Tangible interaction: Benefits and Limitations

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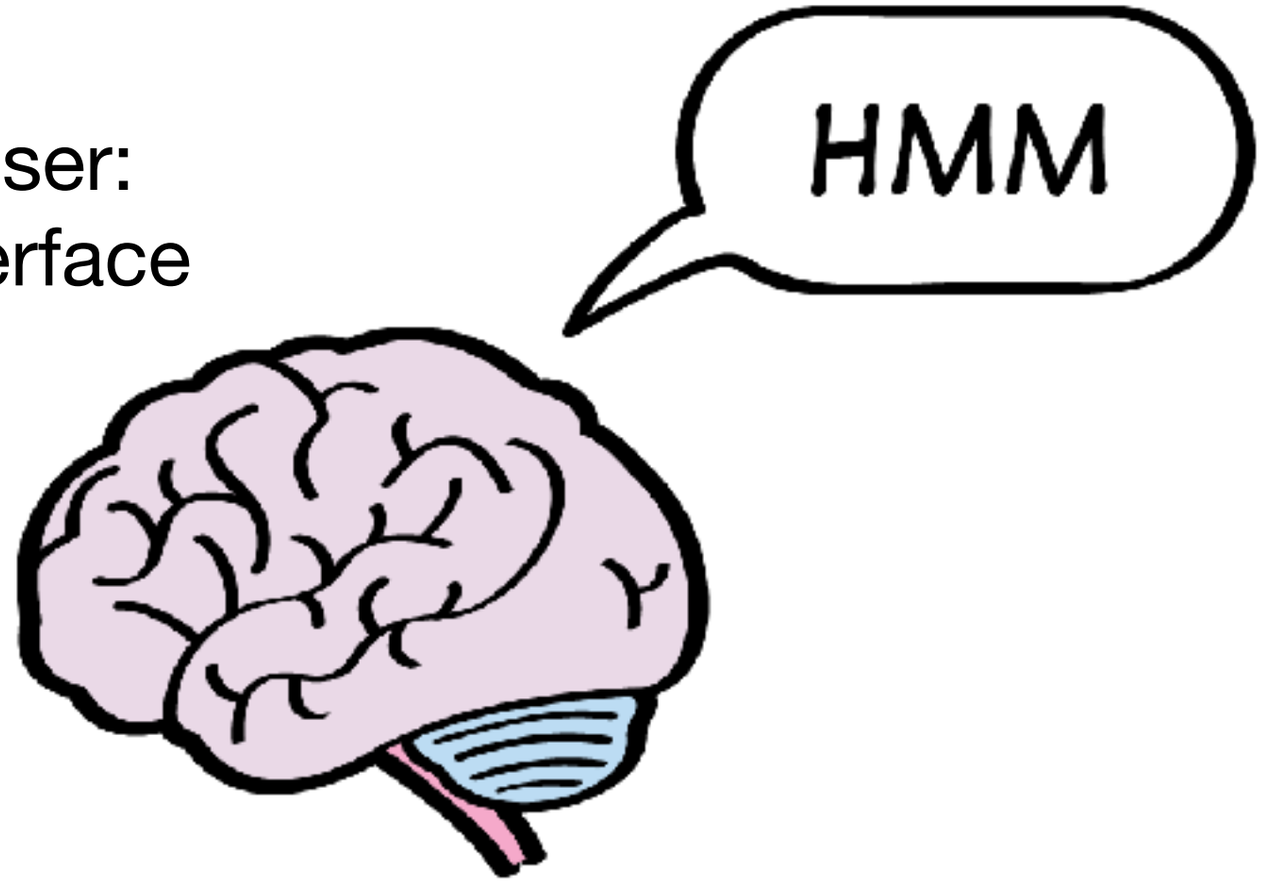
Tangible User Interfaces
What are they good for?

- **Interaction embodied**
  in the physical world of the user:
  Physical User & Physical Interface

- **Performance**:
  Passive haptic feedback



Tangible User Interfaces: What are they good for?

Several experiments demonstrated their benefits

Tangible User Interfaces: Benefit over GUI

- Time-multiplexed vs. Space-multiplexed input: inter-device transaction phases

- Specialized vs. Generic form-factor

Tangible User Interfaces: Benefit over GUI

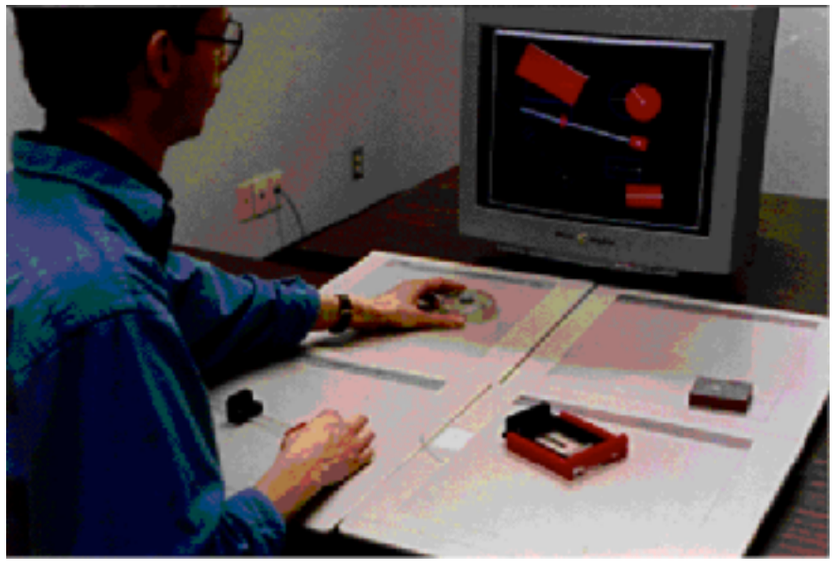
- Time-multiplexed vs. Space-multiplexed input: inter-device transaction phases

GUI	TUI
Acquire physical device | Acquire logical device | Manipulate logical device	Acquire physical device | Manipulate logical device

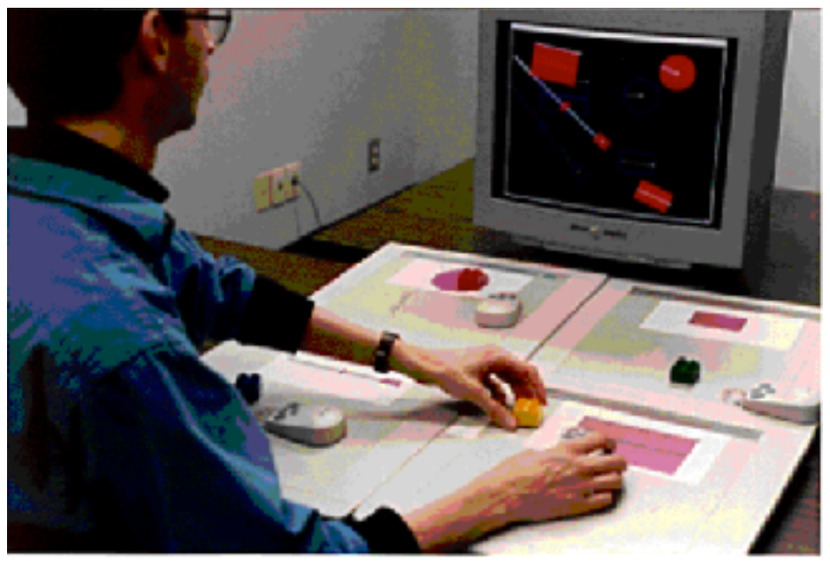
Tangible User Interfaces: Benefit over GUI

Task: continuously track four targets moving randomly on the screen (compound tasks)

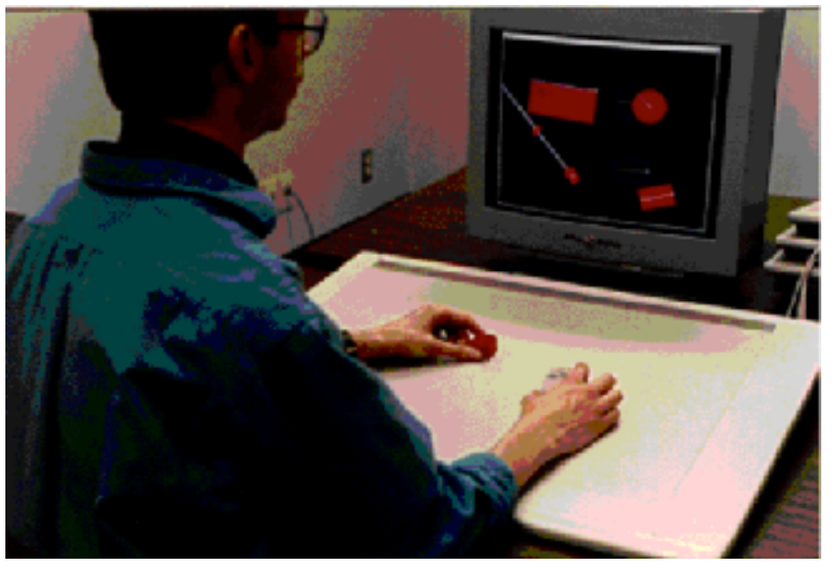
- Rotor: position and rotation
- Brick: position and rotation
- Strechable square: position, rotation and scale
- Ruler: position, rotation and scale



Space-multiplexed
Specialized



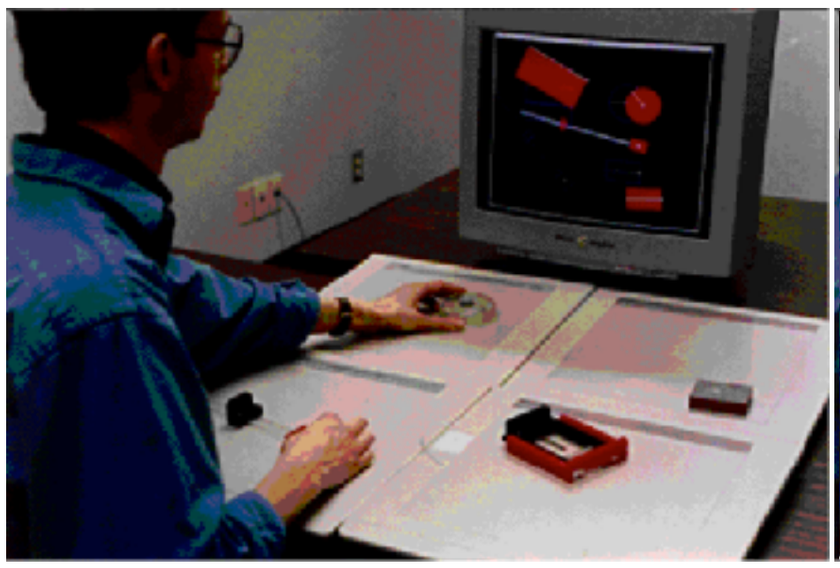
Space-multiplexed
Generic



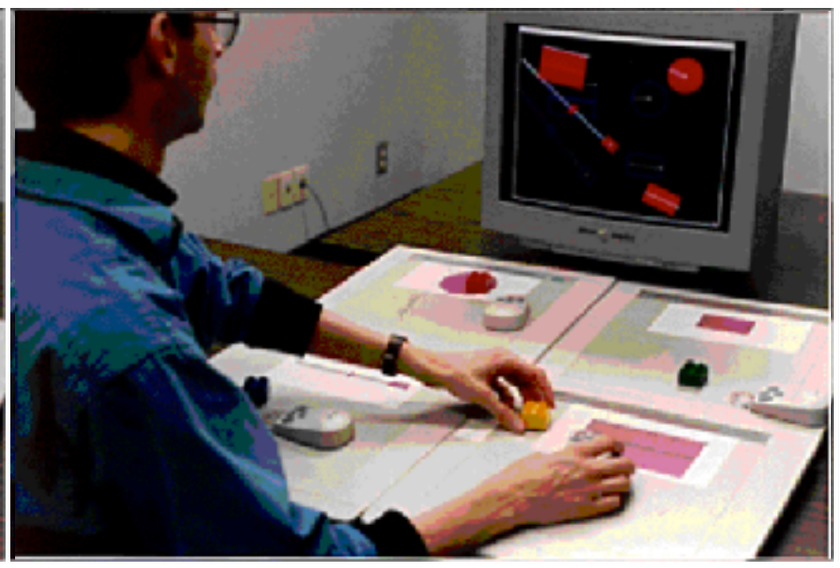
Time-multiplexed

Tangible User Interfaces: Benefit over GUI

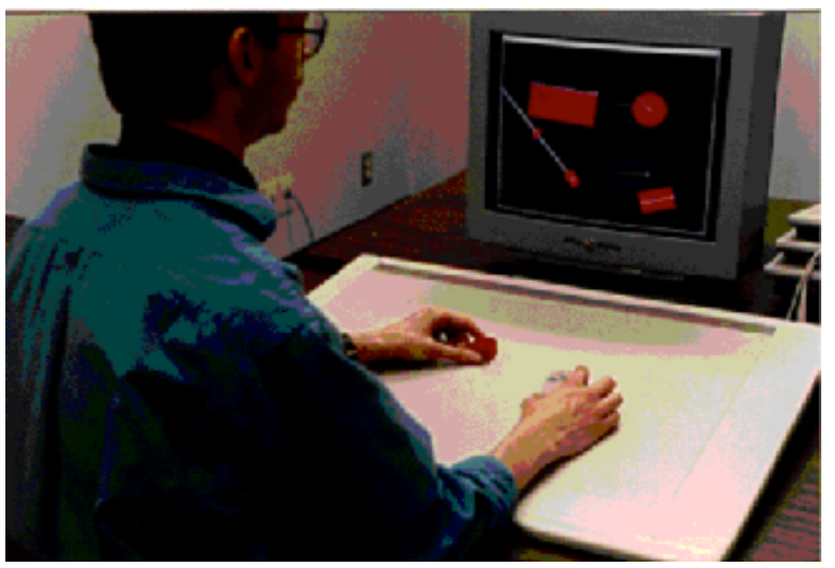
Does the **physical switching** cost more than the **logical switching** between tools?



Space-multiplexed
Specialized



Space-multiplexed
Generic

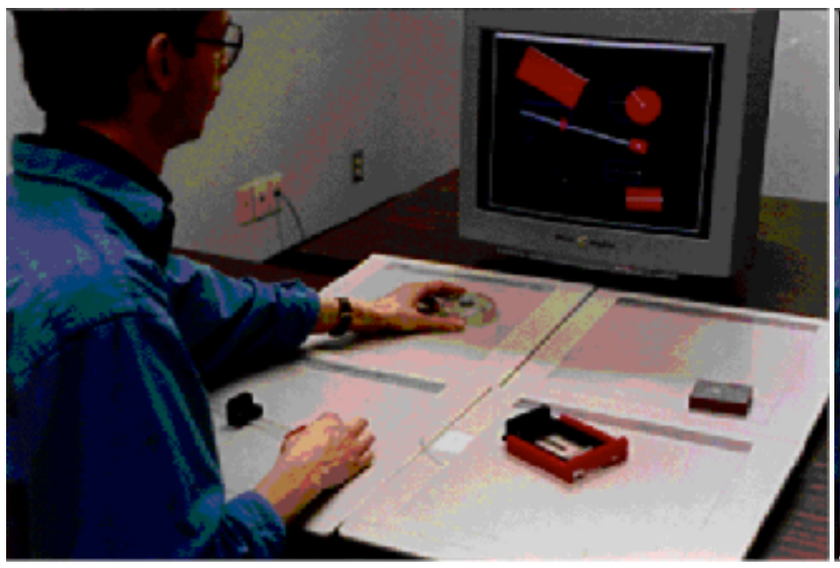


Time-multiplexed

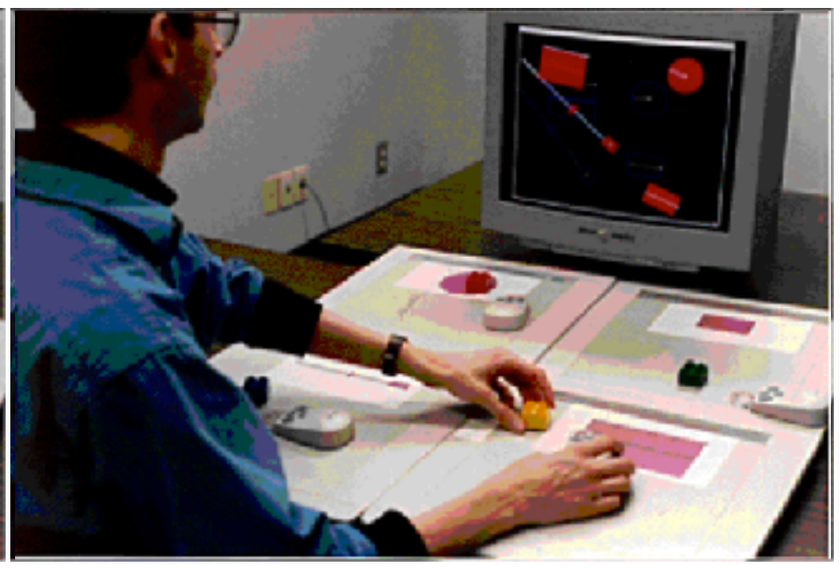
Tangible User Interfaces: Benefit over GUI

Does the **physical switching** cost more than the **logical switching** between tools?

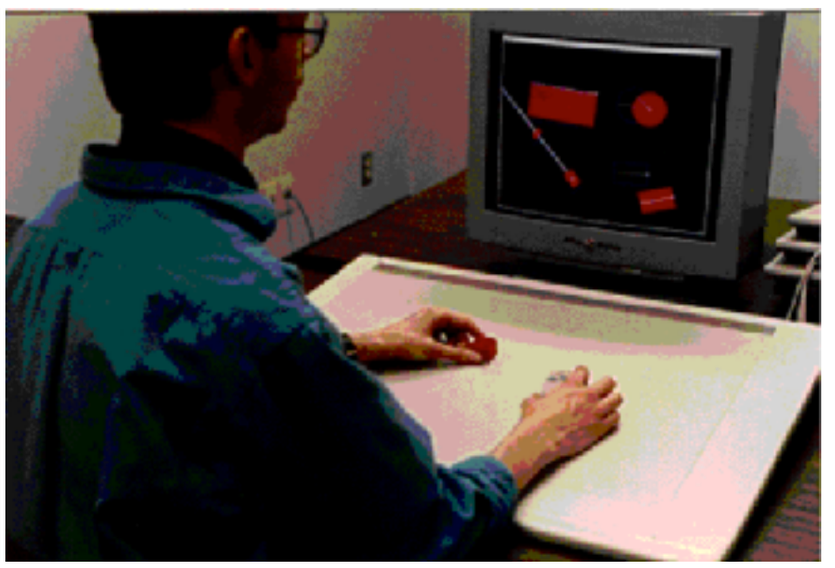
Is the **specialized** input useful?



