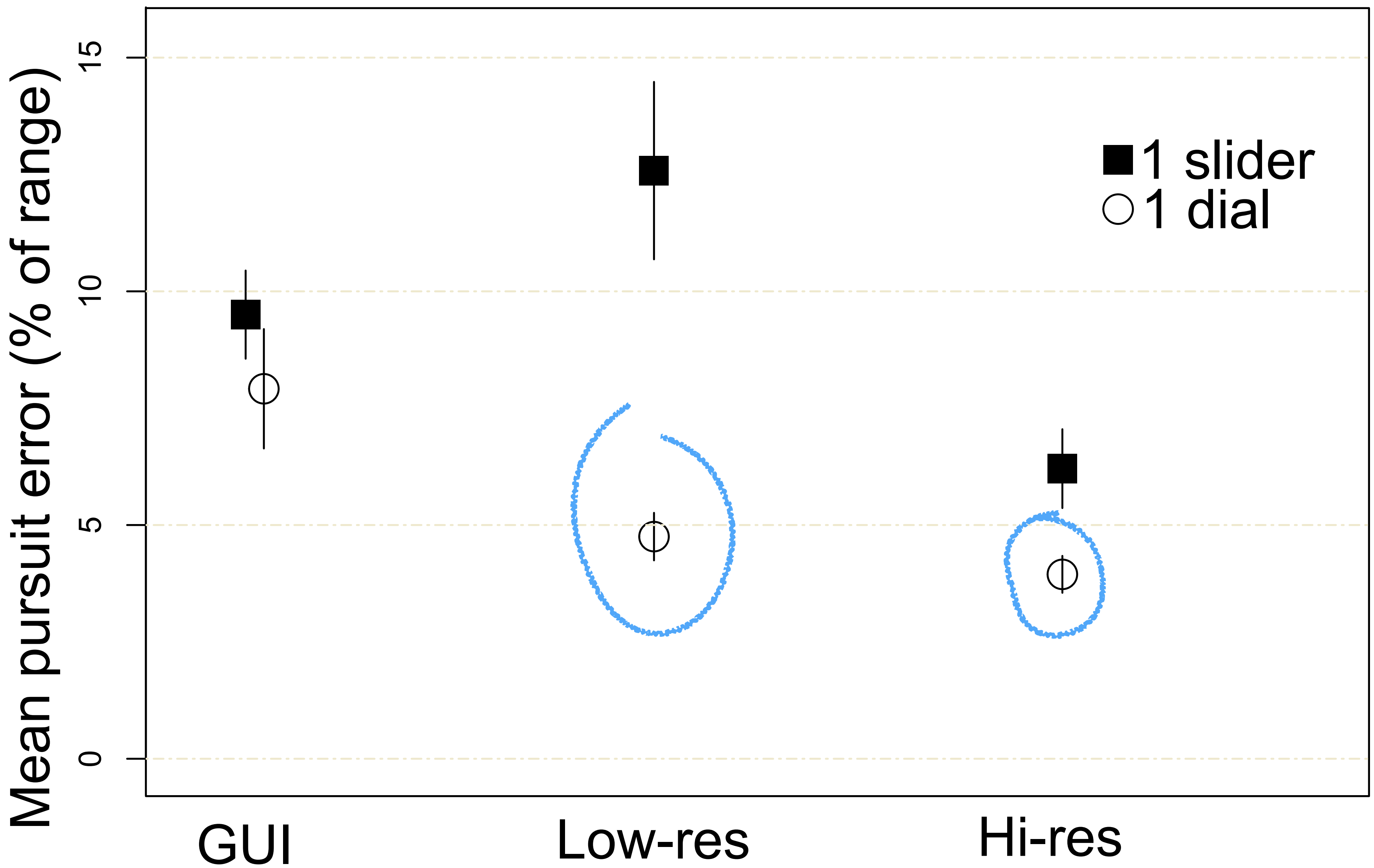
- Pursuit accuracy
- Visual attention required
- Perceived usability
  - Ease of use (1 – 10)
  - Rank interfaces
    in order of perceived visual attention required

