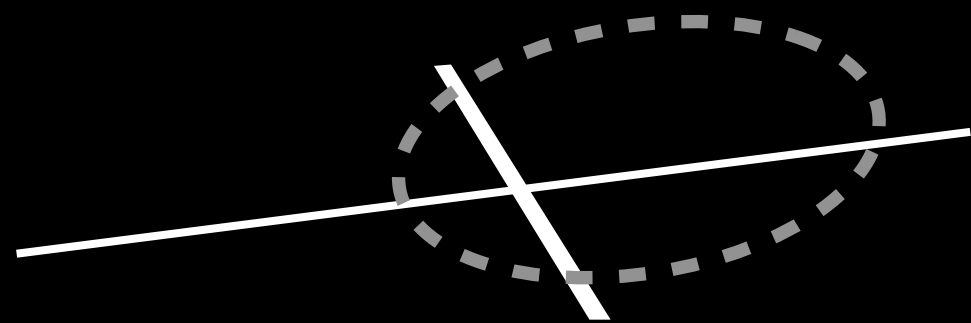


Touch Input

CSE 510
Christian Holz
Microsoft Research
<http://www.christianholz.net>



February 11, 2016



Nokia 5800, 2008

hall of fame/hall of shame?



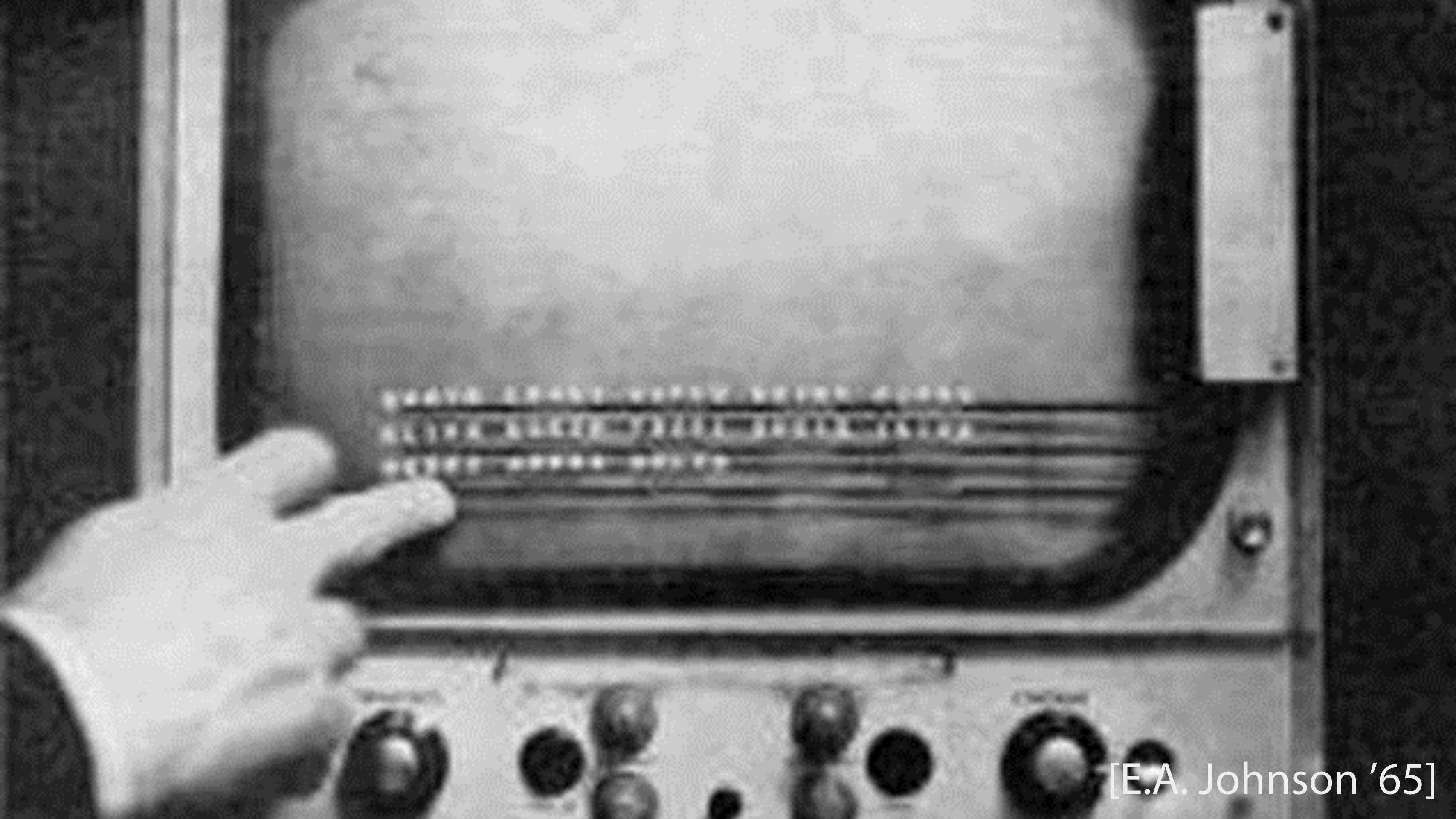
hall of fame/hall of shame?



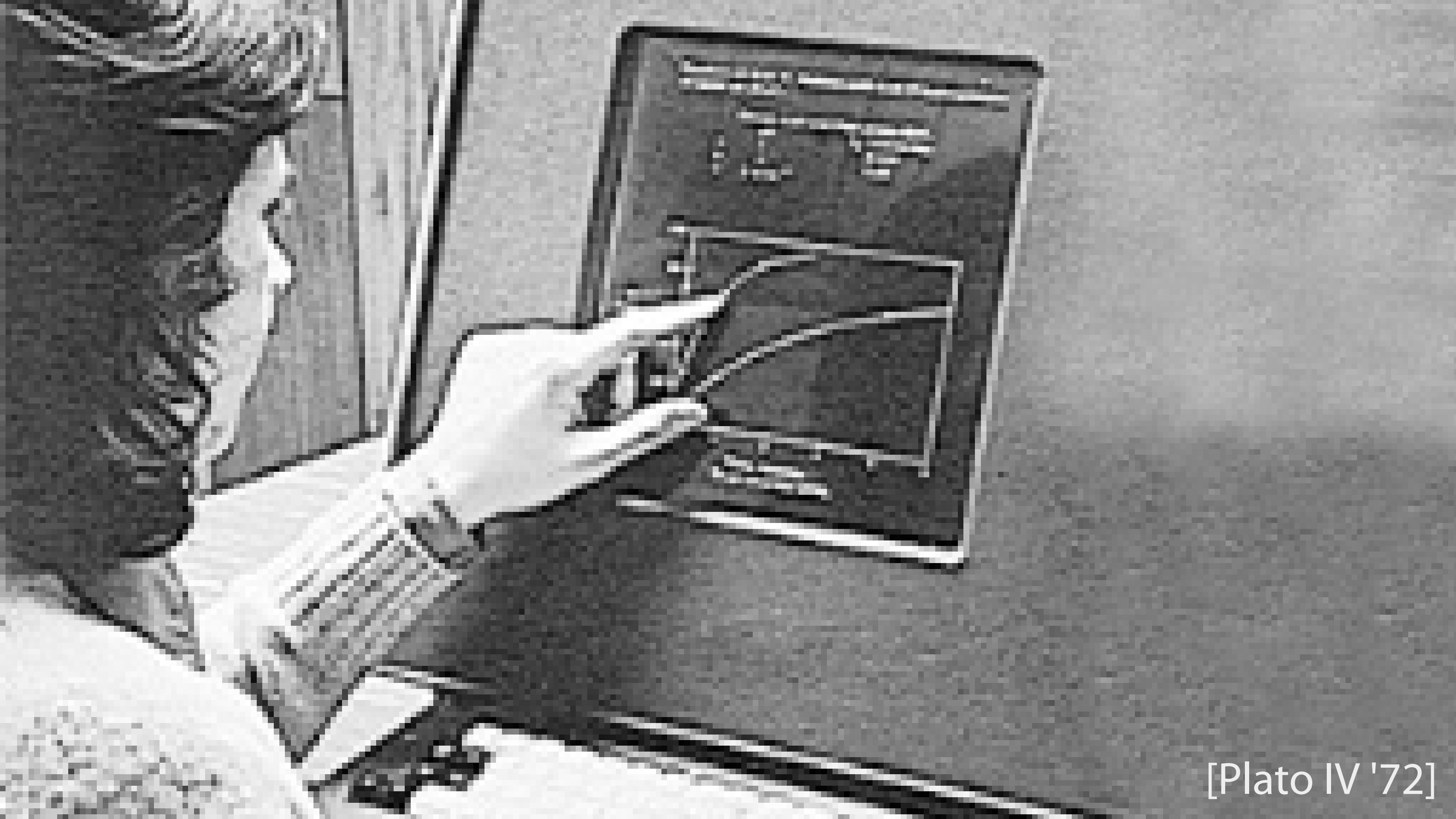
“we’ve invented...”



[Lightpen '62]



[E.A. Johnson '65]



[Plato IV '72]

➔ <http://www.billbuxton.com/multitouchOverview.html>



Works like magic



IBM Simon, 1992



Works like magic

what was the real novelty here?
30 second brainstorming

1

Touch technologies

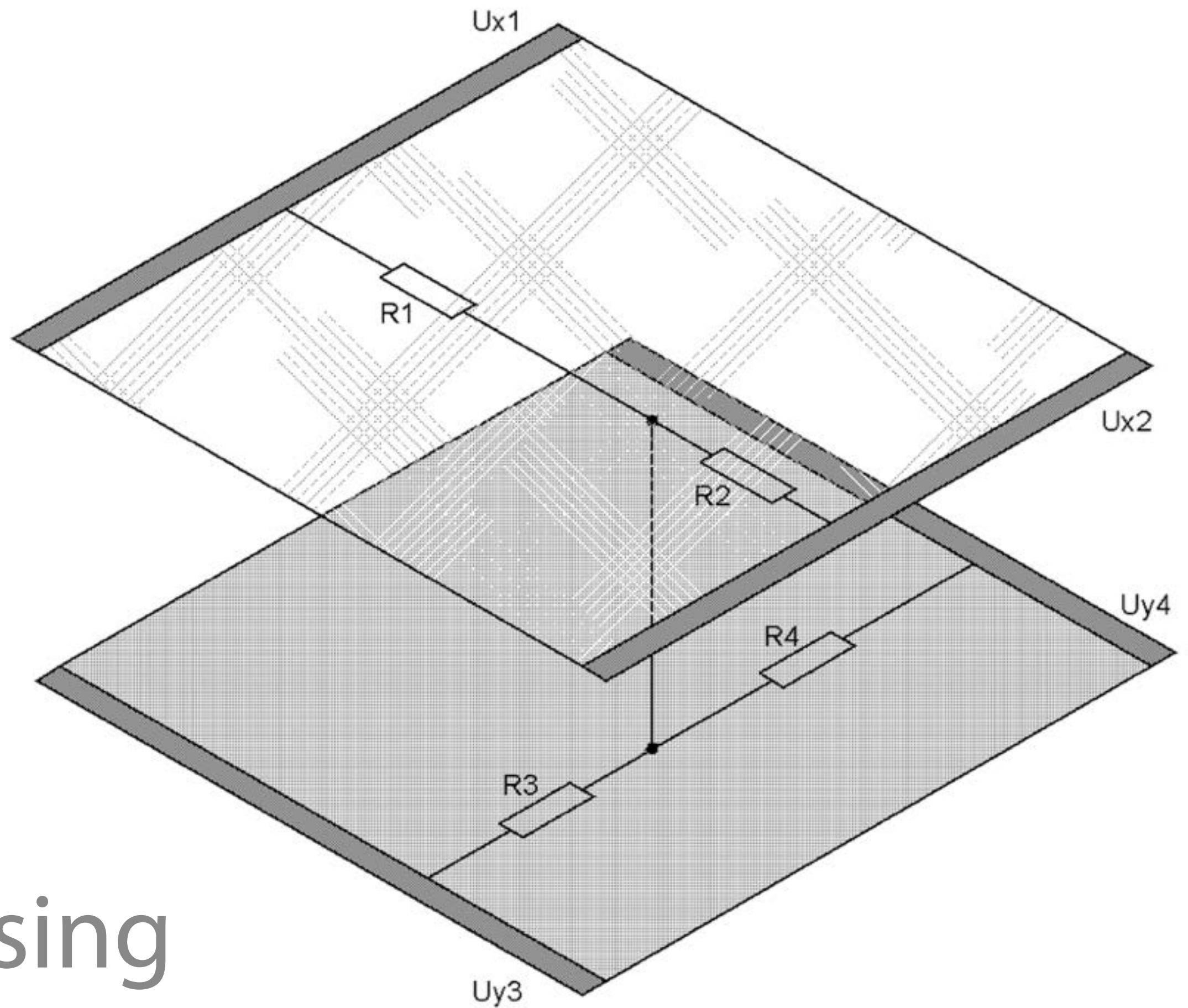
2

Touch accuracy



Touch technologies

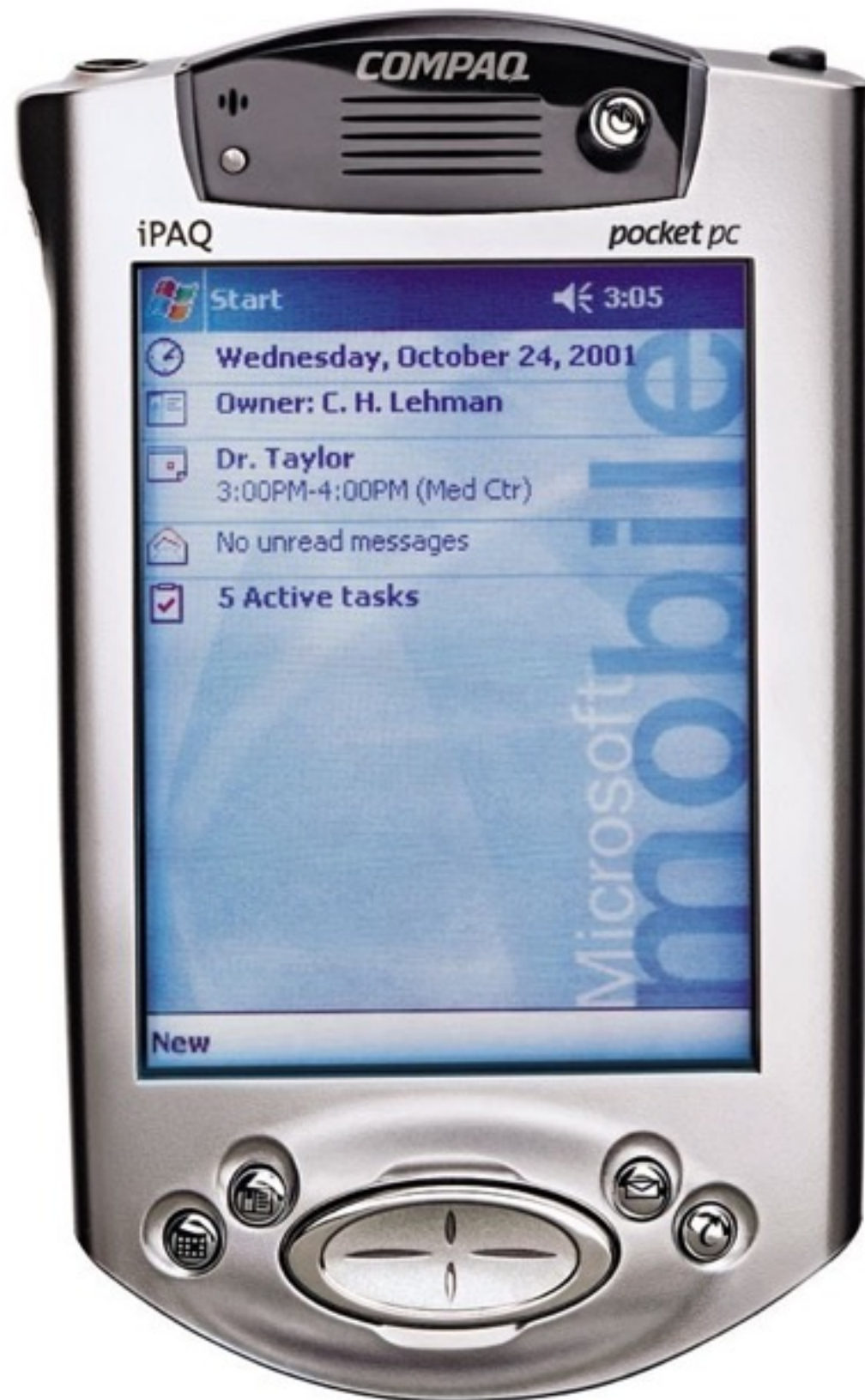
a cursory overview



resistive sensing



Inspiron 7000, 1998



Compaq PDA, 2000

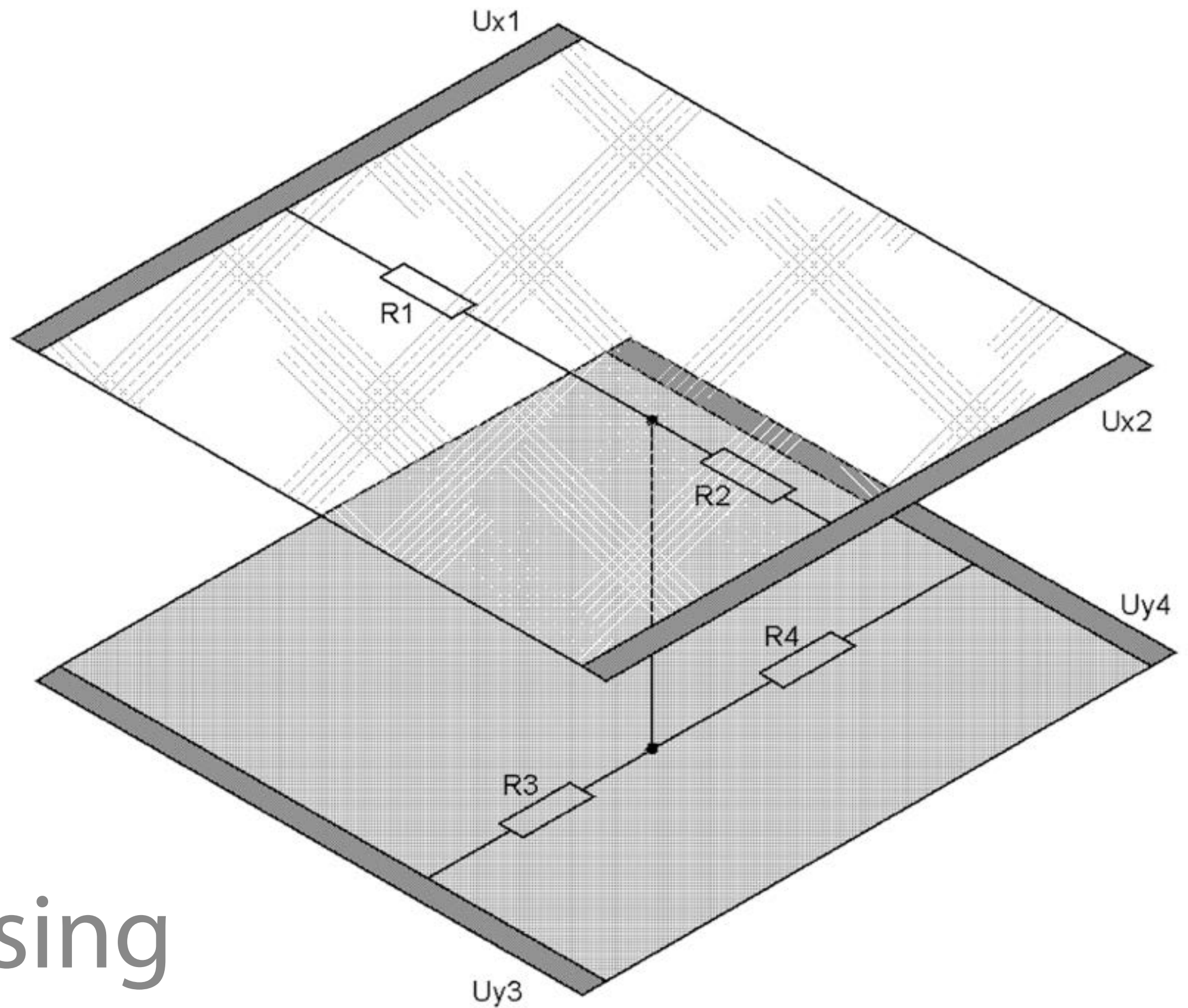


[Matsushita et al., UIST '00]

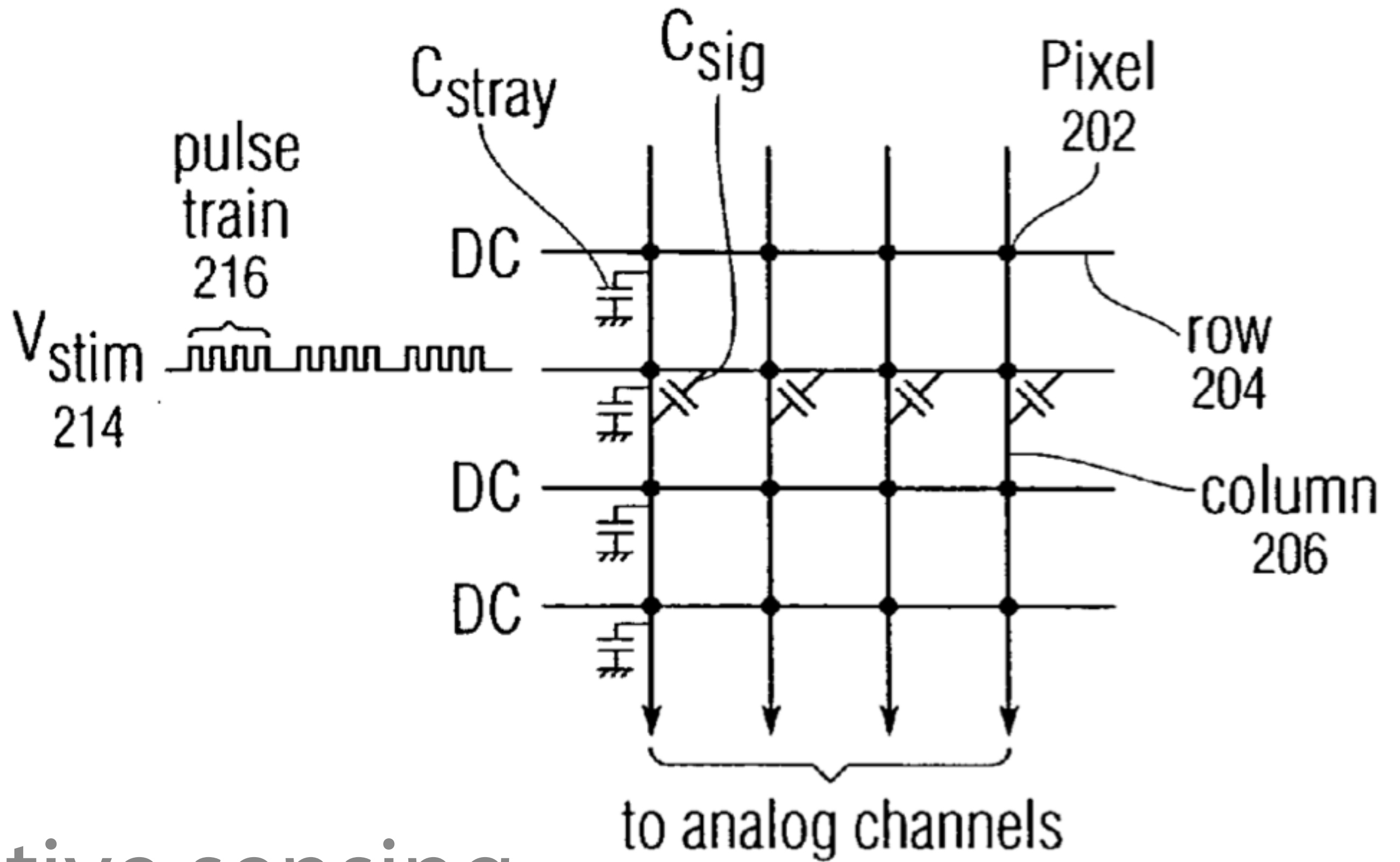
A hand is holding a tablet computer. The screen displays a diagram with a central node and several lines radiating outwards, resembling a network or a mind map. The text '30sec' is visible in the top left corner of the screen, and 'Page 1' is in the top right. The background is a plain, light-colored wall.

how did they enable dual-touch in a single touch sensor?
30 second brainstorming

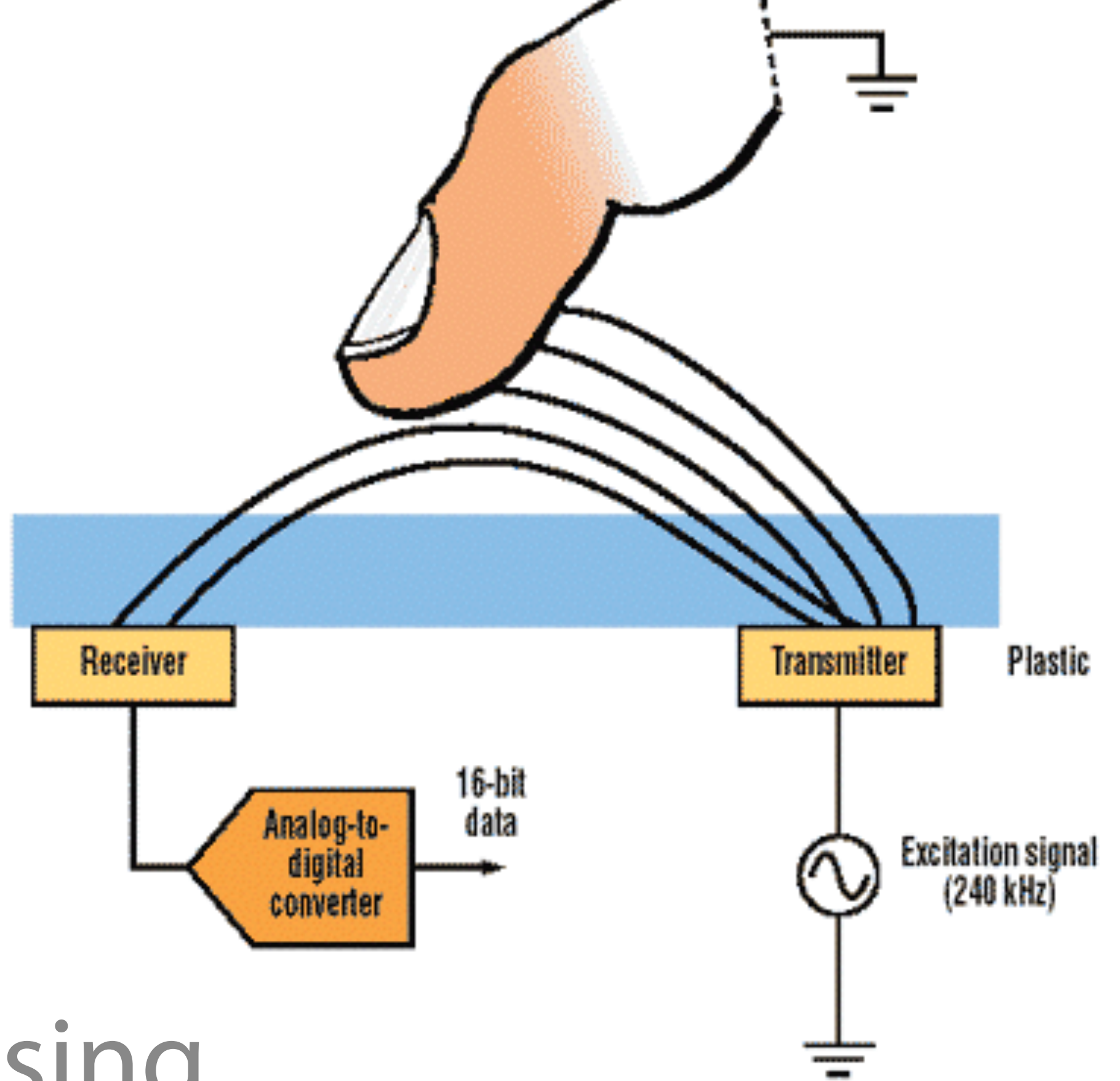
[Matsushita et al., UIST '00]



resistive sensing

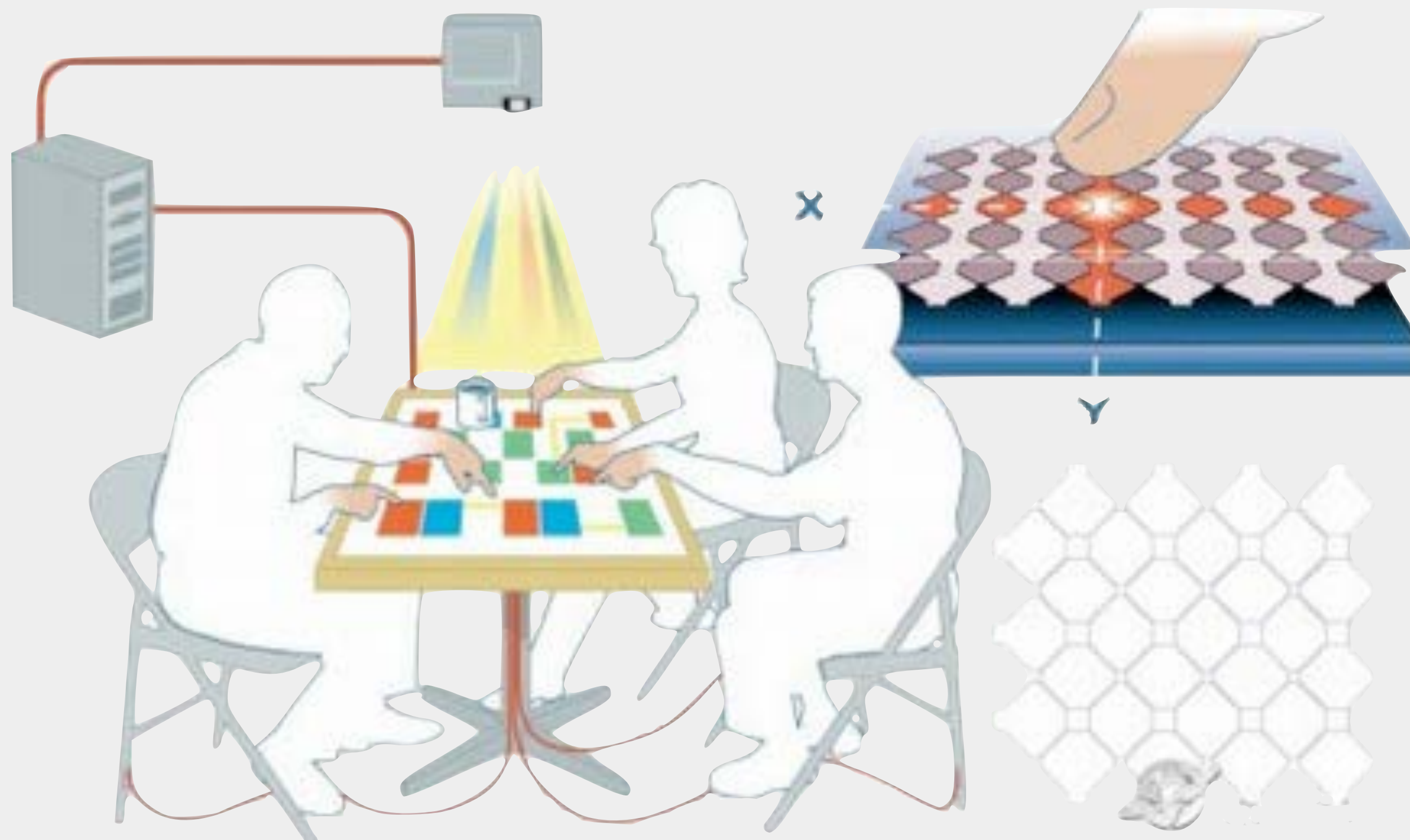


capacitive sensing



capacitive sensing

DT
MERL



DiamondTouch [Dietz & Leigh '01]