Space-multiplexed
Specialized

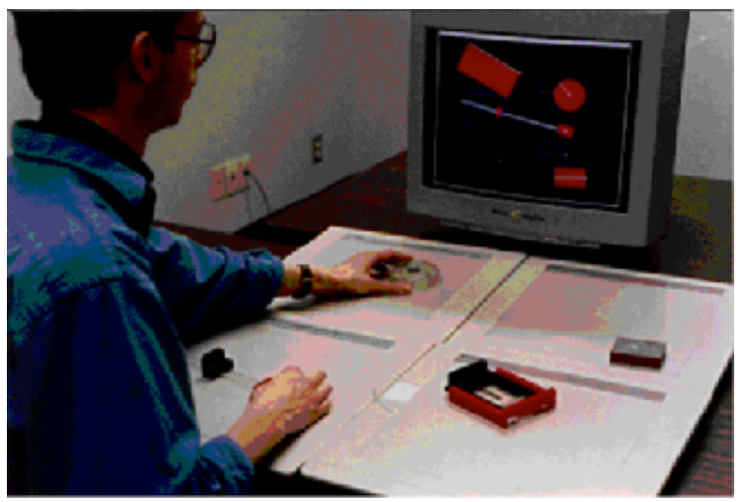


Space-multiplexed
Generic



Time-multiplexed

Tangible User Interfaces: Benefit over GUI



Space-multiplexed
Specialized
performs best

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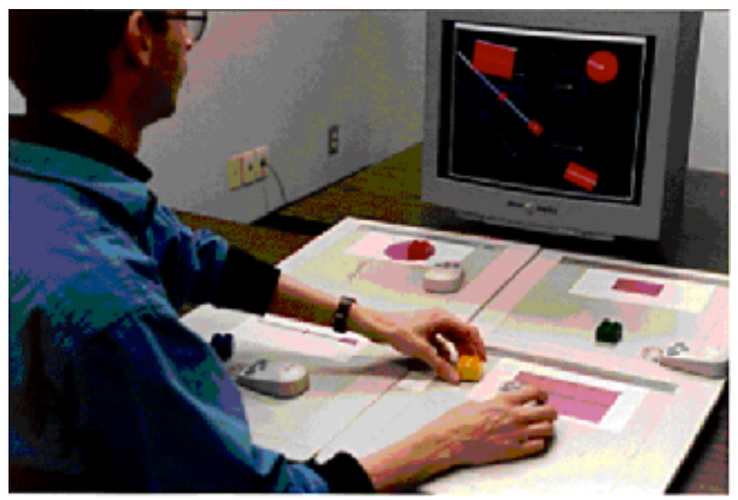

Space-multiplexed
Generic
performs better than Time-multiplexed but worst than Specialized

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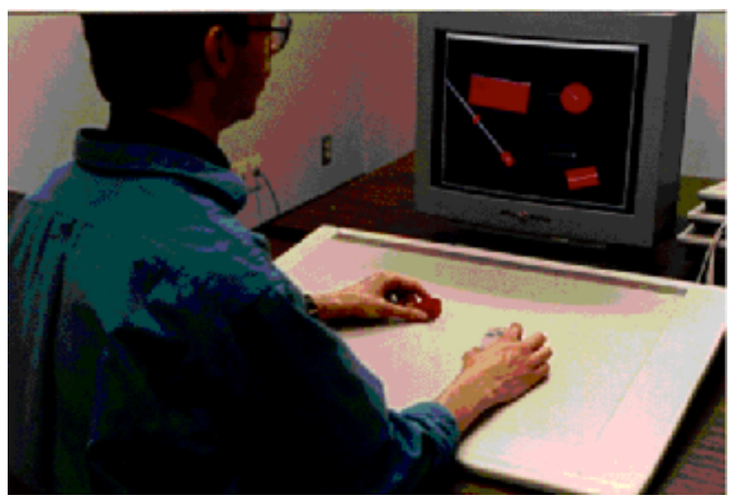
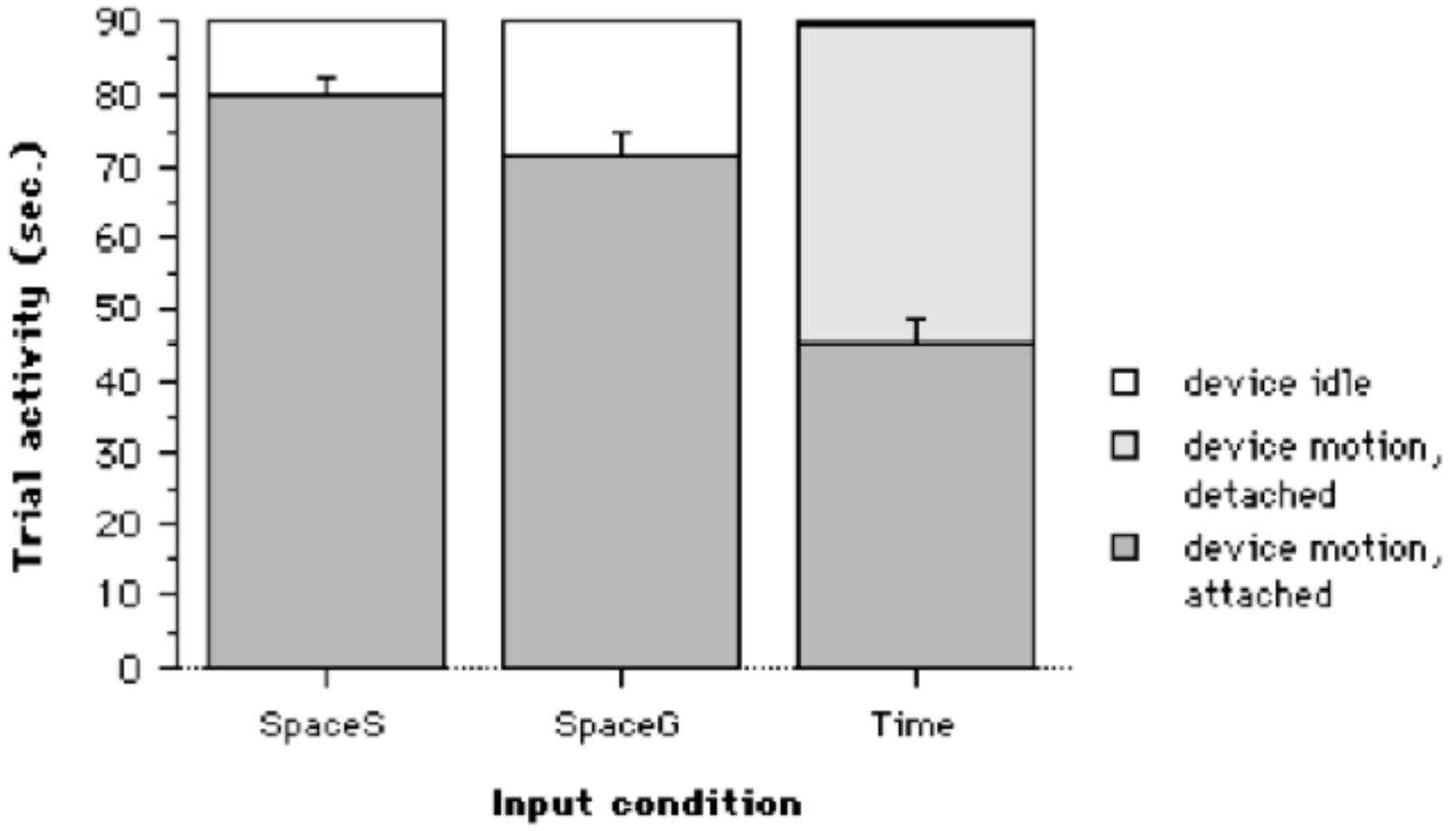


Time-multiplexed

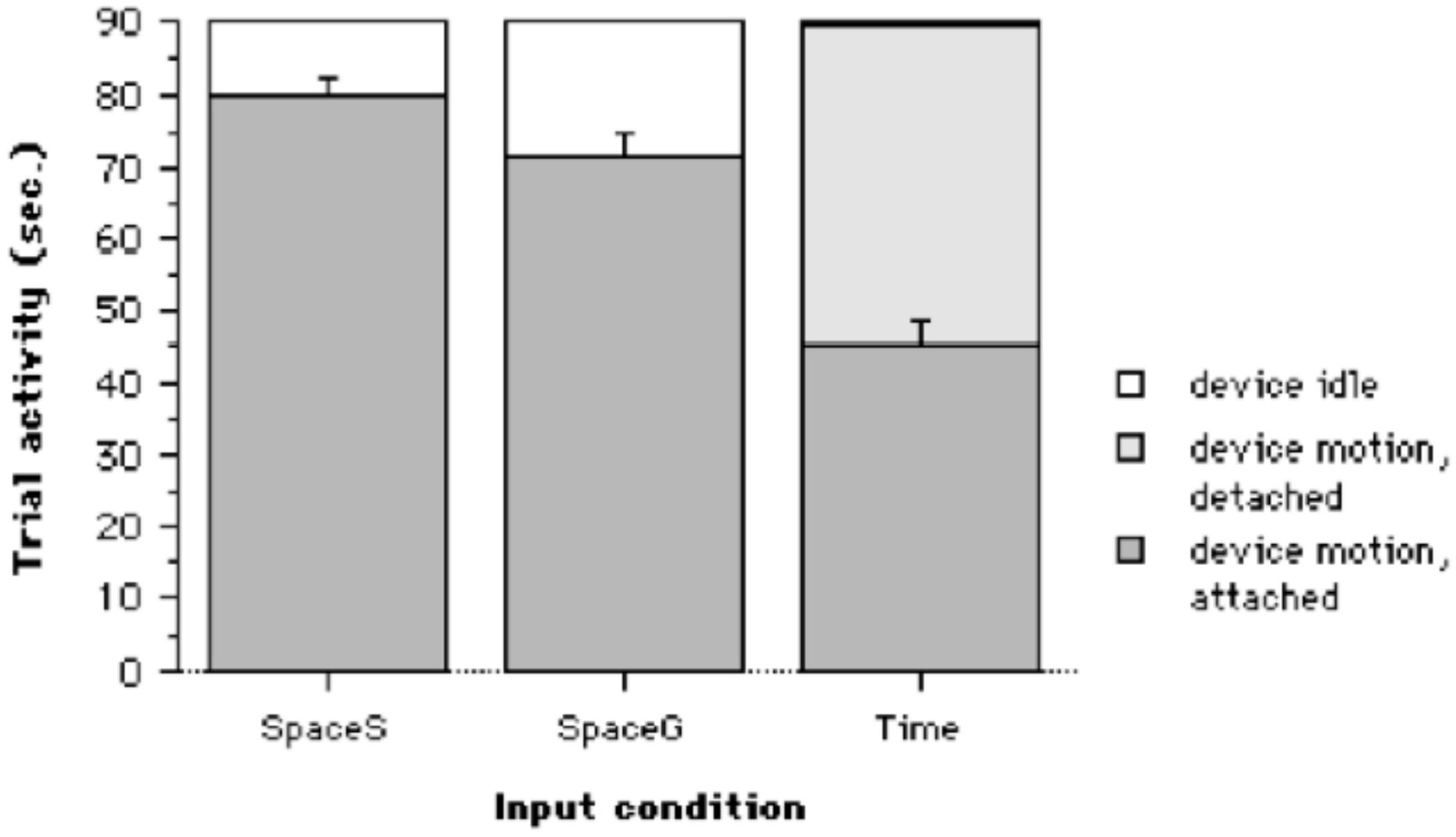
performs worst

- Consistent across the 4 devices
- (Score based on root mean square errors of all dimensions (position, orientation and scale if applicable) of all devices)

Tangible User Interfaces: Benefit over GUI



Tangible User Interfaces: Benefit over GUI



Users spend more time switching between tools with time-multiplexed UI rather than with space-multiplexed UI

Tangible User Interfaces: Benefit over GUI

1. Space-multiplexed > Time-multiplexed input:

    - Persistance of attachement between physical and logical (software, graphical) controllers

    - Parallel 2-handed vs.
      Sequential 1-handed interaction

2. Specialized vs. Generic form-factor

    - Visual and tactile reminder

Tangible User Interfaces: What are they good for?

Several experiments demonstrated their benefits

Tangible User Interfaces: Benefit over multitouch

What about multitouch input?

Tangible User Interfaces: Benefit over multitouch

What about multitouch input?

also space-multiplexed

Tangible User Interfaces: Benefit over multitouch

Two experiments

Acquisition

Manipulation

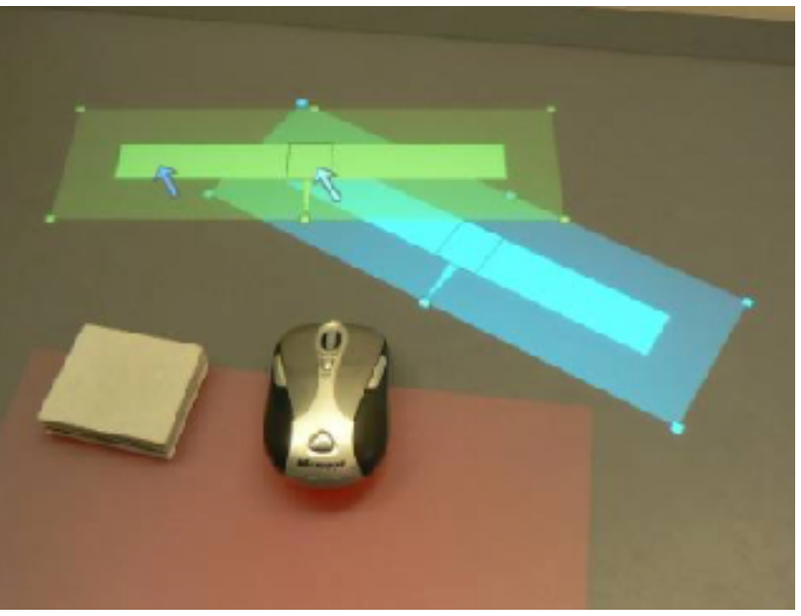
Tangible User Interfaces: Benefit over multitouch

Manipulation

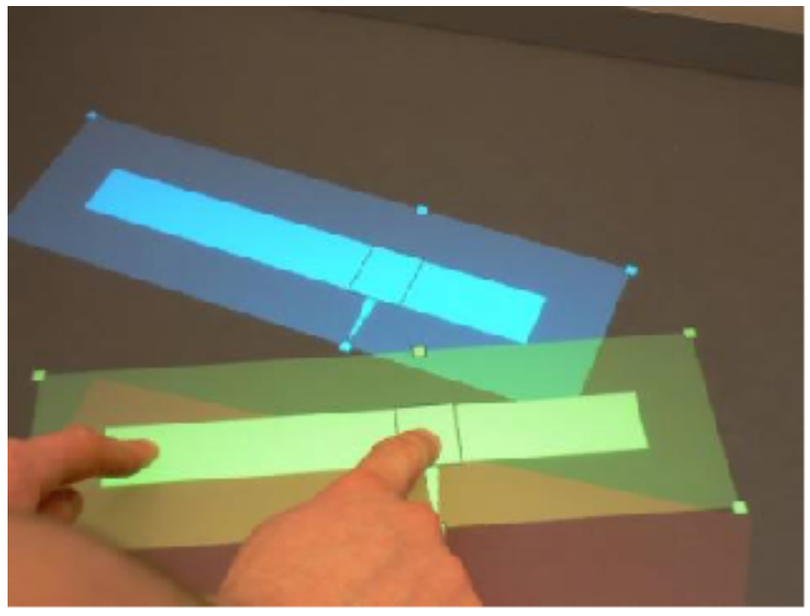
Assumes users already acquired the control widget

Tangible User Interfaces: Benefit over multitouch

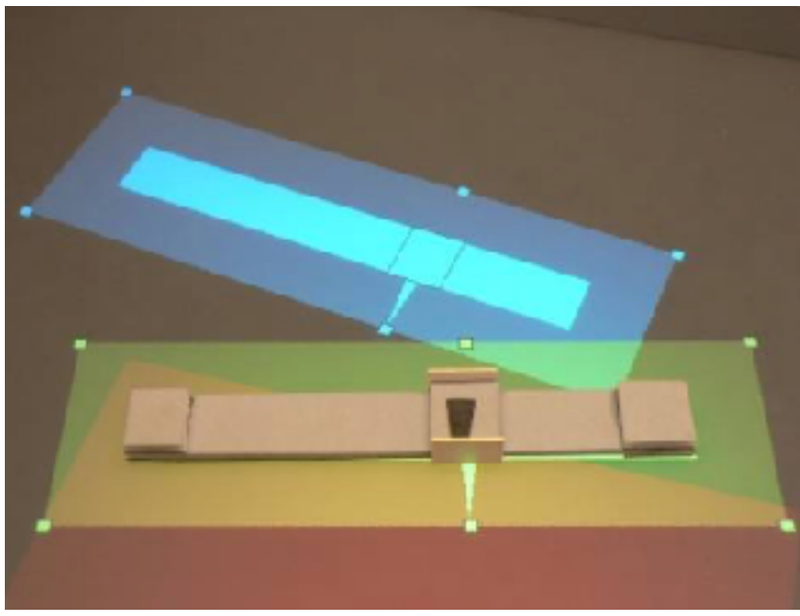
Task: match position+orientation+cursor of blue object
manipulating yellow object
as quickly as possible