Results

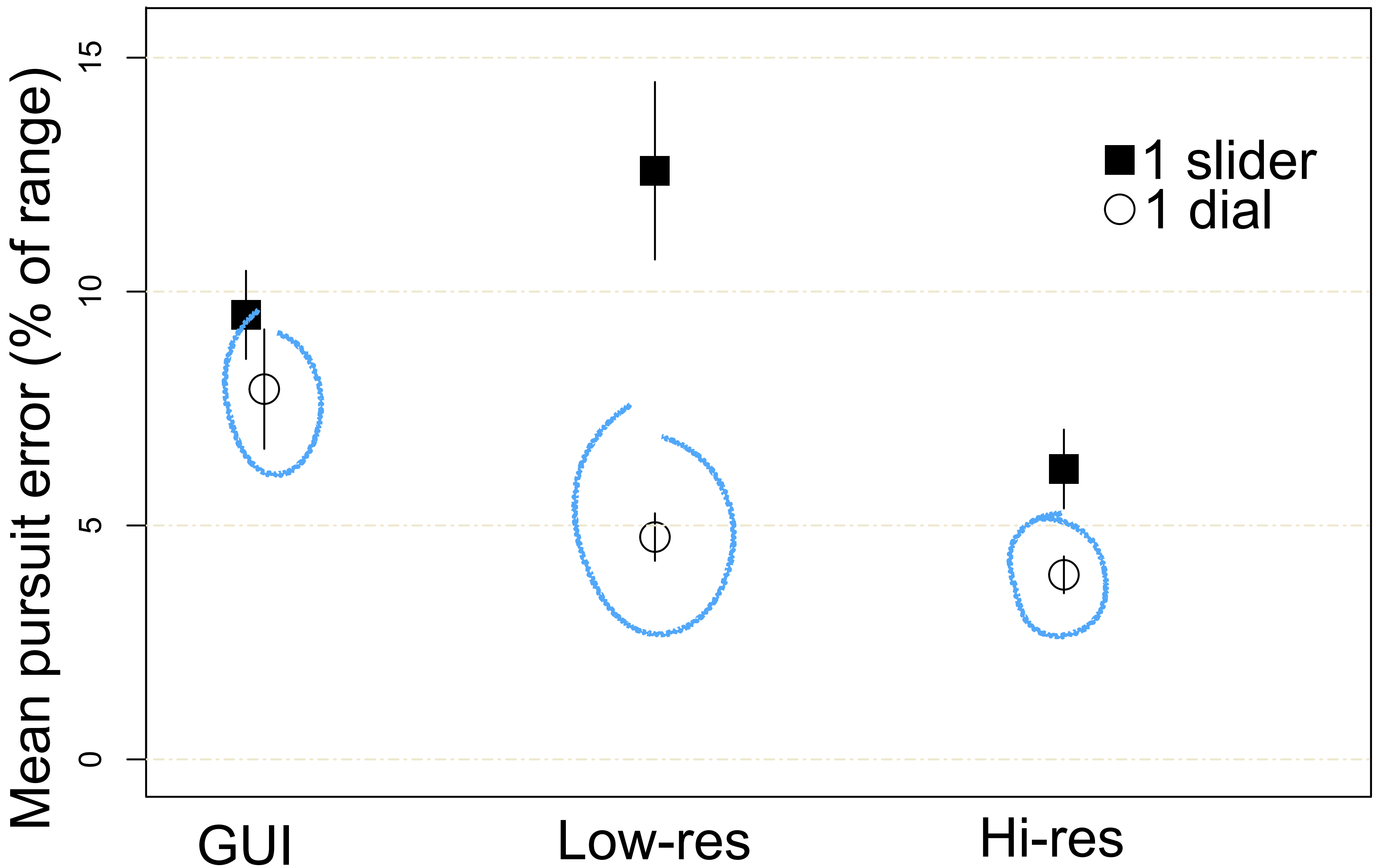
Pursuit error



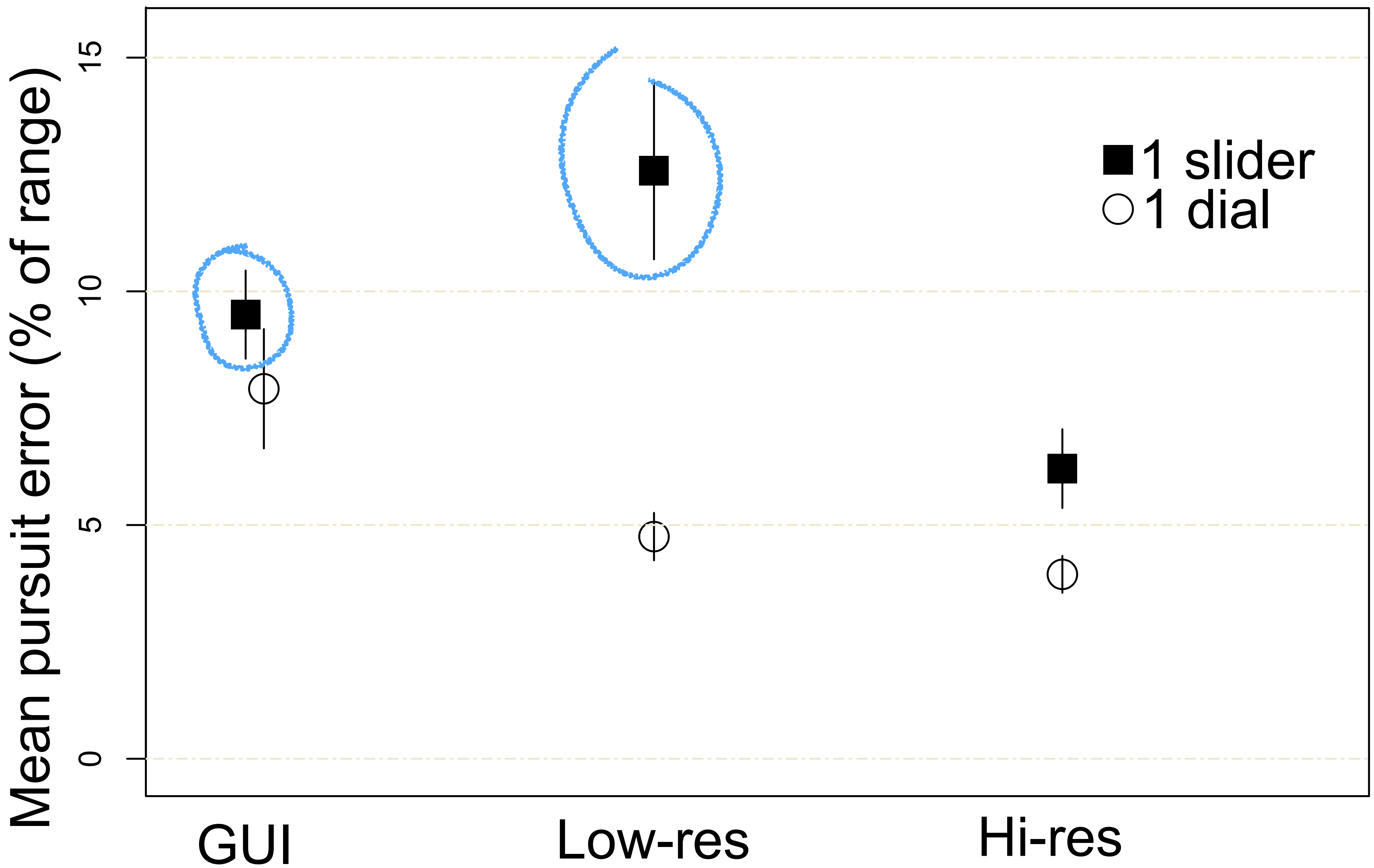