SmartSkin [Rekimoto '02]



SmartSkin [Rekimoto '02]



Fingerworks, 2005



iPhone 1, 2007



...and it prevailed

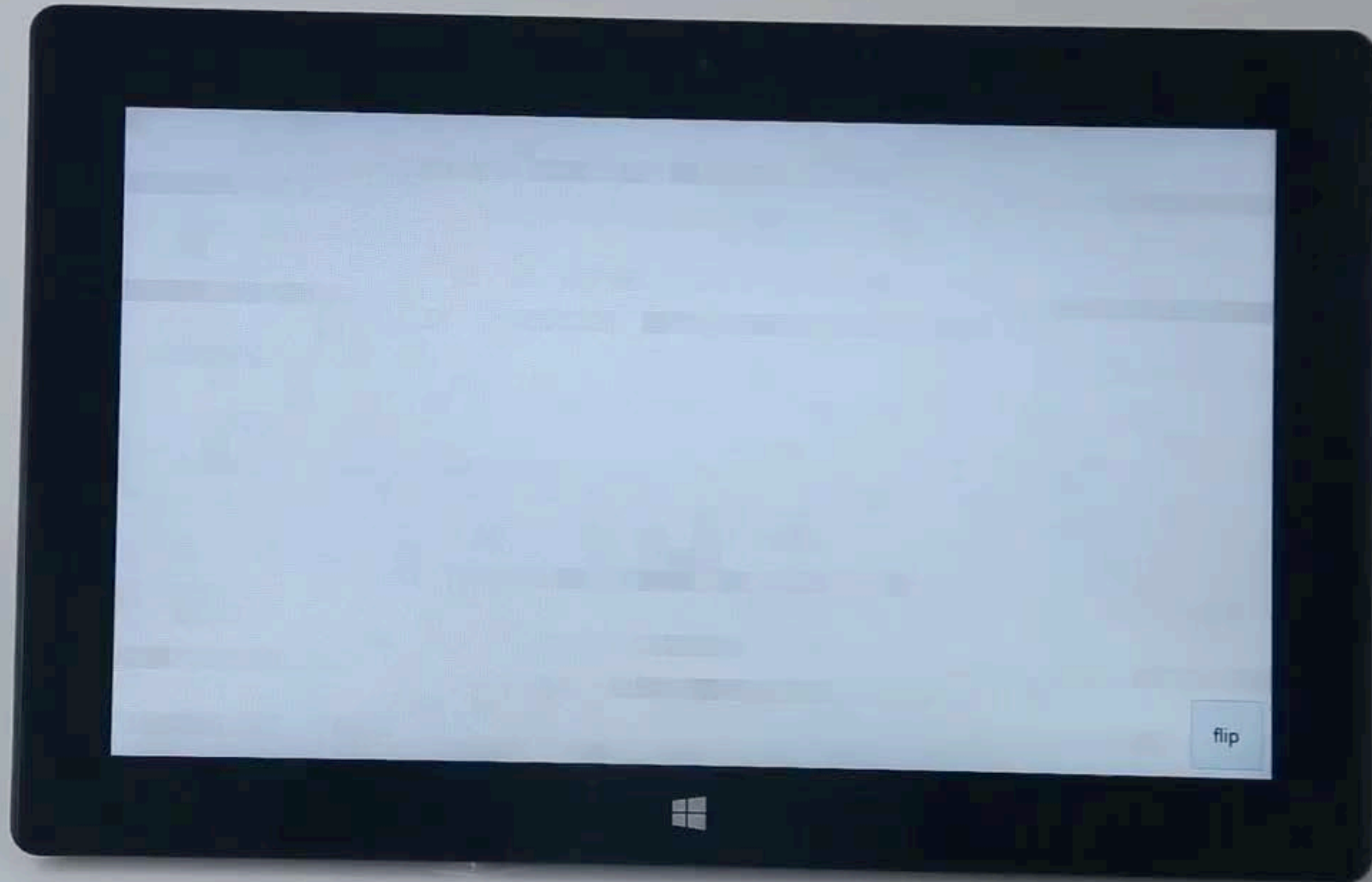


...and it prevailed

Bodyprint [CHI '15]



Biometric Touch Sensing [UIST '15]





optical touch sensing

walls & tables





camera



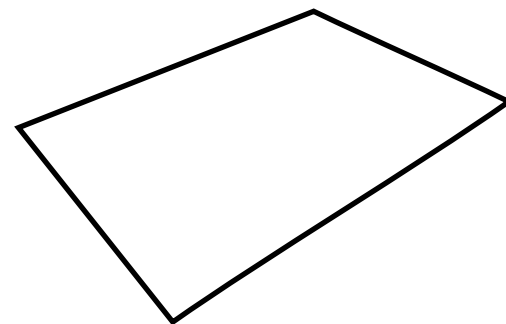
illumination

invisible (infrared)