Mouse+Puck



Multitouch



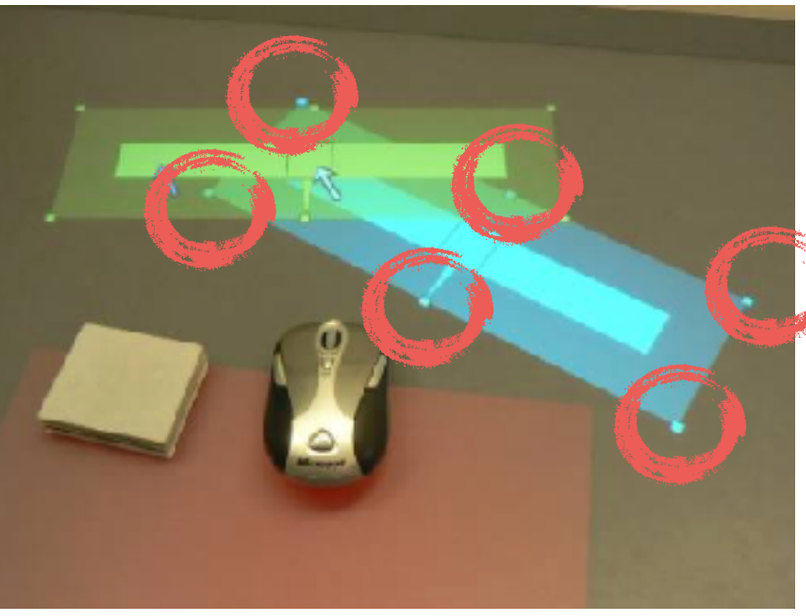
Tangible

(all conditions sensed through multitouch table)

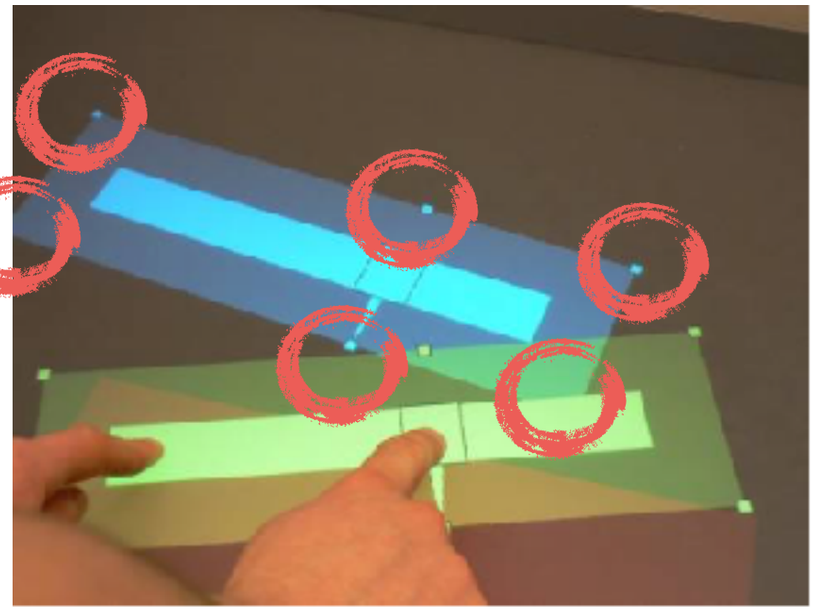
Tangible User Interfaces: Benefit over multitouch

Task: match position+orientation+cursor of blue object
manipulating yellow object
as quickly as possible

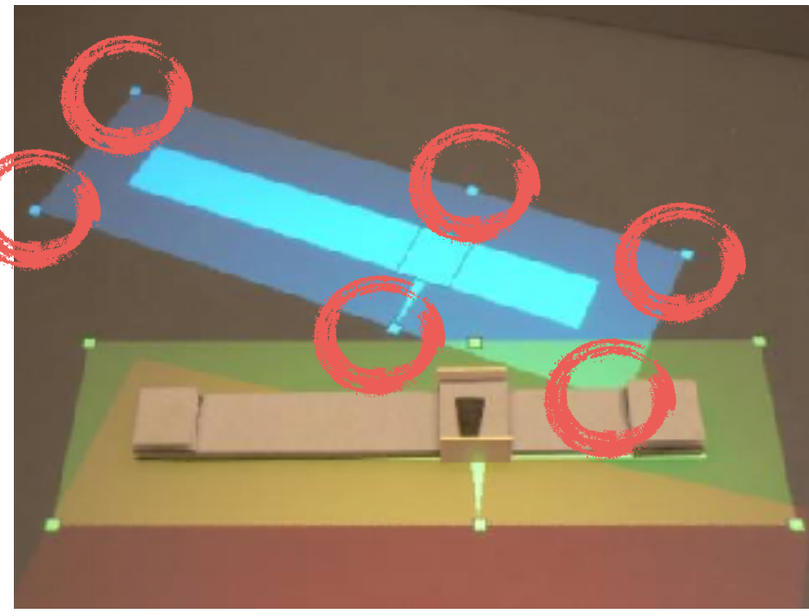
±5px



Mouse+Puck



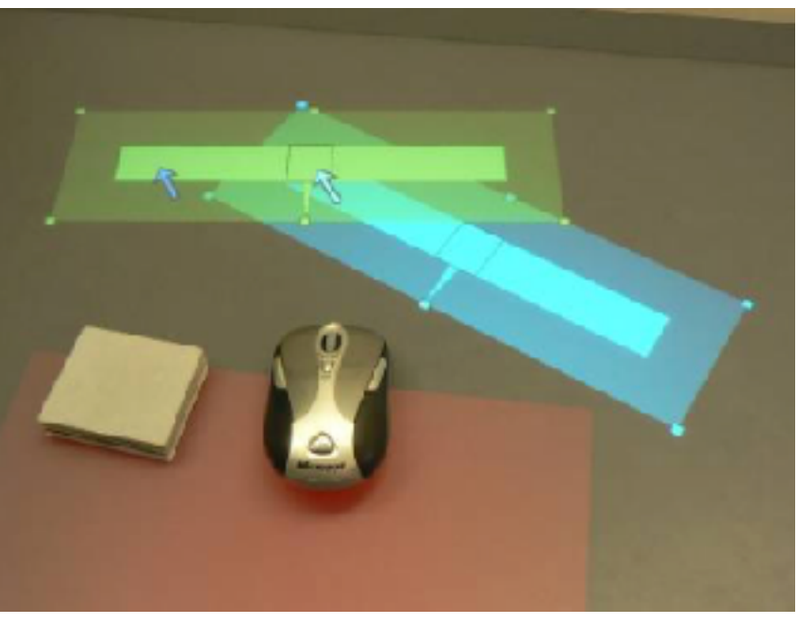
Multitouch



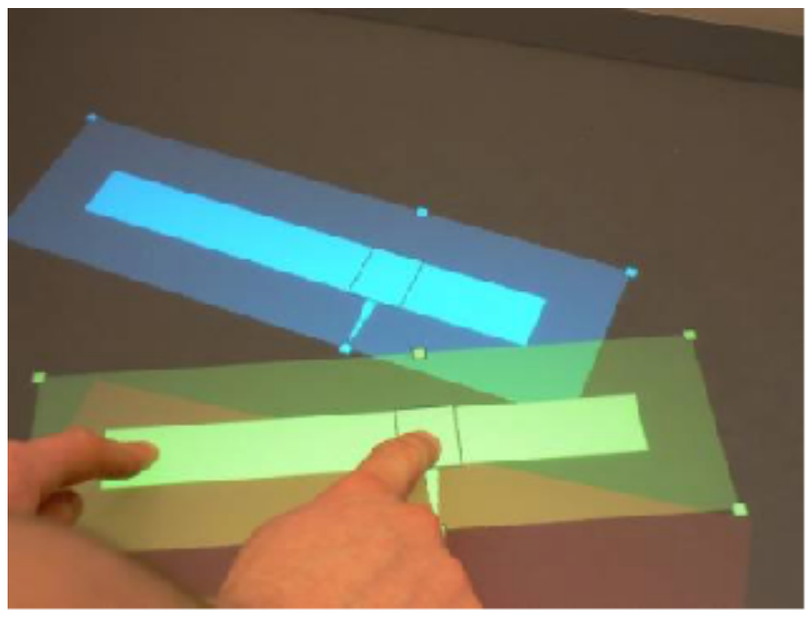
Tangible

Tangible User Interfaces: Benefit over multitouch

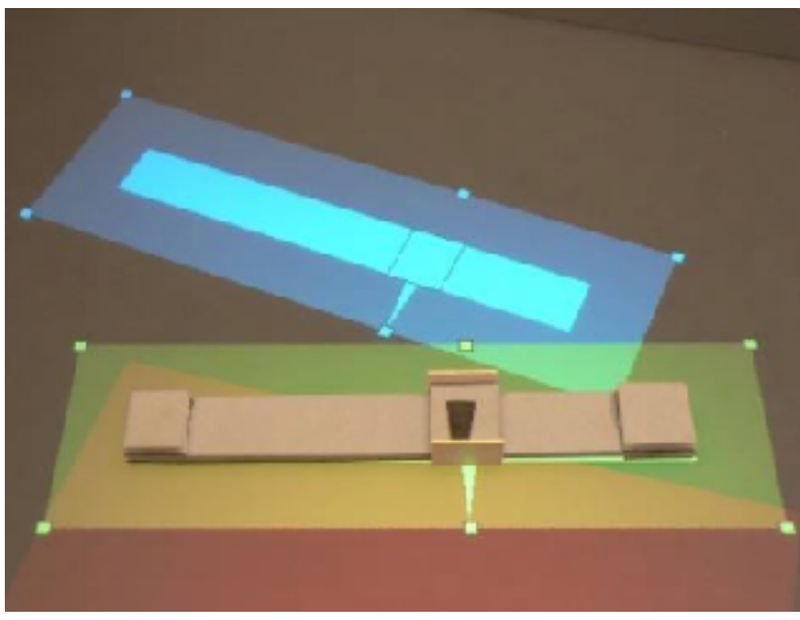
Measures: Time to complete matching task
Subjective comfort
Subjective ease of use



Mouse+Puck

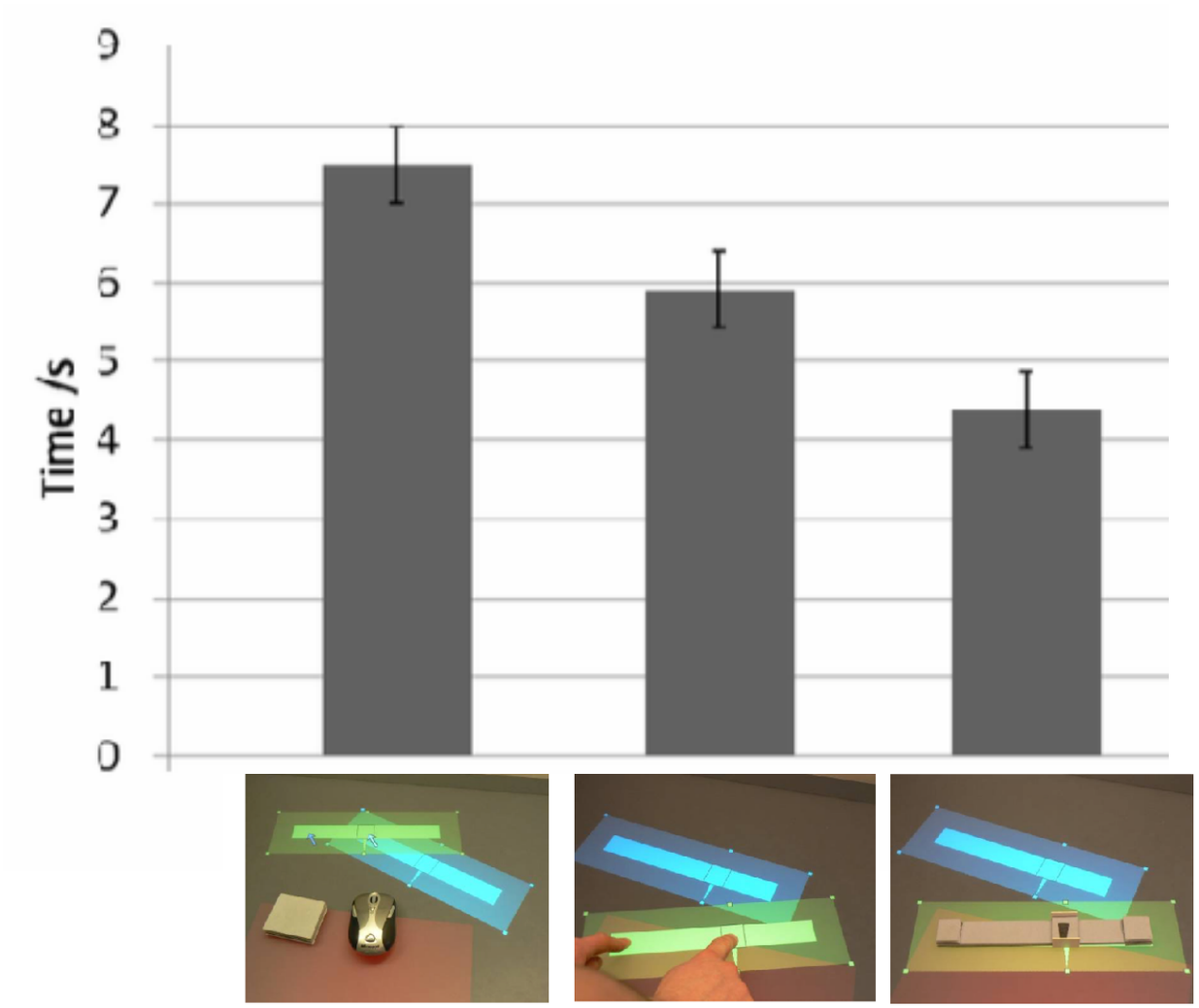


Multitouch

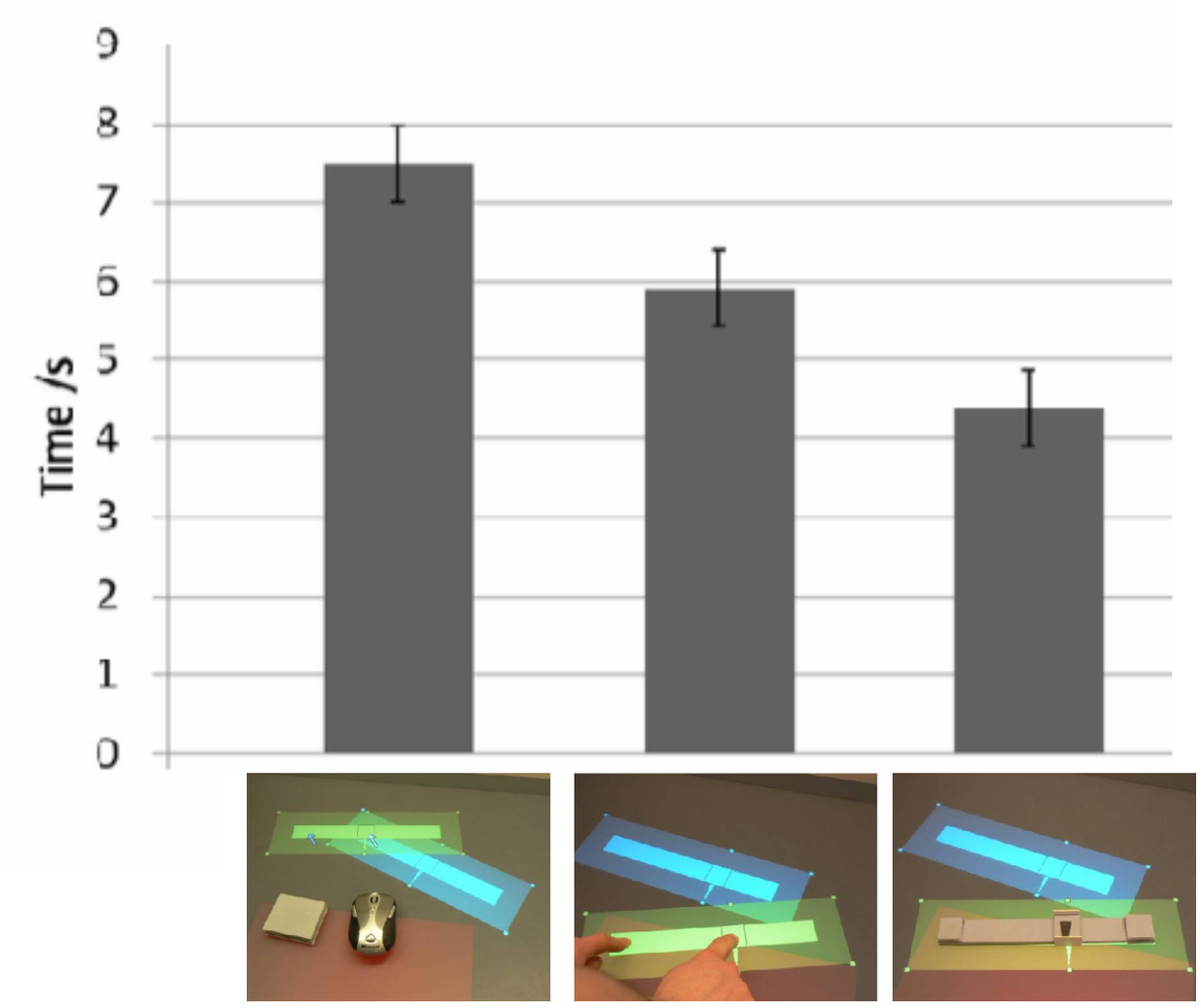


Tangible

Tangible User Interfaces: Benefit over multitouch



Tangible User Interfaces: Benefit over multitouch



+ Little difference in comfort and ease of use

A participant:
« better degree of control with tangibles, especially when rotating »

Tangible User Interfaces: Benefit over multitouch

Manipulation

Tangible User Interfaces: Benefit over multitouch

Two experiments

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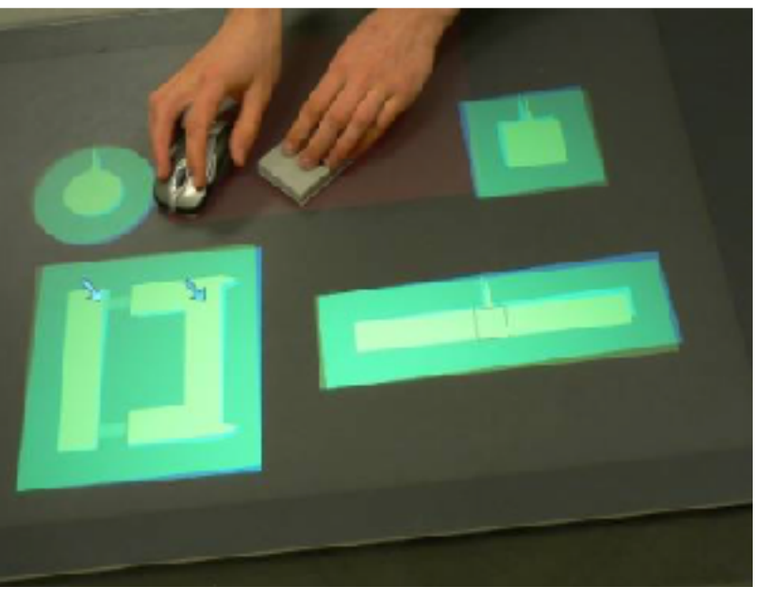
Manipulation