Pursuit error



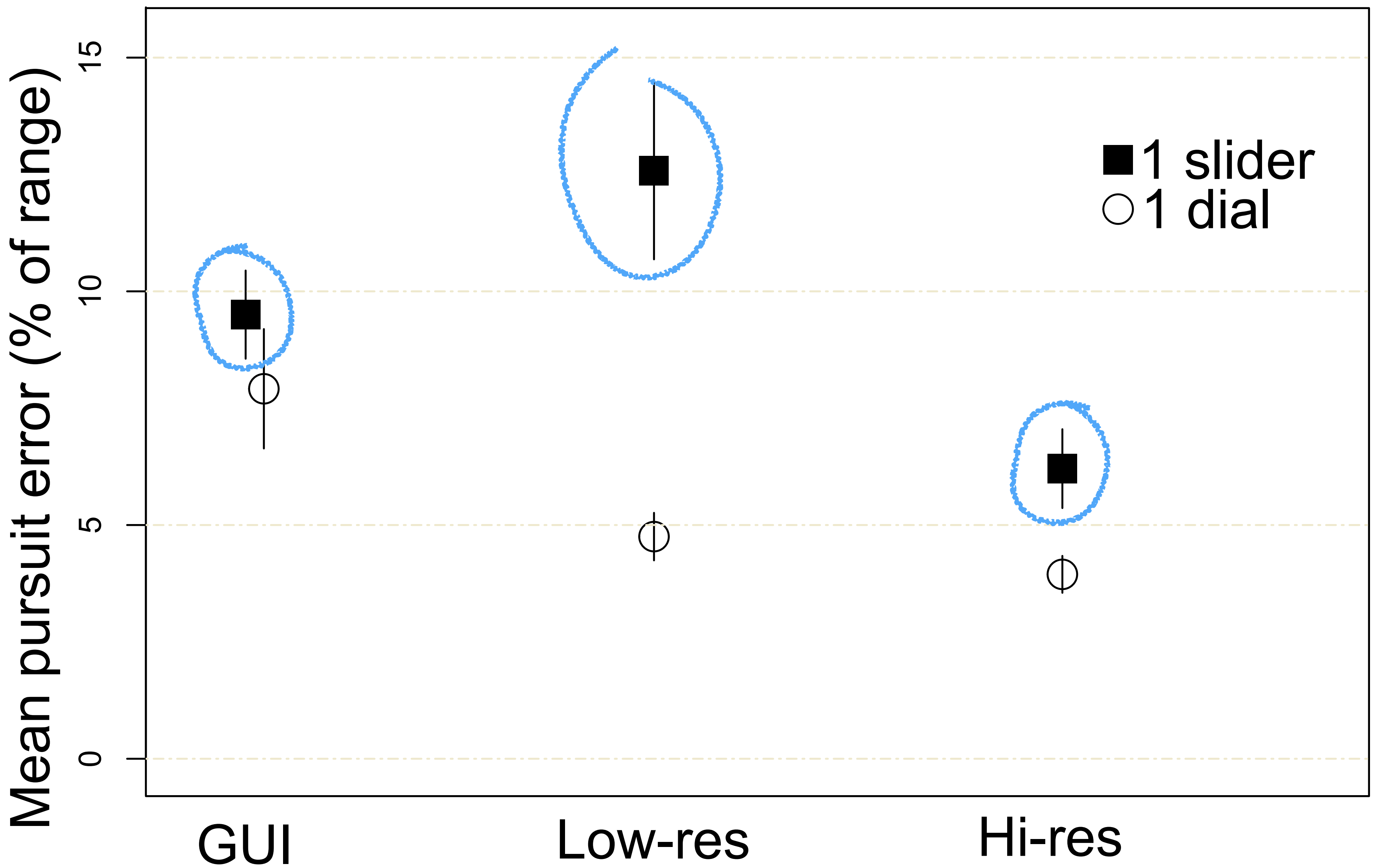
Pursuit error



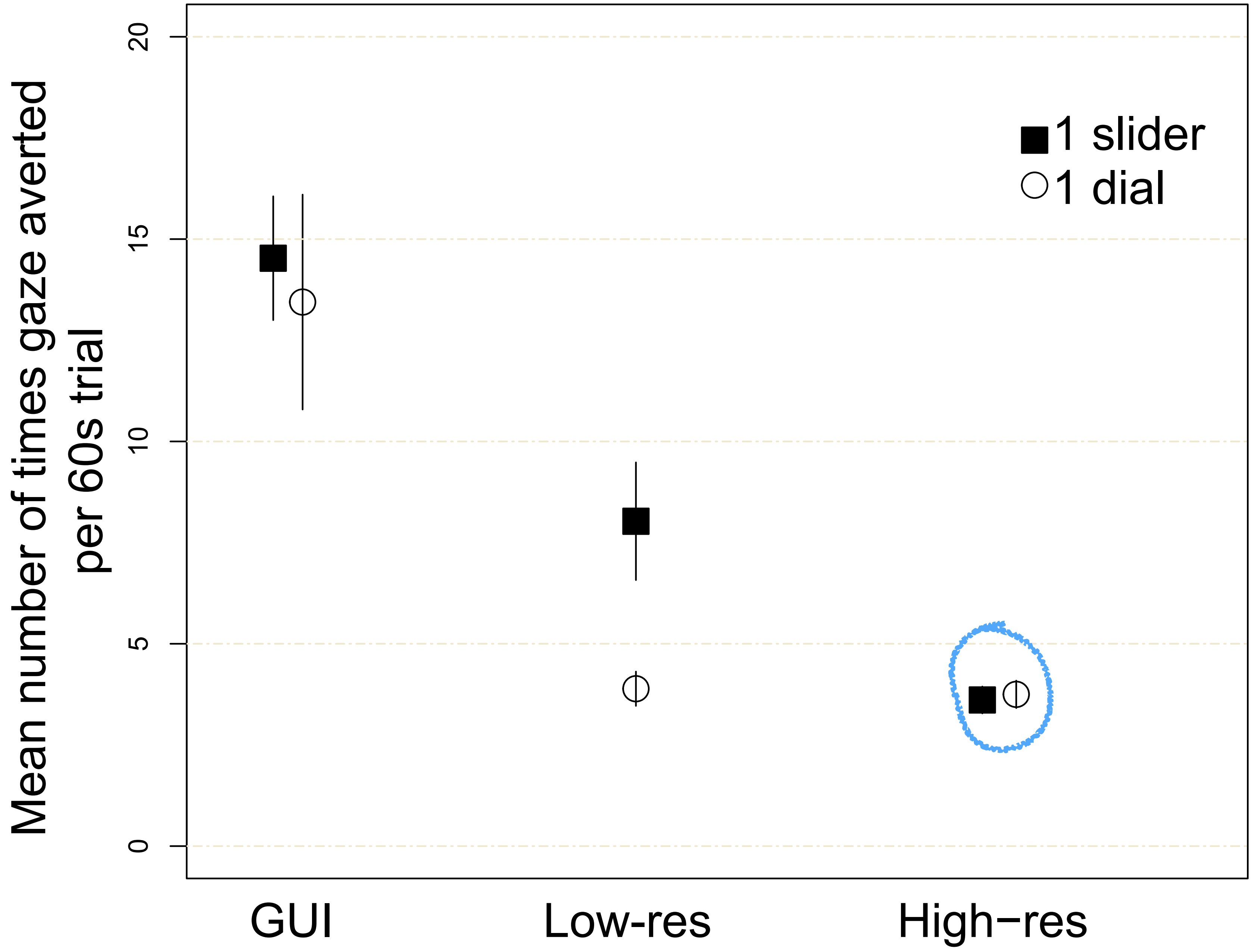