projector

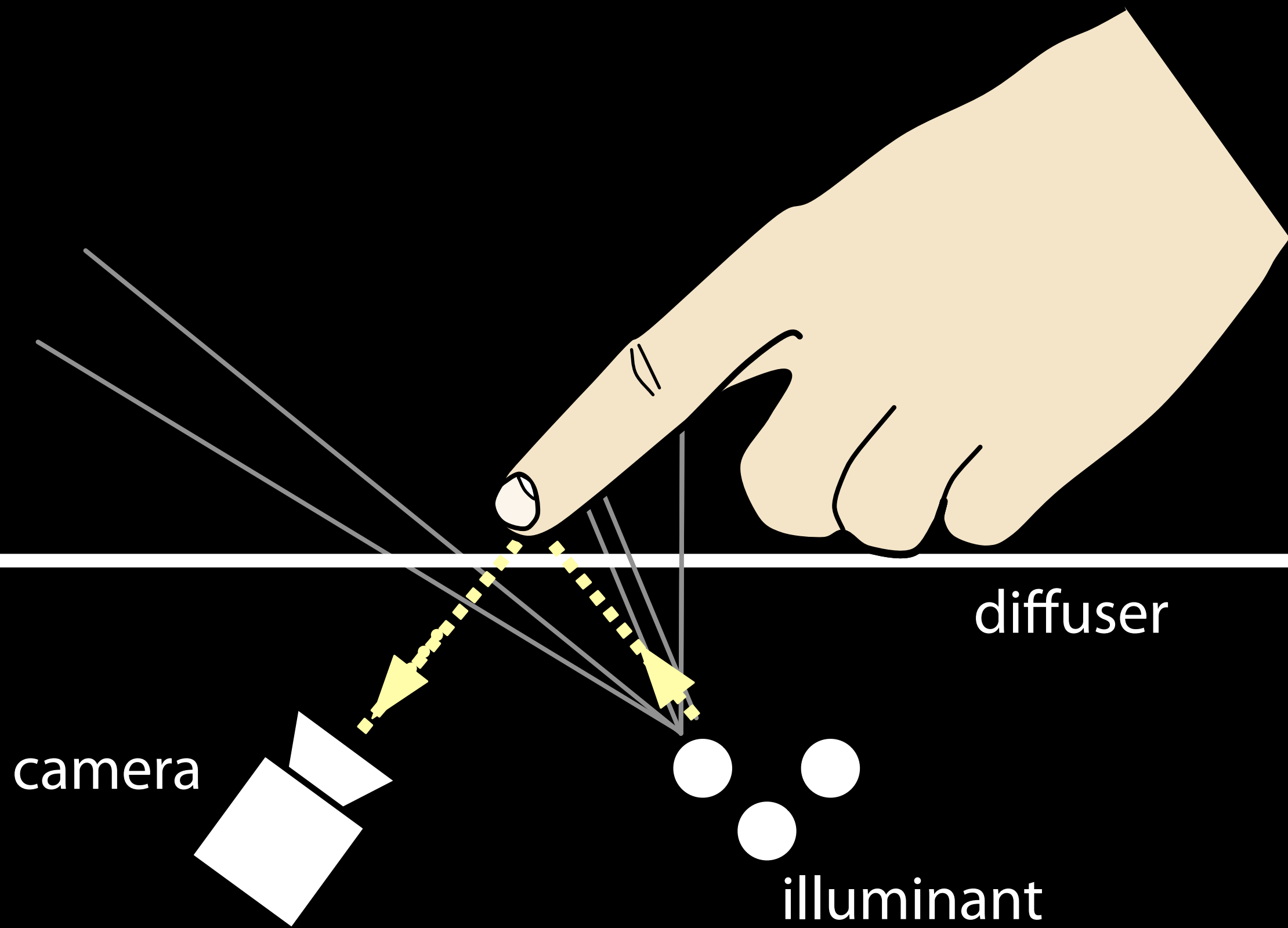
visible



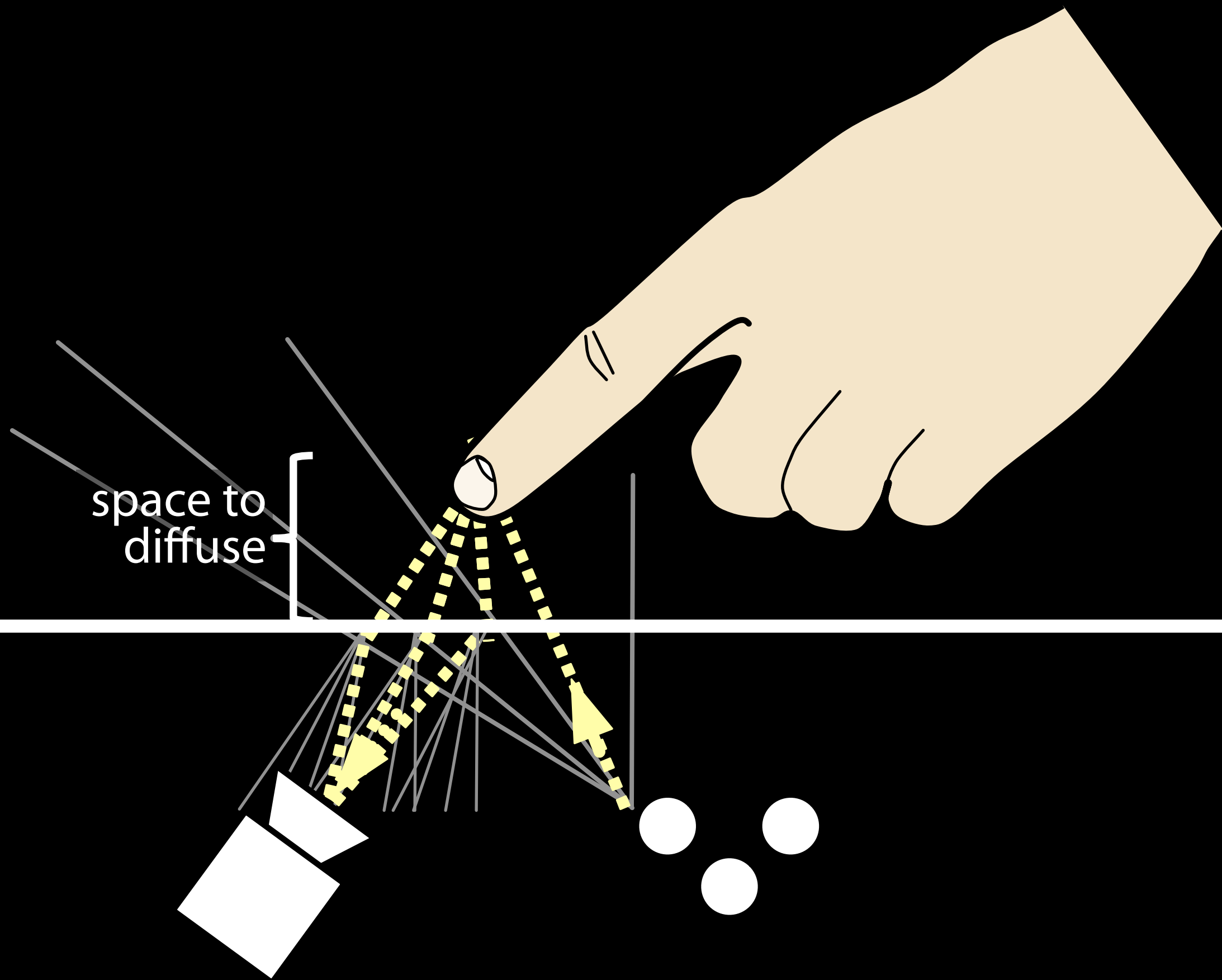
imaging surface

optical touch sensing

diffuse illumination

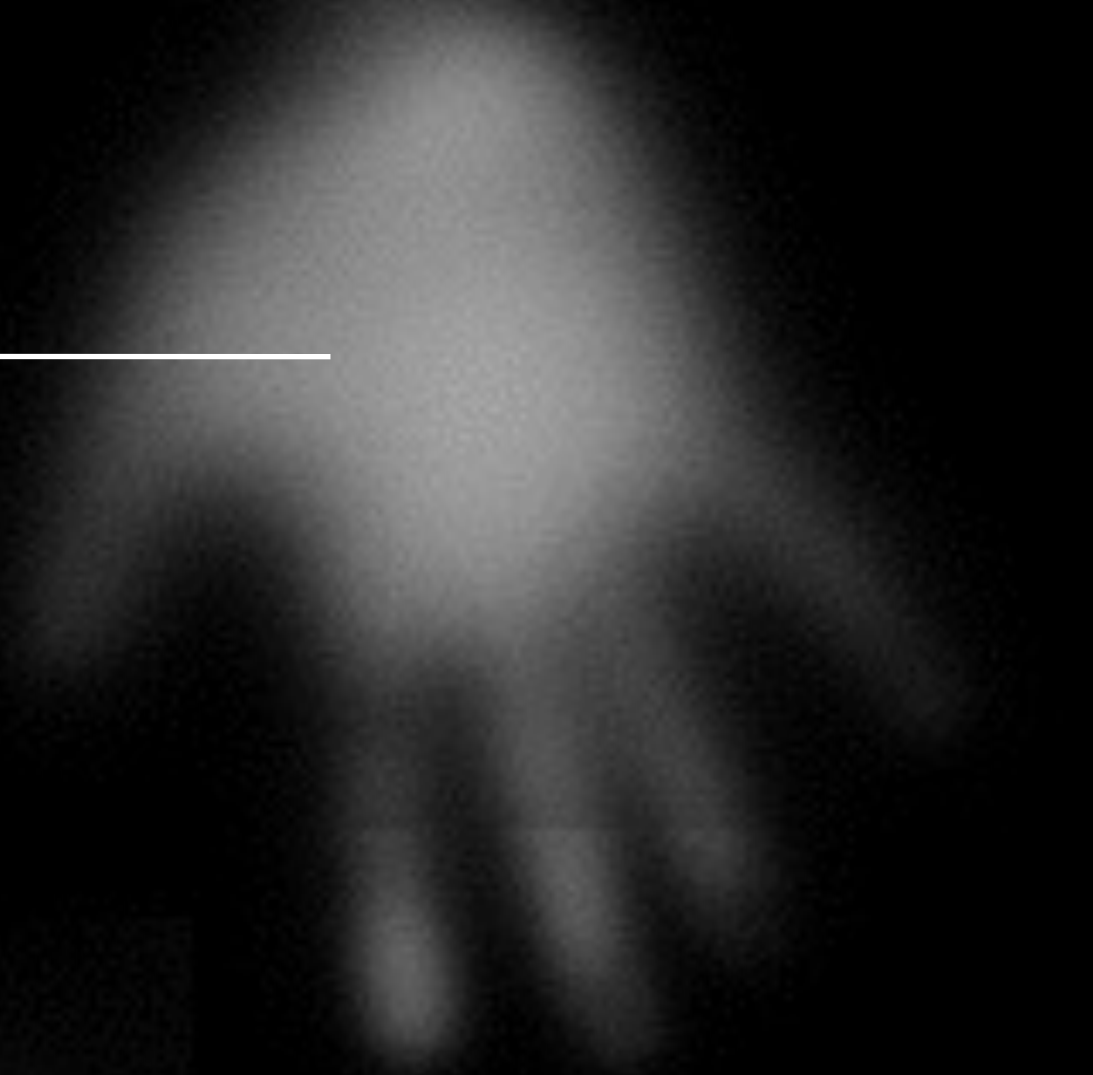




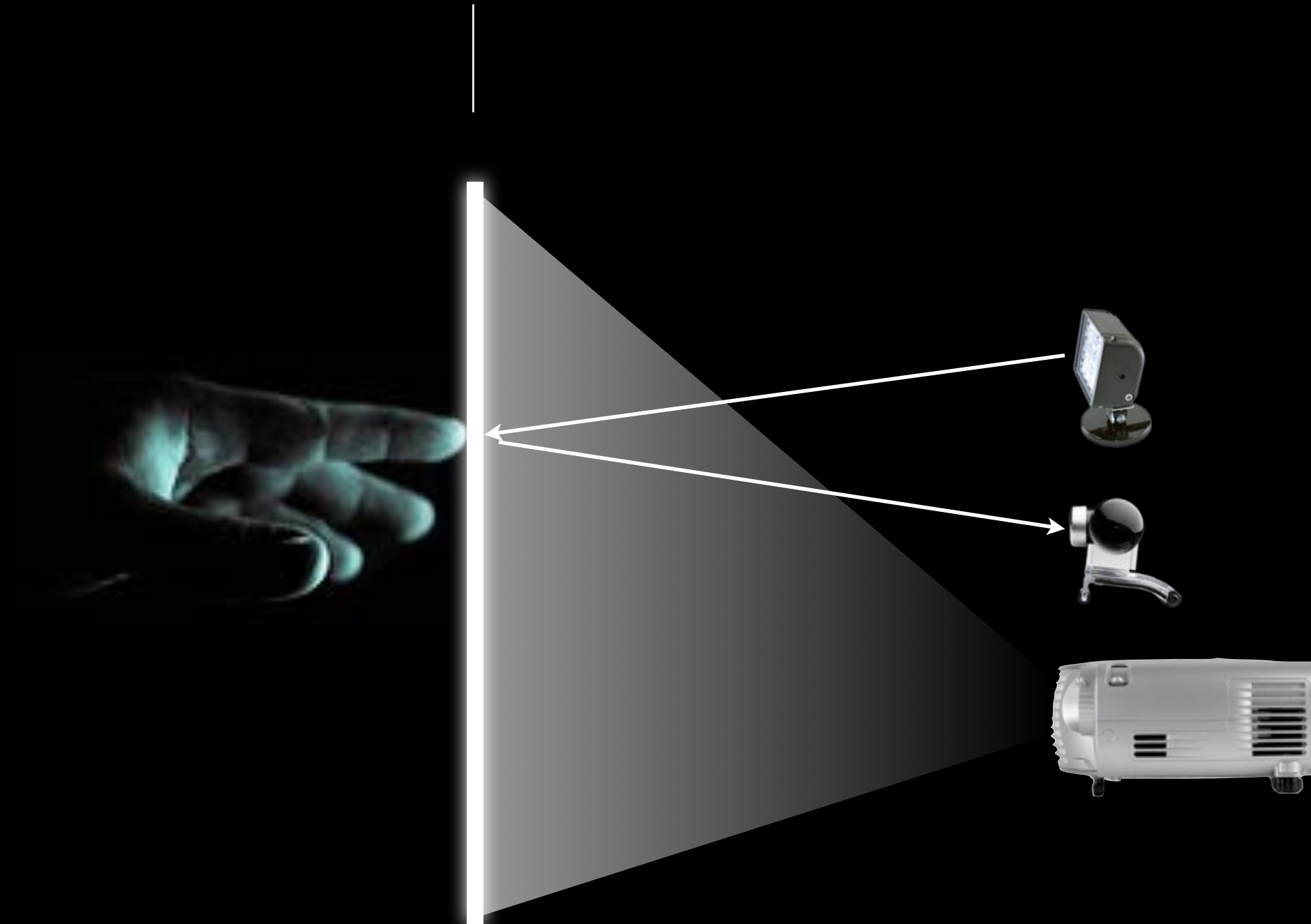


space to
diffuse

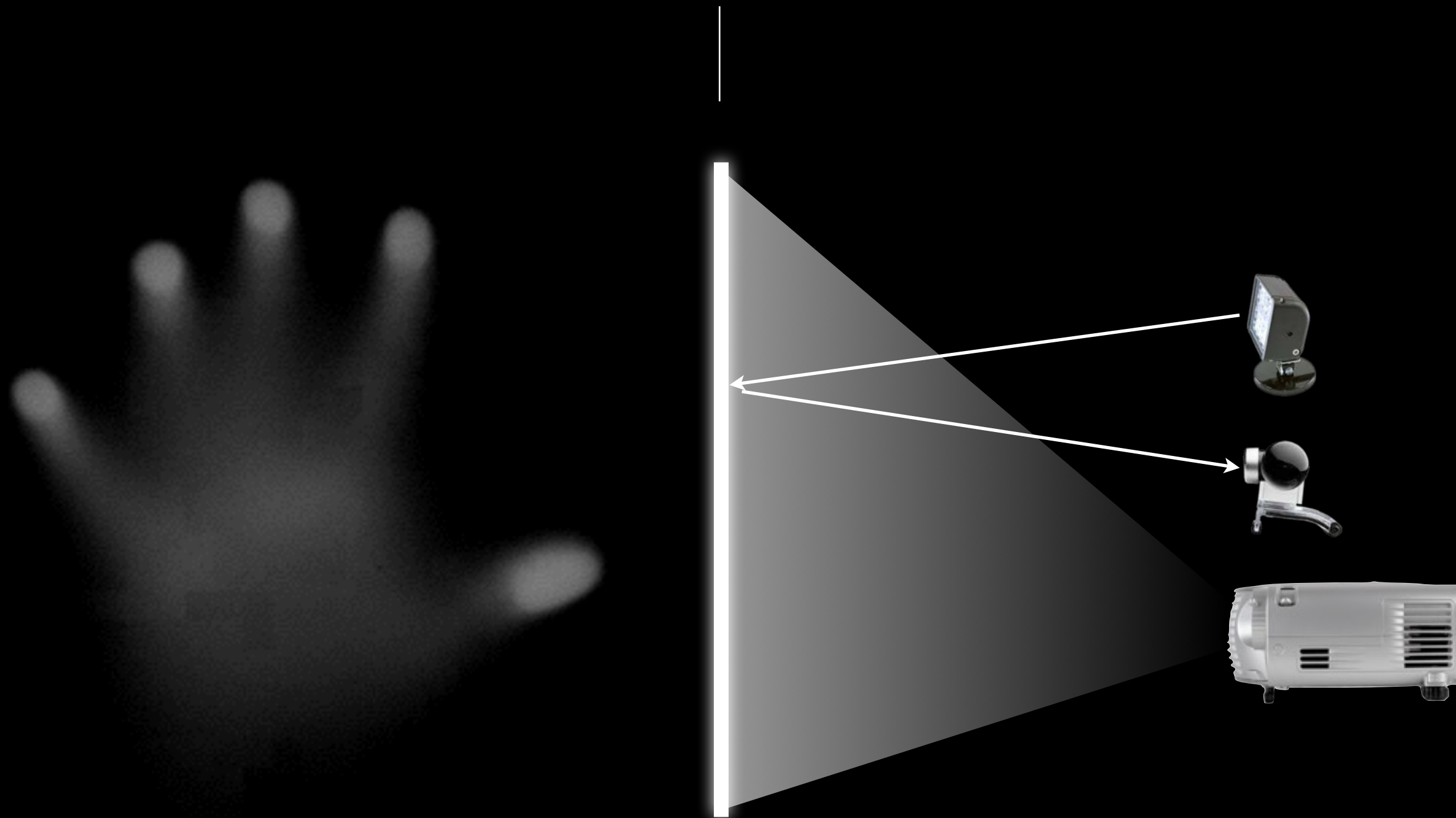
darker and blurry



projection plane



projection plane



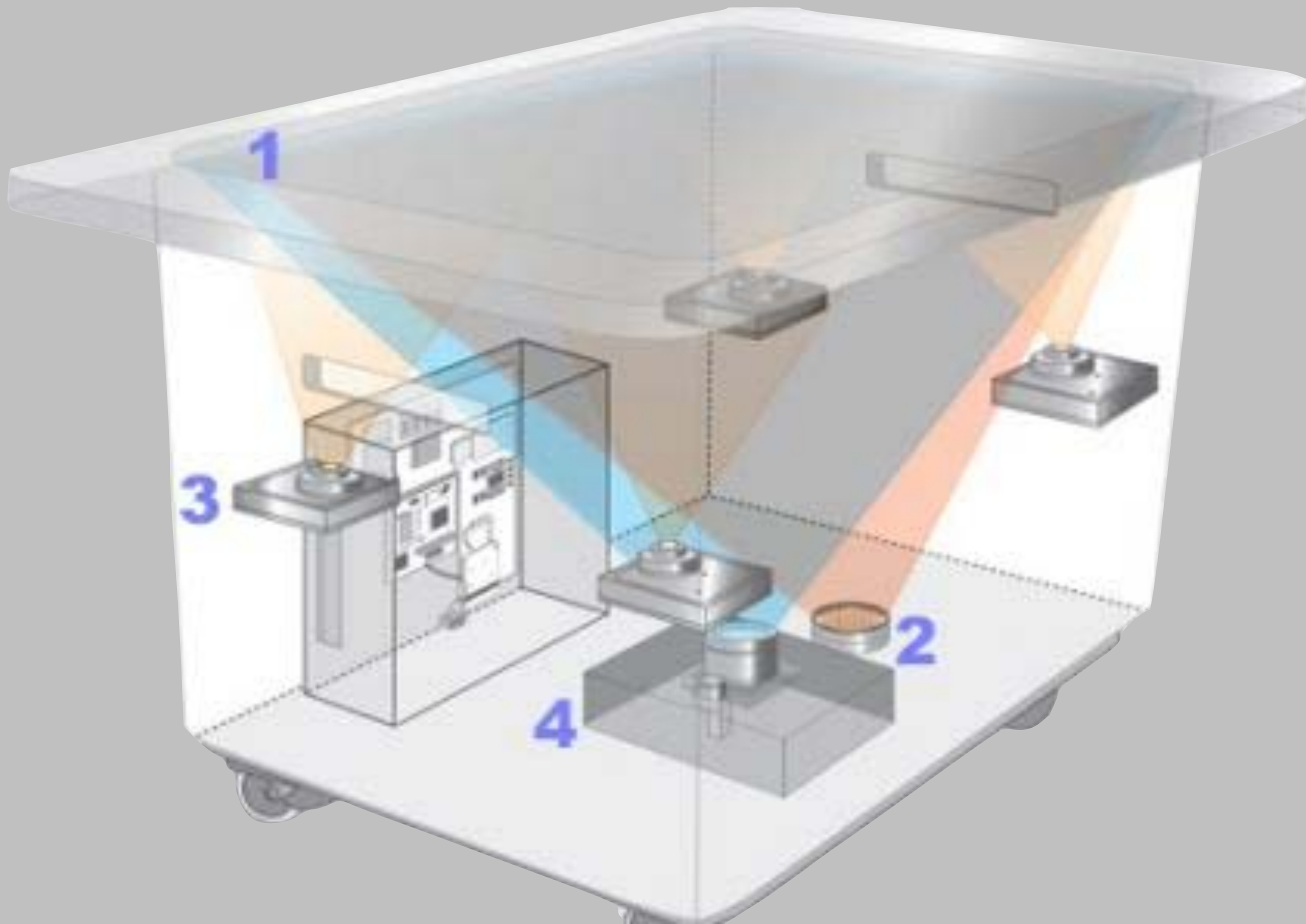
rear DI

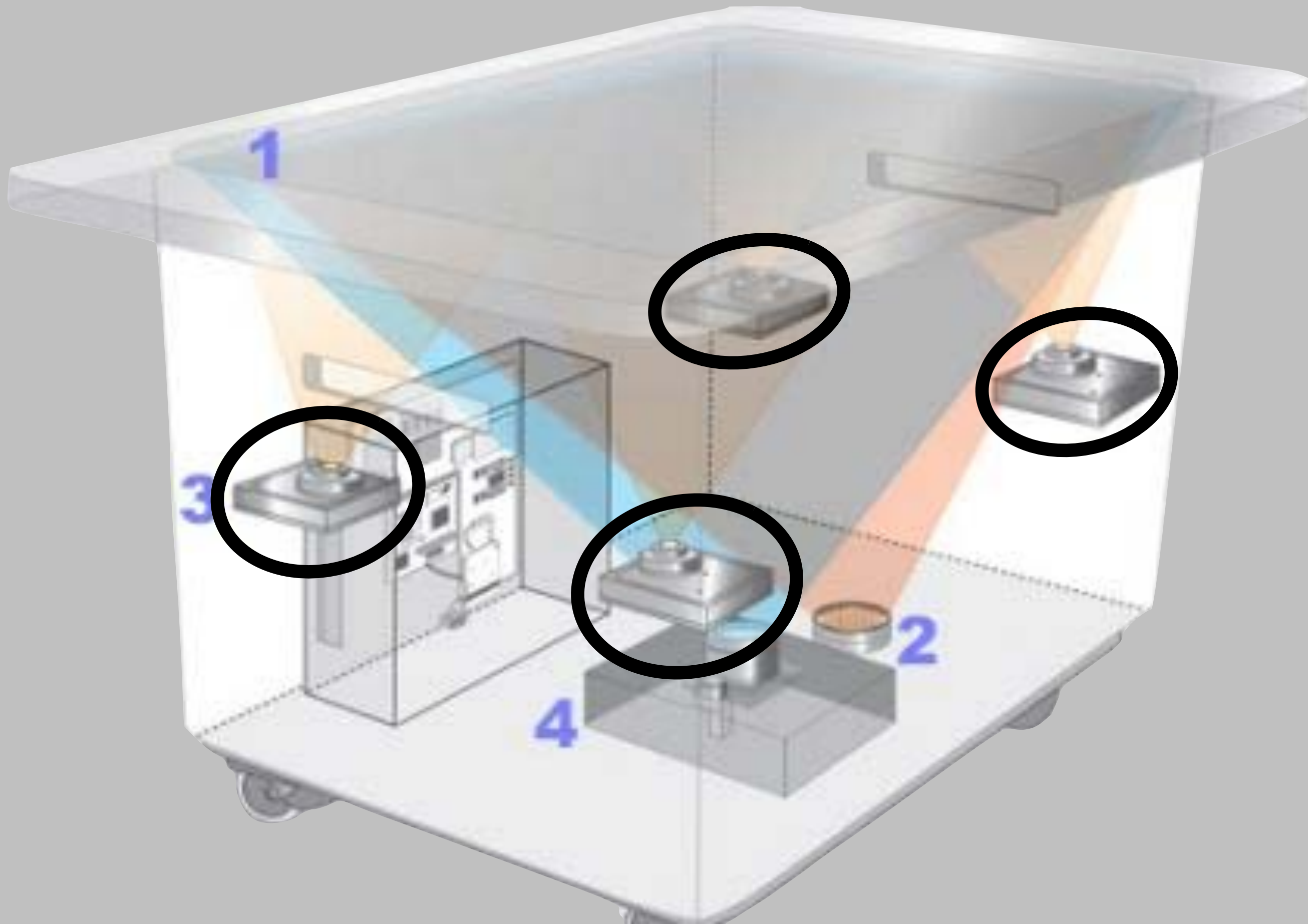


HoloWall [Rekimoto, UIST '97]



Microsoft Surface, 2008



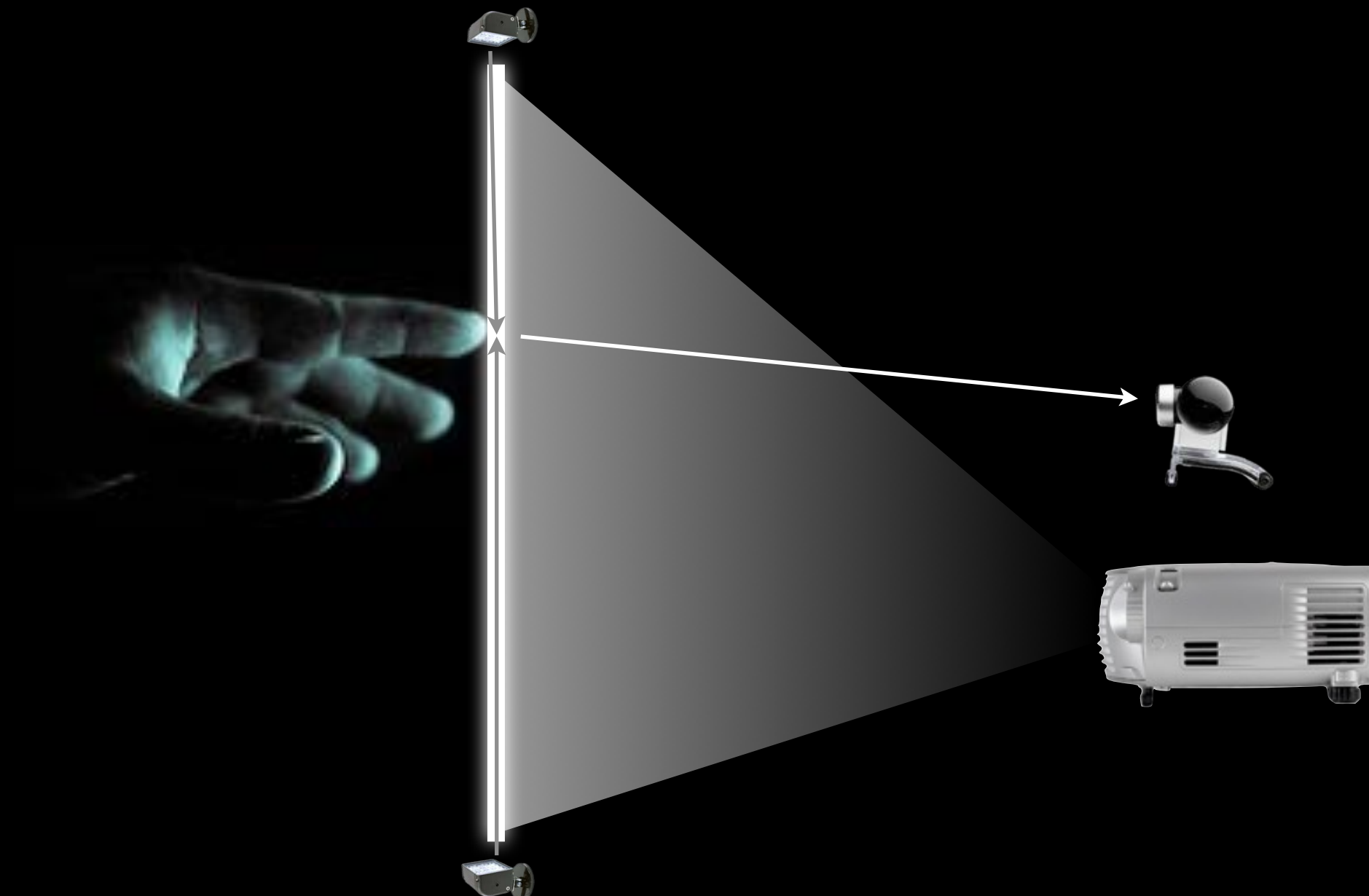


frustrated total internal reflection
the other camp

A hand is shown in silhouette, interacting with a large, vertical, blue-lit surface. The hand is positioned on the right side of the frame, with fingers spread, suggesting a multi-touch gesture. The surface is illuminated from the left, creating a bright blue glow. On the left side, there is a dark, cylindrical component with a small, bright white light source. The overall scene is dimly lit, with the primary light source being the blue glow of the surface. The text at the bottom of the image reads:

*MULTI-TOUCH SENSING THROUGH
FRUSTRATED TOTAL INTERNAL REFLECTANCE*

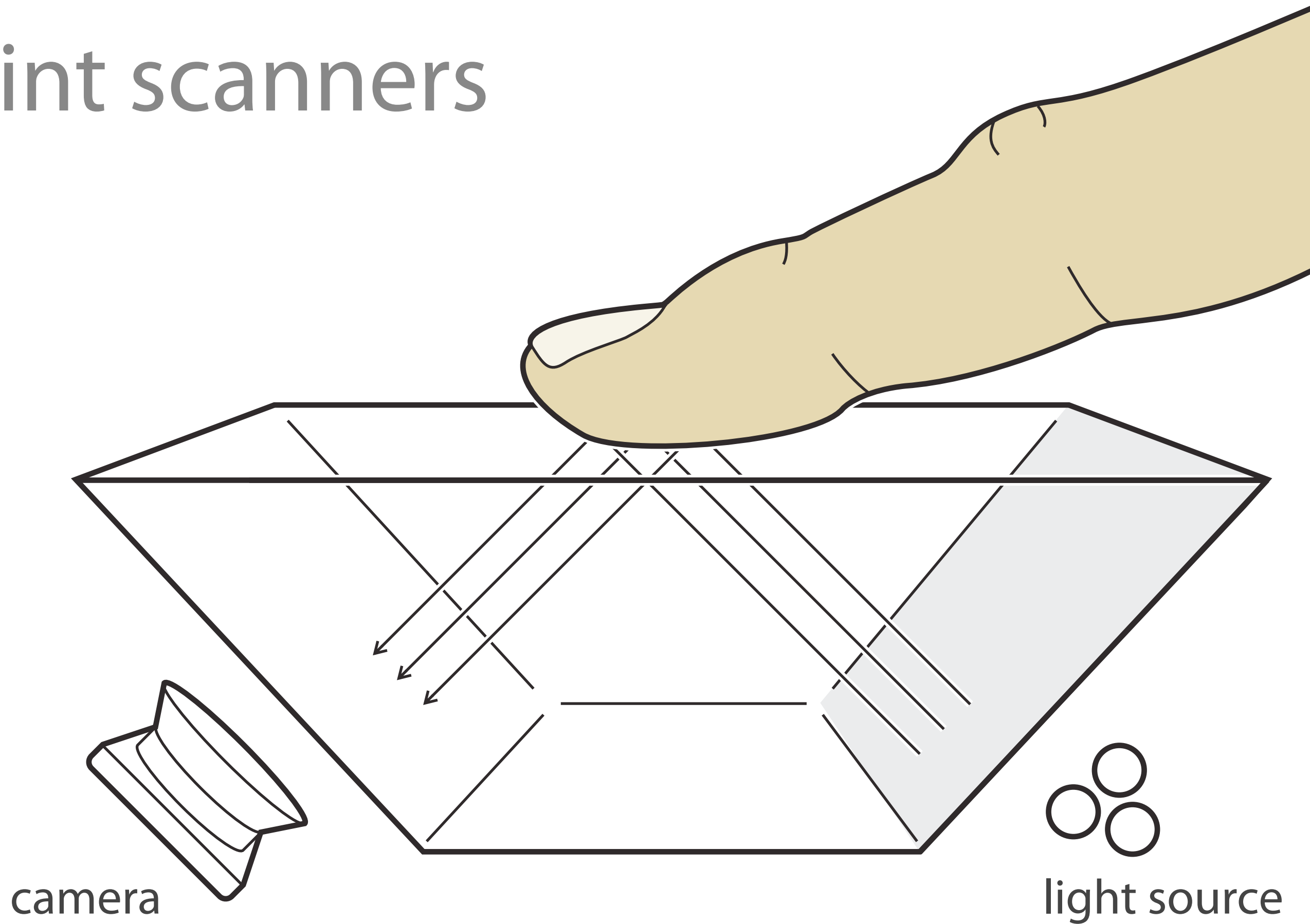
projection plane

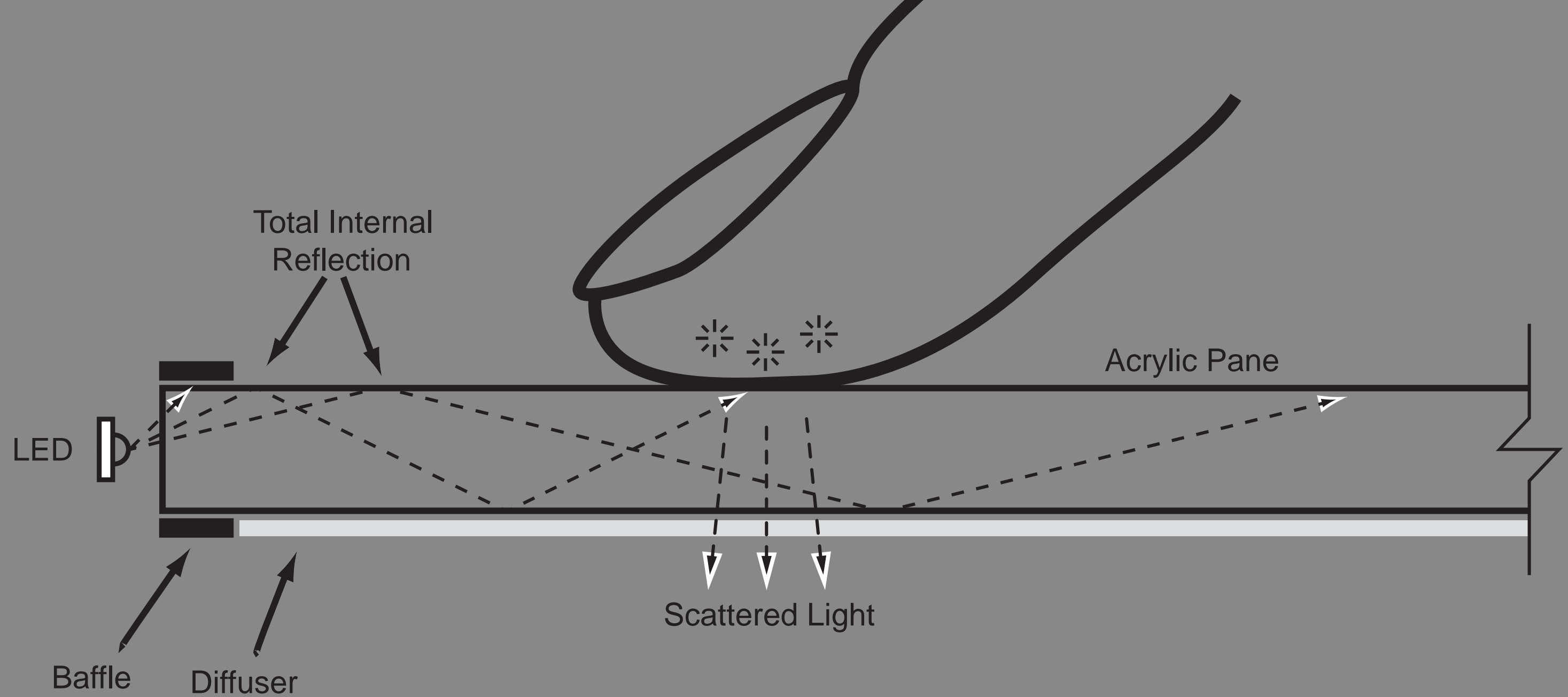


FTIR

[Han, UIST '05]

fingerprint scanners





FTIR

[Han, UIST '05]

[RAW CAMERA OUTPUT IS OVERLAYED ON SURFACE]



[Han, UIST '05]

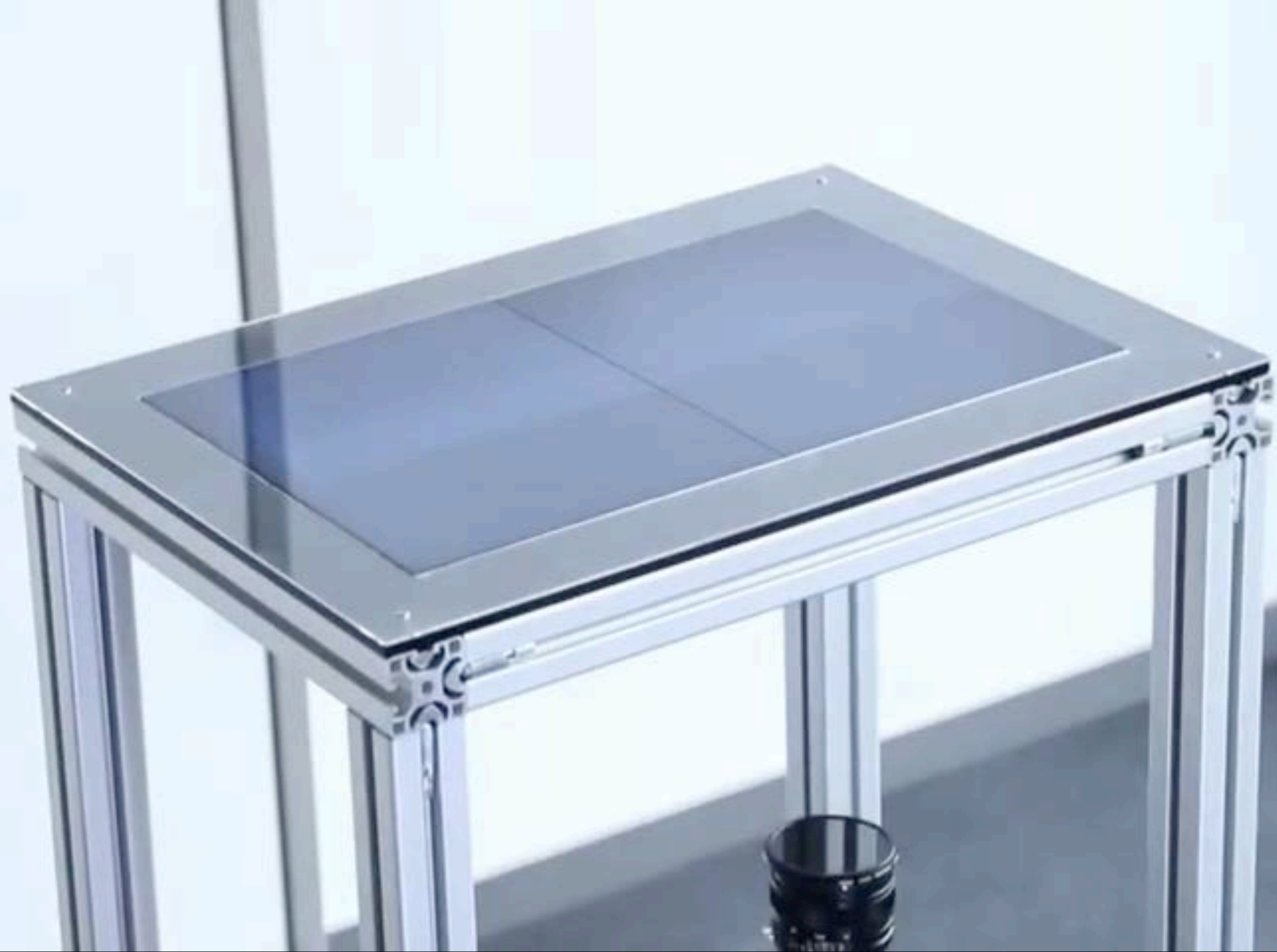


weird mixes

diffuse illumination + frustrated Fresnel reflection



[Fiberio, UIST '15]

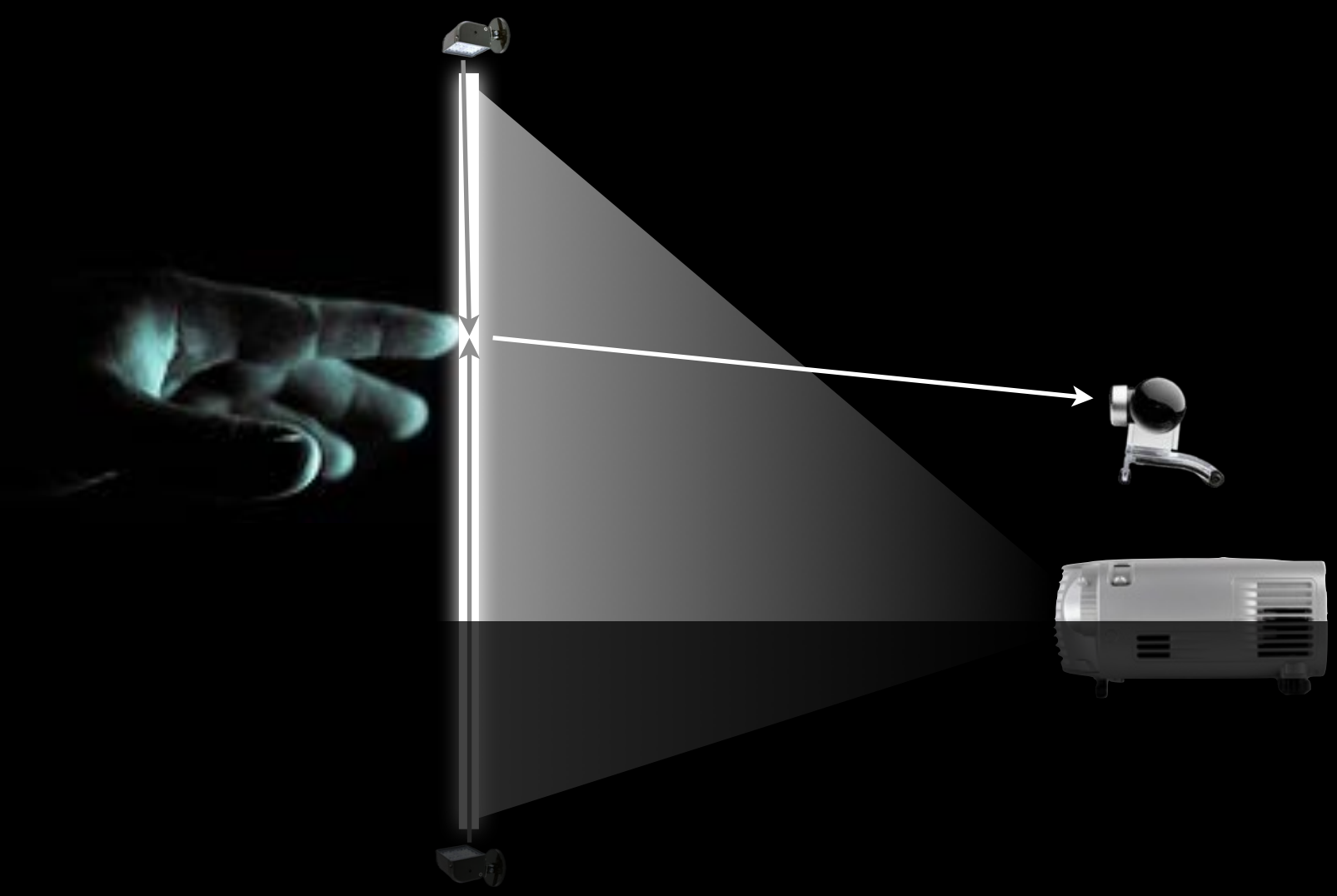
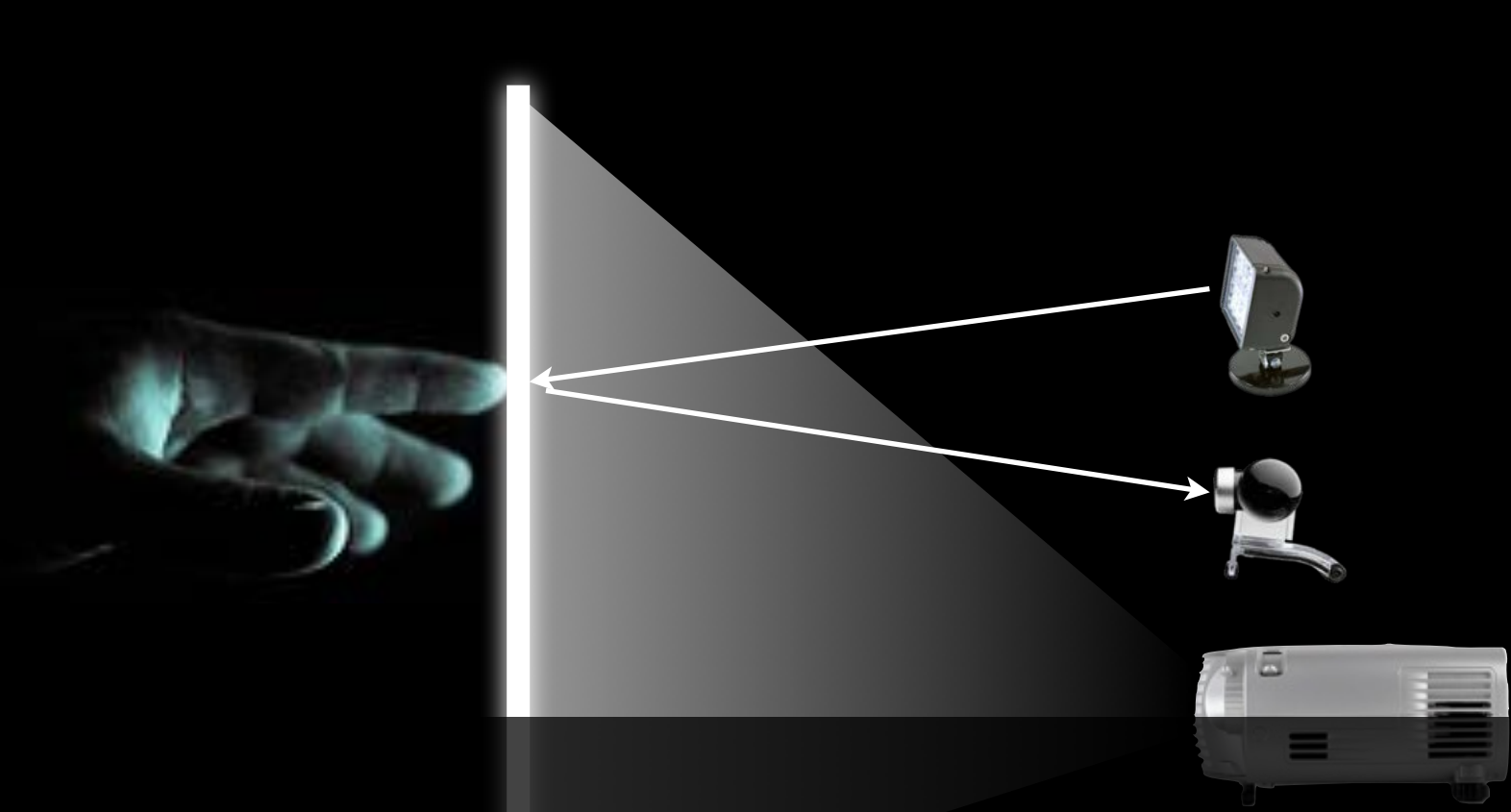