Tangible User Interfaces: Benefit over multitouch

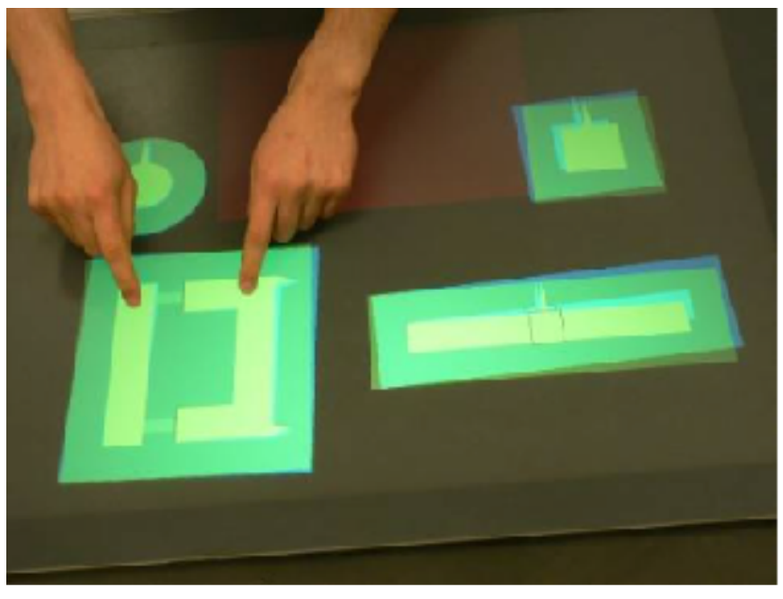
Acquisition

Tangible User Interfaces: Benefit over multitouch

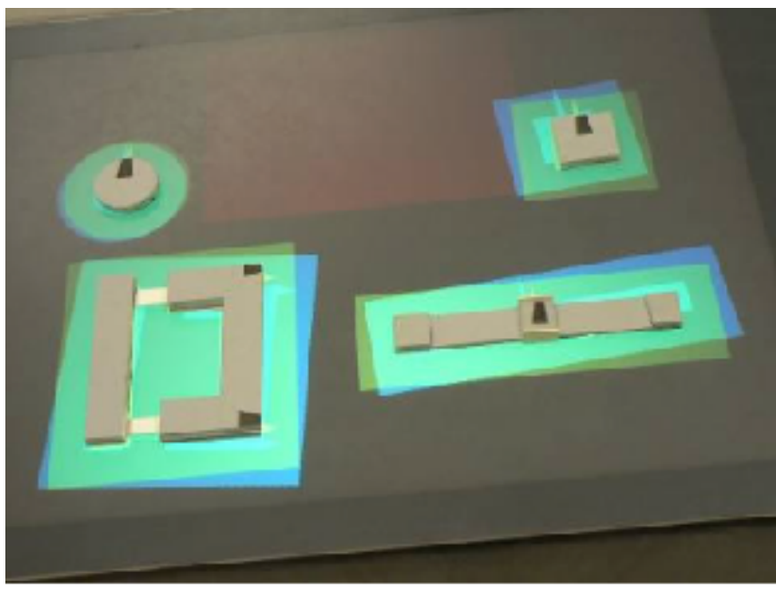
Task: match position+orientation+cursor of blue objects
manipulating yellow objects
at all times



Mouse+Puck



Multitouch



Tangible

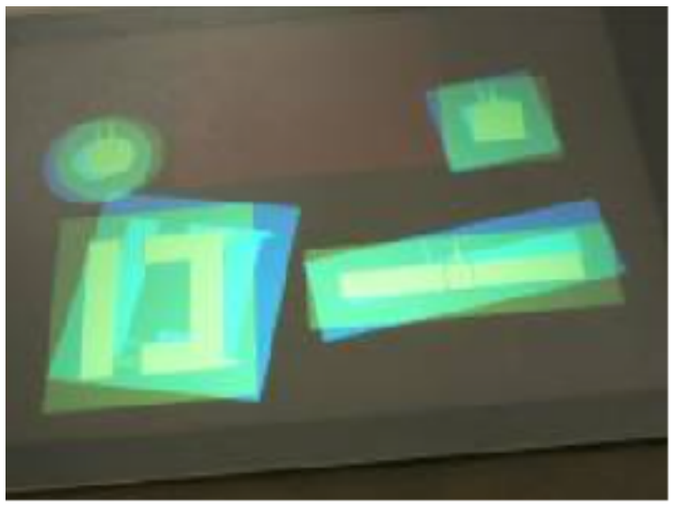
(all conditions sensed through multitouch table)

Tangible User Interfaces: Benefit over multitouch

Task: match position+orientation+cursor of blue objects
manipulating yellow objects
at all times

⇒ move between widgets ⇒ many (re)acquisitions

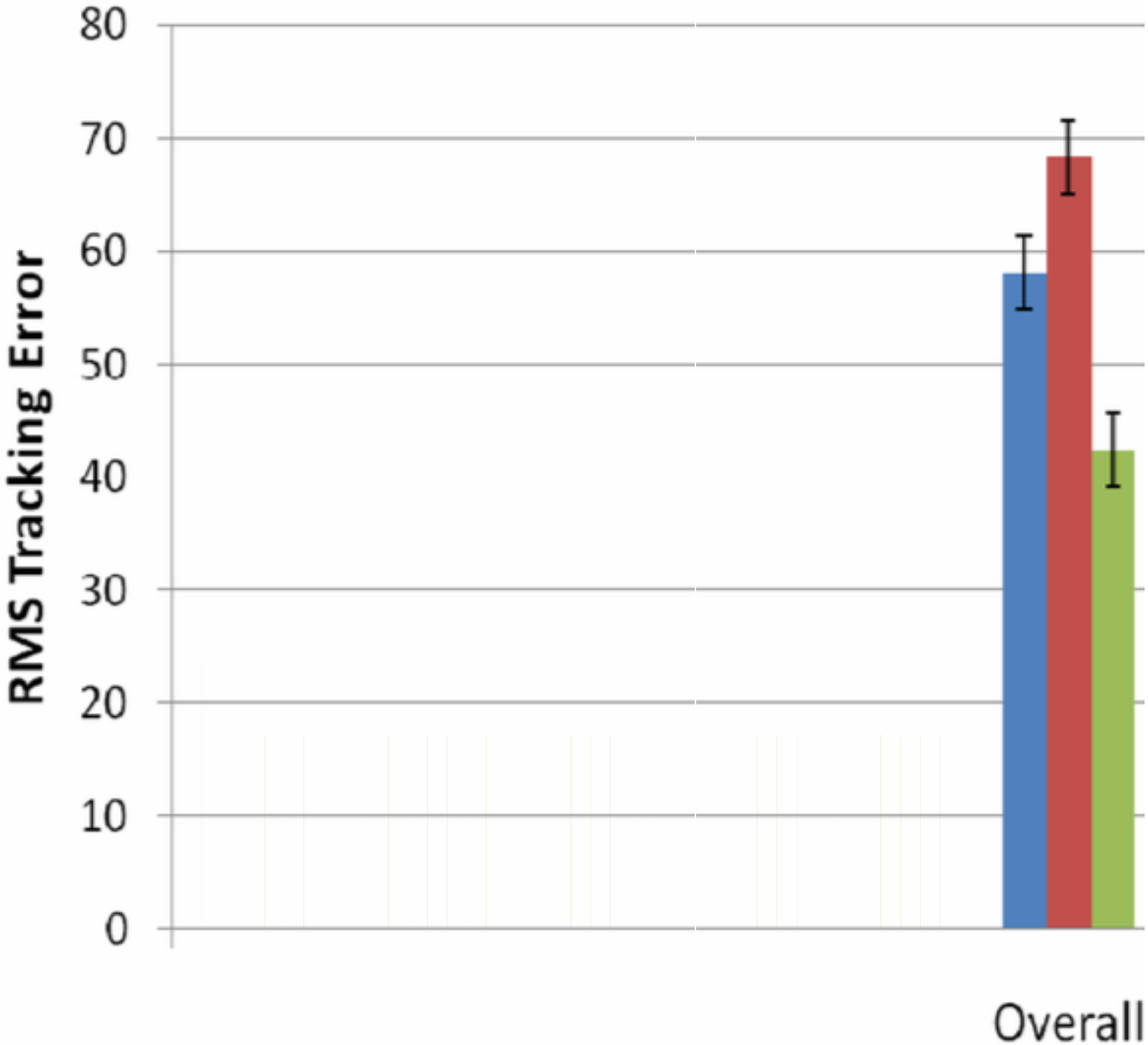
Tangible User Interfaces: Benefit over multitouch

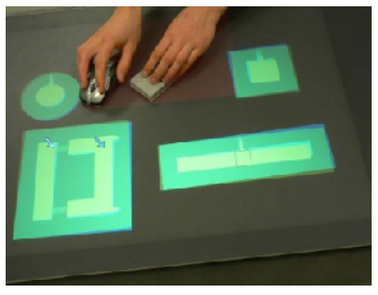


Measures: root-mean-square errors
of all dimensions
(position, orientation and scale or cursor position if applicable)
of all devices

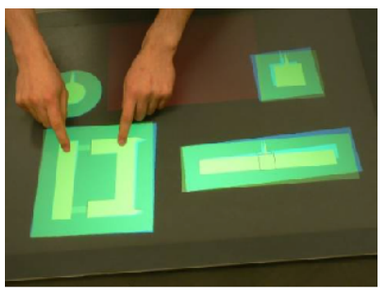
+ subjective preference, confort and ease of use