Pursuit error



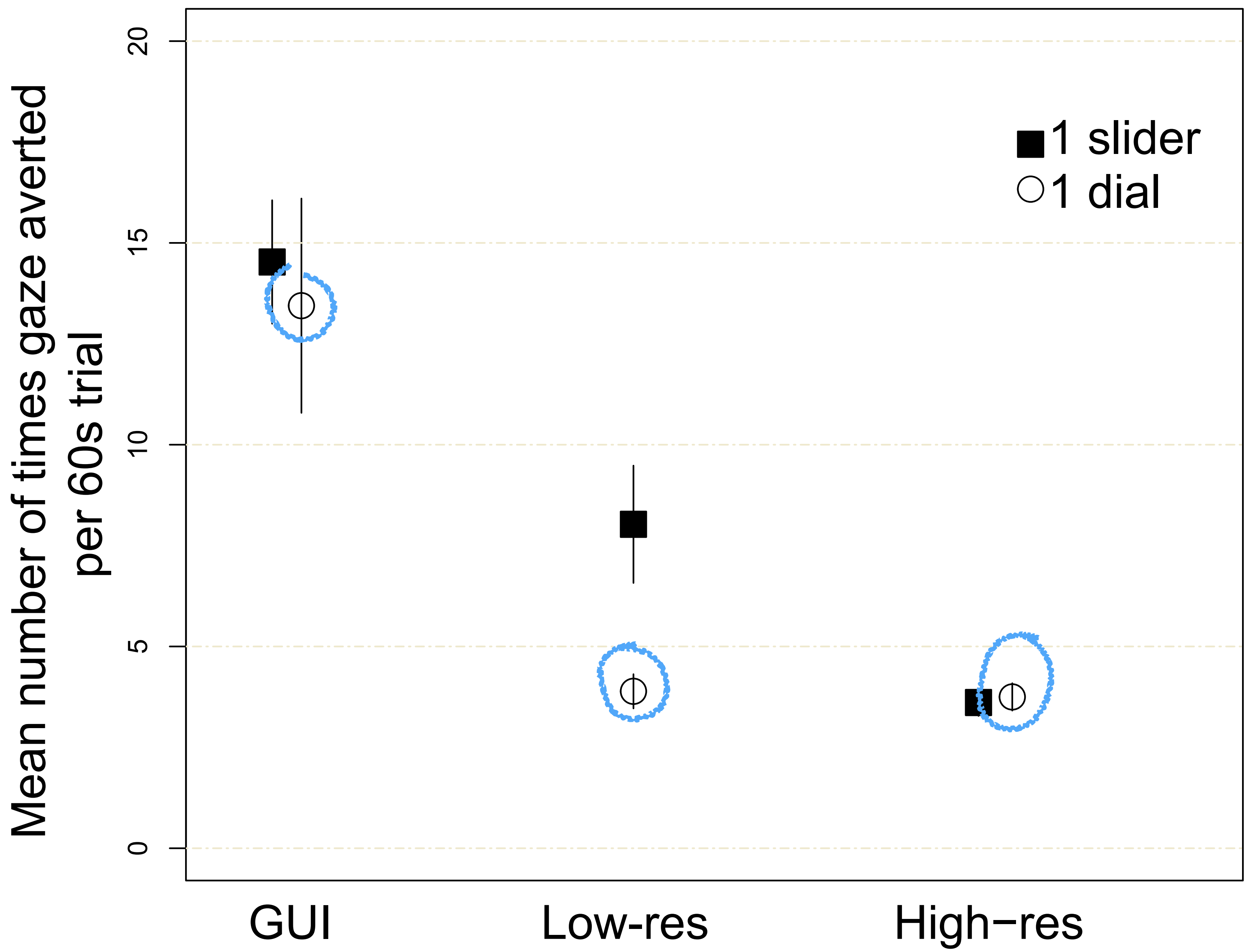
Pursuit error