diffuse reflection + surface reflection

diffuse reflection + surface reflection

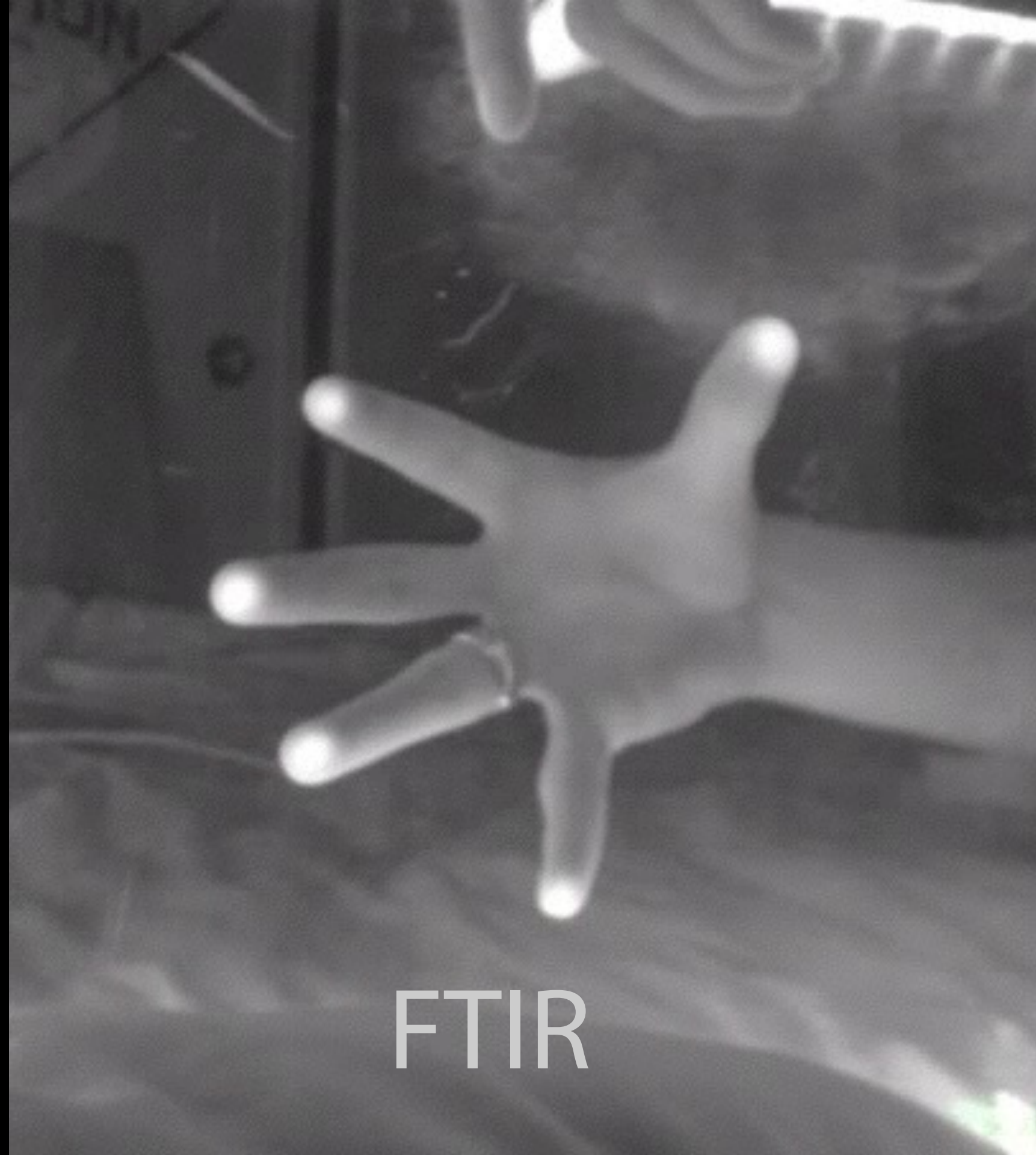
diffuse reflection
frustrated surface reflection



what's the big difference?
30 second brainstorming

diffuse illumination

FTIR

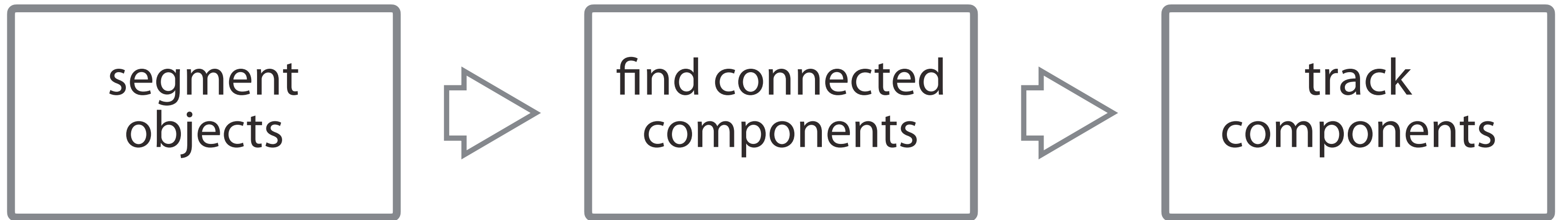


15

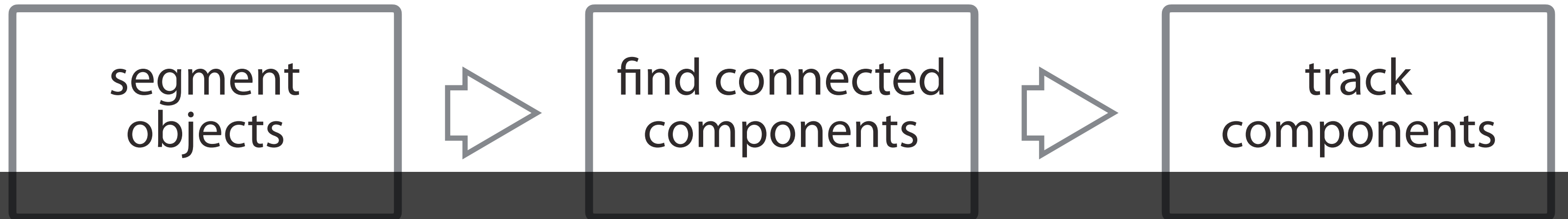
Touch processing



typical processing pipeline

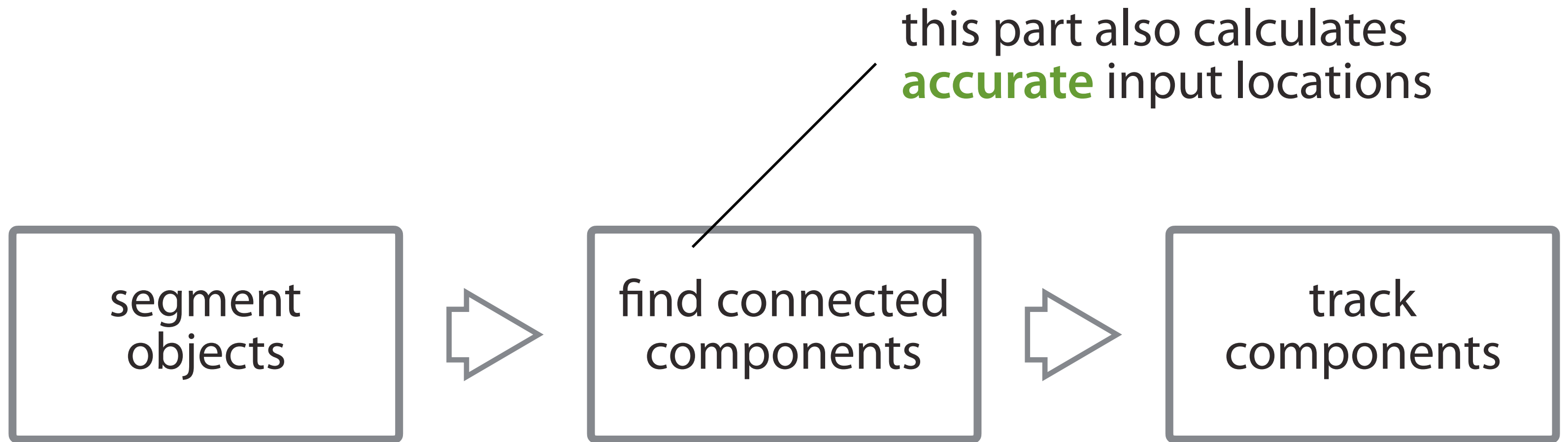


typical processing pipeline



who sees the link to Buxton's Touch, Gesture & Marking?
30 second brainstorming

typical processing pipeline



typical processing pipeline



Touch accuracy

Biometric Touch Sensing [UIST '15]



input resolution: 42 x 33 across a 10" display



map to an accurate input location

screen resolution: 2,160 x 1,440



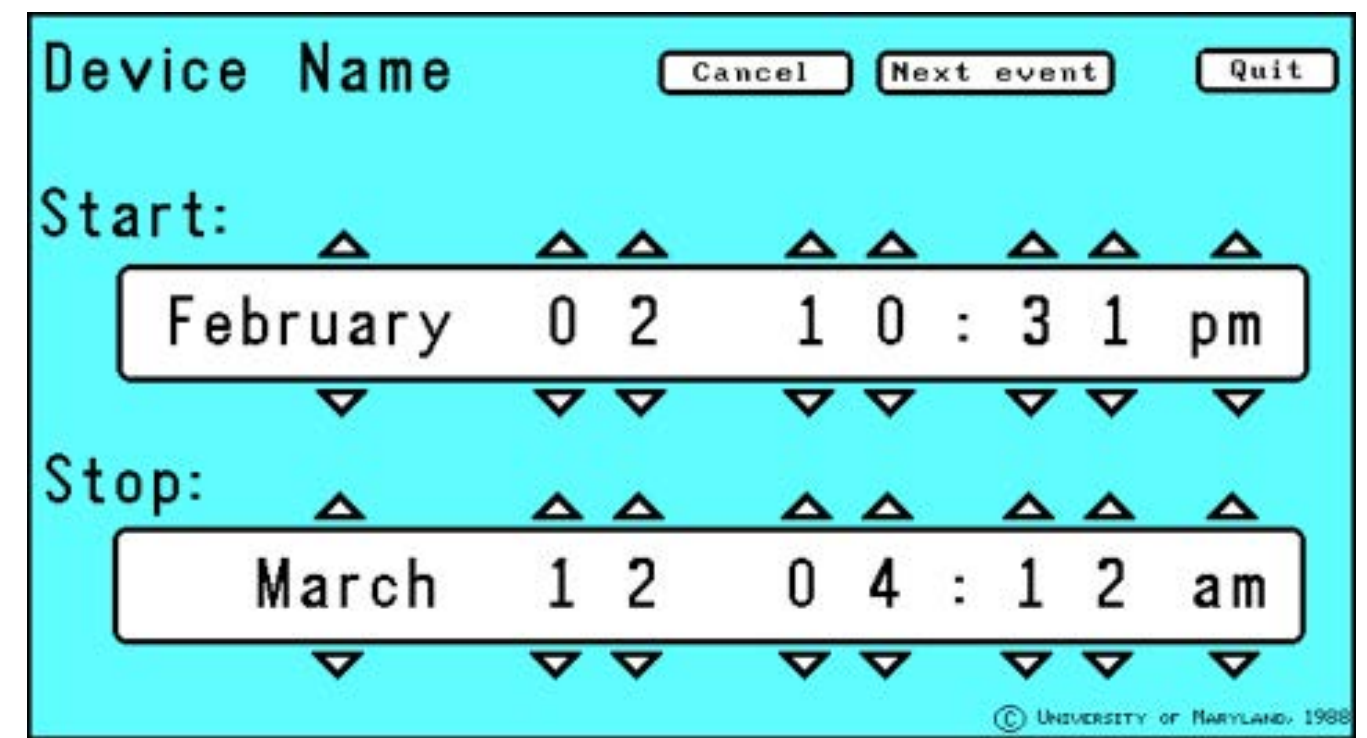
center of gravity



if only it were that easy :-)



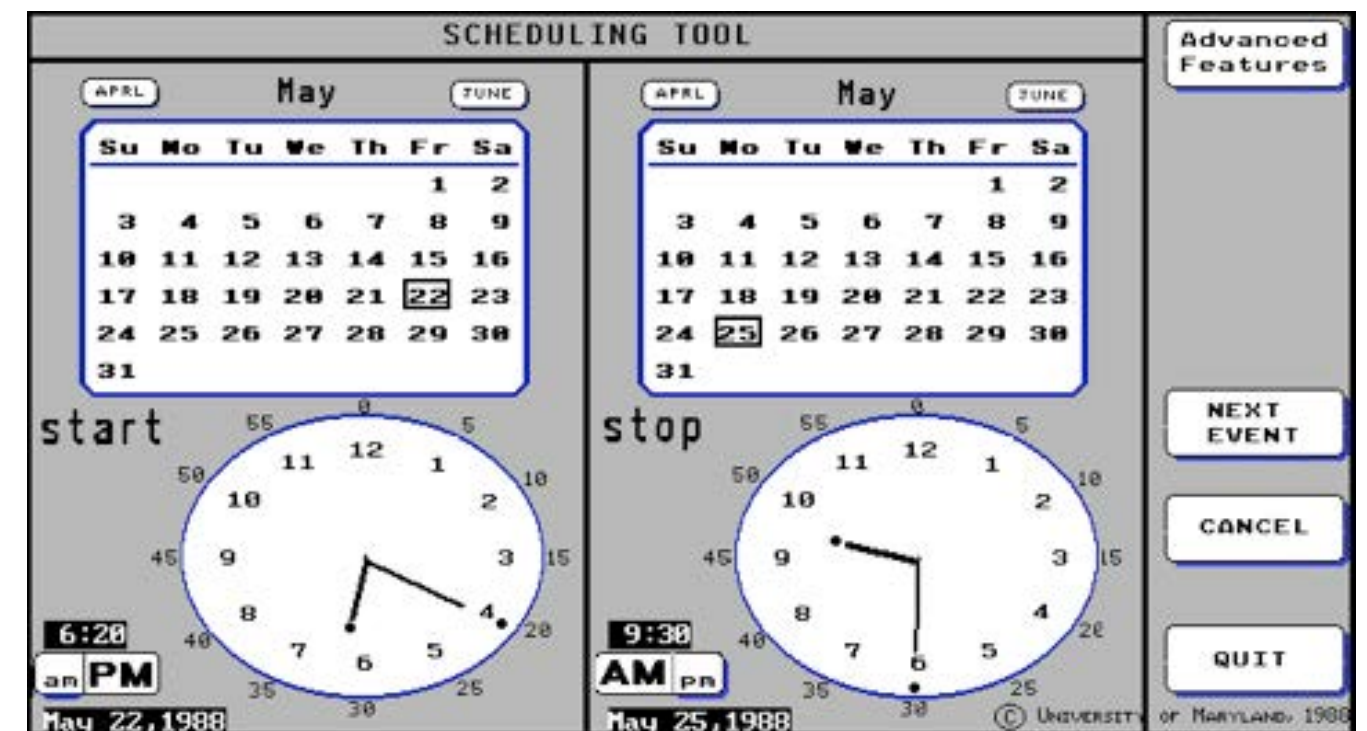
Information Kiosks [Plaisant et al. '88]



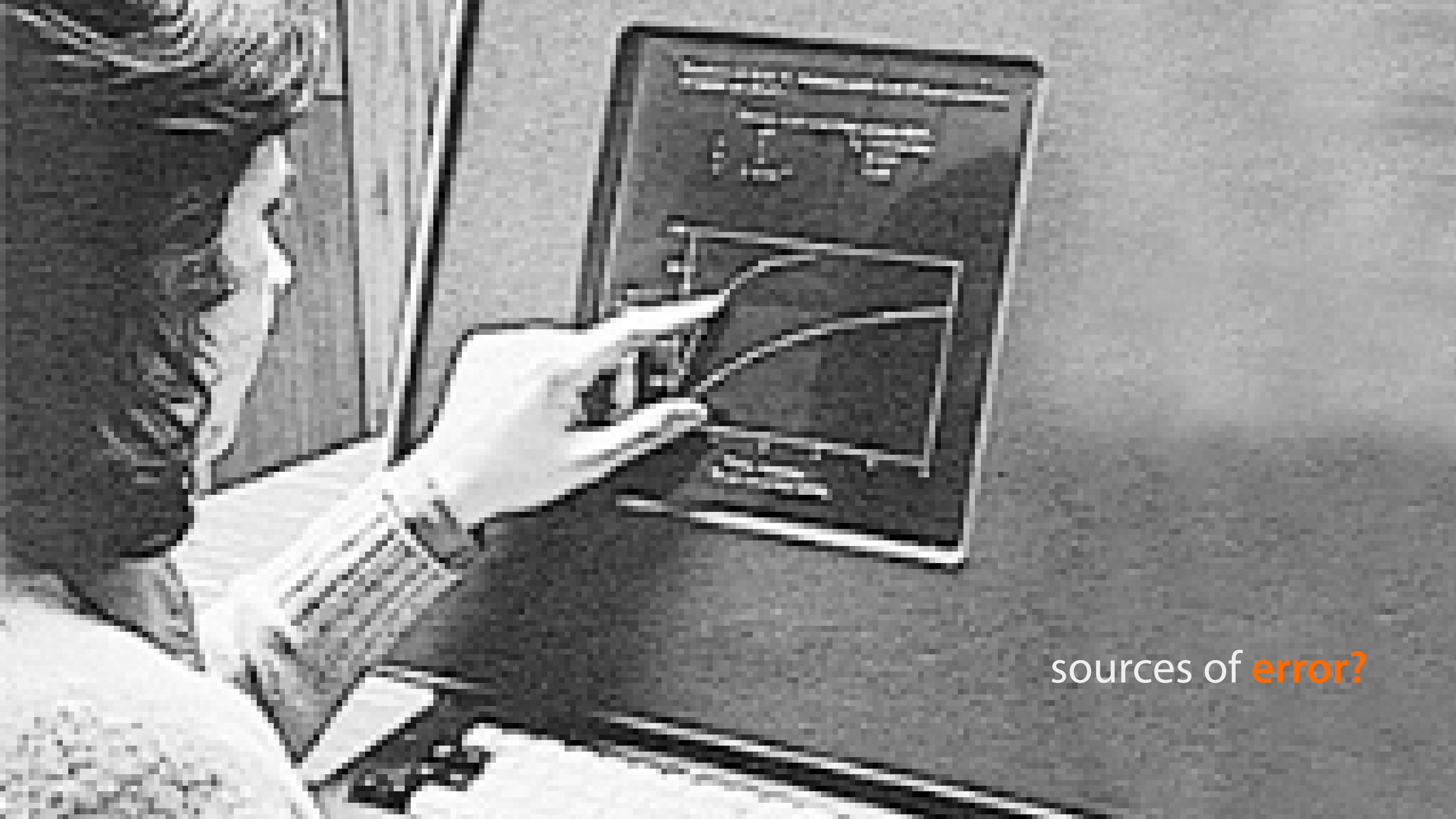
Home Automation [Plaisant et al. '90 and on]



Touch painting [Sears et al. '91]



Home Automation [Plaisant et al. '90 and on]



sources of **error?**

“parallax between the touch screen surface and the display surface”

“high error shown in many studies”

“fatigue in arm motion”

[Potter et al. CHI '88]

“parallax between the touch screen surface and the display surface”

“high error shown in many studies”

“fatigue in arm motion”

solution: “finger mouse”, a cursor the user drags on the screen

[Potter et al. CHI '88]

AK	HI	ME	NJ	SD
AL	IA	MI	NM	TN
AR	ID	MN	NV	TX
AZ	IL	MO	NY	UT
CA	IN	MS	OH	VA
CO	KS	MT	OK	VT
CT	KY	NC	OR	WA
DE	LA	ND	PA	WI
FL	MA	NE	RI	WV
GA	MD	NH	SC	WY

[Potter et al. CHI '88]

“parallax between the touch screen surface and the display surface”

“high error shown in many studies”

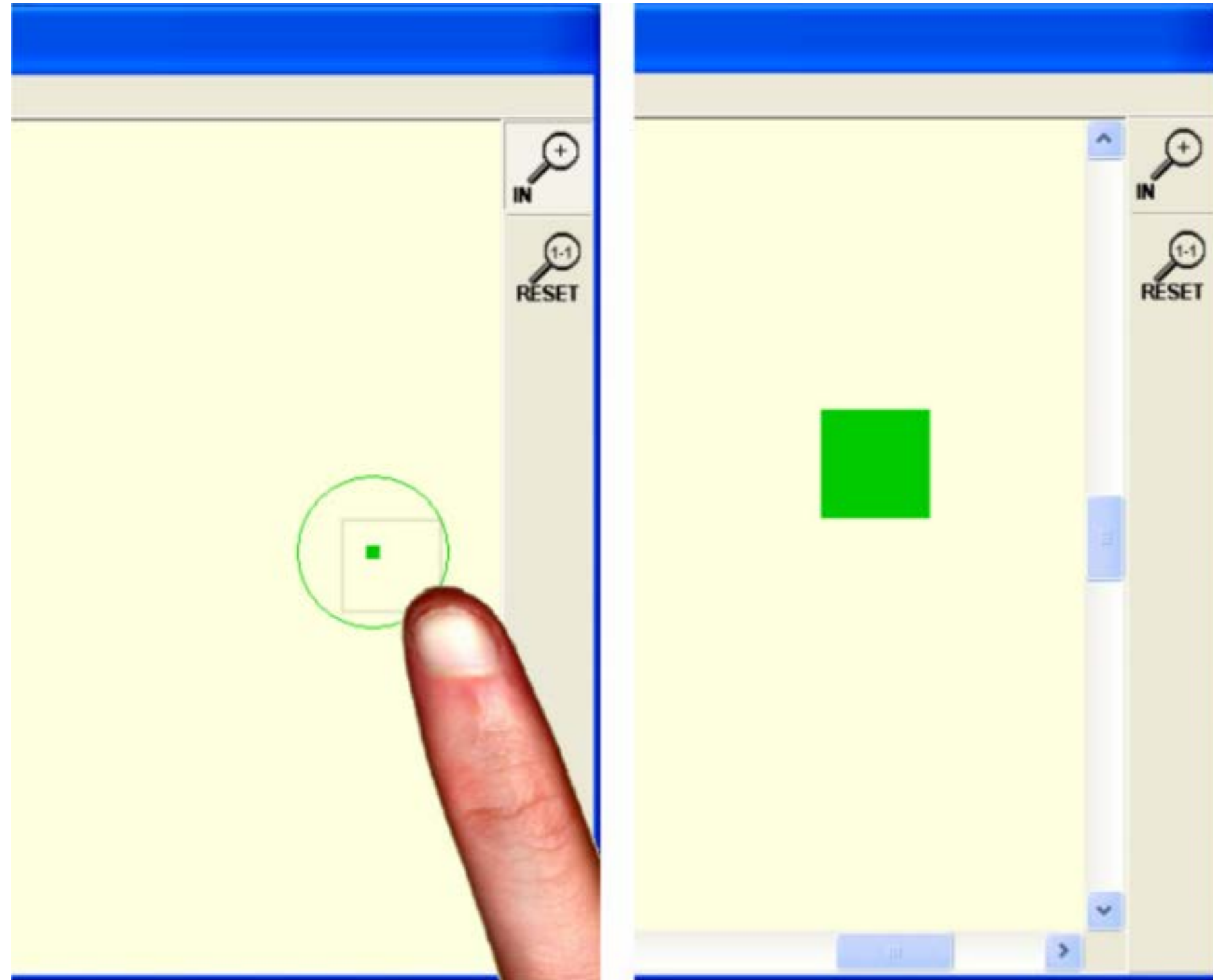
“fatigue in arm motion”

solution: “finger mouse”, a cursor the user drags on the screen

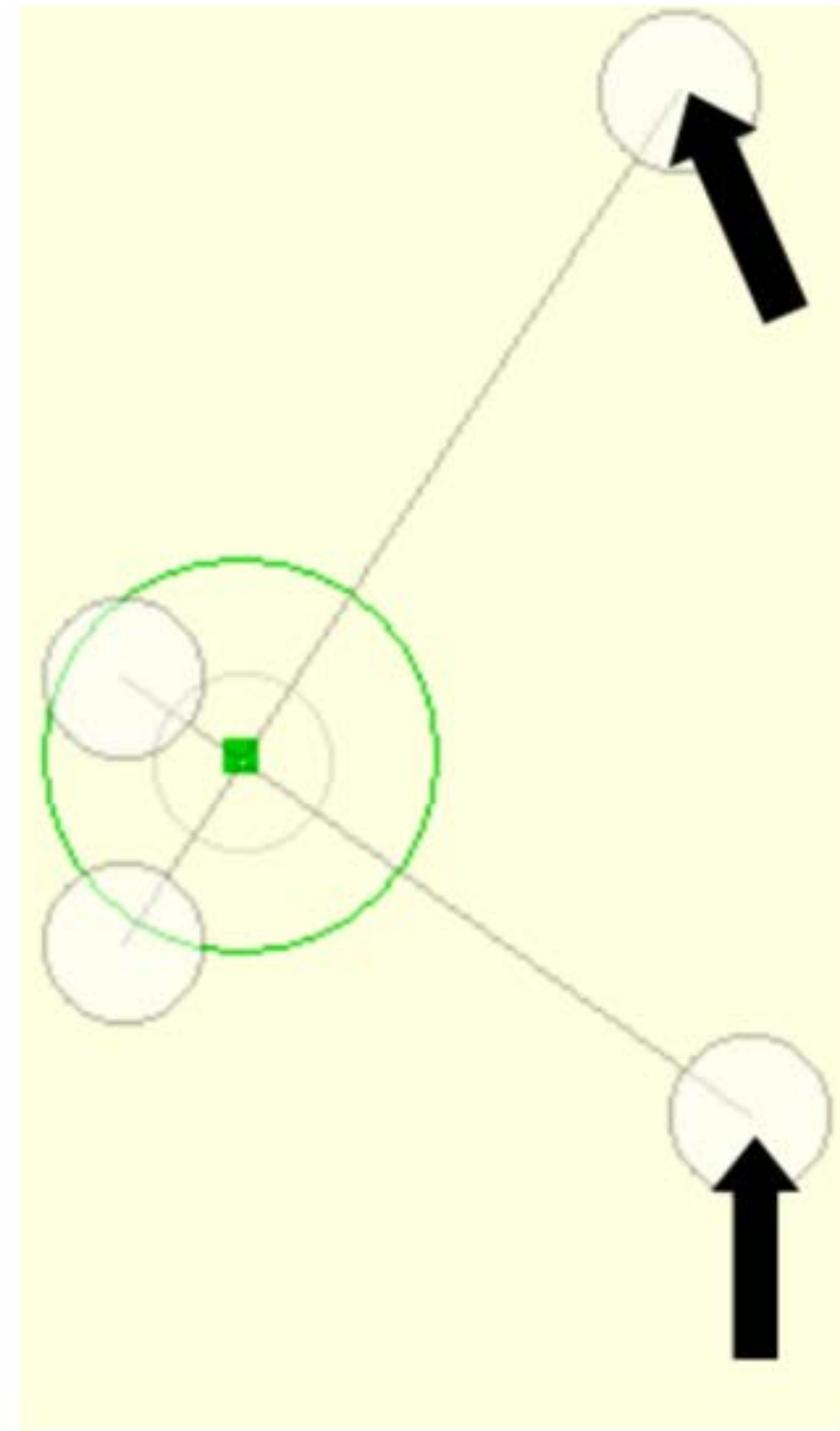
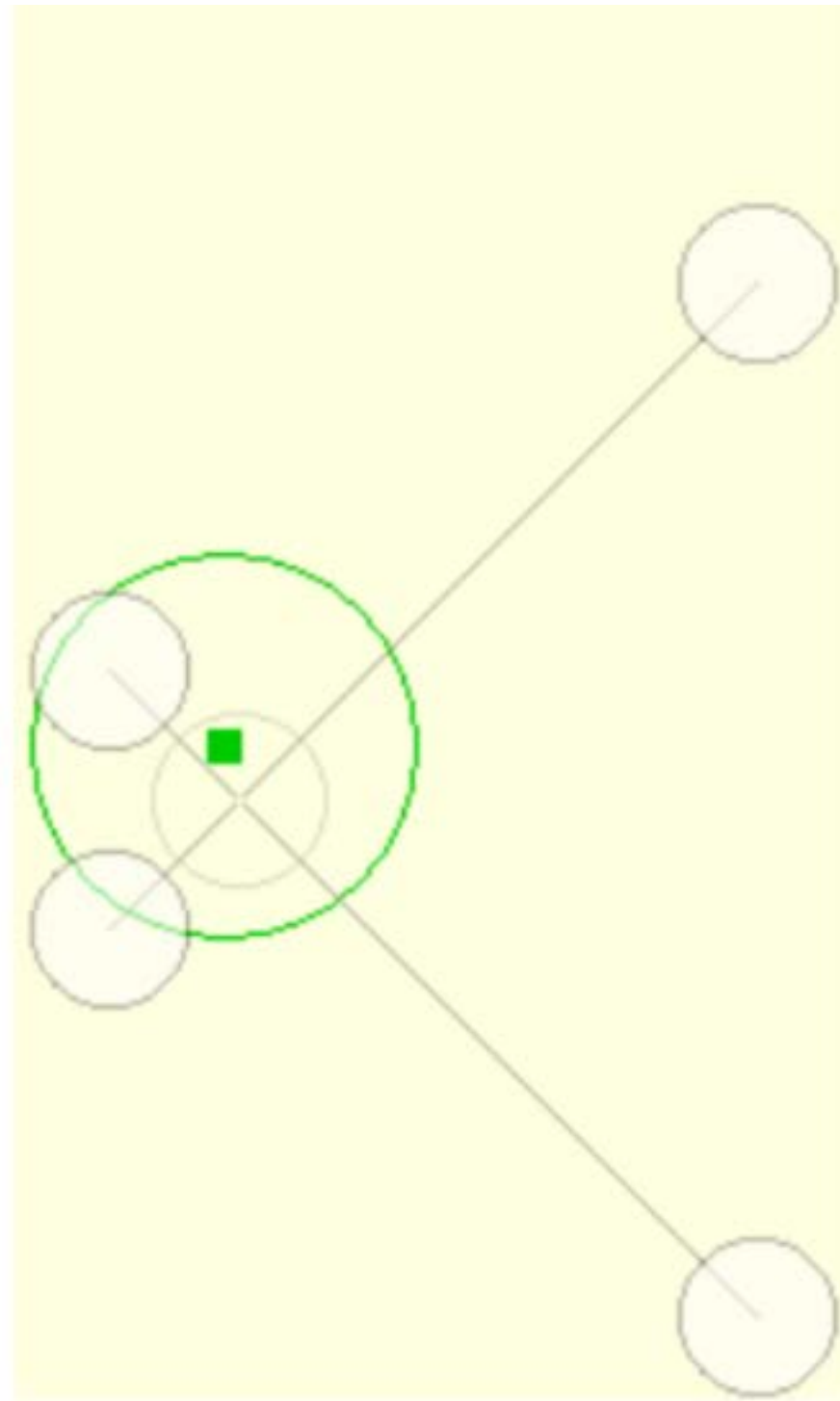
strategies: touch-down, first-contact, lift-off + **offset cursor**