Tangible User Interfaces: Benefit over multitouch

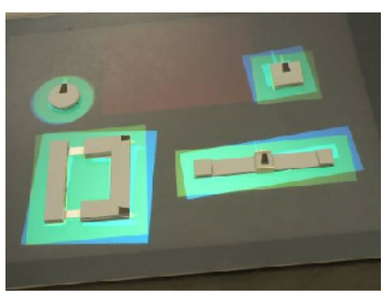




Mouse+Puck

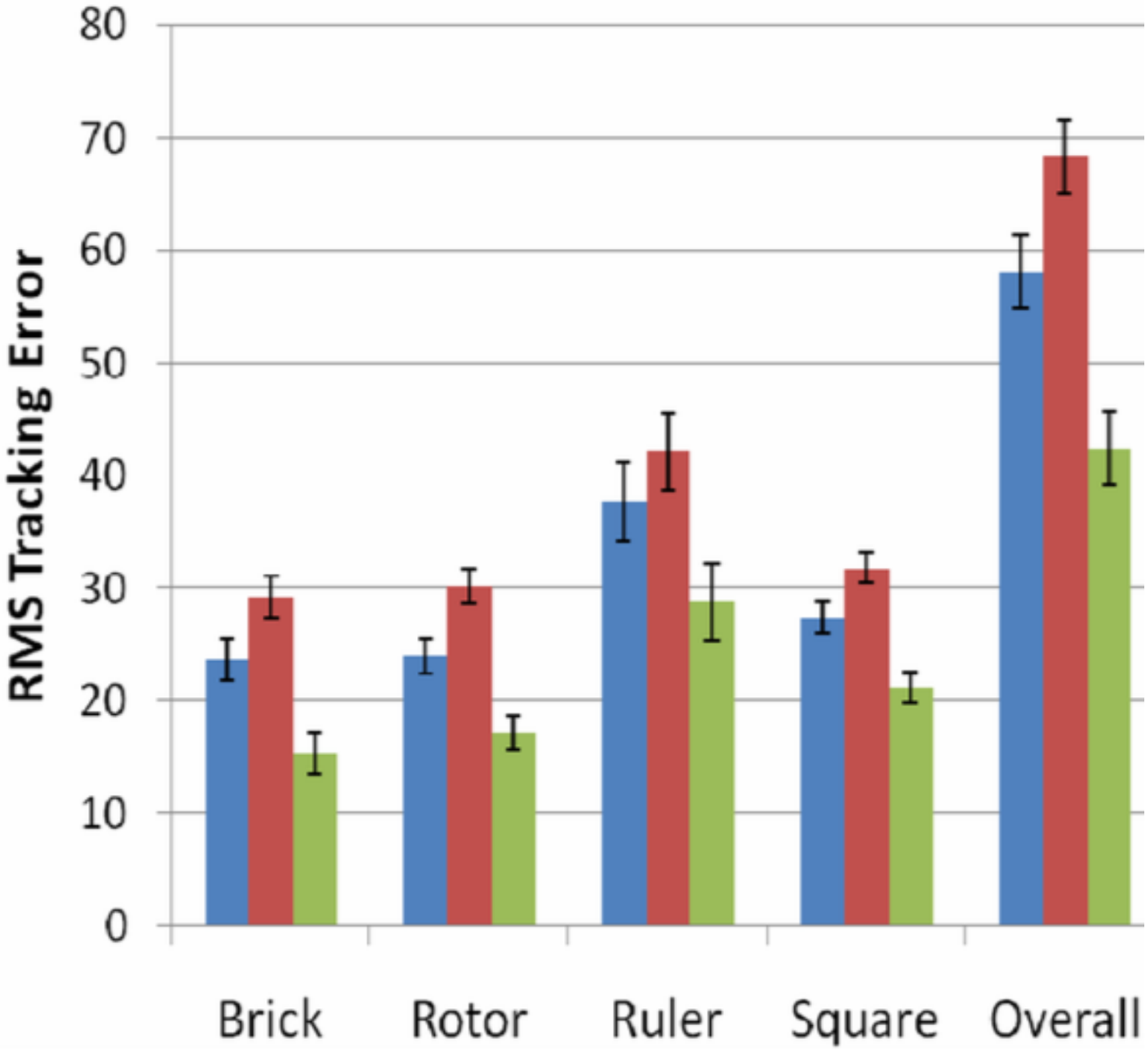


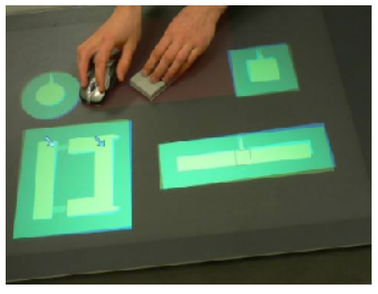
Multitouch



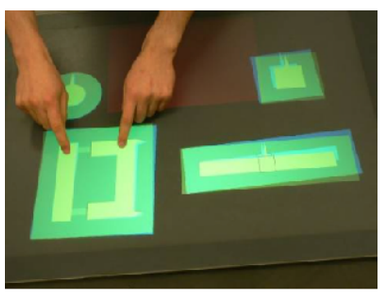
Tangible

Tangible User Interfaces: Benefit over multitouch

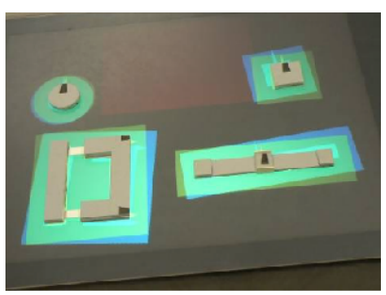




Mouse+Puck

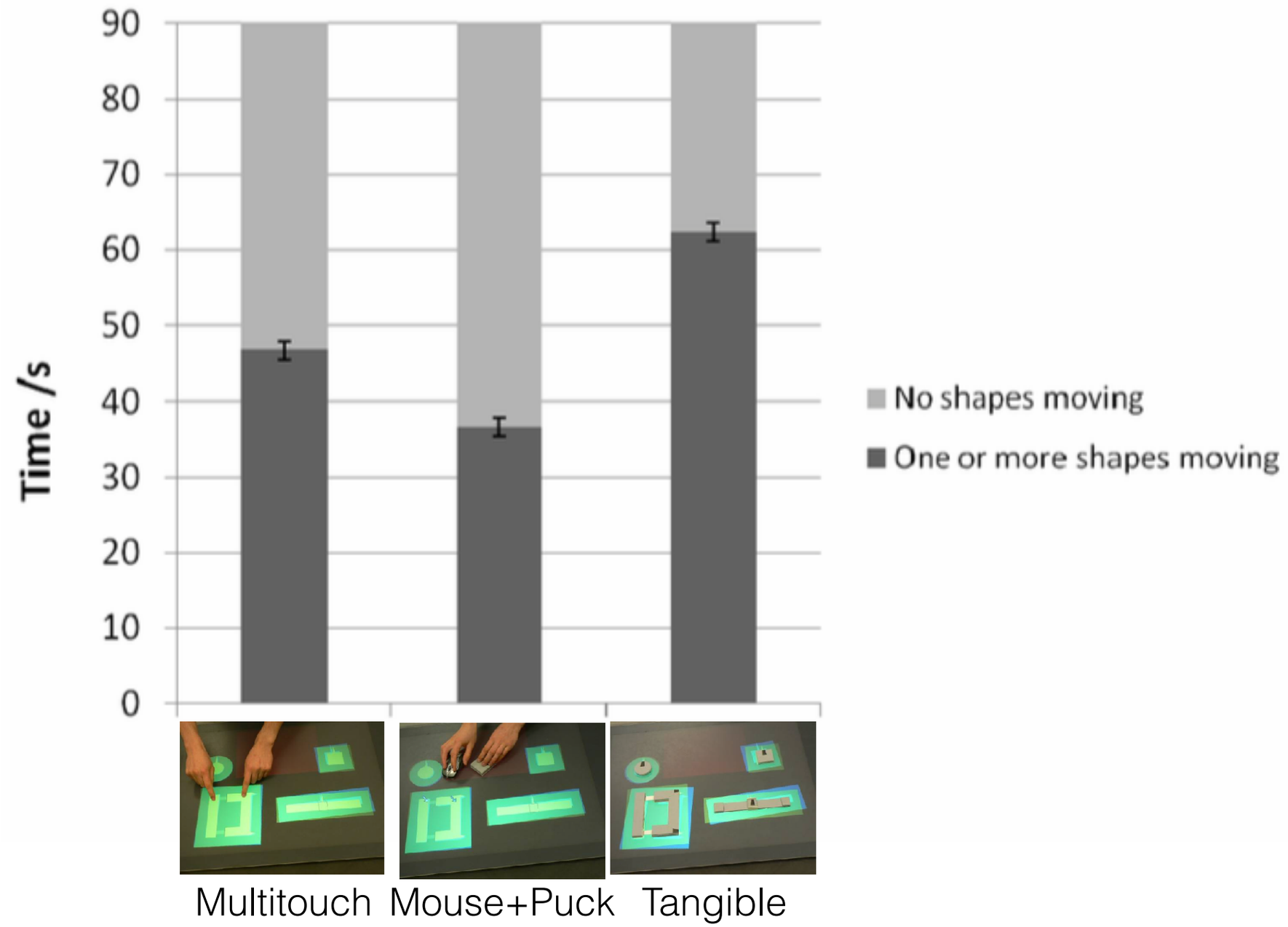


Multitouch

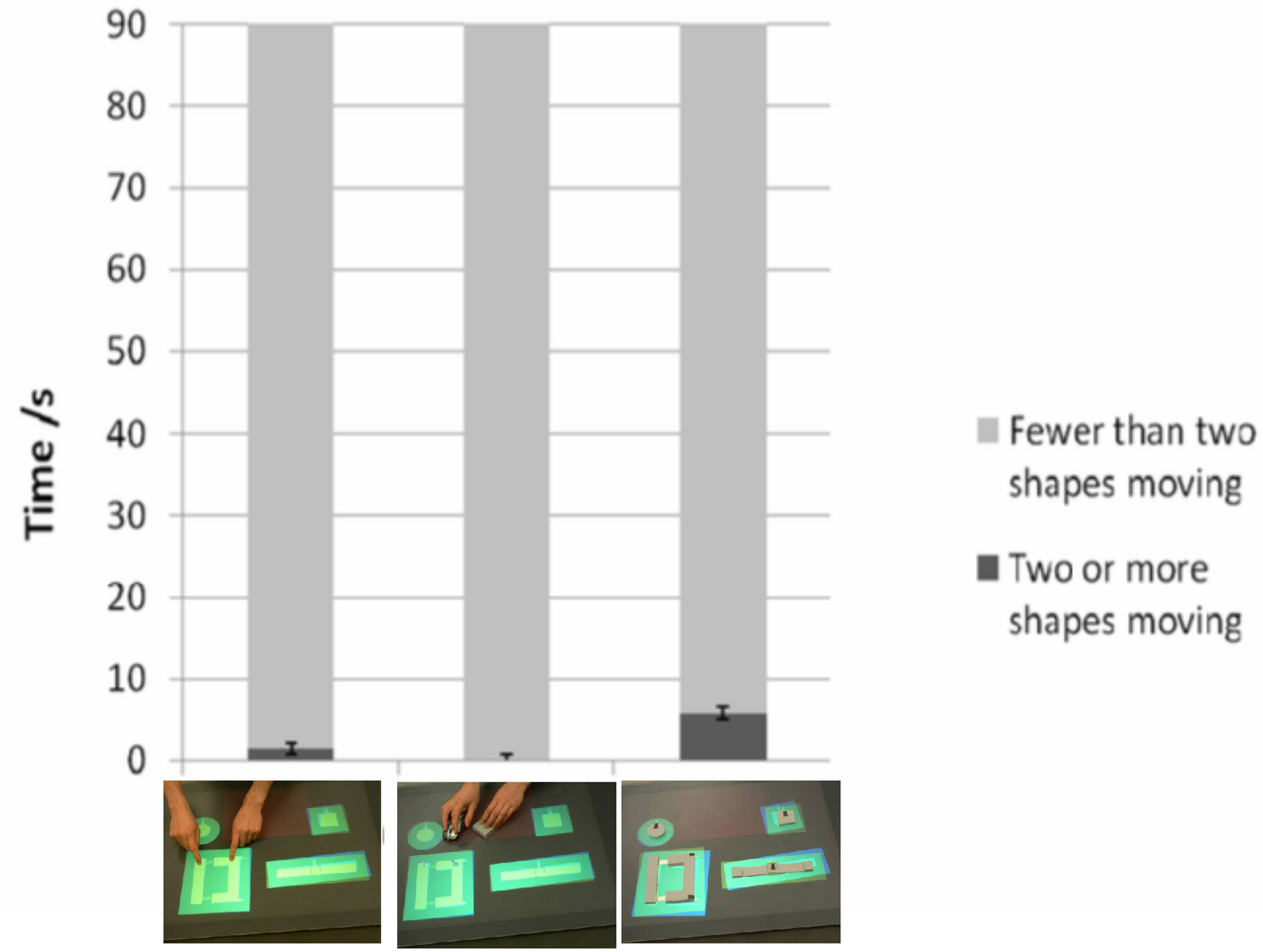


Tangible

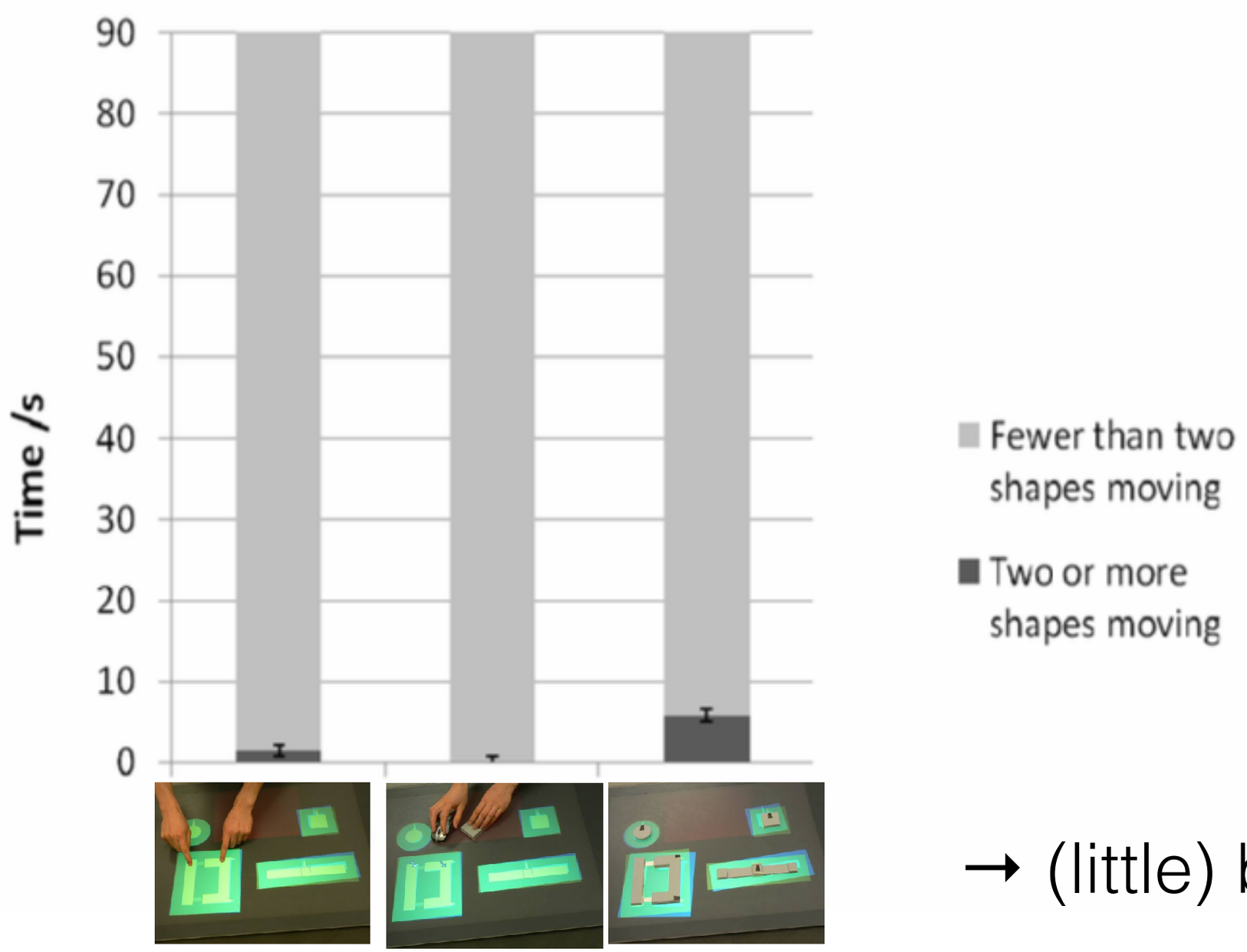
Tangible User Interfaces: Benefit over multitouch



Tangible User Interfaces: Benefit over multitouch



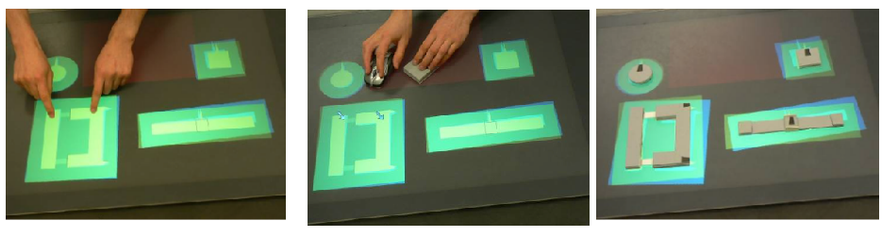
Tangible User Interfaces: Benefit over multitouch



→ (little) bimanualism

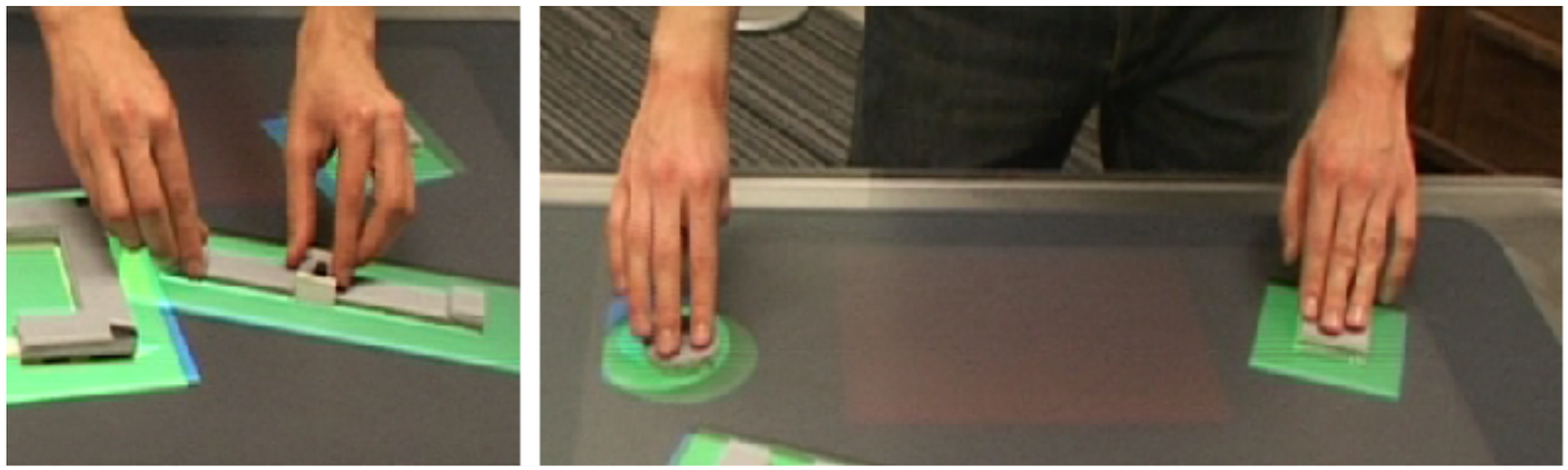
Tangible User Interfaces: Benefit over multitouch

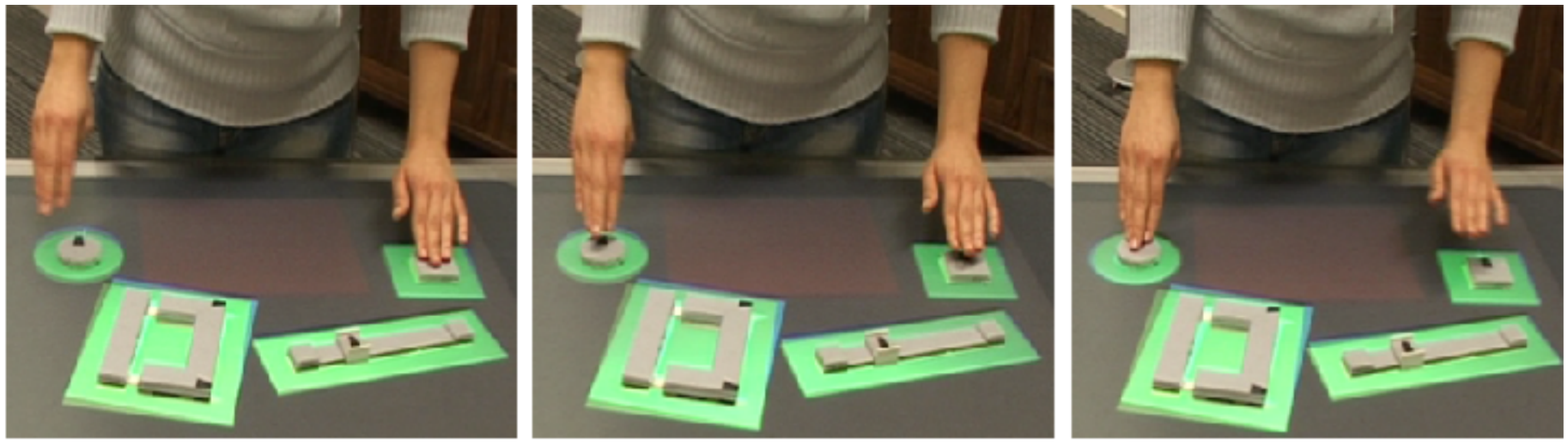
+ Little difference in preference, comfort and ease of use



Multitouch Mouse+Puck Tangible

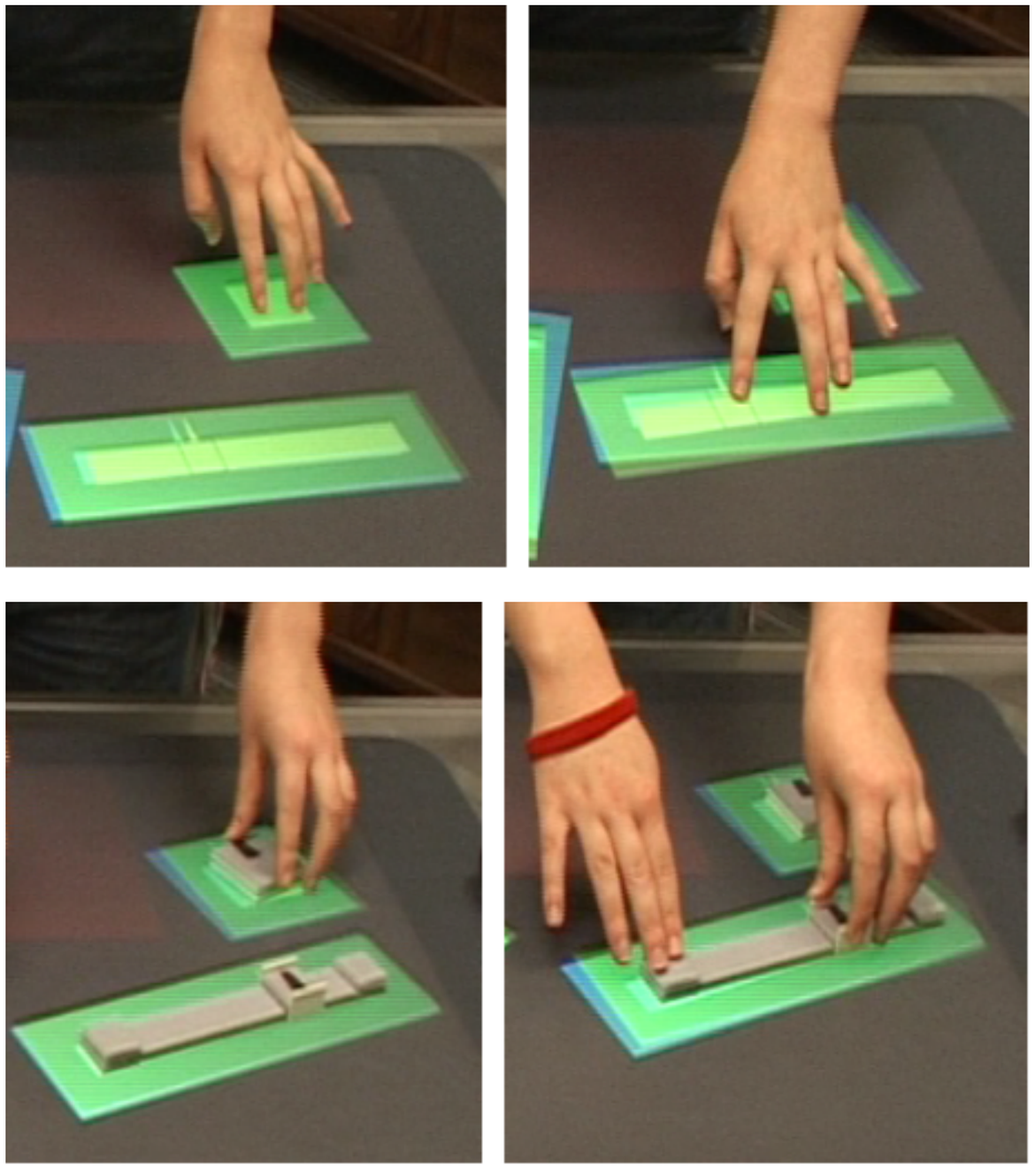
Tangible User Interfaces: Benefit over multitouch