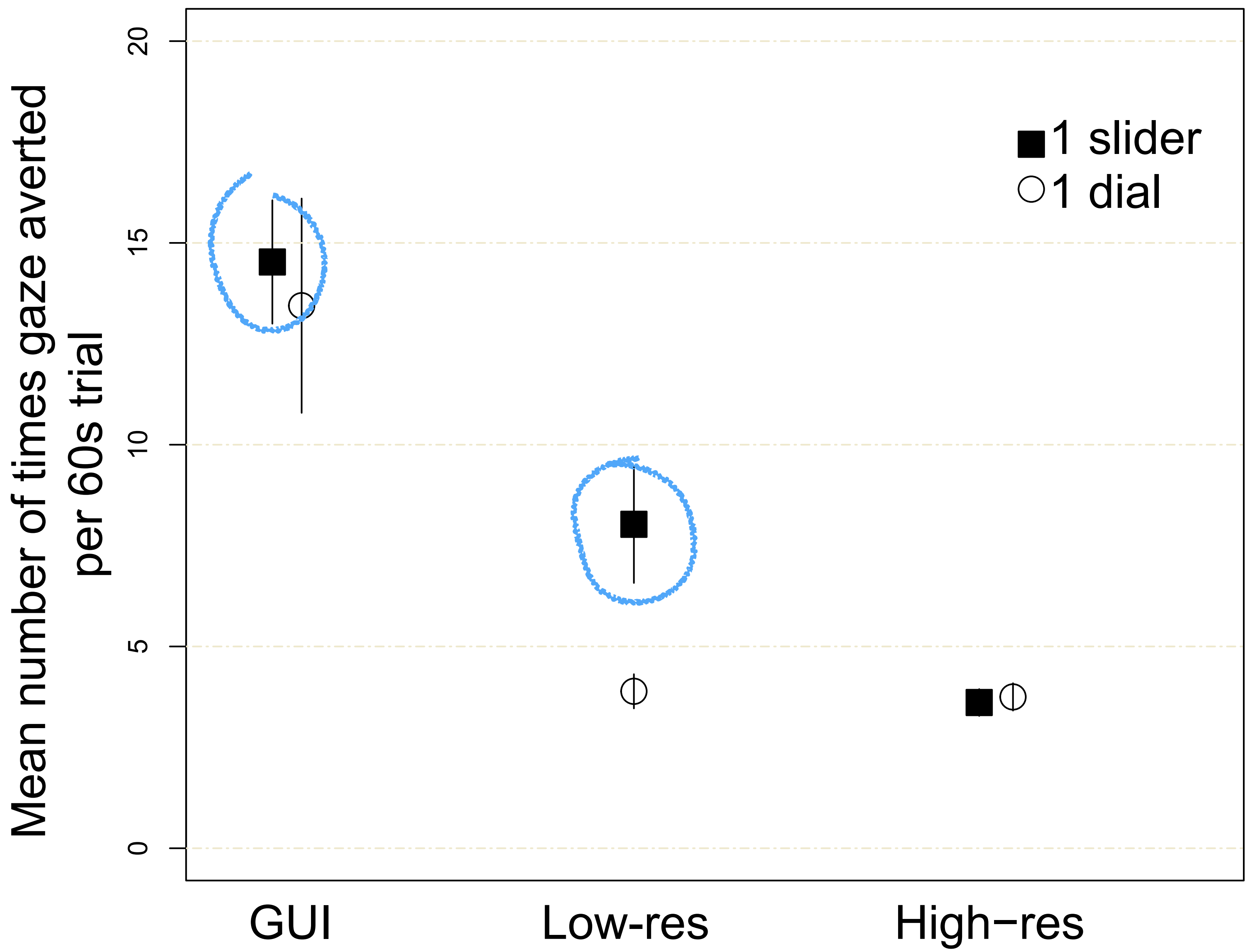
Visual Attention



Visual Attention



Visual Attention



Users’ preferences

- Hi-res most preferred (8.8 / 10)
- Low-res promising (4.8 / 10)
- GUI least preferred (3.4 / 10)

Future work

- How to do higher resolution emergeable dials?
- How to improve interaction with emergeable sliders?