[Potter et al. CHI '88]

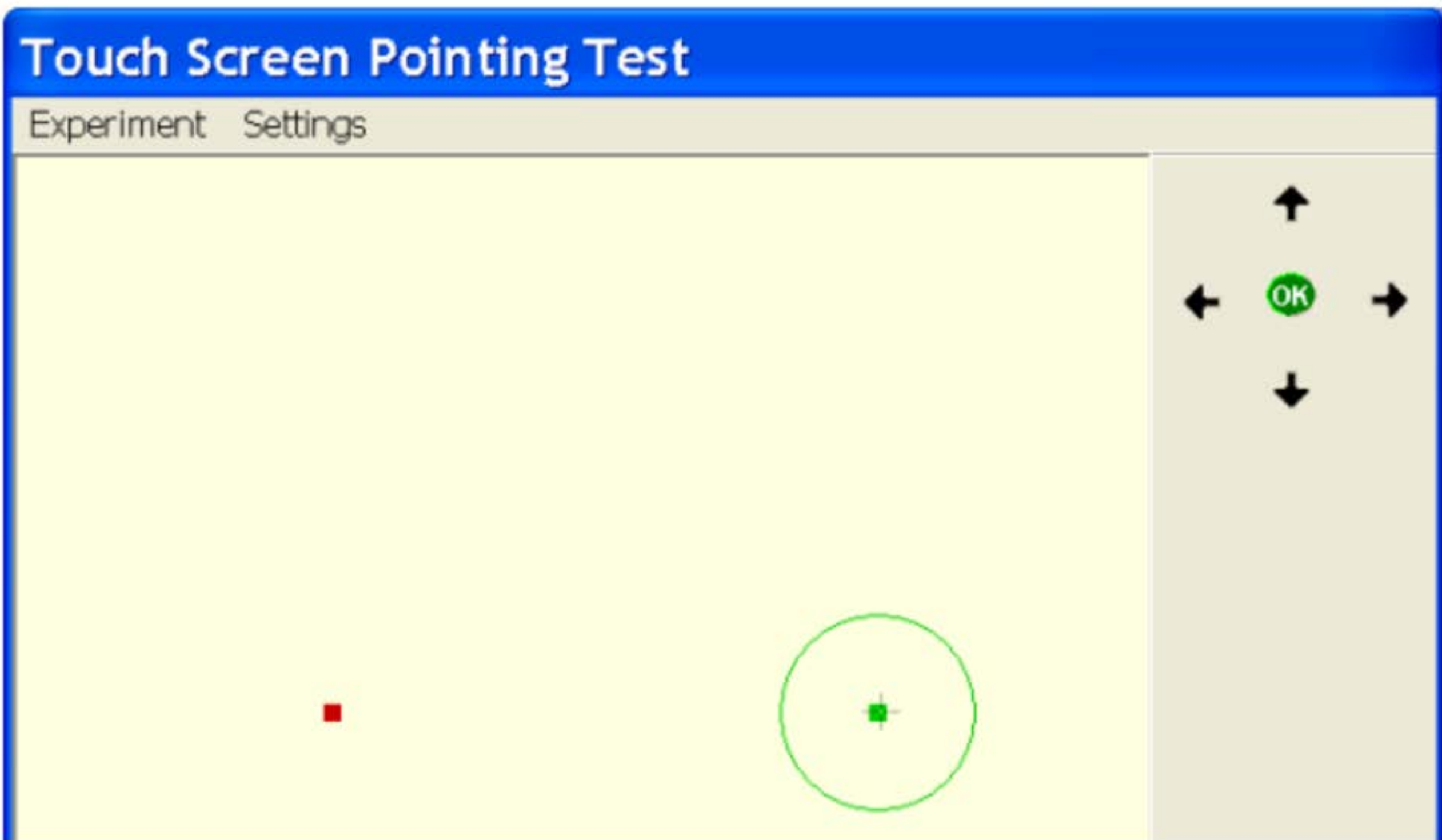
okay, let's use cursors then...



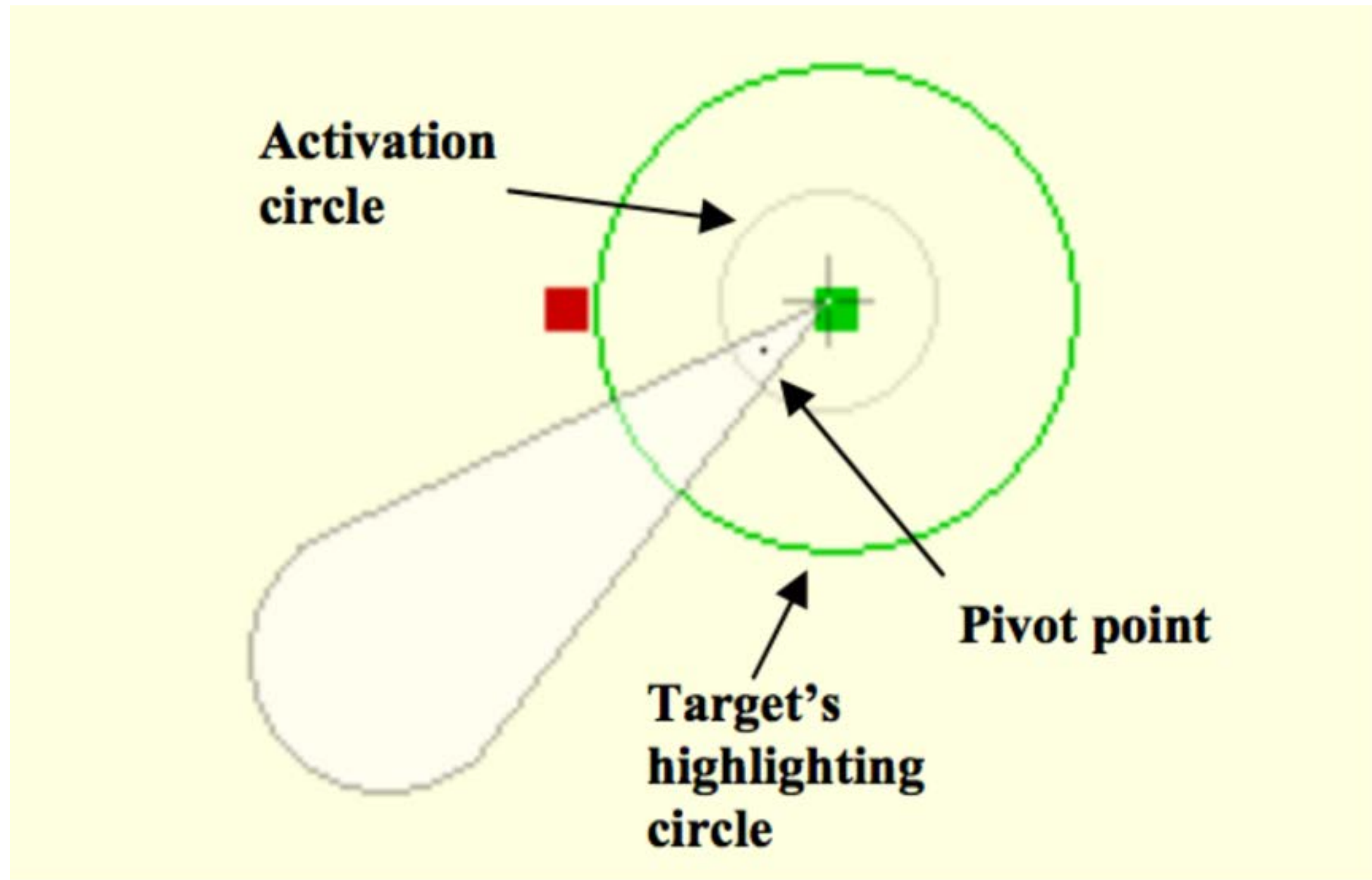
High precision touch screen interaction
[Albinsson and Zhai, CHI '03]



High precision touch screen interaction
[Albinsson and Zhai, CHI '03]



High precision touch screen interaction
[Albinsson and Zhai, CHI '03]



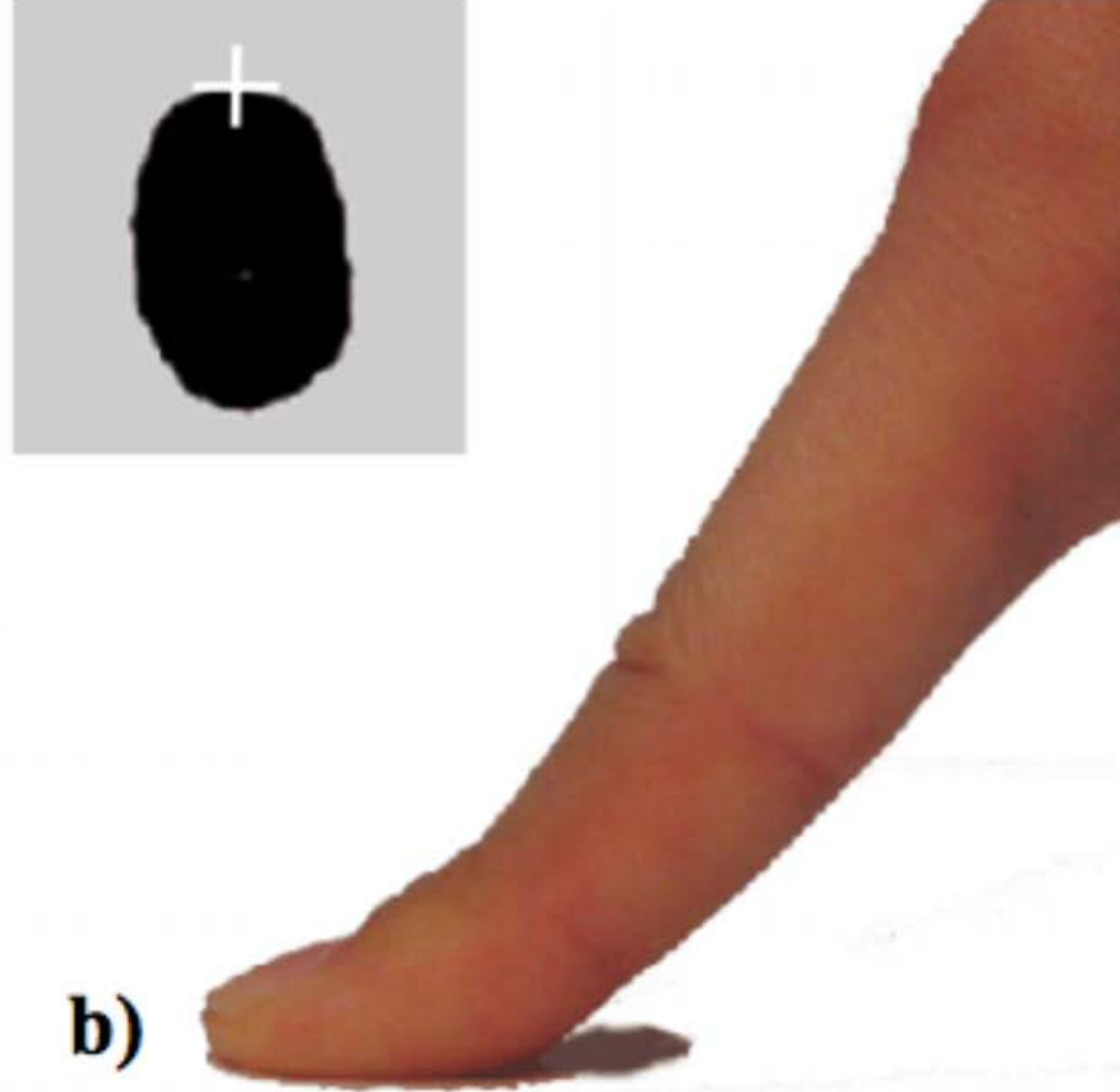
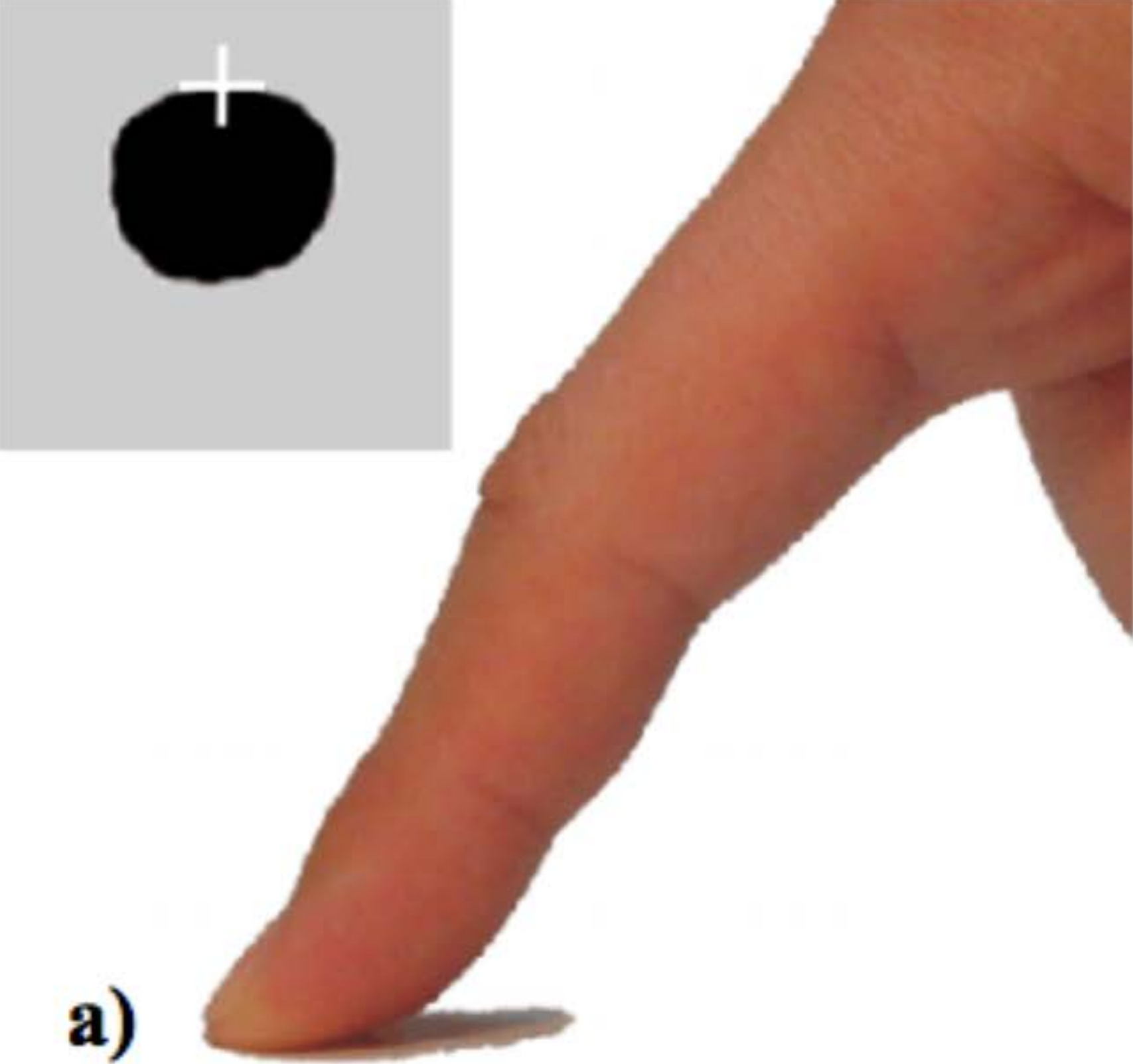
High precision touch screen interaction
[Albinsson and Zhai, CHI '03]

Precise Selection Techniques

[Benko et al., CHI '06]

Precise Selection Techniques

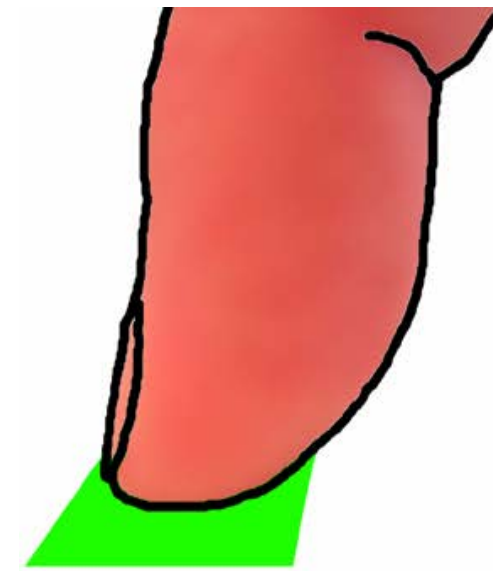
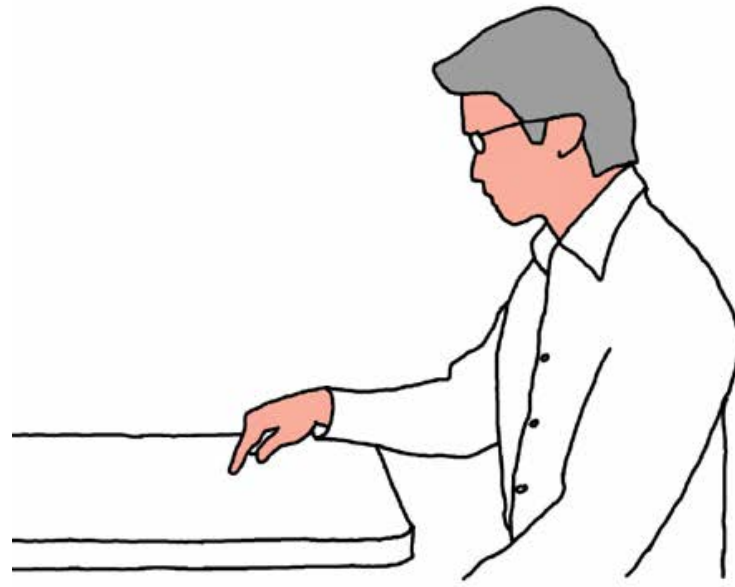
[Benko et al., CHI '06]



Precise Selection Techniques

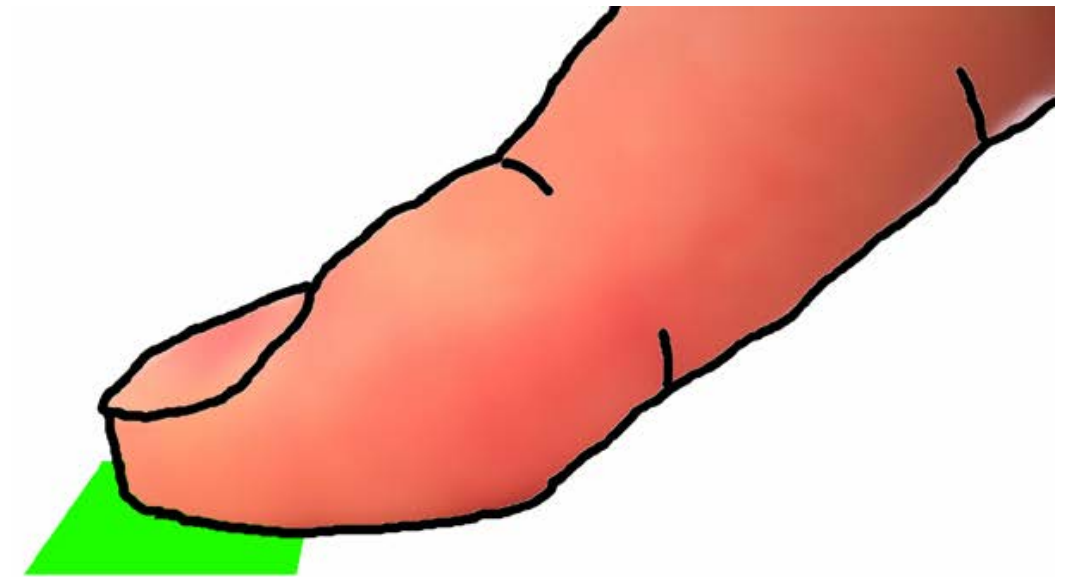
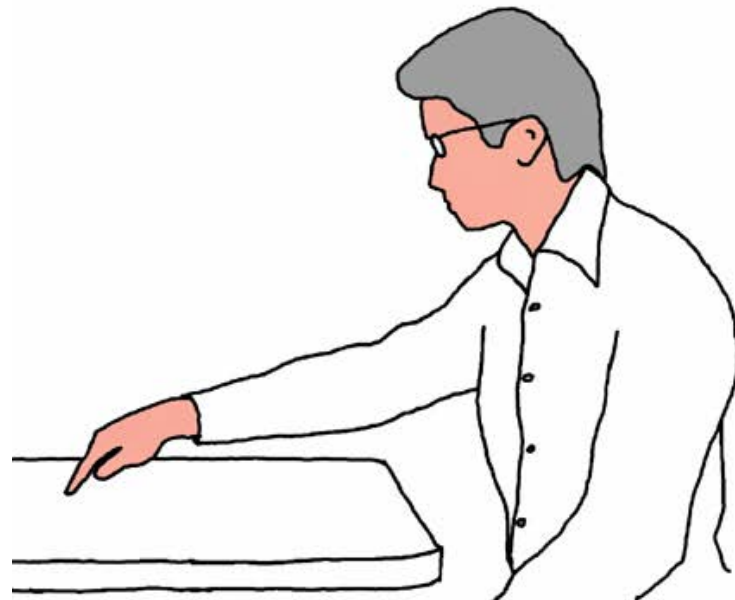
[Benko et al., CHI '06]

vertical finger pitch



contact area

flat finger pitch



Direct-touch vs. mouse input

[Forlines et al., CHI '07]

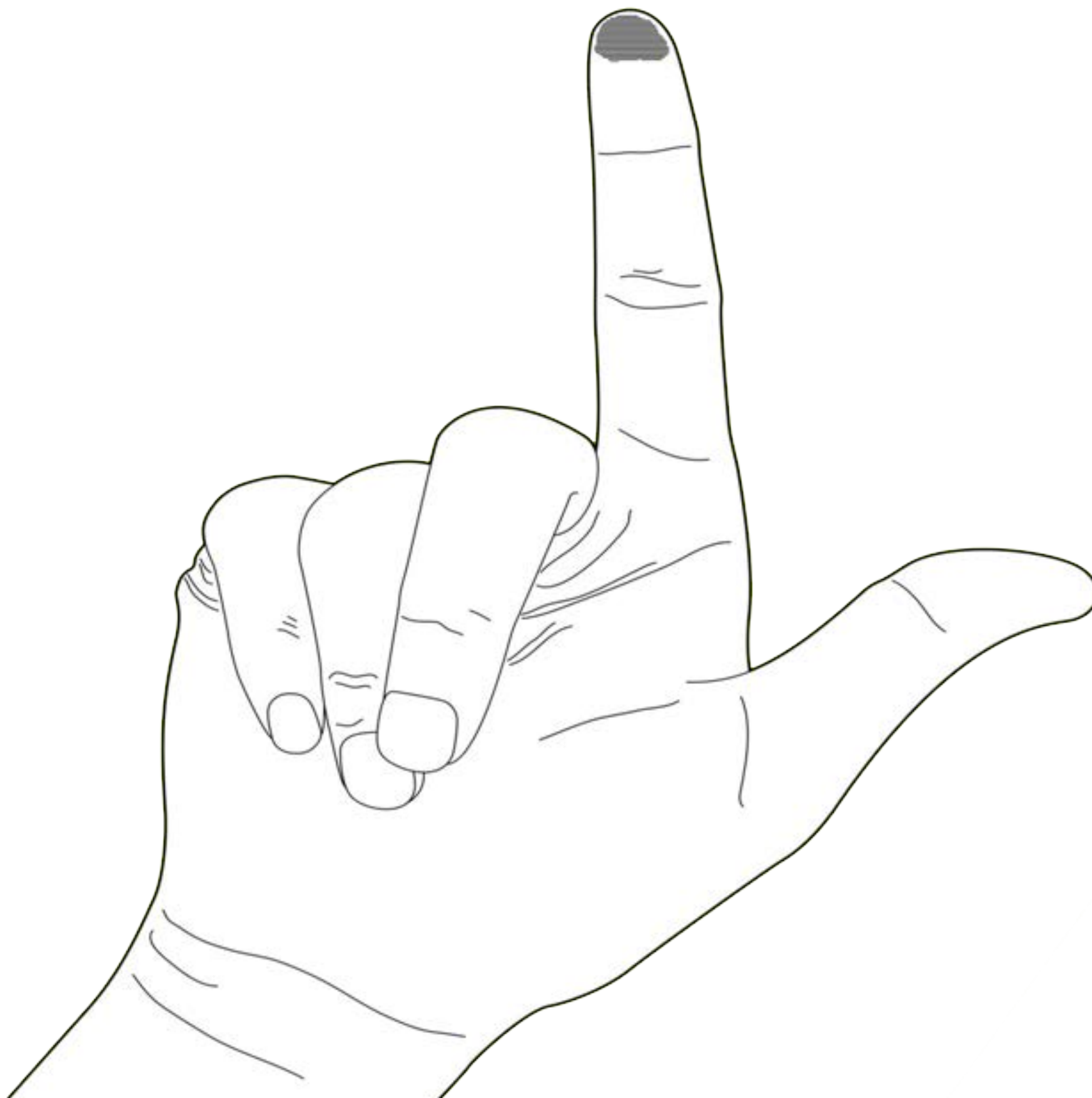
the culprit:

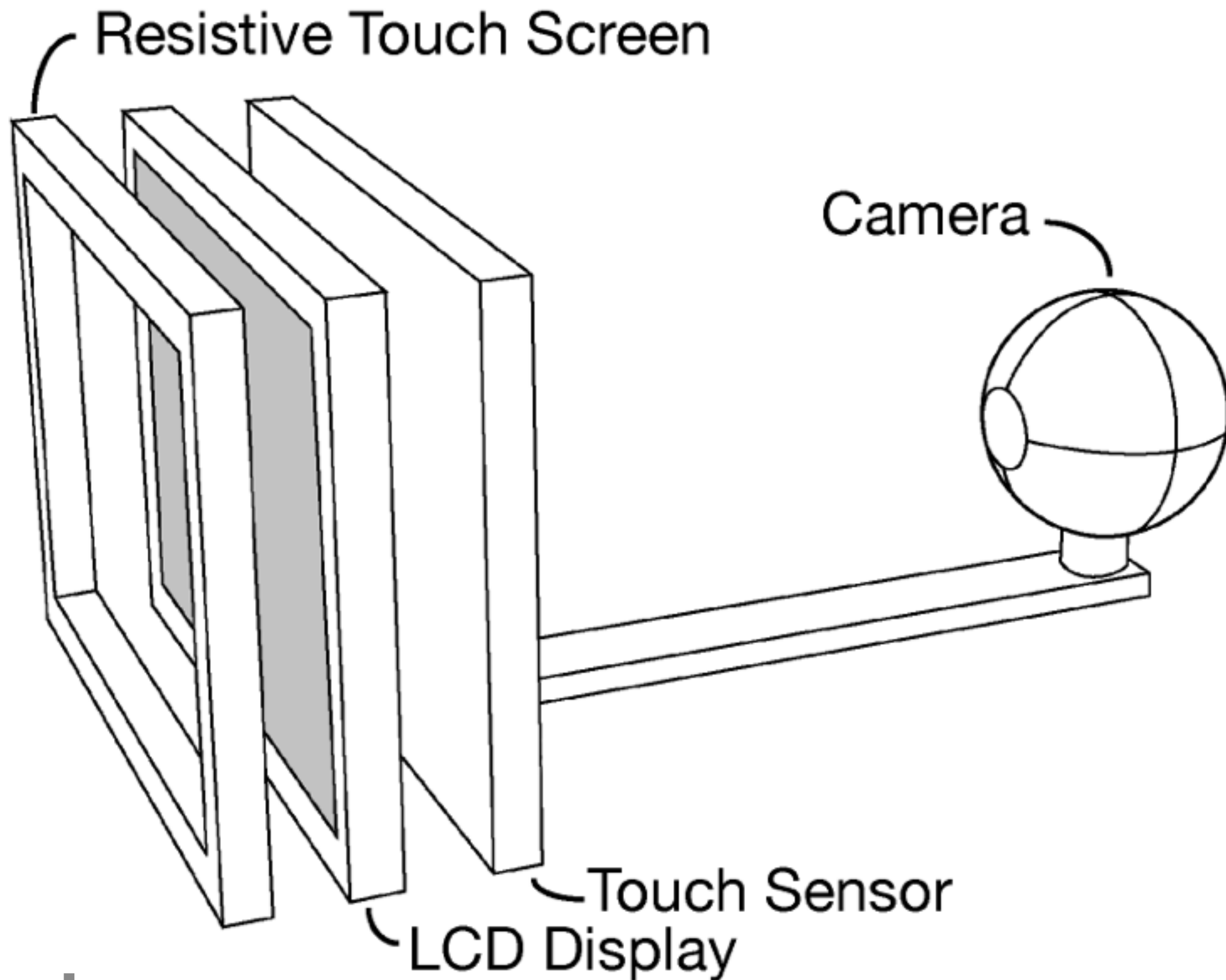
the **fat-finger** problem



fat finger

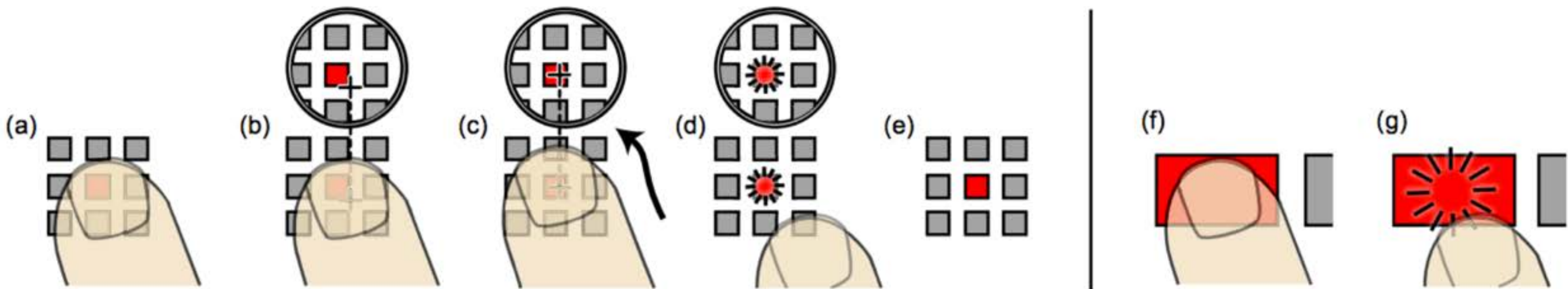
fat finger





LucidTouch

[Wigdor et al., CHI '07]