Same pattern for multitouch and tangible

Tangible User Interfaces: Benefit over multitouch



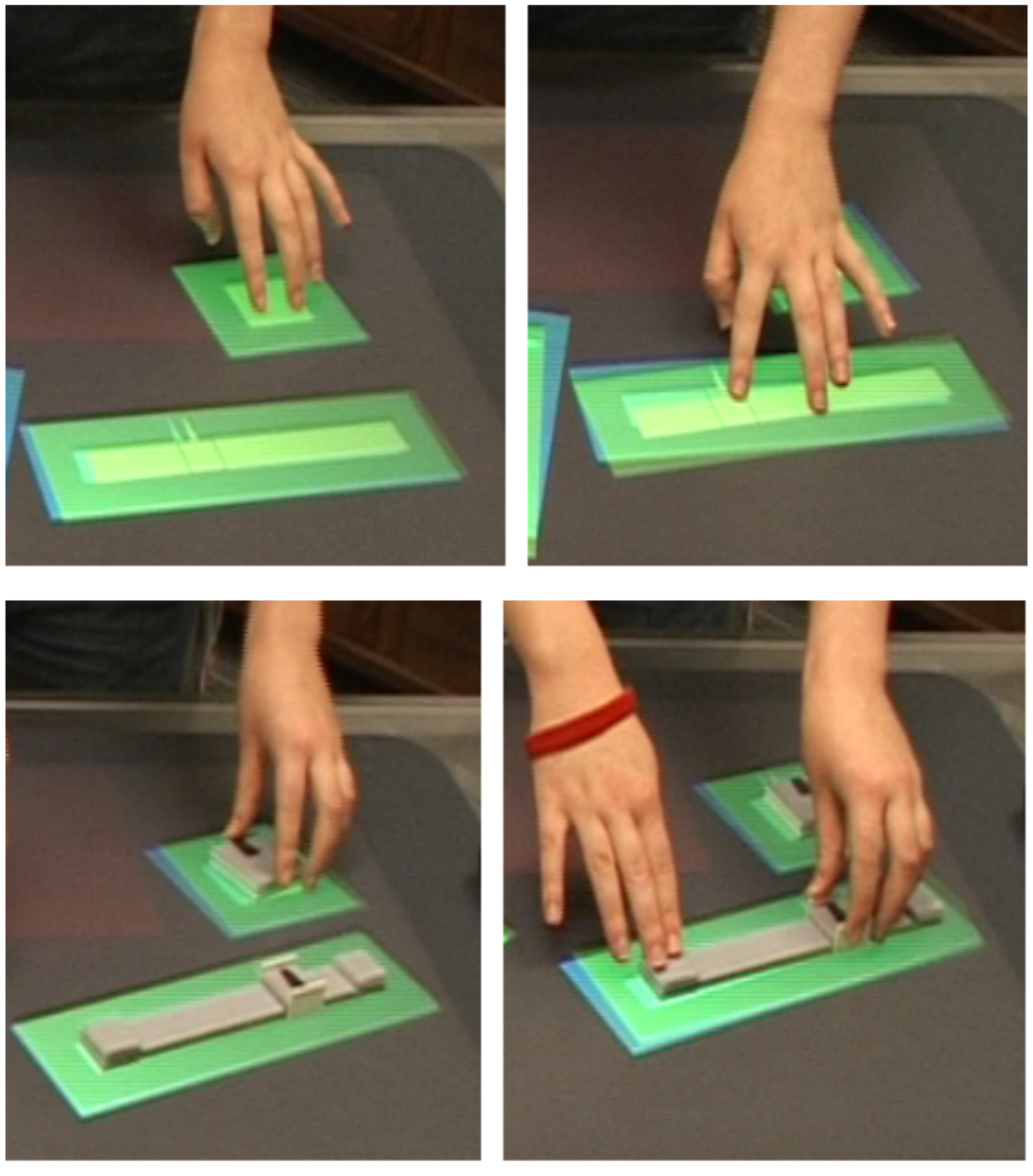
multitouch

≠

tangible

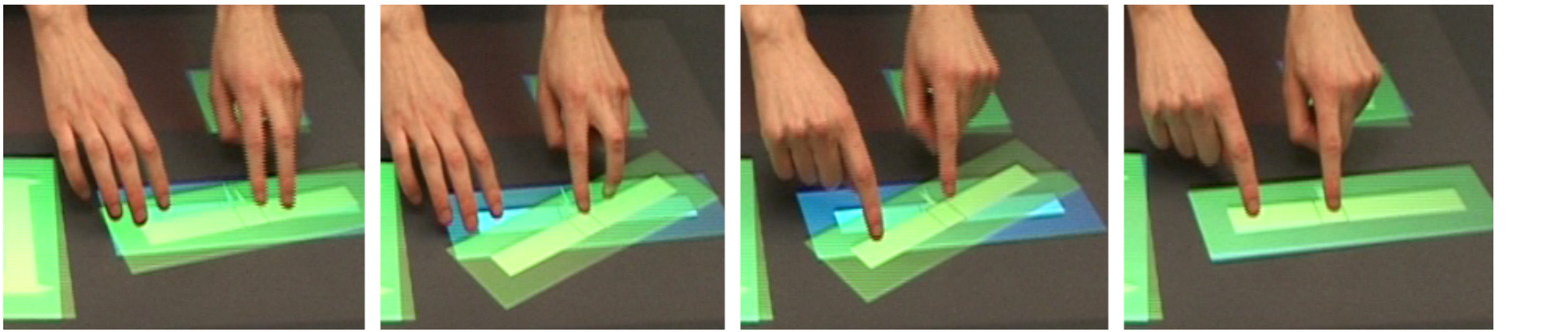
Tangible User Interfaces: Benefit over multitouch

number of contact points



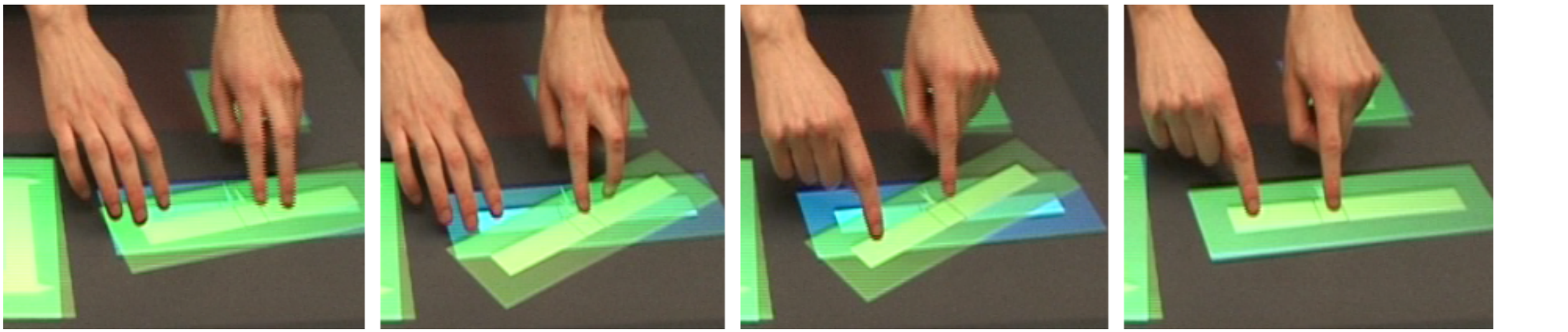
multitouch
≠
tangible

Tangible User Interfaces: Benefit over multitouch



multitouch:
number of contact points

Tangible User Interfaces: Benefit over multitouch



multitouch:
number of contact points decrease ⇒ more accurate

tangible:
number of contact points increase ⇒ more accurate

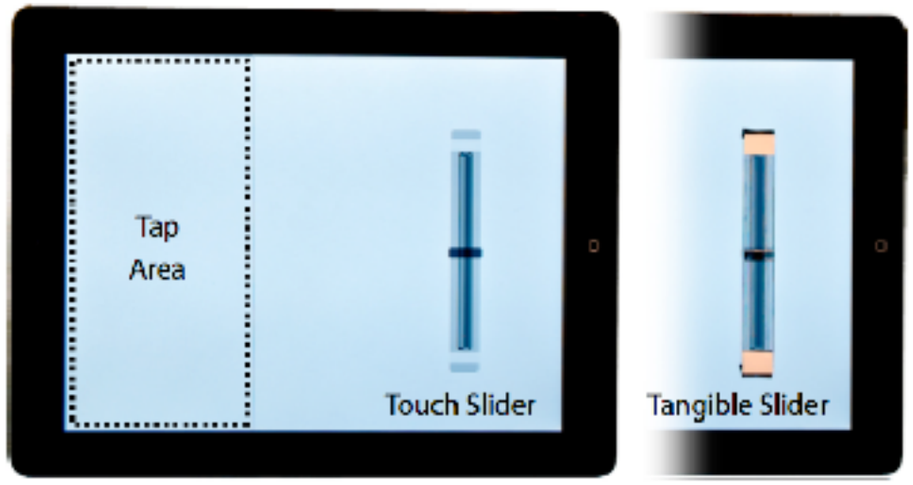
+ greater variability within and between participants

Tangible User Interfaces: What are they good for?

Several experiments demonstrated their benefits

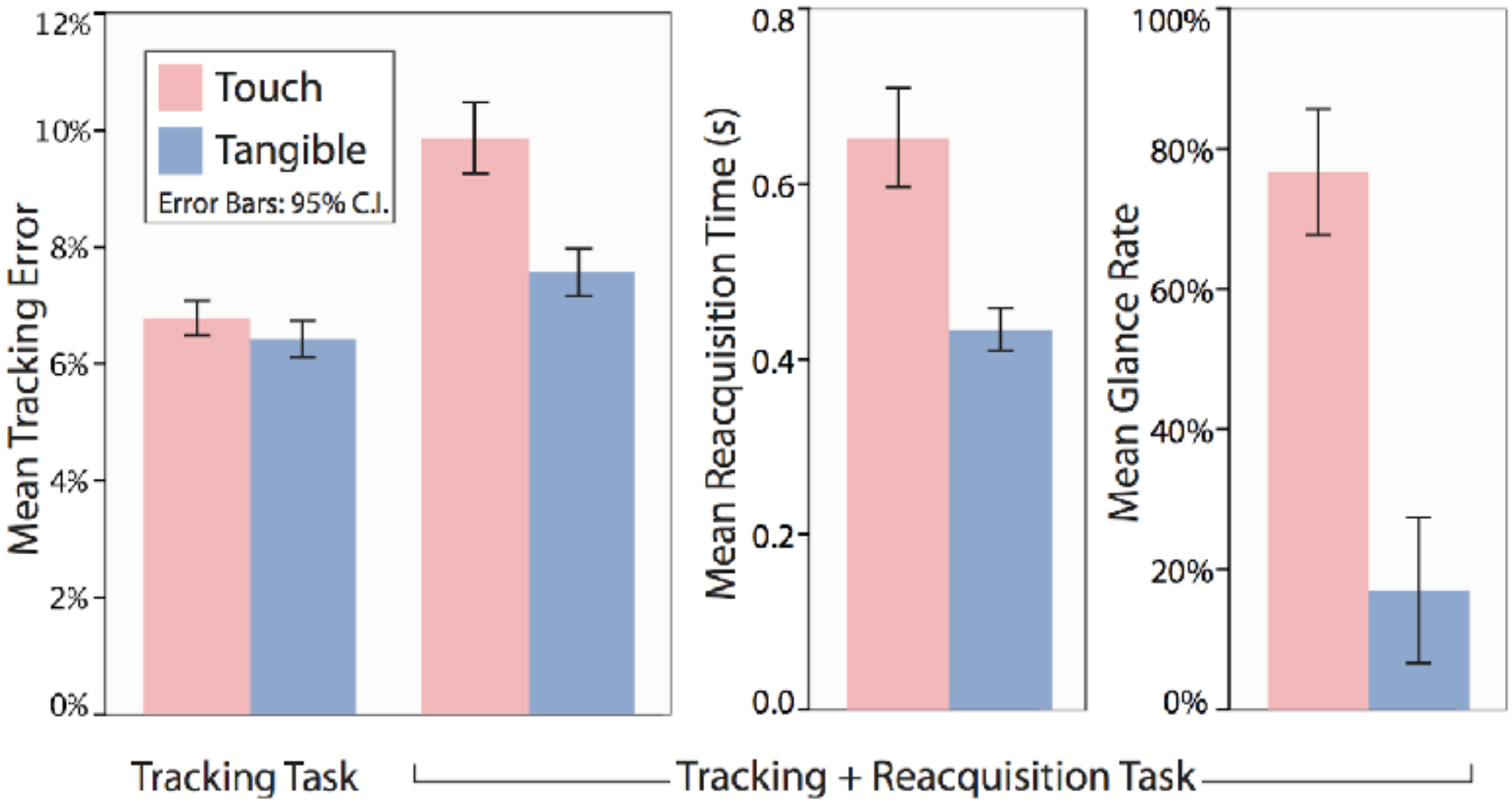
Tangible User Interfaces: Benefit for distant interaction

- Techniques: Touch vs. Tangible slider
- Tasks: Tracking vs. Tracking + additional tapping



Tangible User Interfaces: Benefit for distant interaction

- Comparing touch and tangible interaction

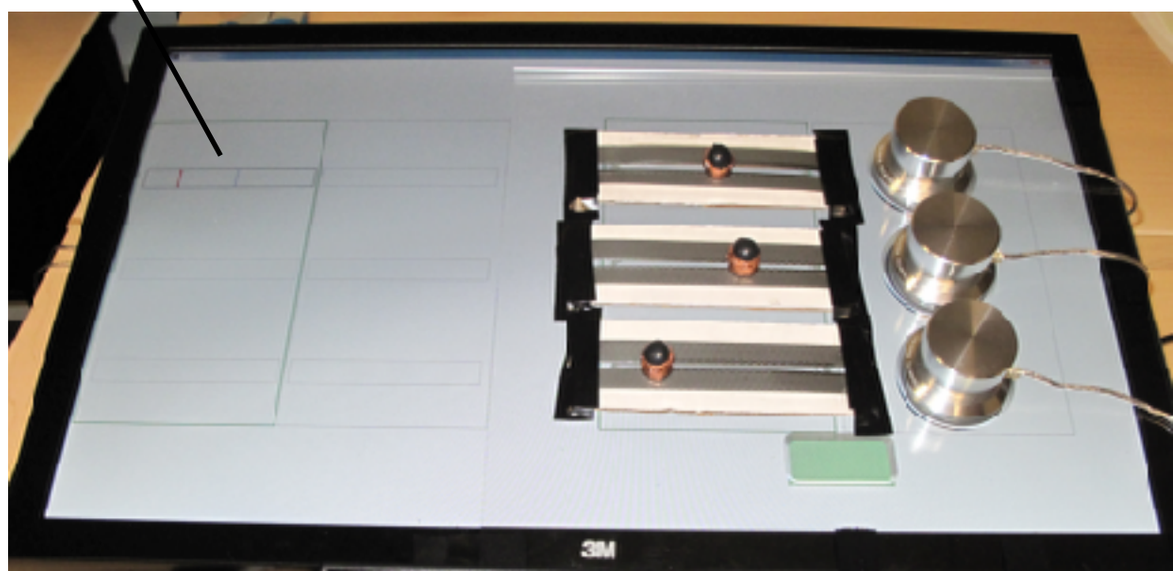


Tangible User Interfaces: What are they good for?

Several experiments demonstrated their benefits

Tangible User Interfaces: Benefit over touch and overlay

Tasks: set horizontal position of cursor

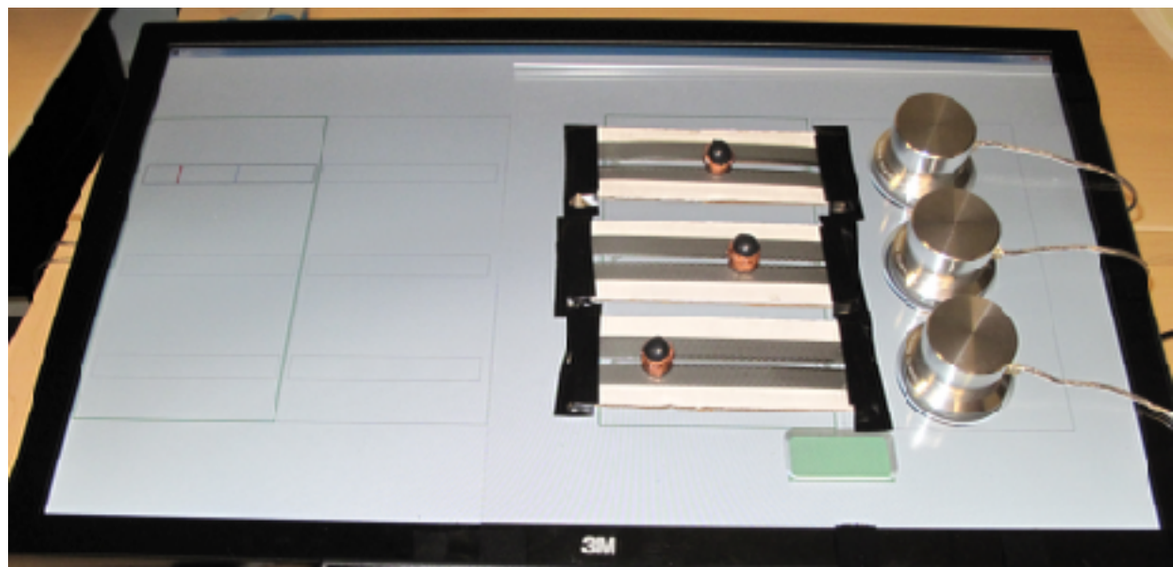


Tangible User Interfaces: Benefit over touch and overlay

Tasks: set horizontal position of cursor

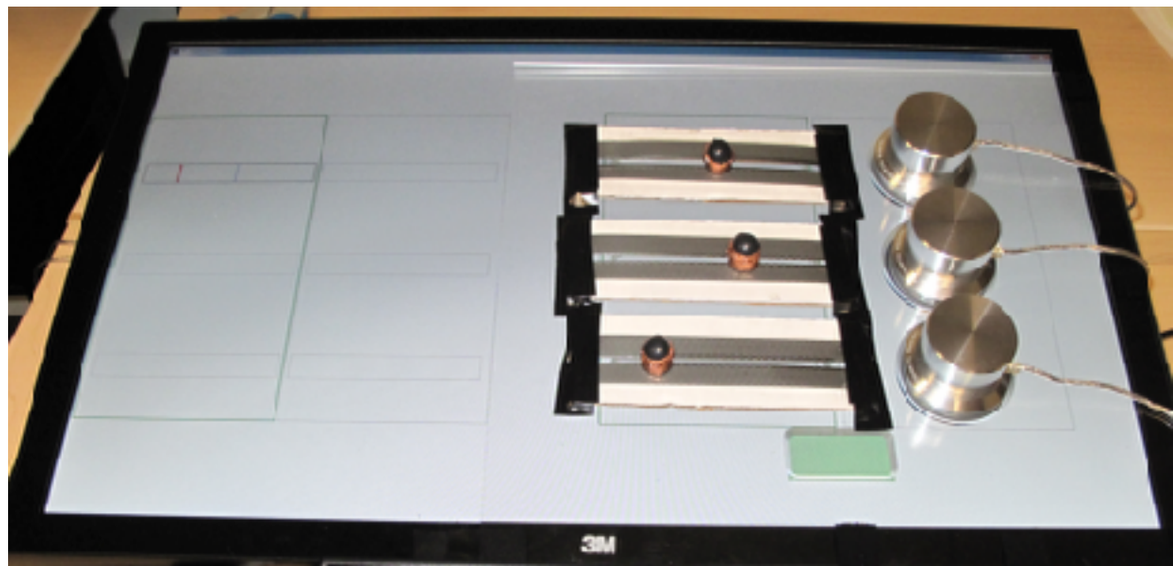
1. Press green button;
   Acquisition of required tool;
   Move towards and stay in target for 1 second;