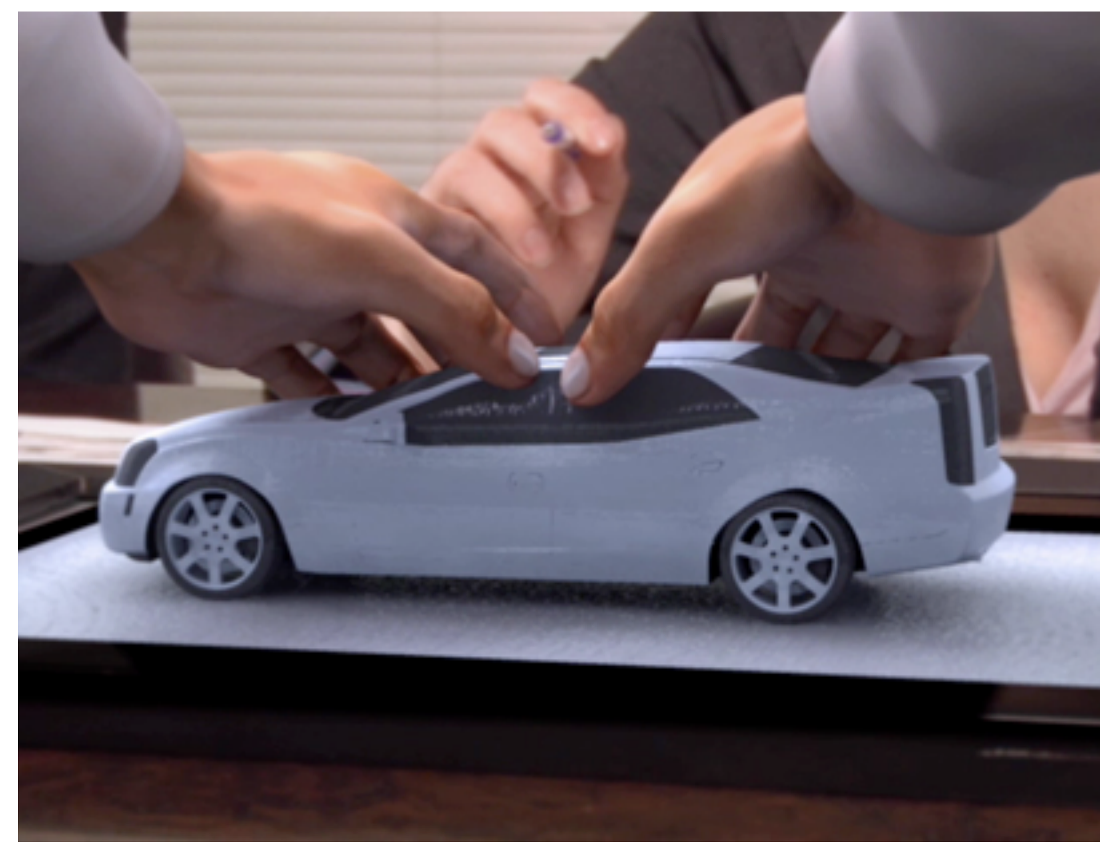
Design space is large
(and largely unexplored)

- Balancing footprint and performance
- Notifications
- Switching between controls and flat screen
- etc.

Future of Tangible Interaction

Flexibility will not be software's monopoly
and will reach Tangibles

Radical Atoms & Perfect Red
https://vimeo.com/61141209



Claytronics
http://www.cs.cmu.edu/~claytronics/movies/carDesign_12_vo_H264.mov

Future of Tangible Interaction (getting there)

- bitDrones
  https://www.youtube.com/watch?v=hHBYMWc3ux8
- SwarmUI
  https://www.youtube.com/watch?v=ZVdAfDMP3m0