Shift

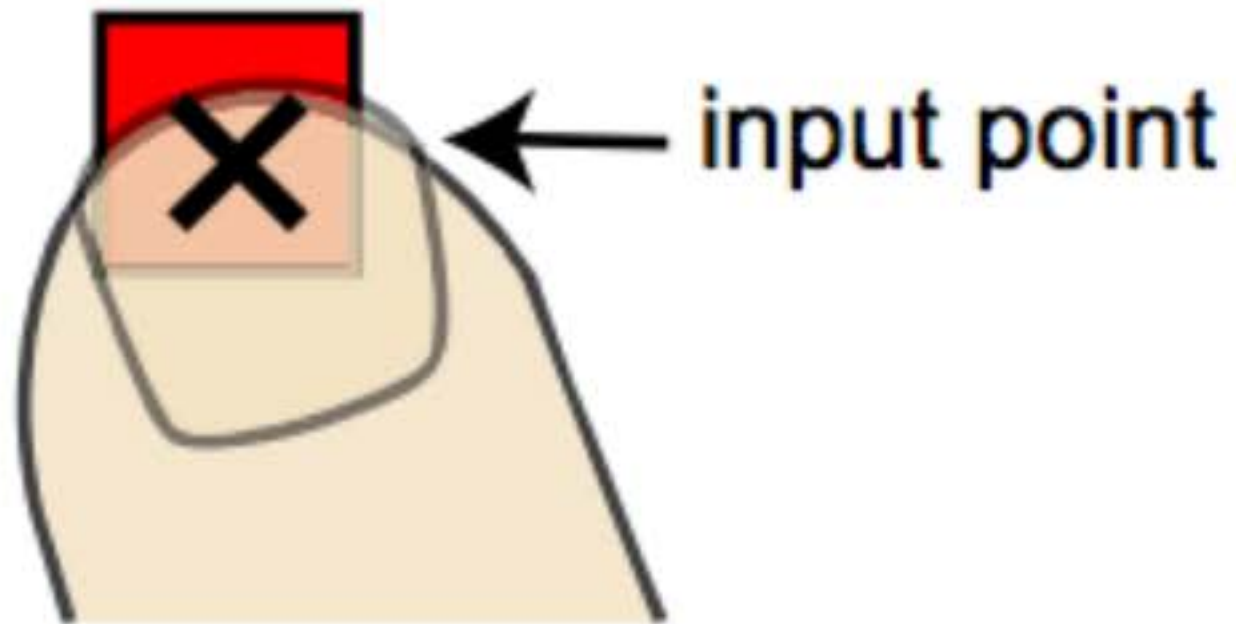
[Vogel and Baudisch, CHI '07]

why did you read this paper?
30 second brainstorming

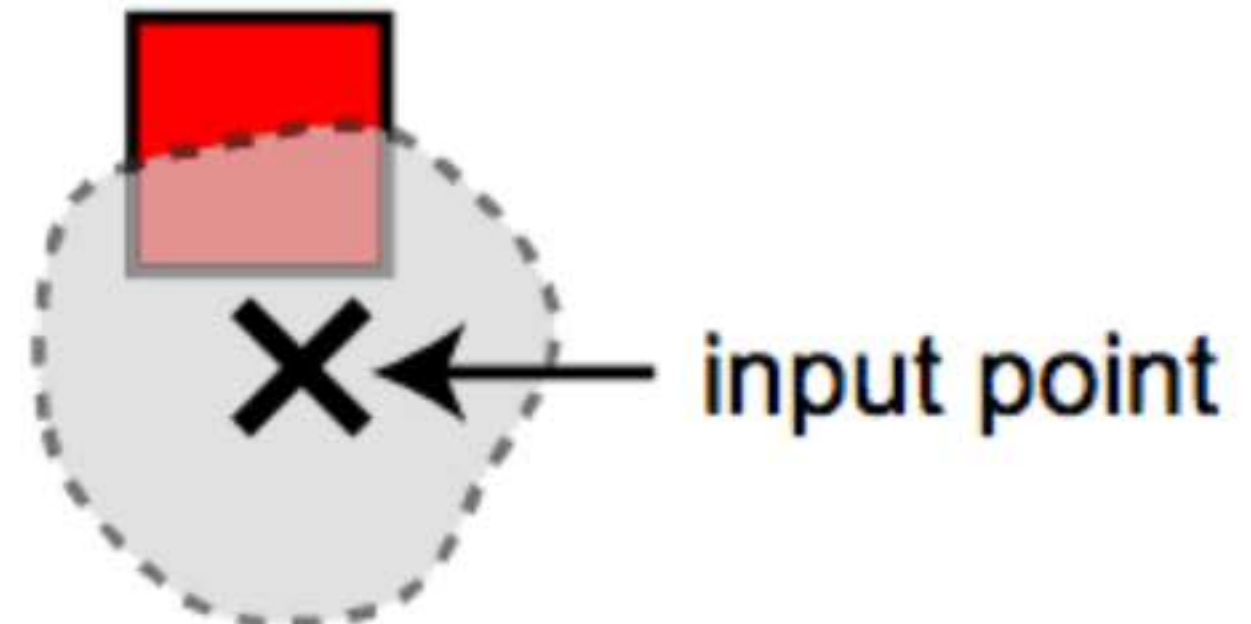
Shift

[Vogel and Baudisch, CHI '07]

(a) user view



(b) hardware view



perceived input point problem

[Vogel and Baudisch, CHI '07]

showing cursors is **cheating!**

...and they almost convinced us!



what's the real problem here?



the problem is **underspecified!**

Toolbox
What links here
Related changes
Upload file
Special pages
Permanent link
Page information
Data item

Print/export
Create a book
Download as PDF
Printable version

Languages
Simple English
العربية
Bahasa Indonesia
Bahasa Melayu
Български
Català
Česky
Dansk
Deutsch
Eesti
Ελληνικά
Español
Esperanto
Euskara
فارسی
Français
Galego
한국어
עברית

backs *Carnell Williams* (pictured) and *Ronnie Brown* were considered among the best at their position; for Tech, senior quarterback *Eric Randall* had had a record-breaking season. Both teams also had ranked defenses and in a defensive struggle, Auburn earned a victory despite a late-game rally by Virginia Tech. In recognition of game-winning performance, Auburn quarterback *Jason Campbell* named the game's most valuable player. Several players from each team were selected in the 2005 NFL Draft and went on to careers in the National Football League. (Full article...)

Recently featured: *The Hunger Games* – *Otto Becher* – Middle
[Archive](#) – [By email](#) – [More featured articles](#)

Did you know...

From Wikipedia's newest content:

- ... that *Kirkpatrick Chapel* (pictured) at Rutgers University, built in 1873, was designed by architect *Henry Janeway Hardenbergh*, and features four stained-glass windows from the studios of *Louis Comfort Tiffany*?
- ... that *Arthur Fields* took over 180,000 photographs of Dublin pedestrians?
- ... that according to the 1871 census, the first in British India, *Chappalli* had a population of 76,530 making it the second largest town in the *Madras Presidency*, next only to *Madras*?
- ... that the song "It Right", featuring *Panda Bear* of *Animal Collective*, was produced by both *Pitchfork Media* and *Animal Collective*?

which link
am I selecting?





could it be

that it is **not the fingers**
but our **touch devices** that are **wrong?**

let's assume for a second that there is

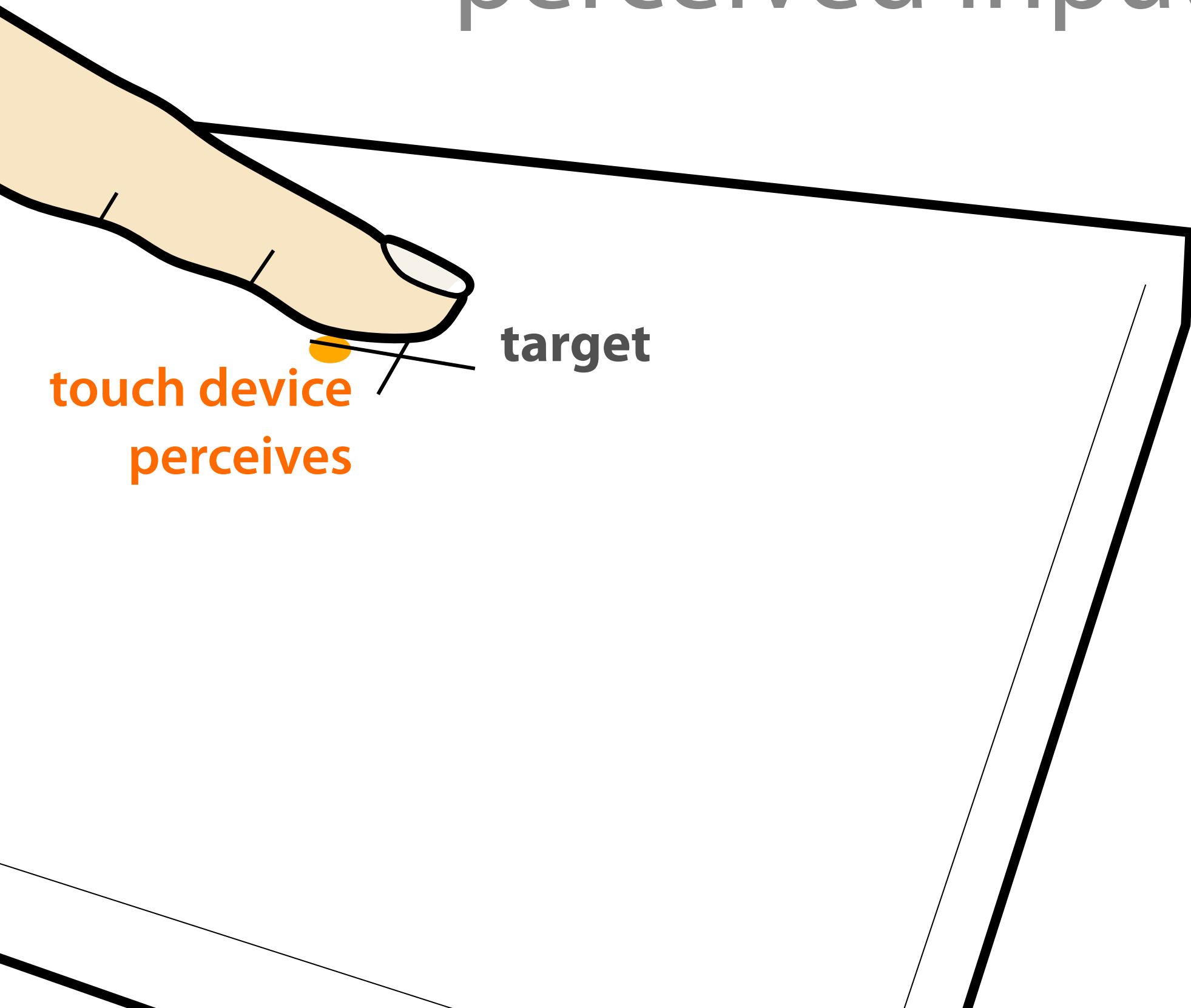
no fat finger
problem

instead, almost all observed targeting error comes from

perceived
input point

problem

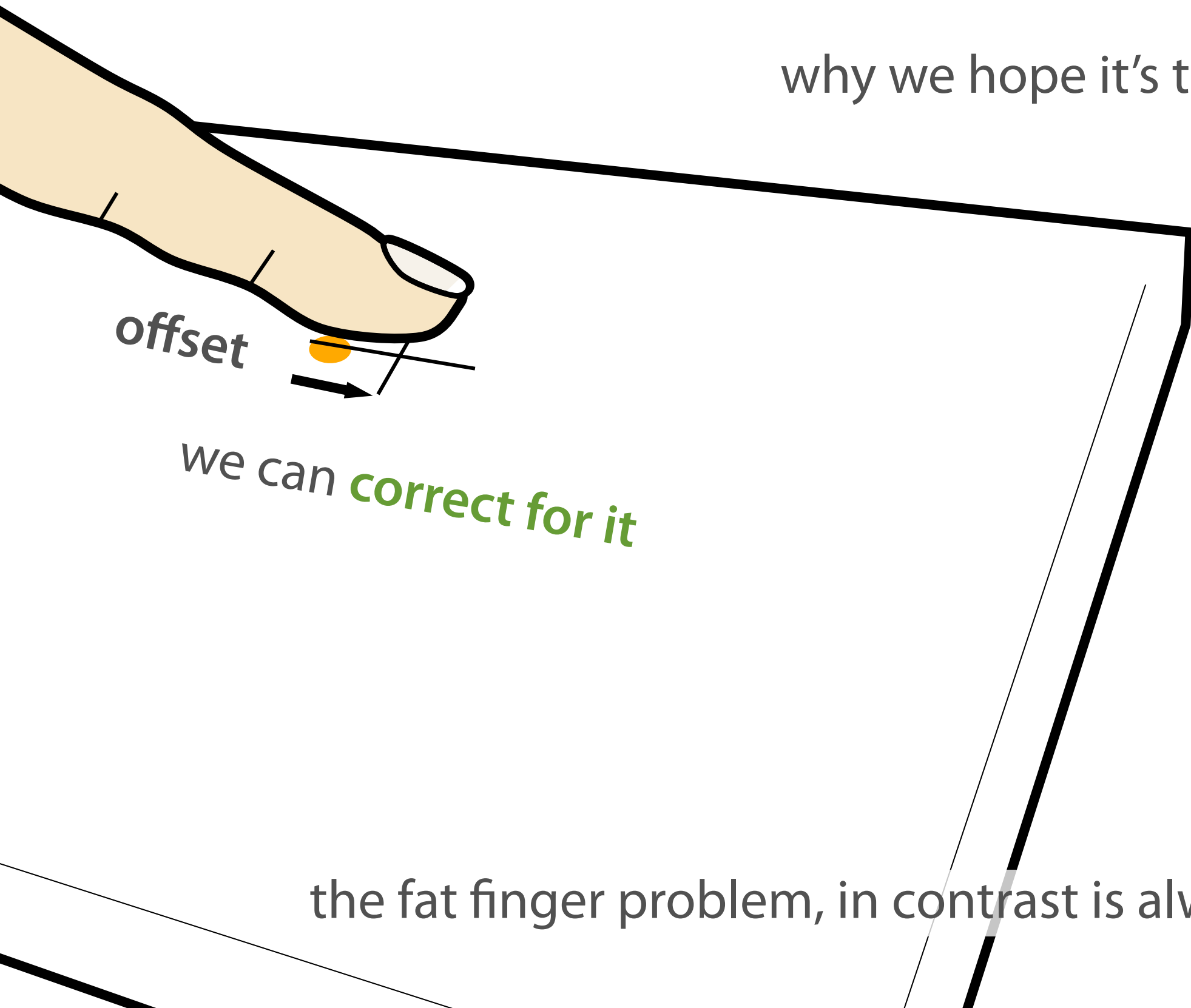
perceived input point problem



touch device
perceives

target

why we hope it's the perceived input point problem?



offset

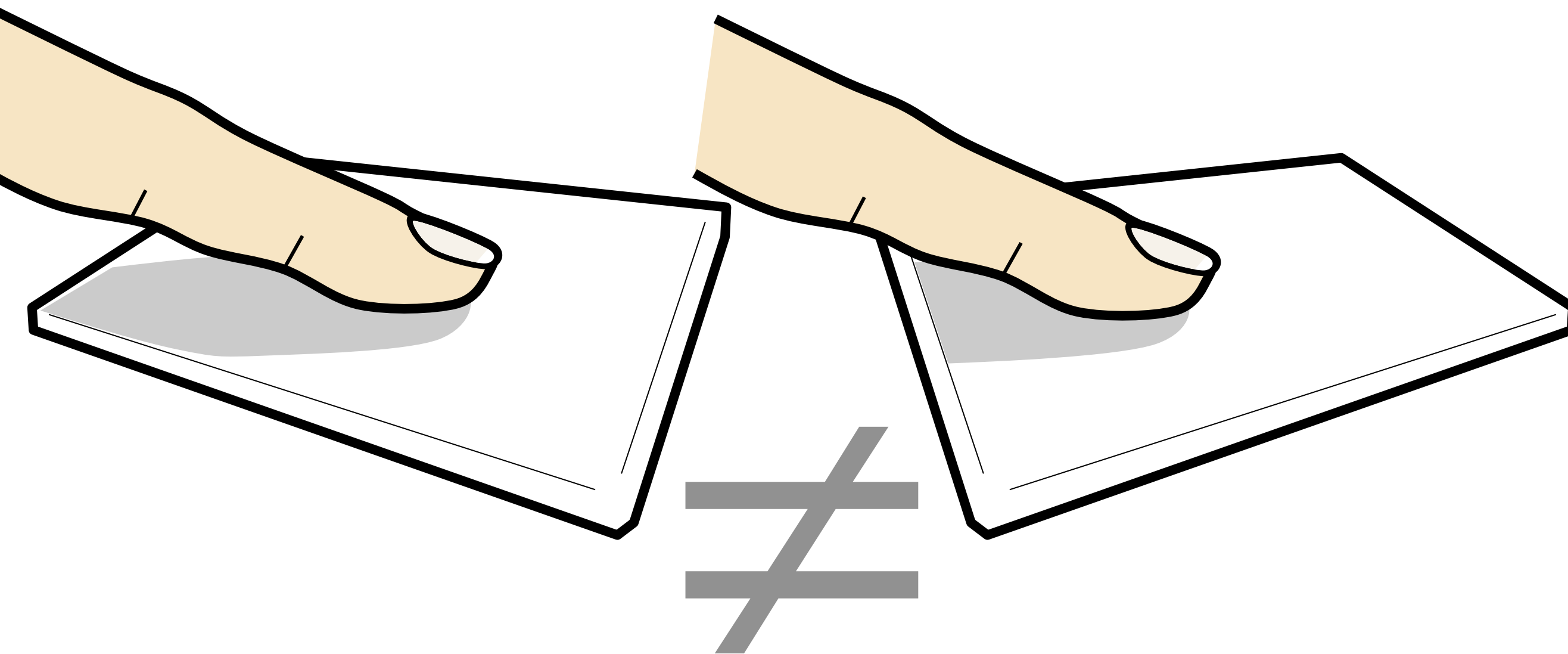
we can **correct** for it

the fat finger problem, in contrast is always noise = error

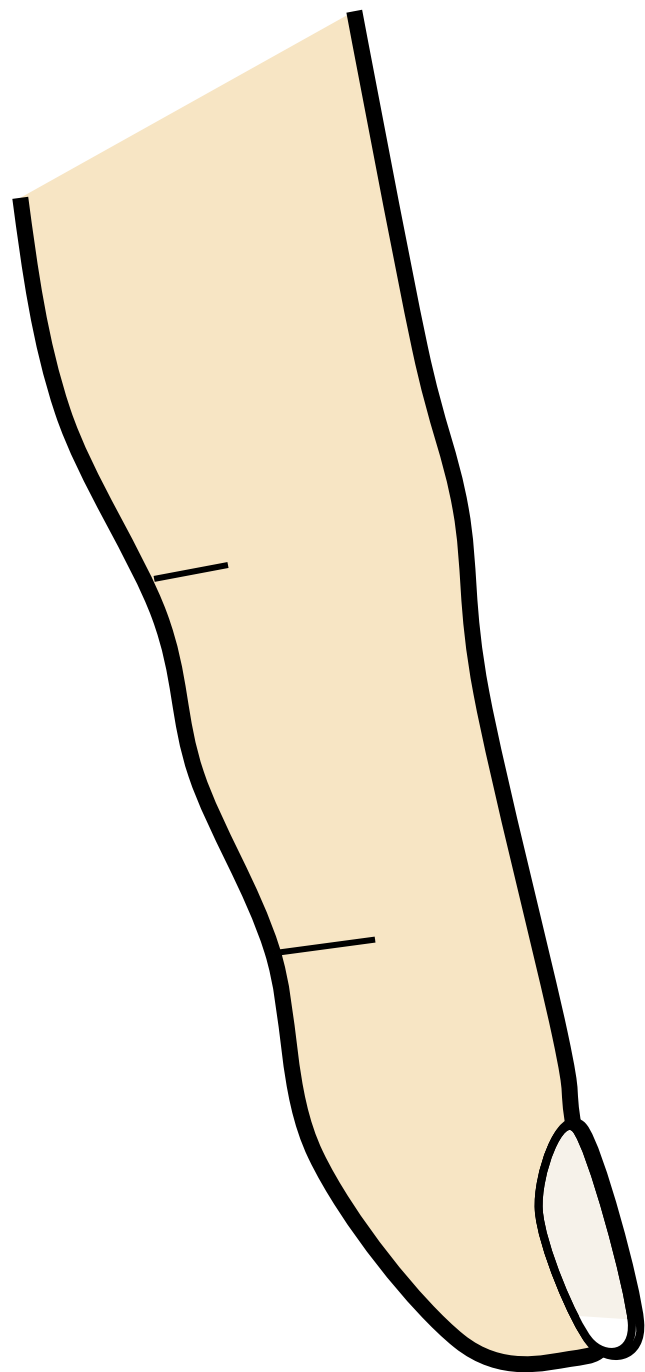
our main hypothesis

while there is always an offset, we hypothesize that
the offset **depends on the pointing situation**