2. Move cursor back and forth 5 times
   between two targets



Tangible User Interfaces: Benefit over touch and overlay

	Touch	Overlay	Tangible
Slider			
Single-turn dial			
Multi-turn dial (Task 2 only: with CD gain 3x)			



Tangible User Interfaces: Benefit over touch and overlay

- Task 1: acquisition and movement

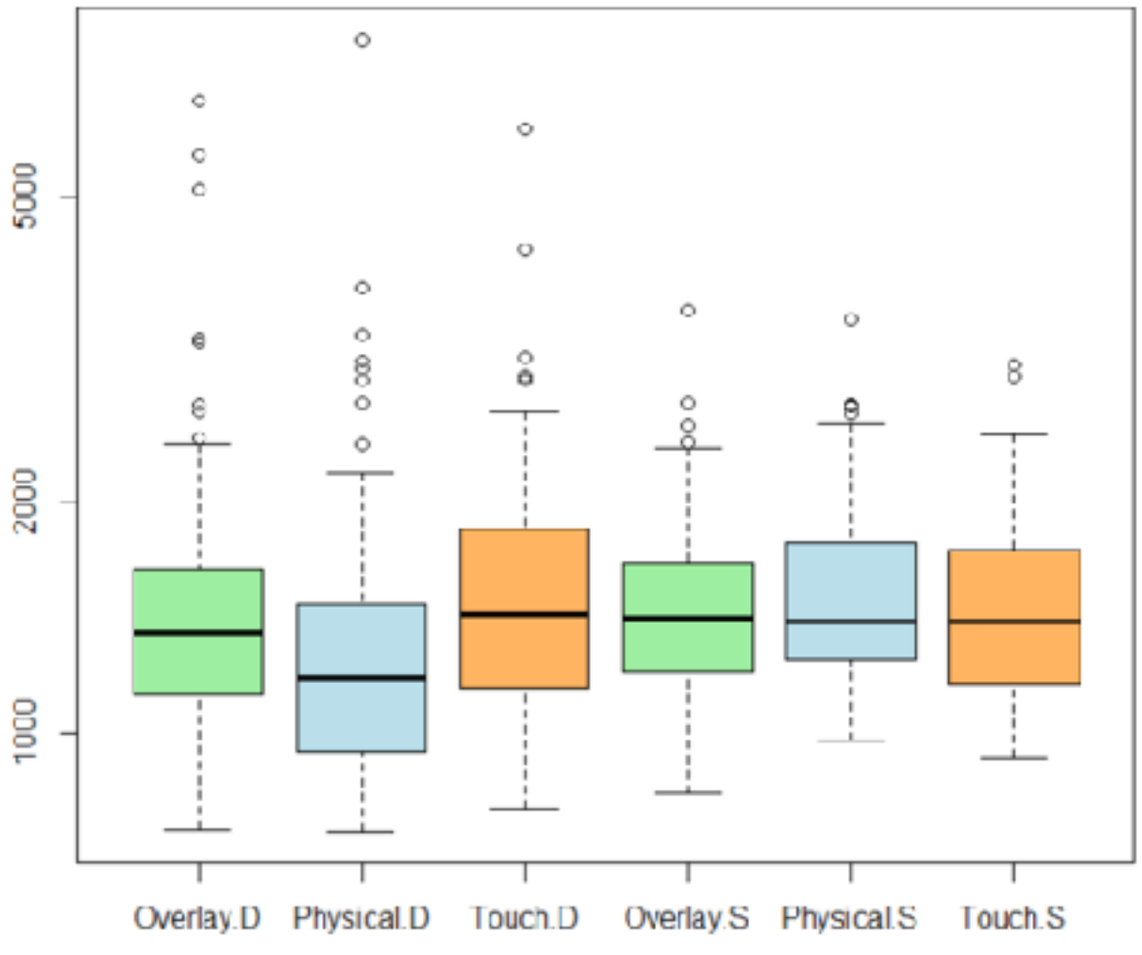
	Touch	Overlay	Tangible
Slider		?	
Single-turn dial			

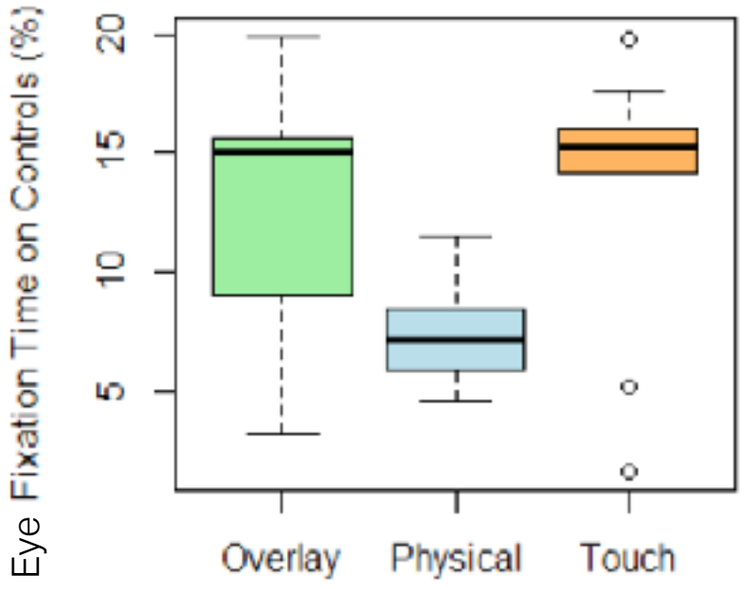
- Task 2: repetitive task

	Touch	Overlay	Tangible
Slider		?	
Single-turn dial			
Multi-turn dial (with CD gain 3x)			

Tangible User Interfaces: Benefit over touch and overlay

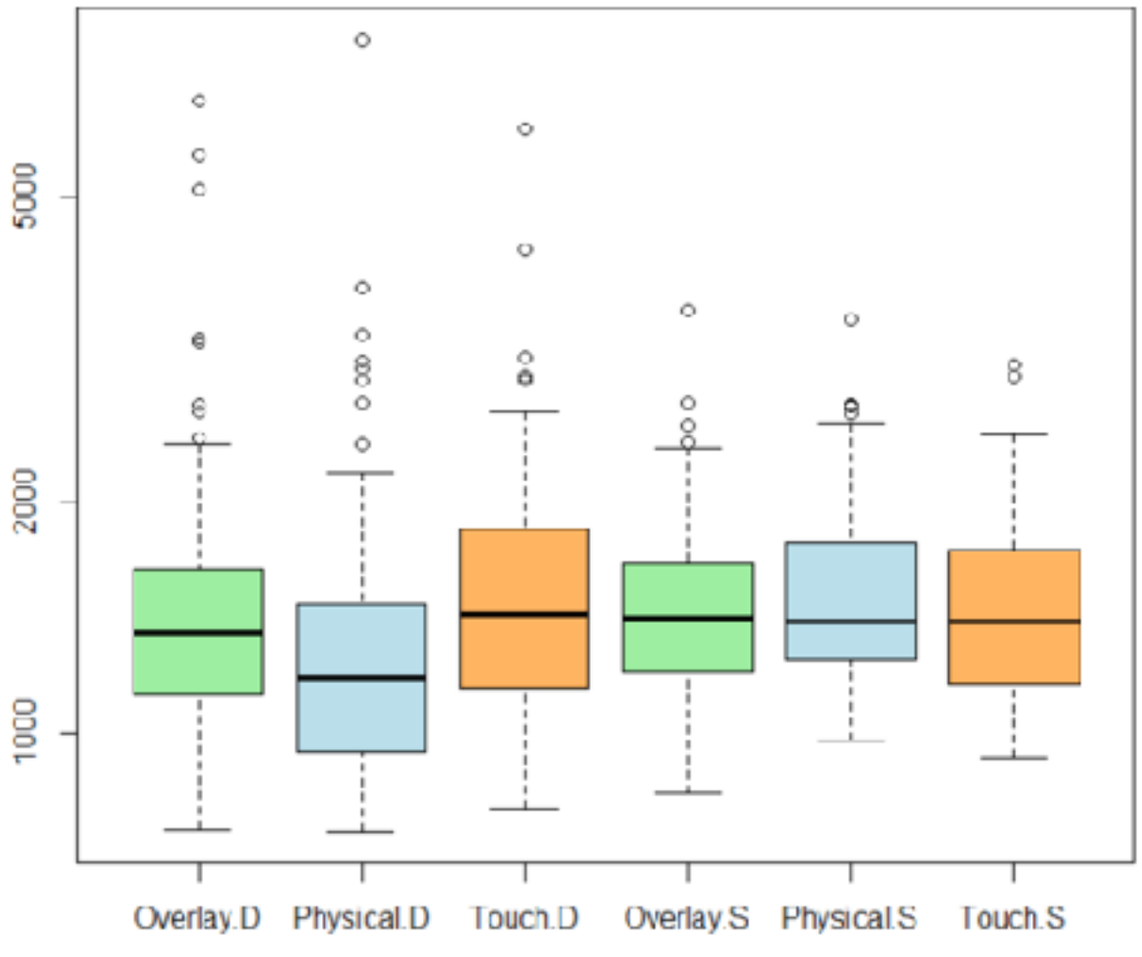
Task 1: acquisition and movement

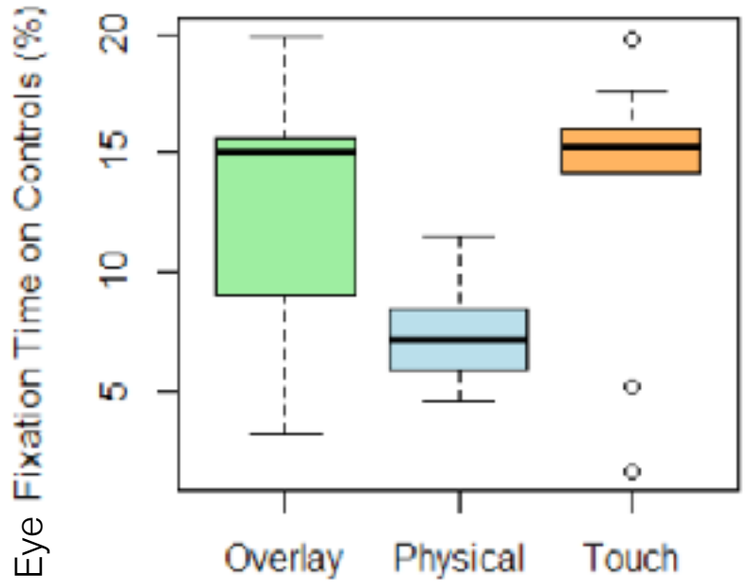




Tangible User Interfaces: Benefit over touch and overlay

Task 1: acquisition and movement

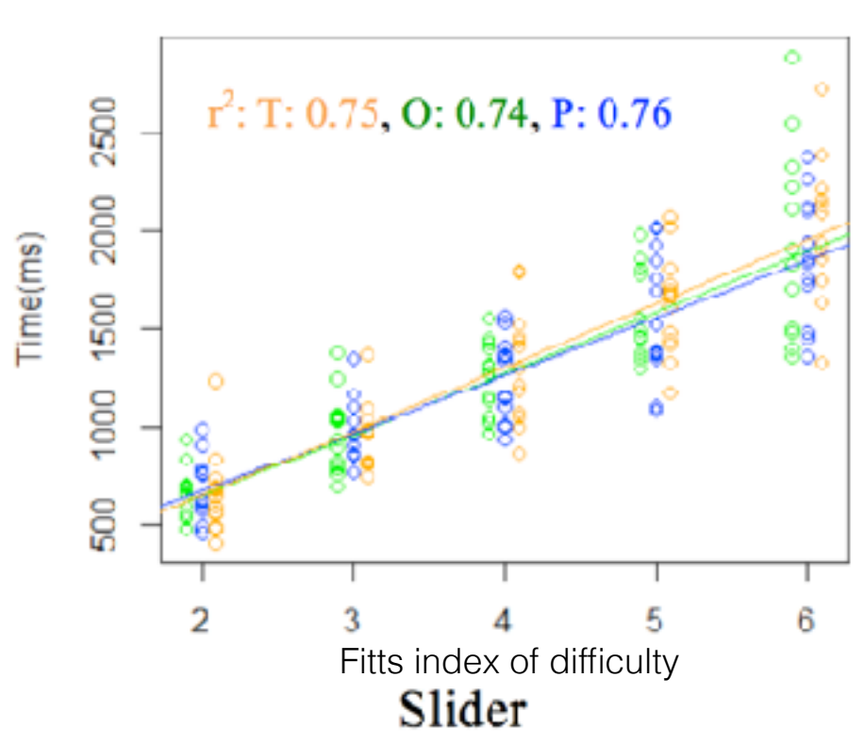


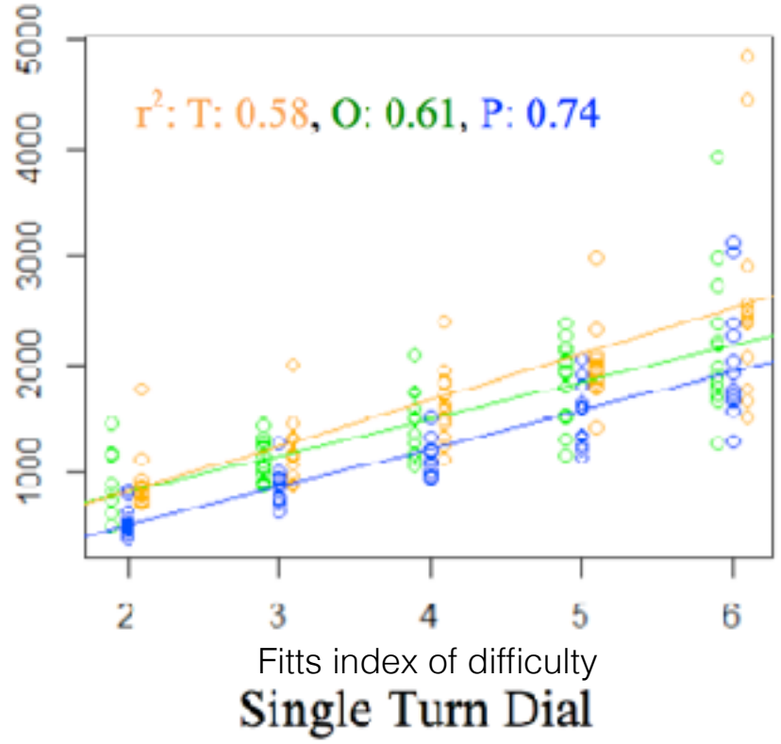


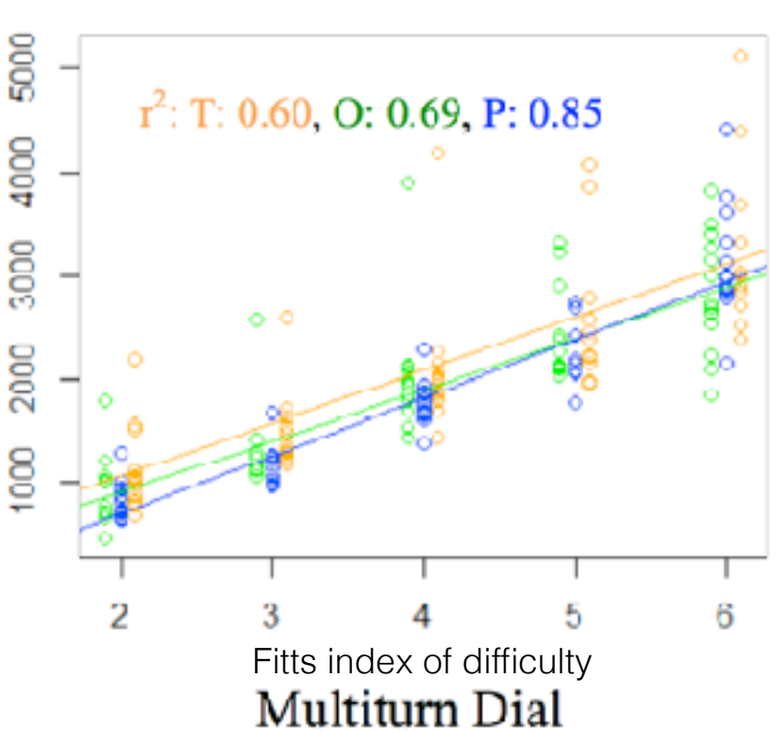
No difference found for sliders: because of manipulation problem with tangible sliders: *“participants complained that they were wobbly and required some pressure”*

Tangible User Interfaces: Benefit over touch and overlay

Task 2: Repetitive movement

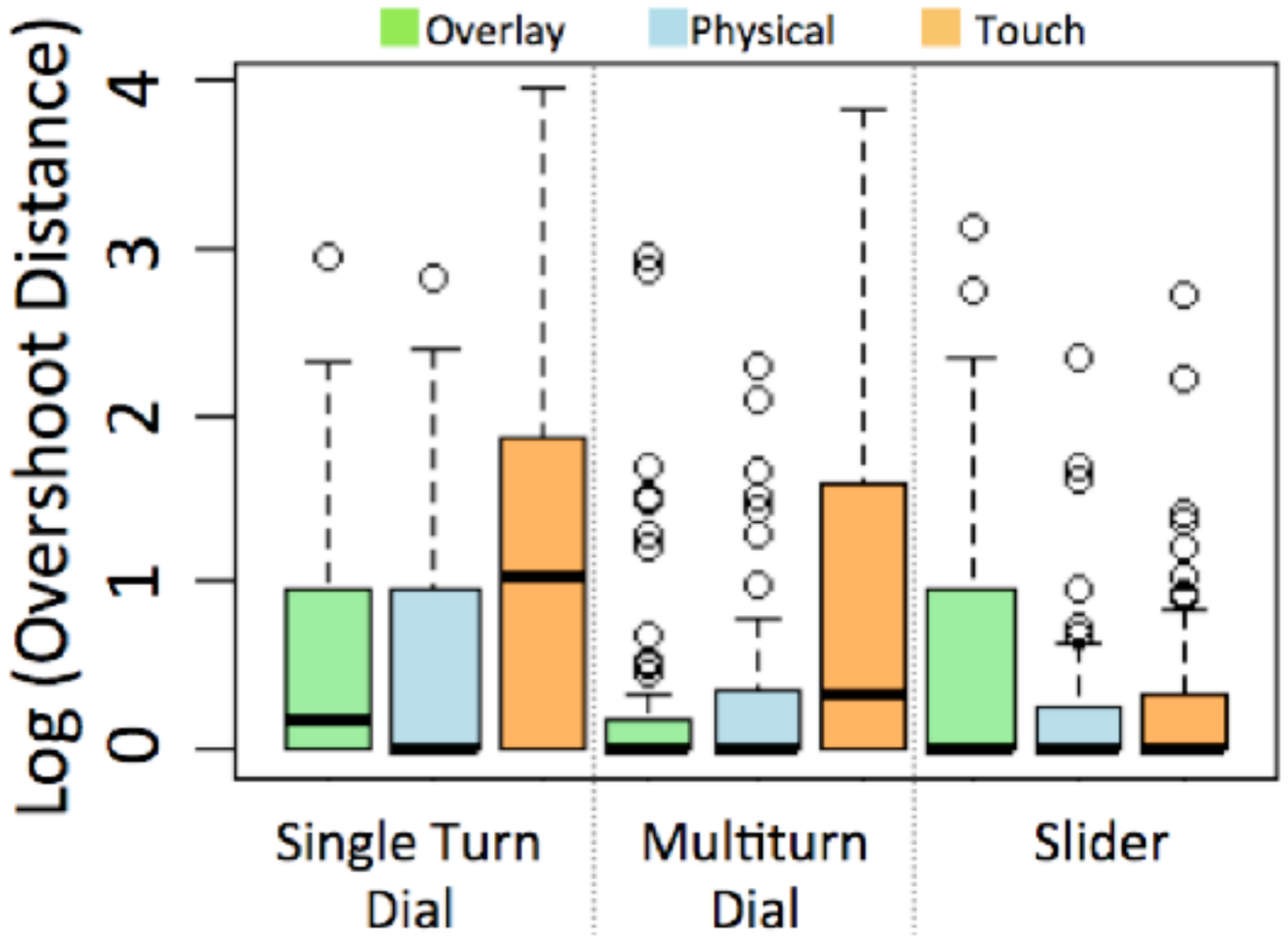






Tangible User Interfaces: Benefit over touch and overlay

Task 2: Repetitive movement



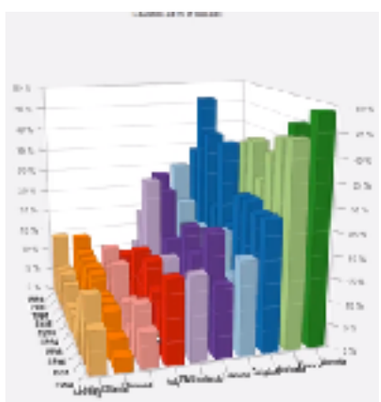
Tangible User Interfaces: What are they good for?

Several experiments demonstrated their benefits

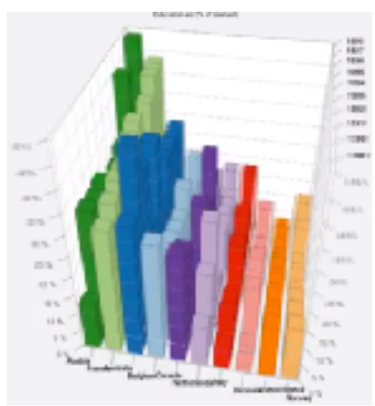
Tangible User Interfaces: What are they good for?

2D

3D Mono



3D Stereo



Tangible

Tasks

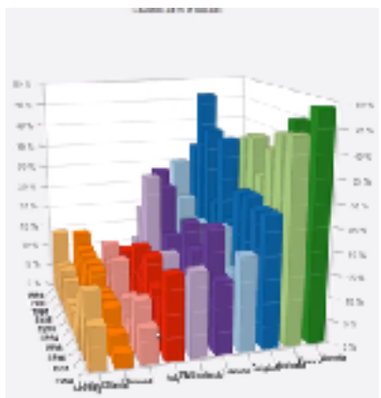
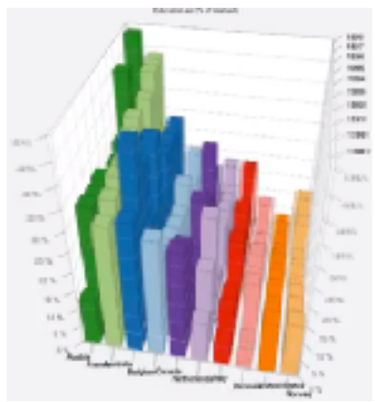
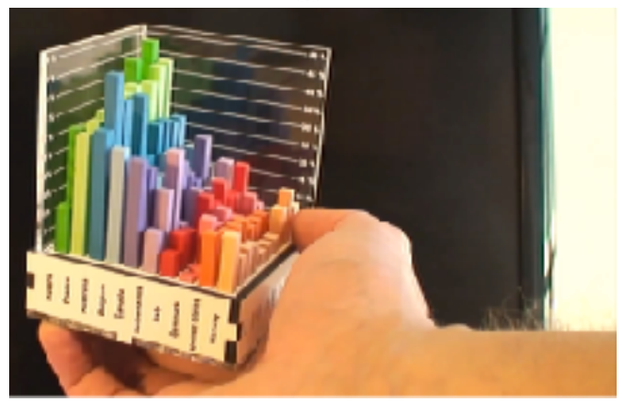
- Find and indicate a range of values
- Find and sort values
- Find and compare values

Measures

- Time
- Error rate

Tangible User Interfaces: What are they good for?

2D | 3D Mono | 3D Stereo | Tangible

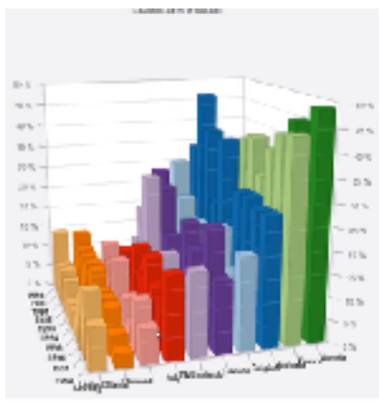





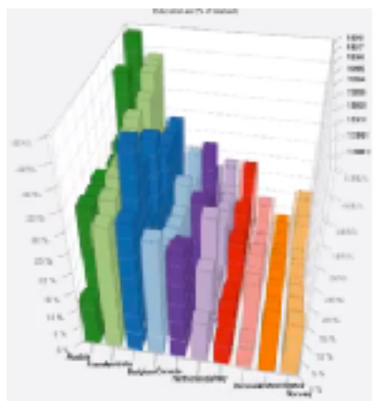
Users are:

- Around 20% faster with Tangible than with 3D
- Around 40% faster with 2D than with Tangible
  - however, effect weaker if the task cannot be solved by one 2D cut

Tangible User Interfaces: What are they good for?

2D 3D Mono 3D Stereo Tangible





Among possible explanation: Touch & Proprioception

3D mono/stereo	**Tangible**
sequential: rotate; mark; rotate; etc.	parallel: rotate // mark*
occluded bars impossible to reach with the mouse cursor	occluded bars reachable with the fingers
mouse cursor does not occlude the bars	proprioception compensate for fingers that occlude the bars

Proprioception

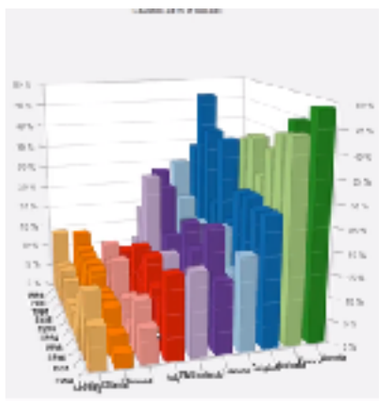
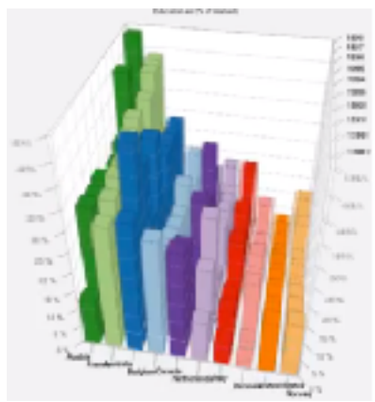
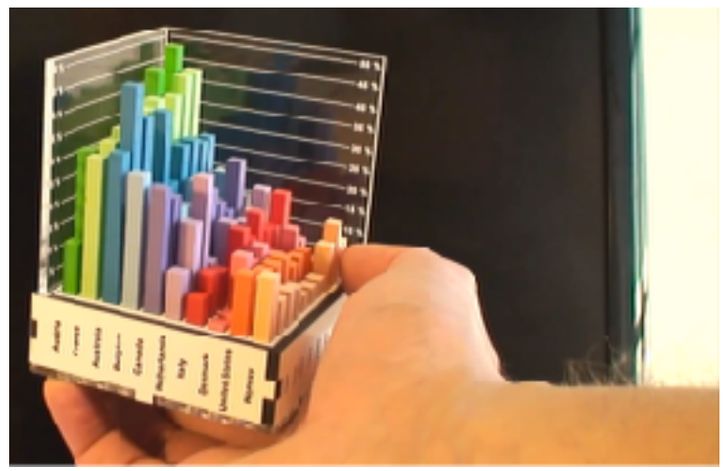
Definition:

- Perception of our own body

- Sense of the relative position of our limbs through our skin, muscle, joints and inner ear

Tangible User Interfaces: What are they good for?

2D 3D Mono 3D Stereo Tangible

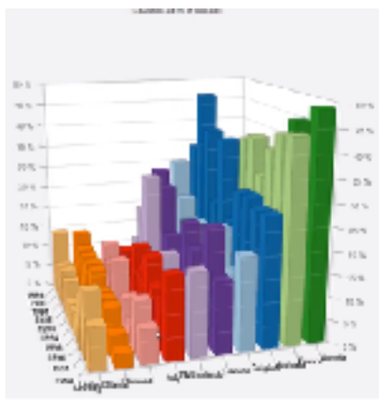





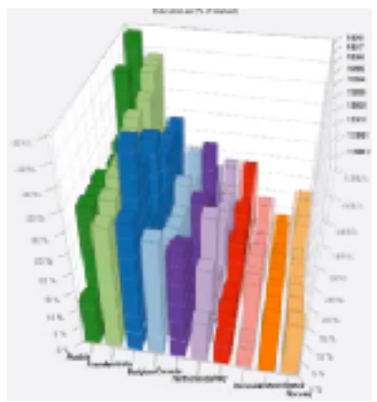
Among possible explanation: Direct rotation

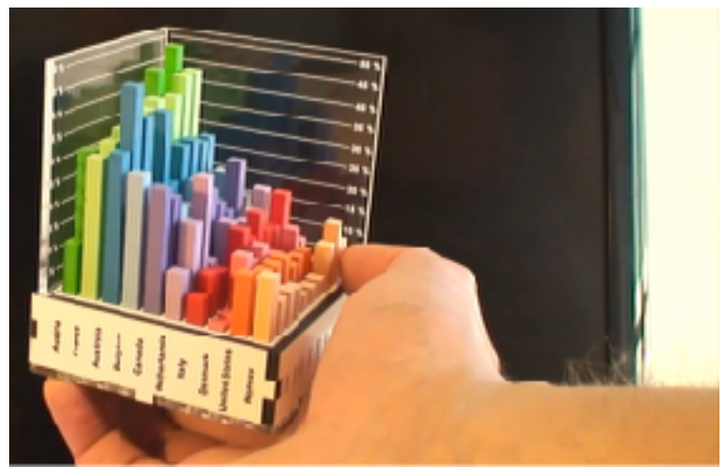
3D mono/stereo	**Tangible**
"Indirect" rotation (mapped to x and y axis of mouse)	"Direct" rotation

Tangible User Interfaces: What are they good for?

2D 3D Mono 3D Stereo Tangible





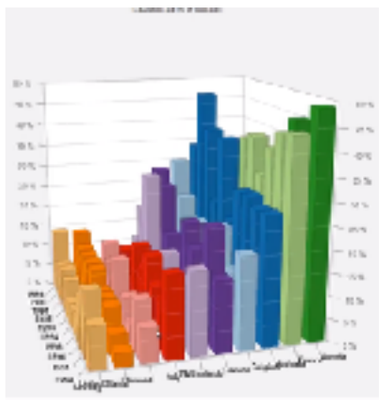
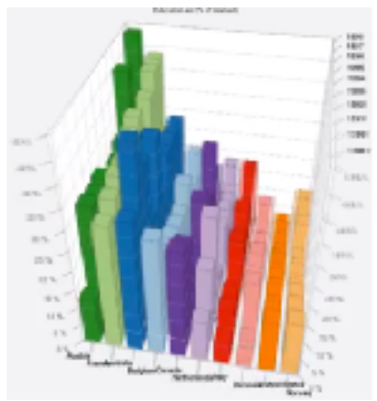
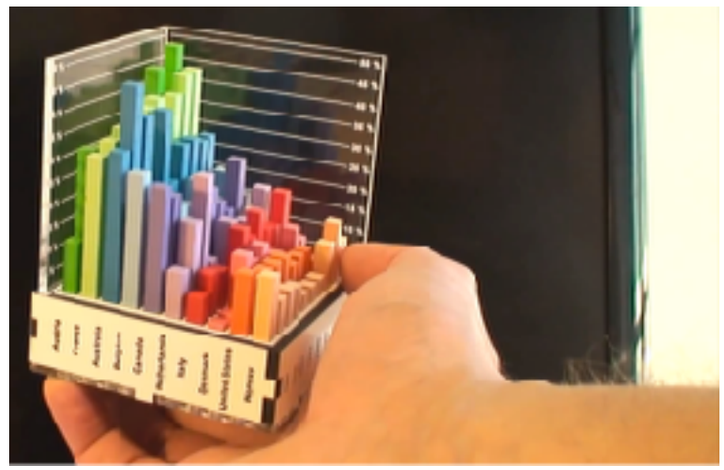


Among possible explanation: Visual Realism

	3D mono/stereo	**Tangible**
Resolution	1920 x 1080 px for 23”	0.5mm
Stereoscopic cues (Images L and R different)	no / yes	yes
Accomodation cues	at screen distance	at any distance
Shading and shadows	computer-generated	natural
Texture	none	spray paint imperfections

Tangible User Interfaces: What are they good for?

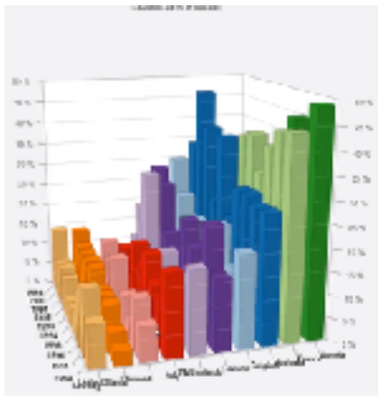
2D 3D Mono 3D Stereo Tangible

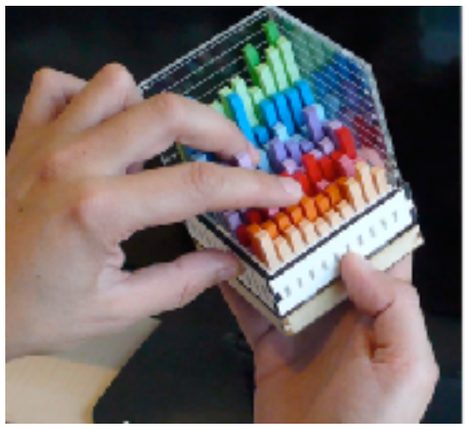
Impact of all possible explanations?

- Touch & Proprioception?
- Direct rotation?
- Visual Realism?

Tangible User Interfaces: What are they good for?



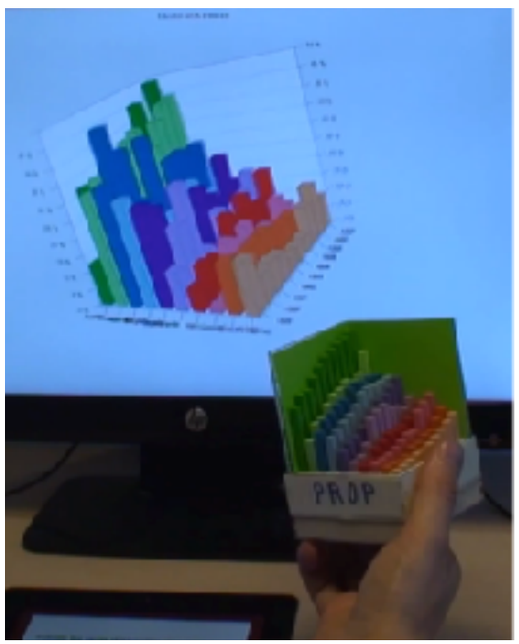
3D Mono &
Indirect mouse rotation &
No bar marking



Tangible
Direct rotation
& Touch

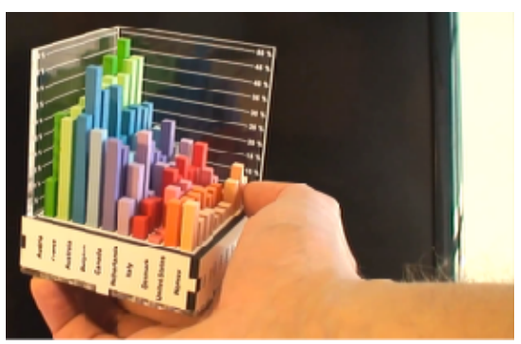
Direct rotation

Touch & Proprioception



3D Mono &
Prop-based direct rotation &
No bar marking

Tangible
Direct rotation &
No touch



Visual realism

Tangibles User Interfaces: What are they good for?

- Direct rotation: very little faster compared to indirect rotation
- Visual Realism: around 13% faster compared to on-screen
- Touch & Proprioception: around 15% faster than no touch
    - unload cognitive effort into a physical action

Tangible User Interfaces
What are their limitations?