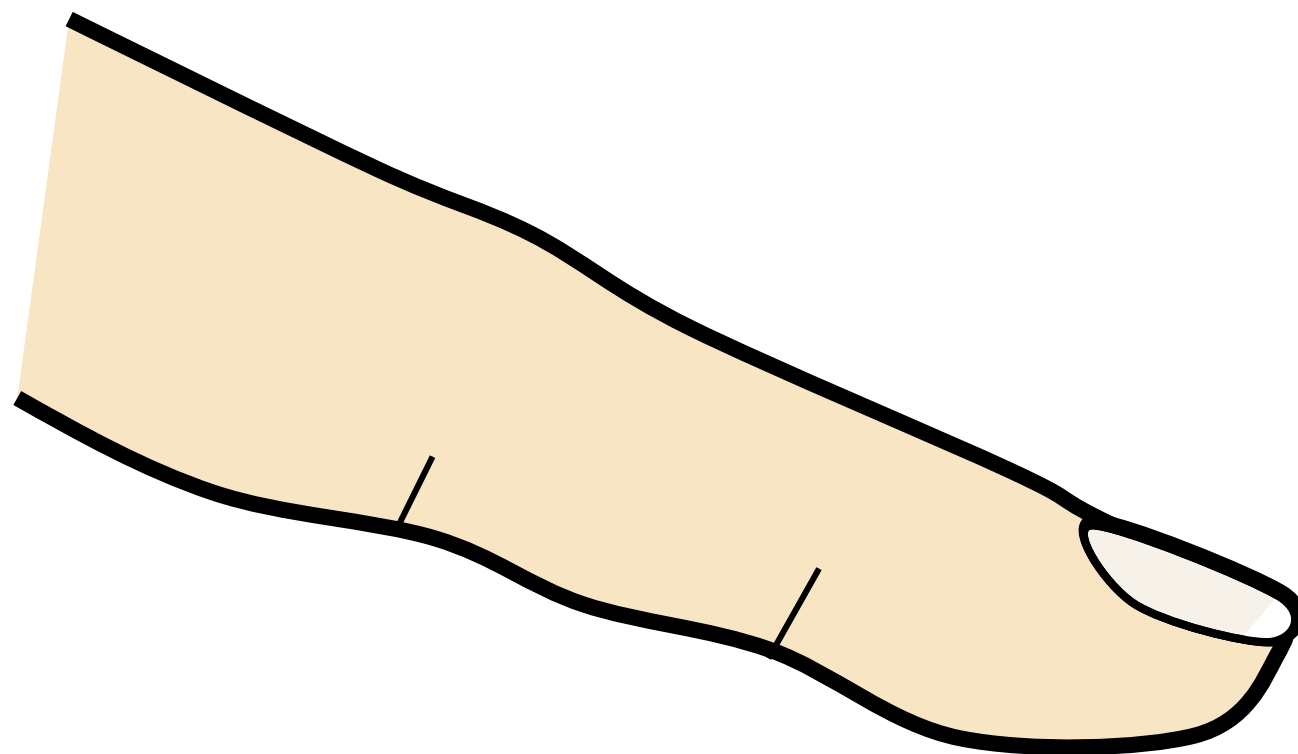
1 yaw



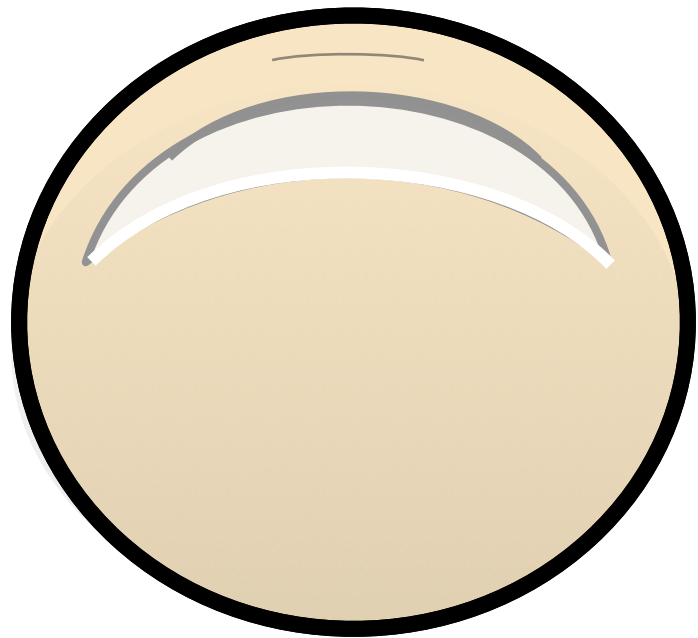
2 pitch



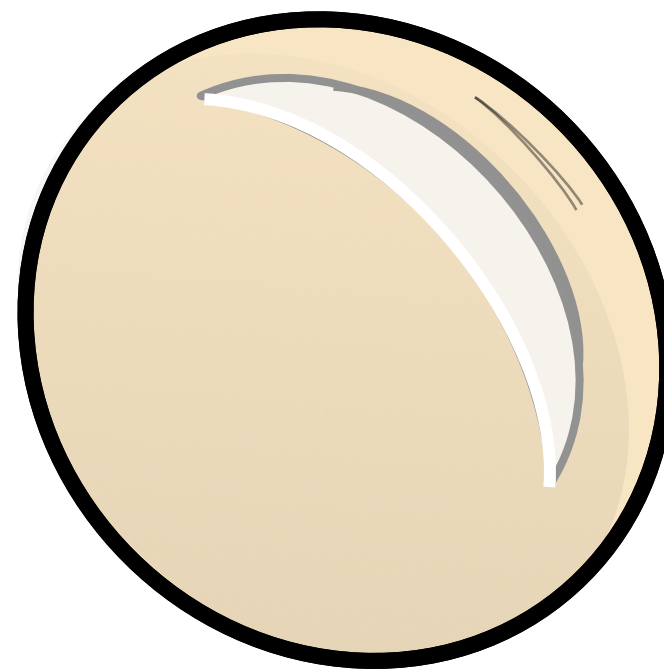
≠



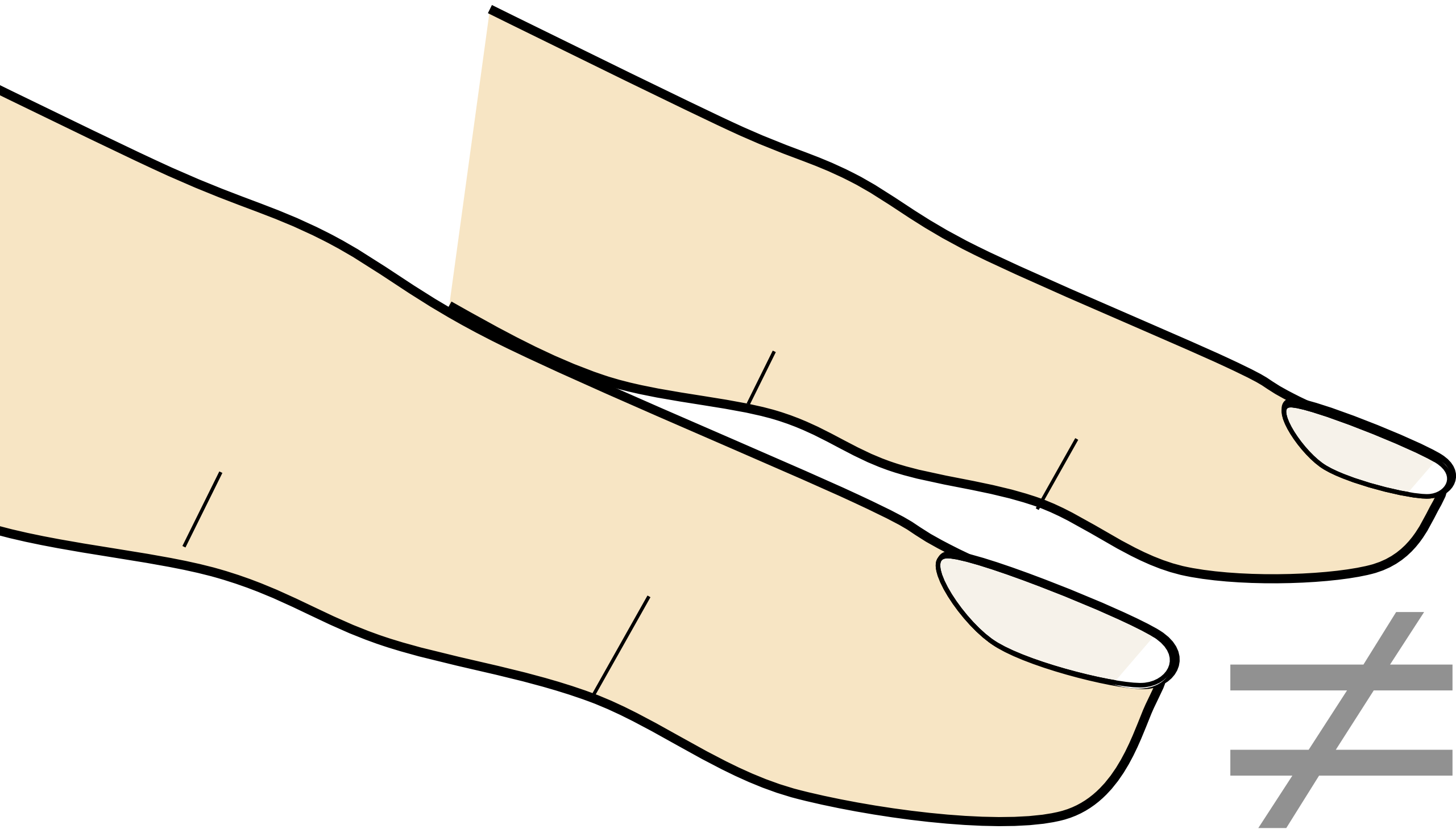
3 roll



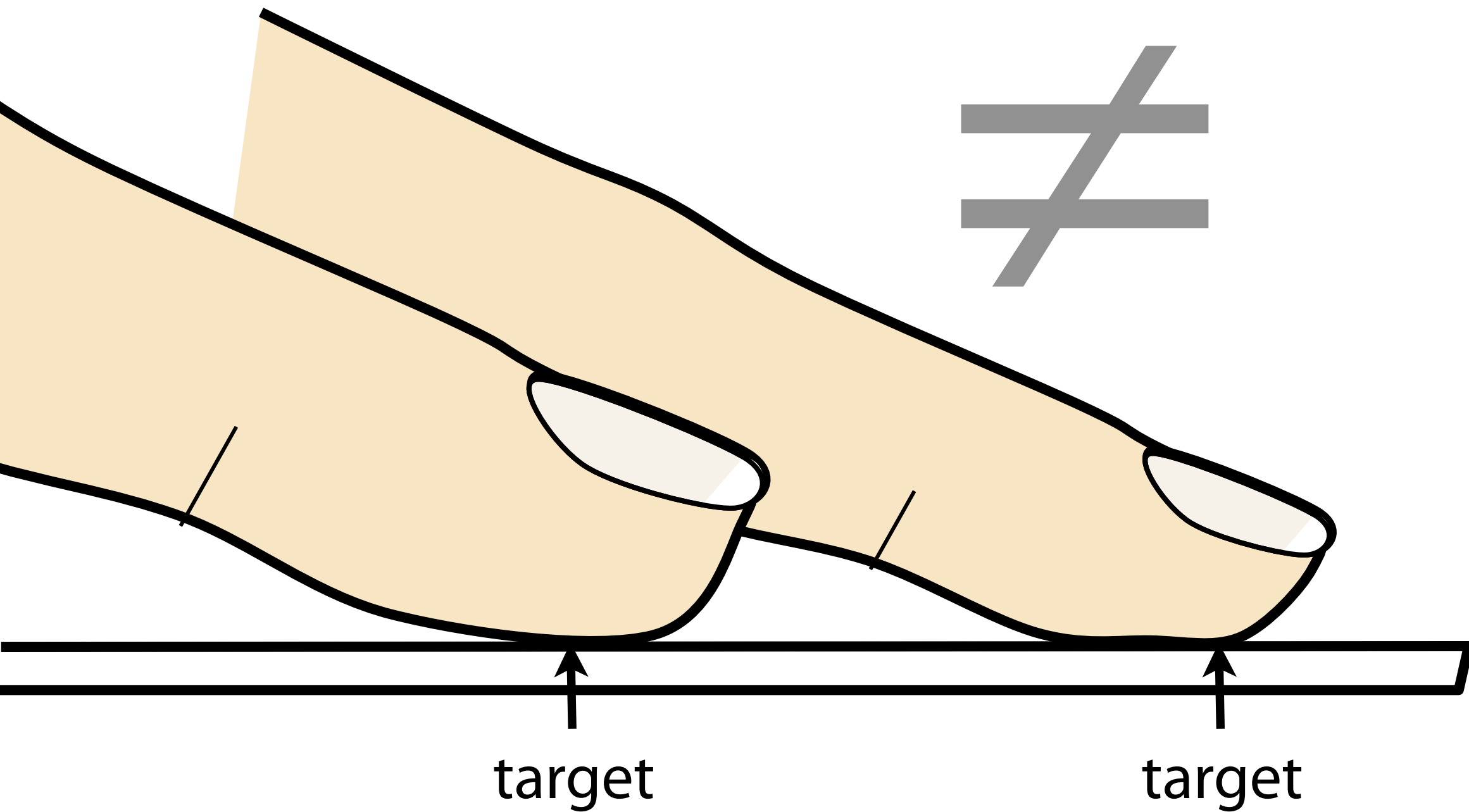
\neq



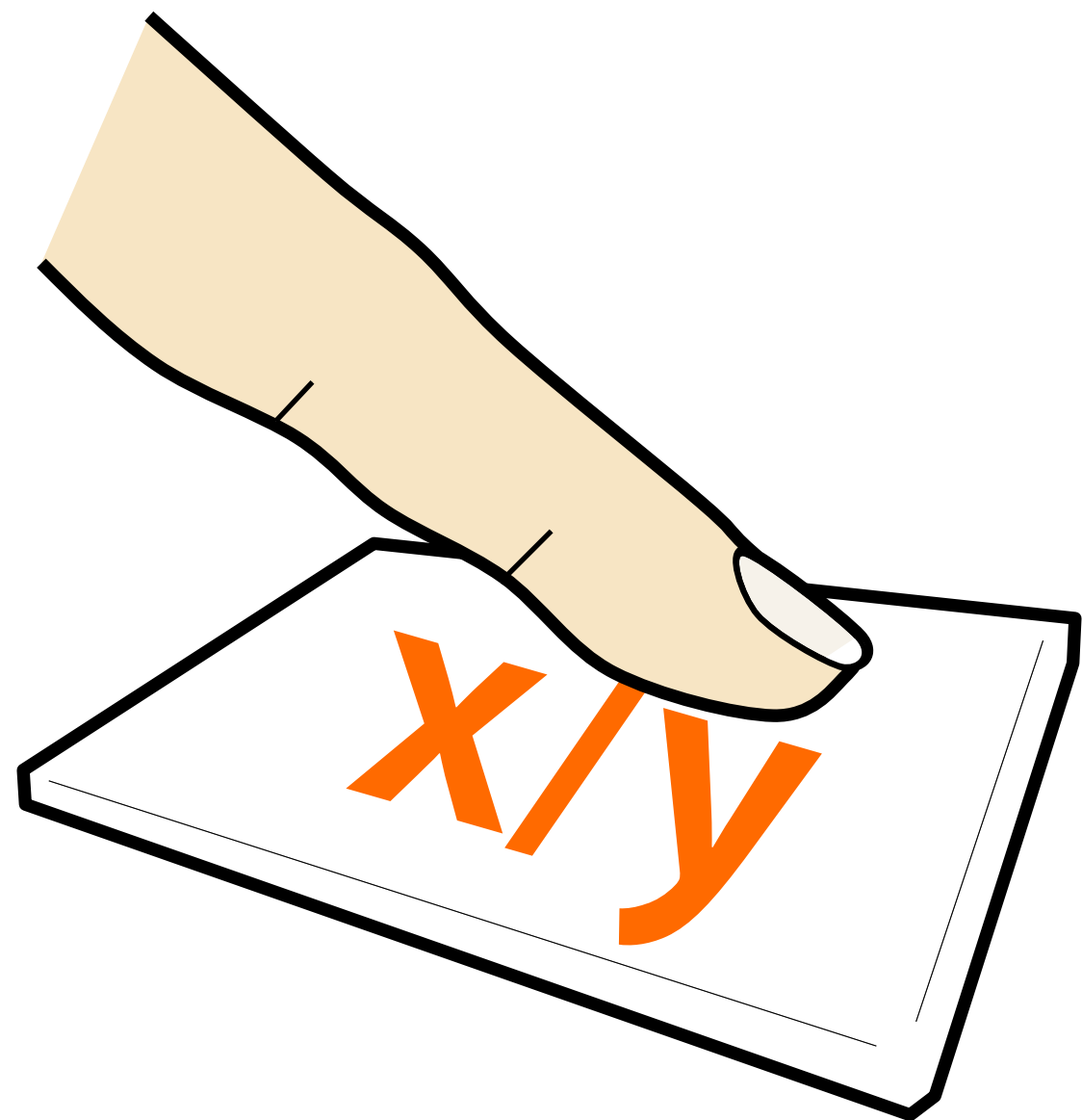
4 users: finger shape



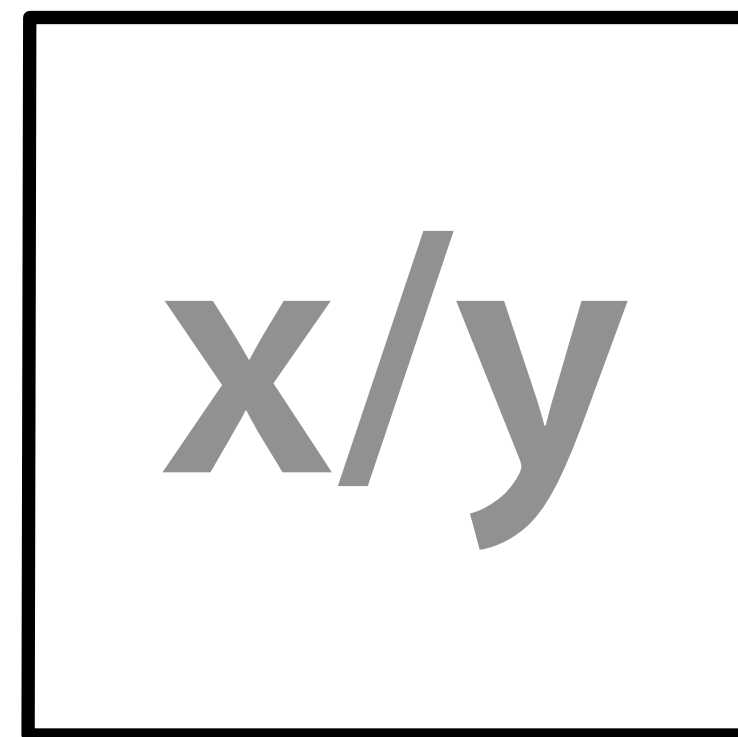
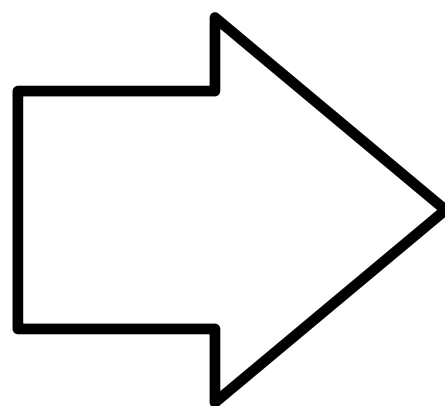
4 users: mental model



current model

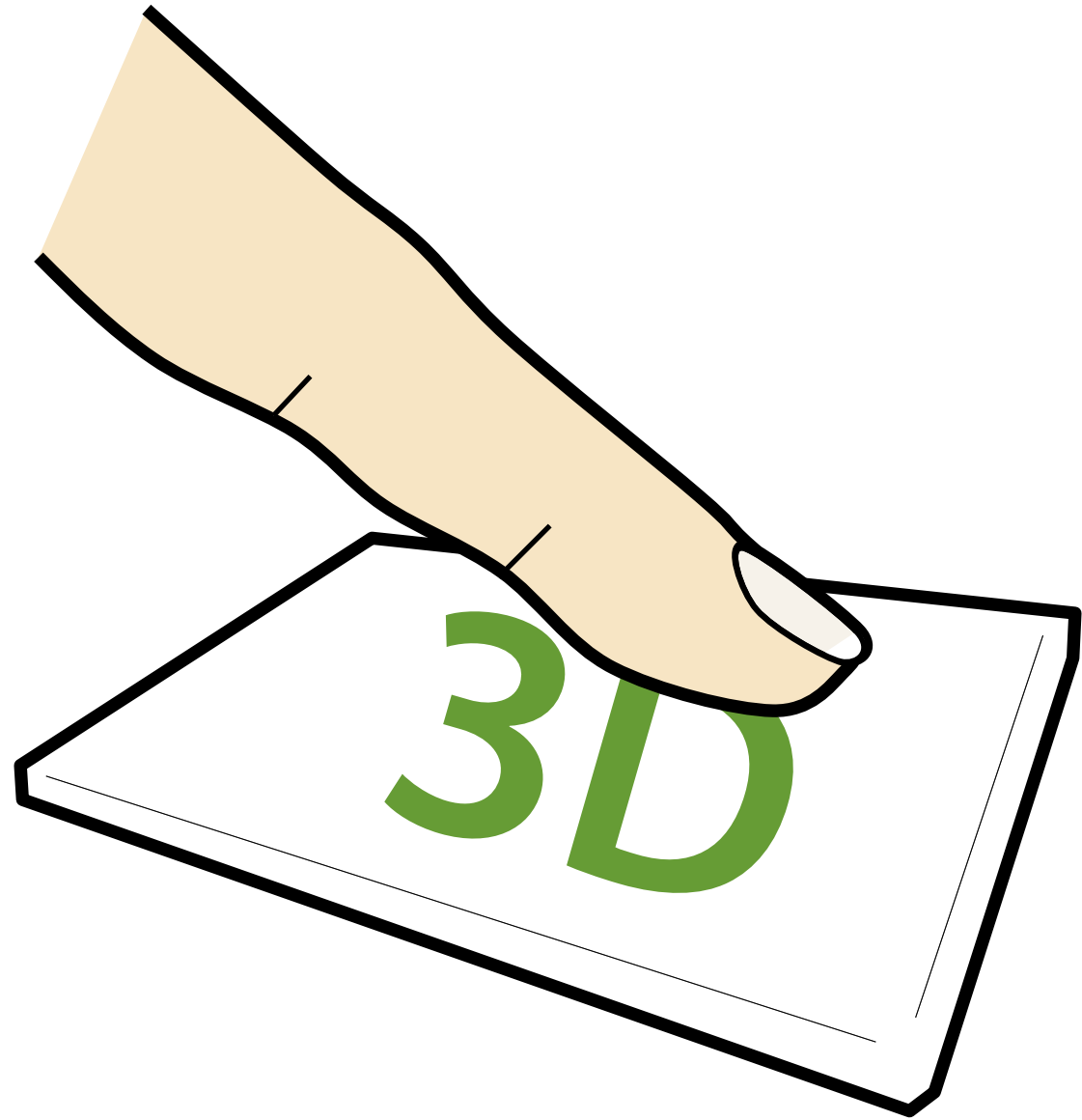


center of contact area

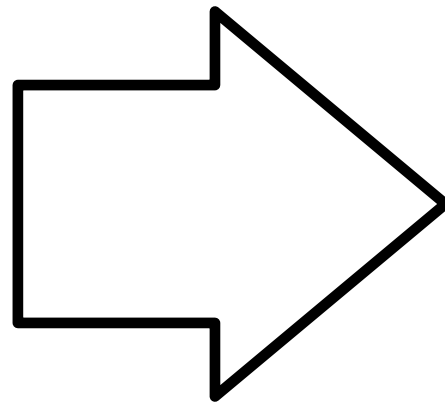


2D screen

we propose



sensing the finger in 3D



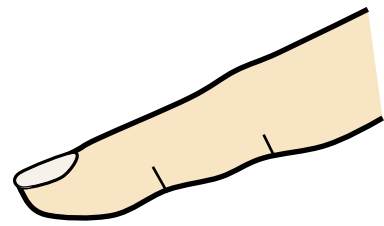
2D screen



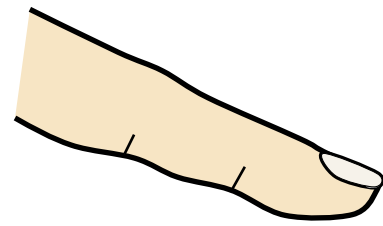
user study

independent variables

yaw

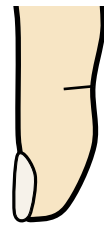


0°

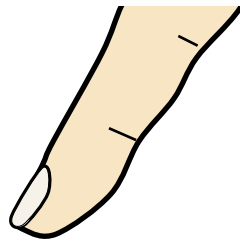


180°

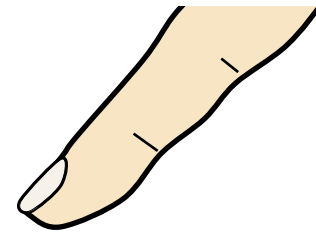
pitch



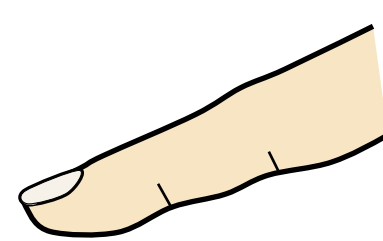
90°



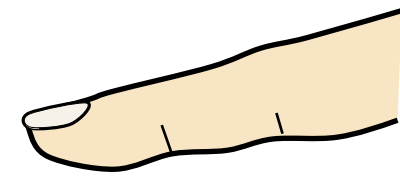
65°



45°

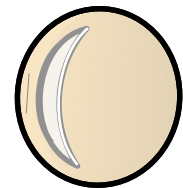


25°

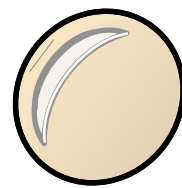


15°

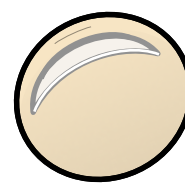
roll



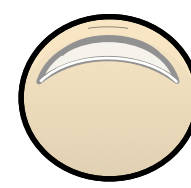
90°



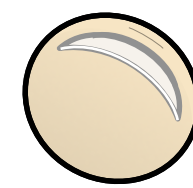
45°



15°

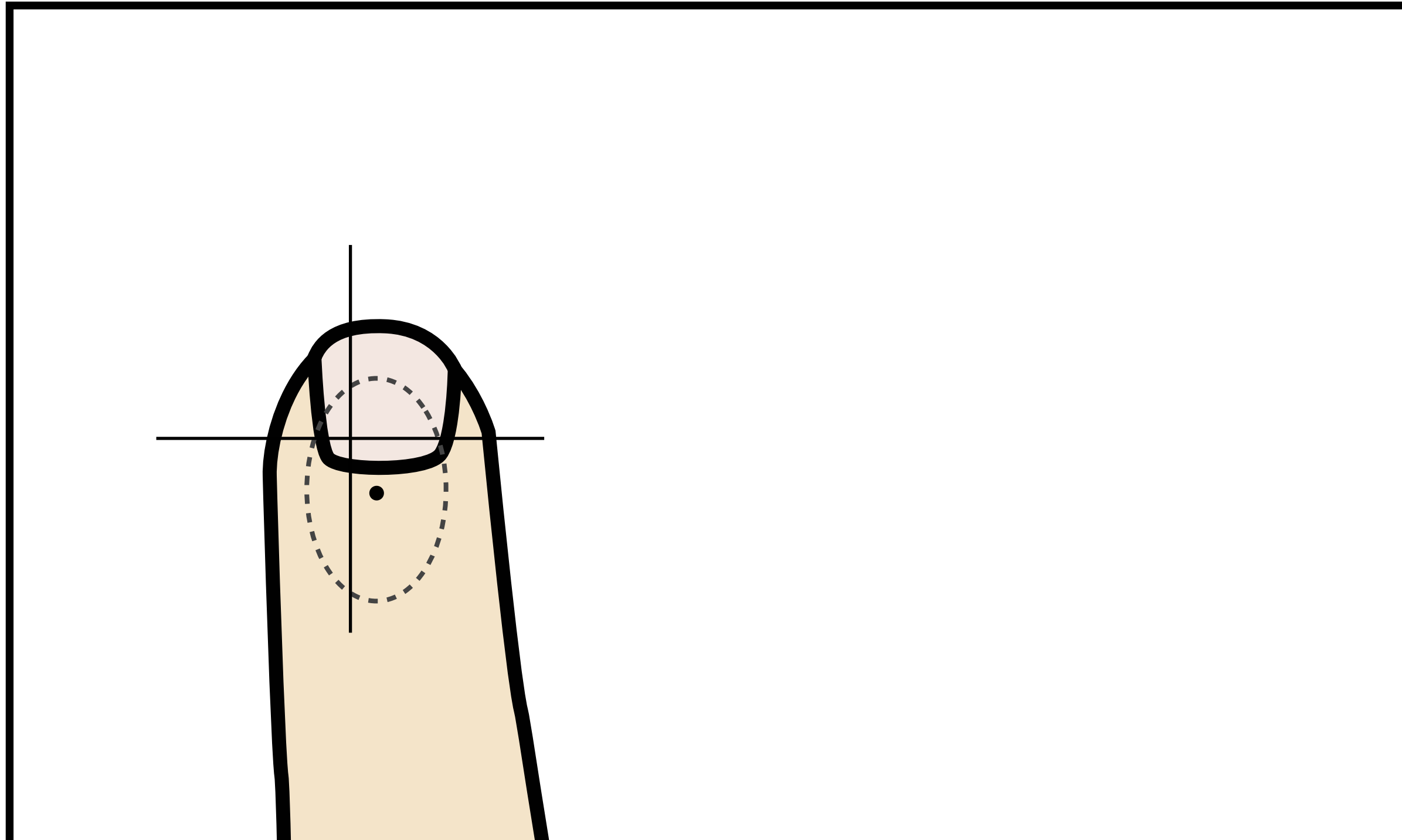


0°

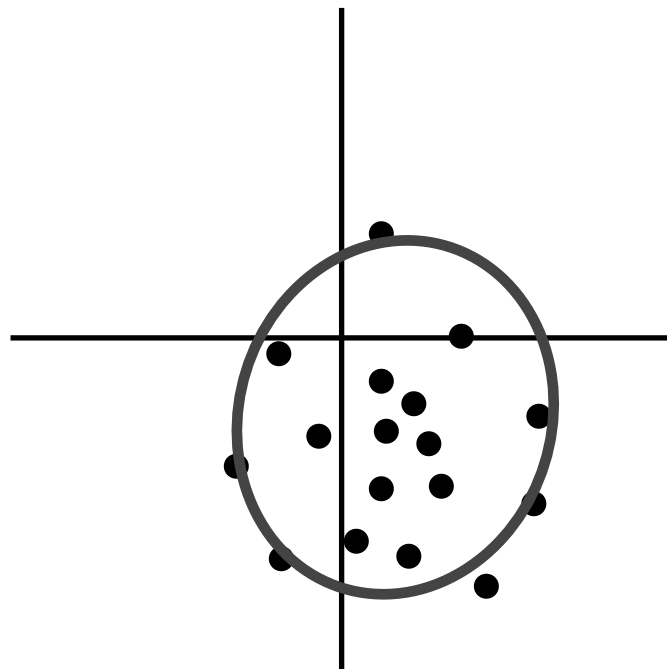


-15°

error metric

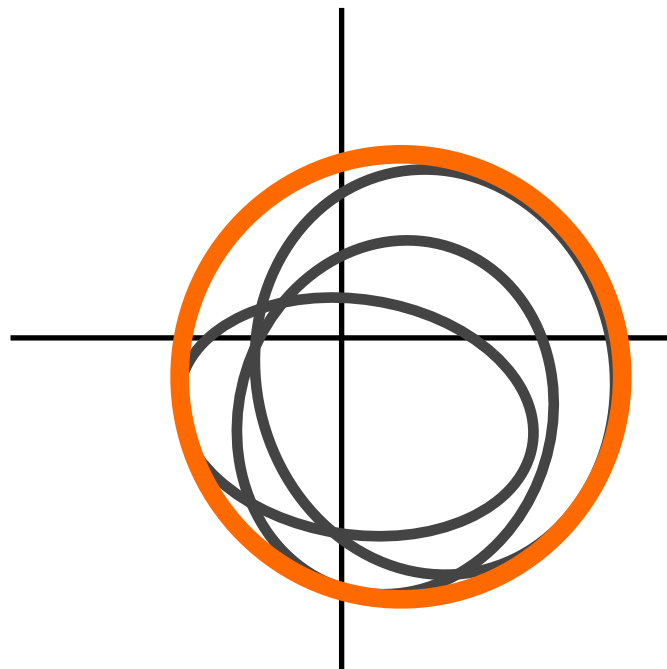


error metric



spread
:= variation **within** a condition

error metric



spread
:= variation **within** a condition

minimum button size
:= 95% of samples
across conditions

study design

2 yaw

× 2 sessions (pitch, roll)

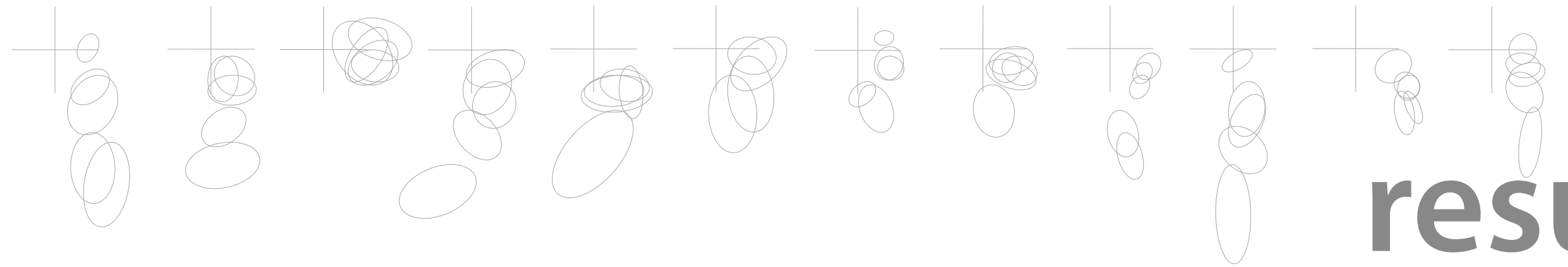
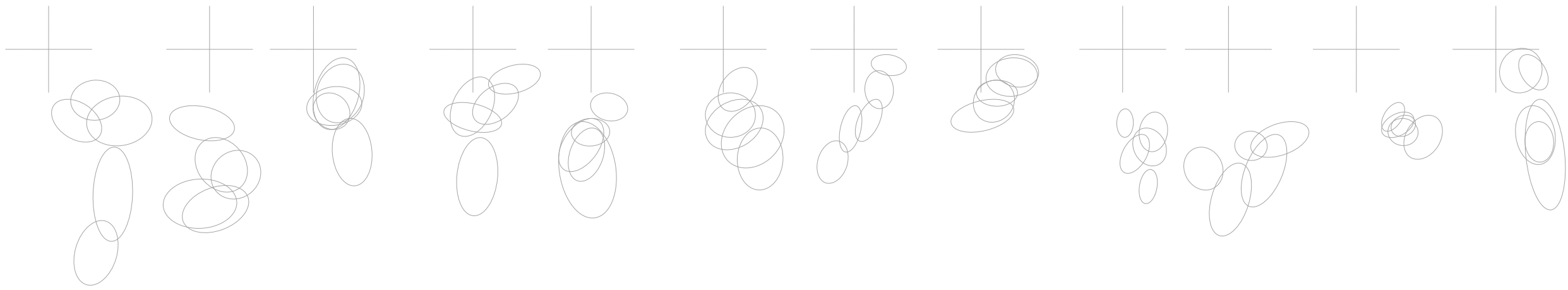
× 5 angles

× 6 repetitions per angle

× 5 blocks

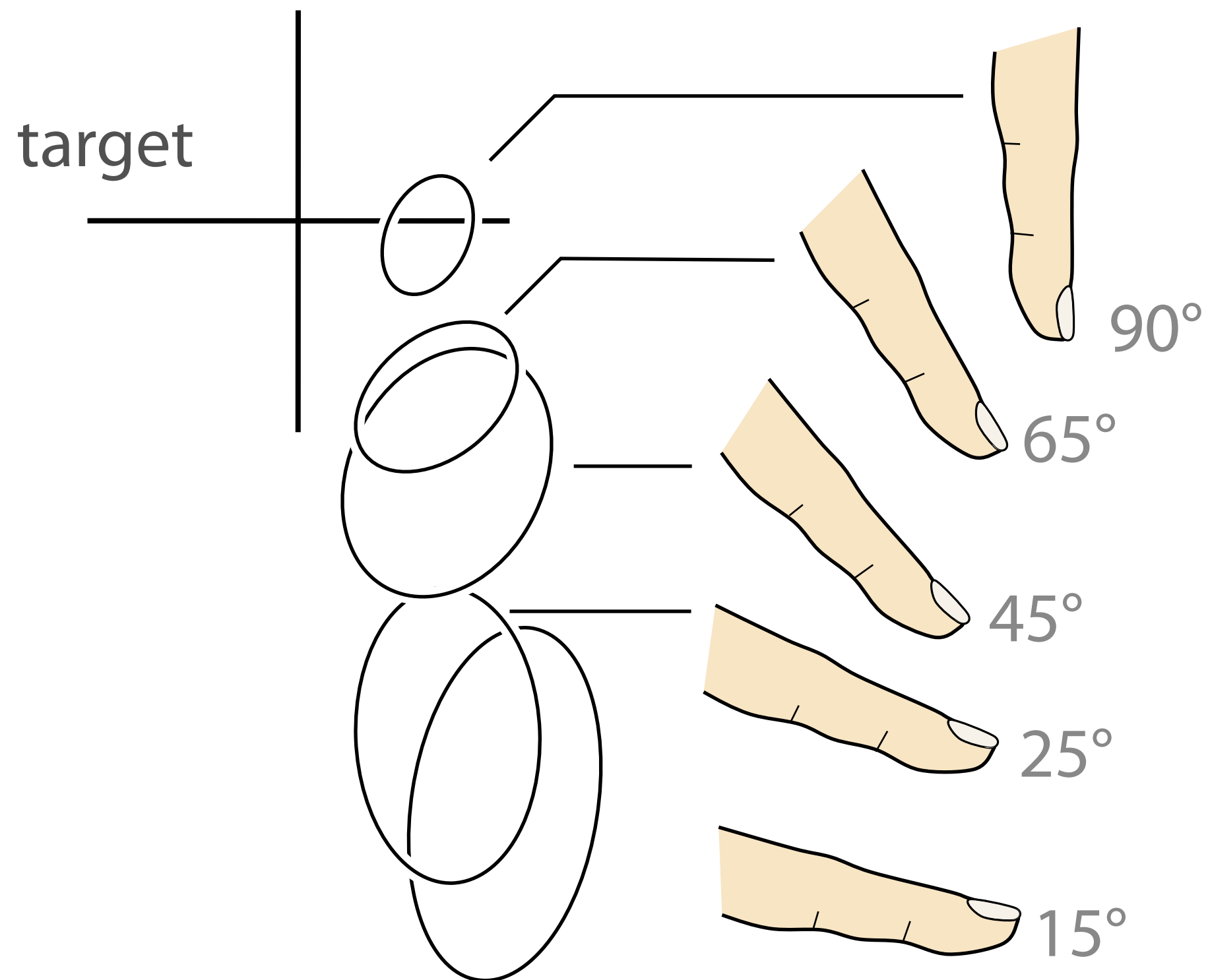
= 600 trials / participant

12 participants



results

pitch

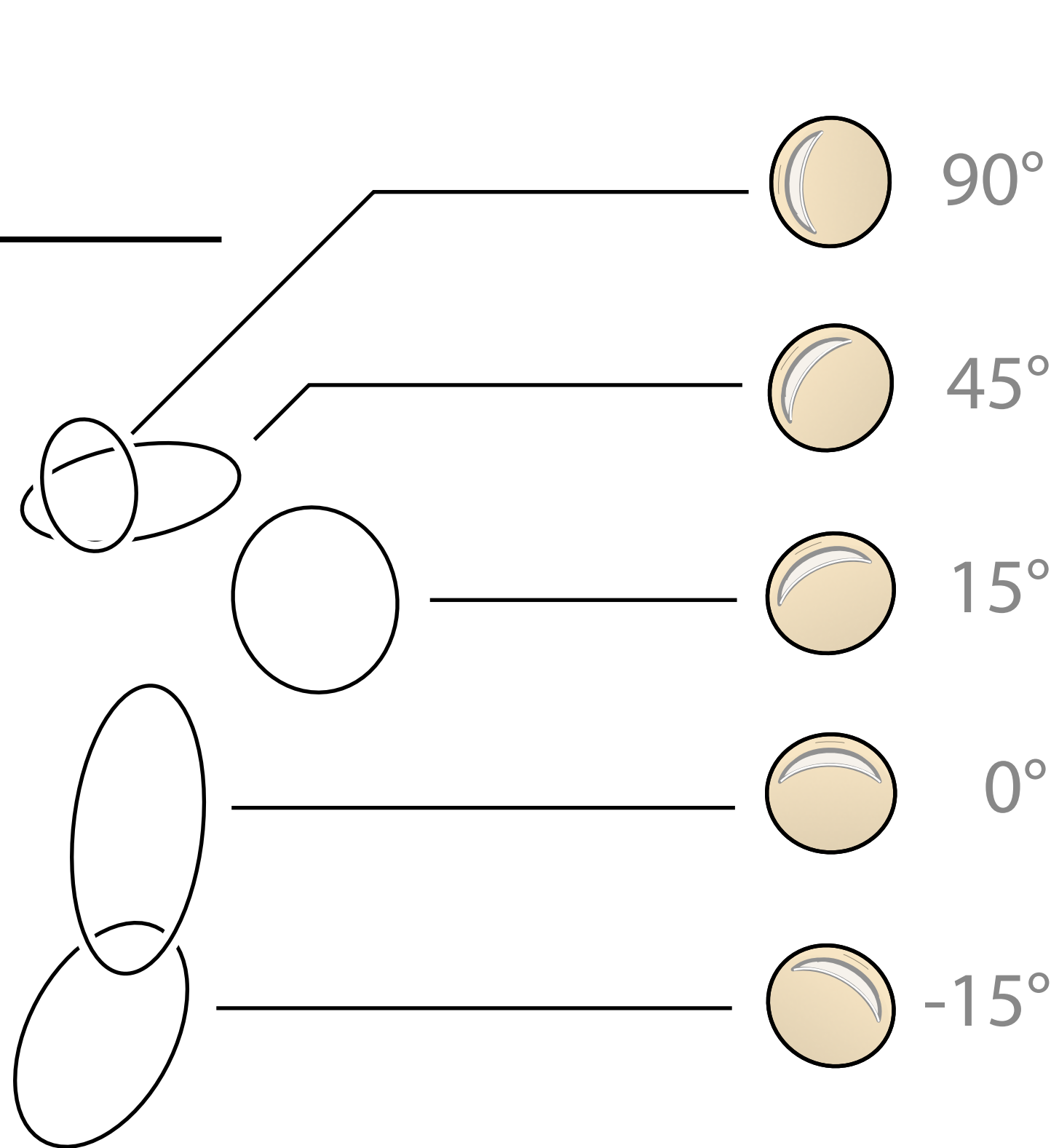


1cm

roll

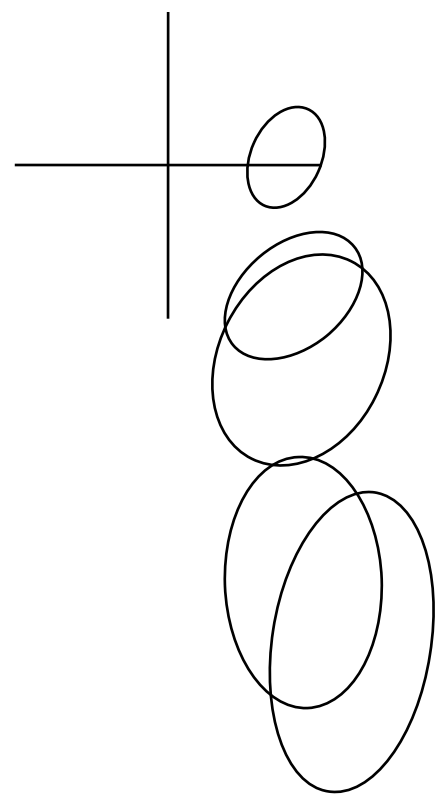
target

1cm

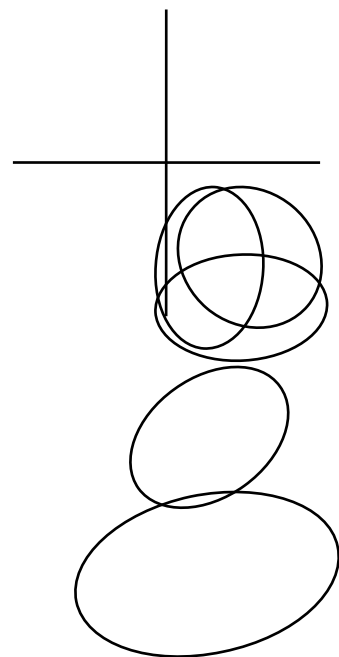


user

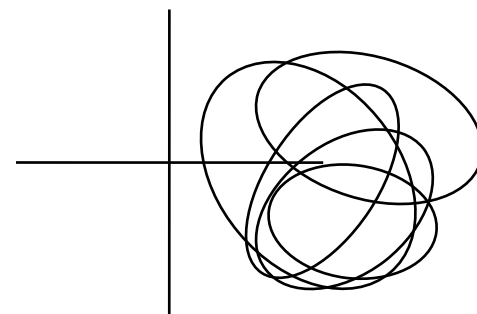
#1



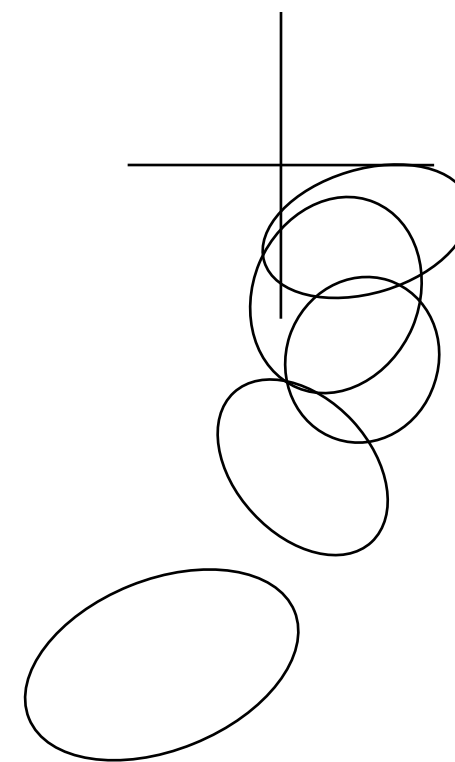
#2



#3



#4

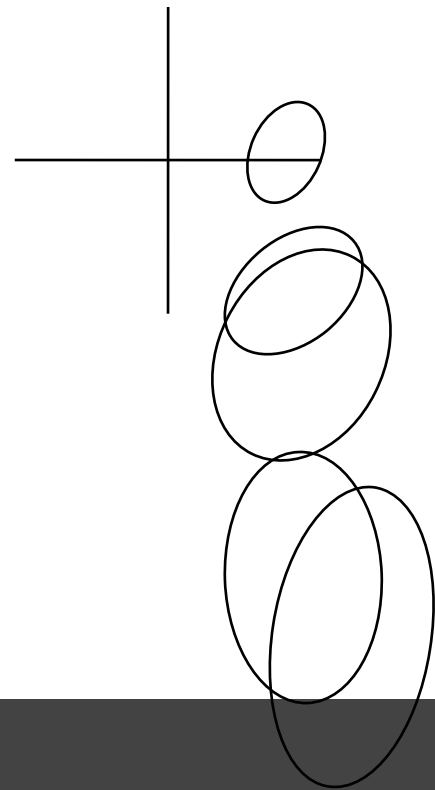


pitch

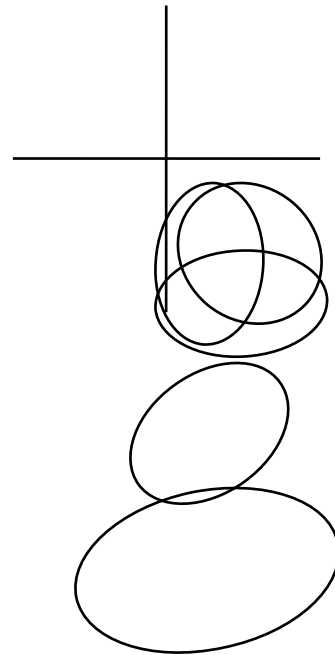
1cm

user

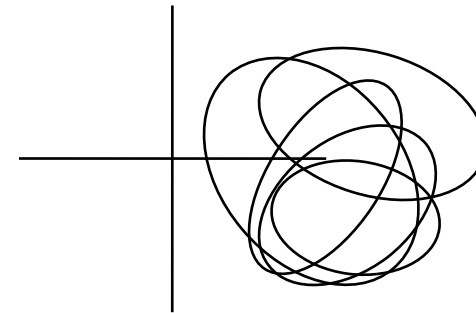
#1



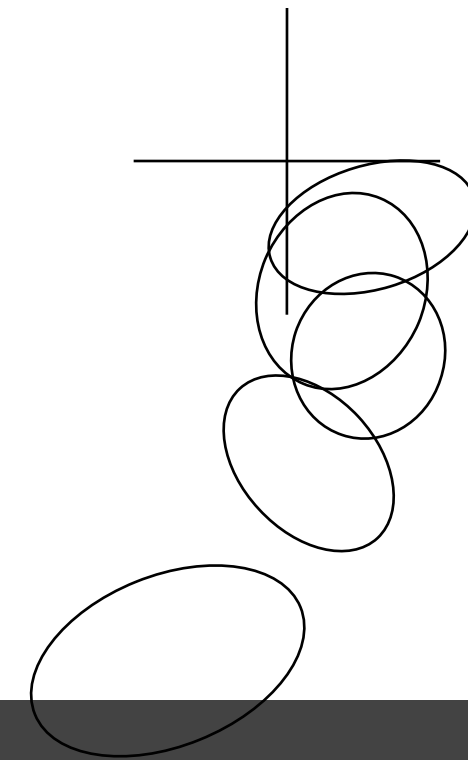
#2



#3



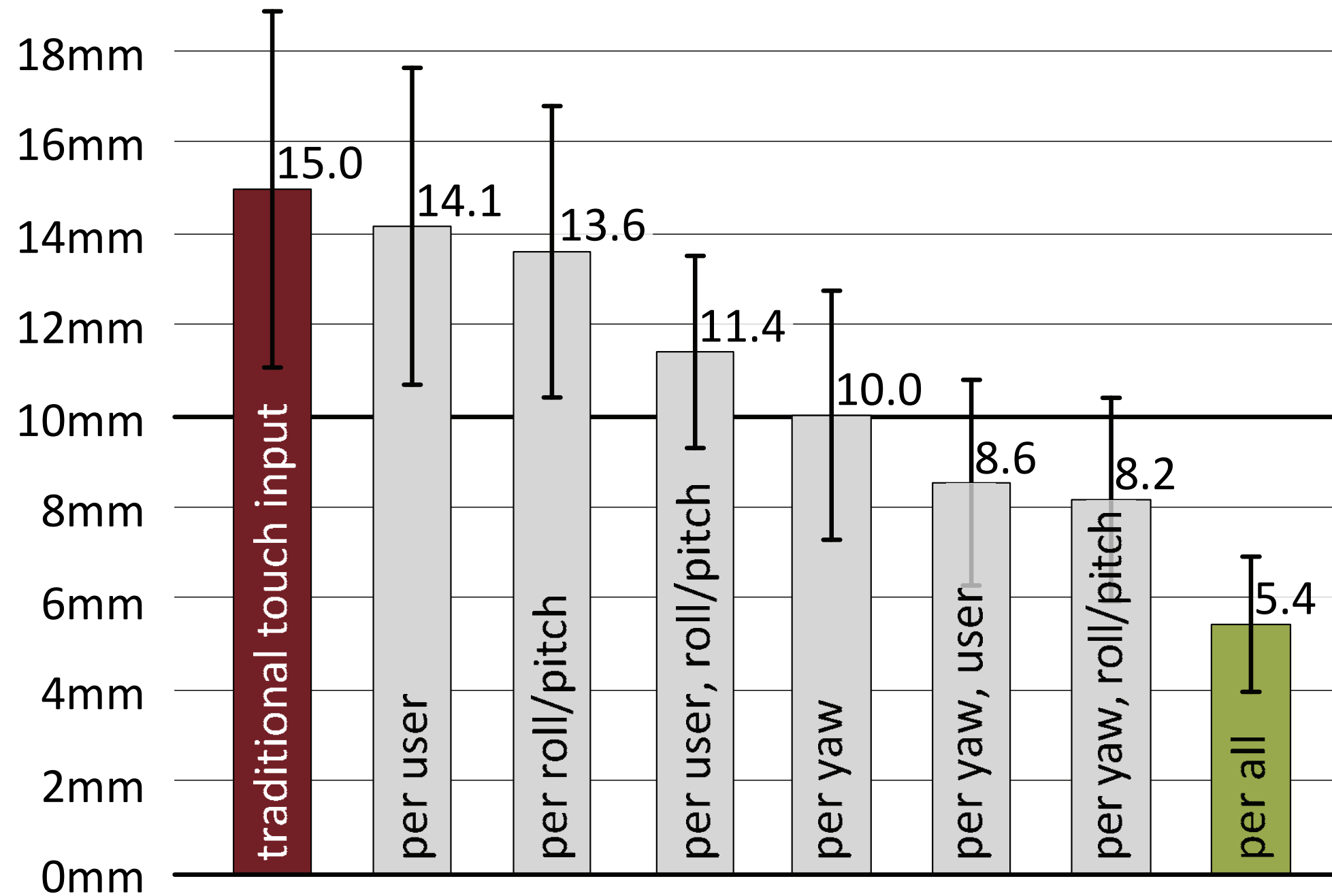
#4



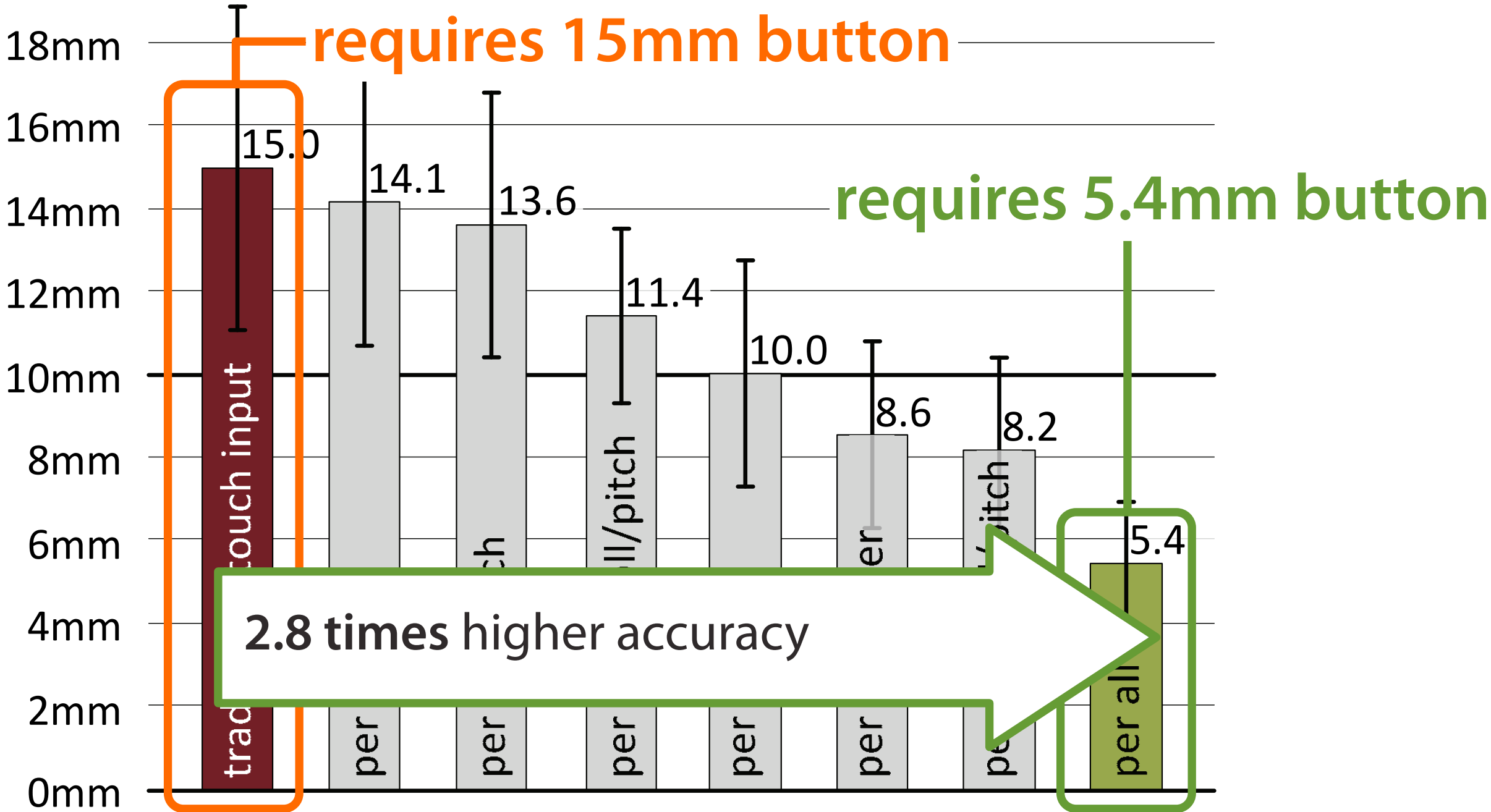
which user is the most accurate?
30 second brainstorming

1cm

minimum button size



minimum button size



can we make this real?

Ridgepad

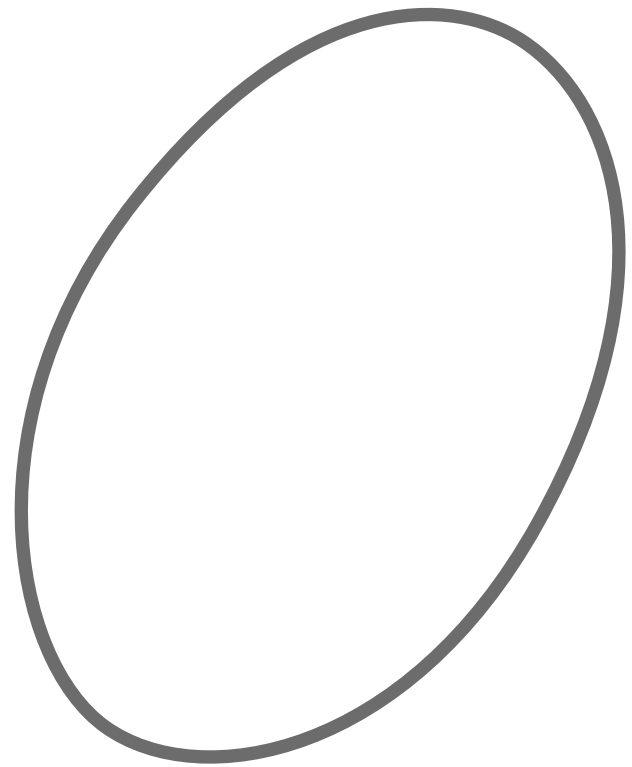
optical fingerprint scanner

500 dpi

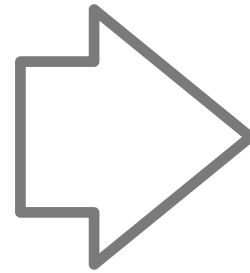
1600 × 1500 pixels



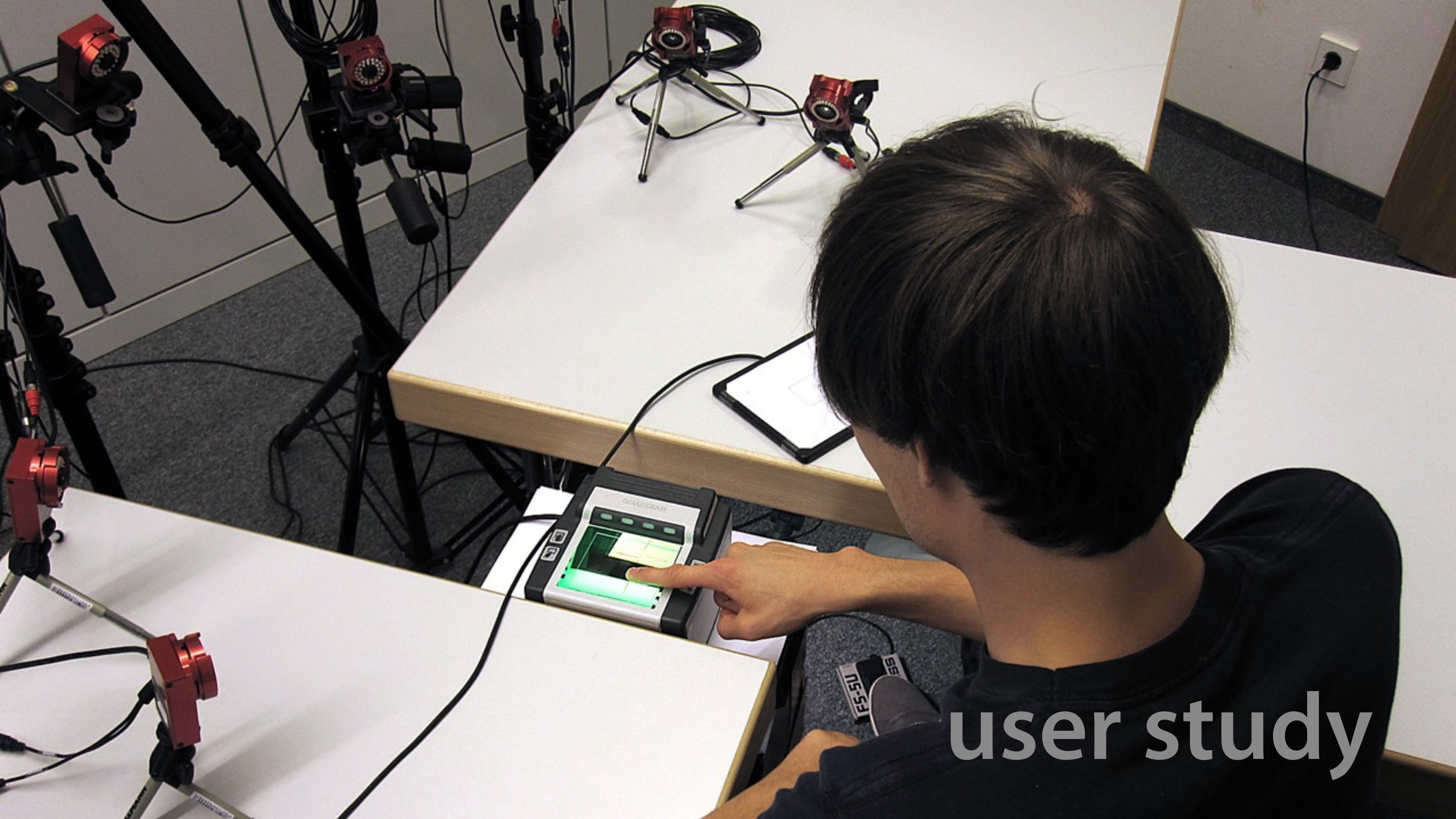
touchpad vs. fingerprint scanner



2D contact area

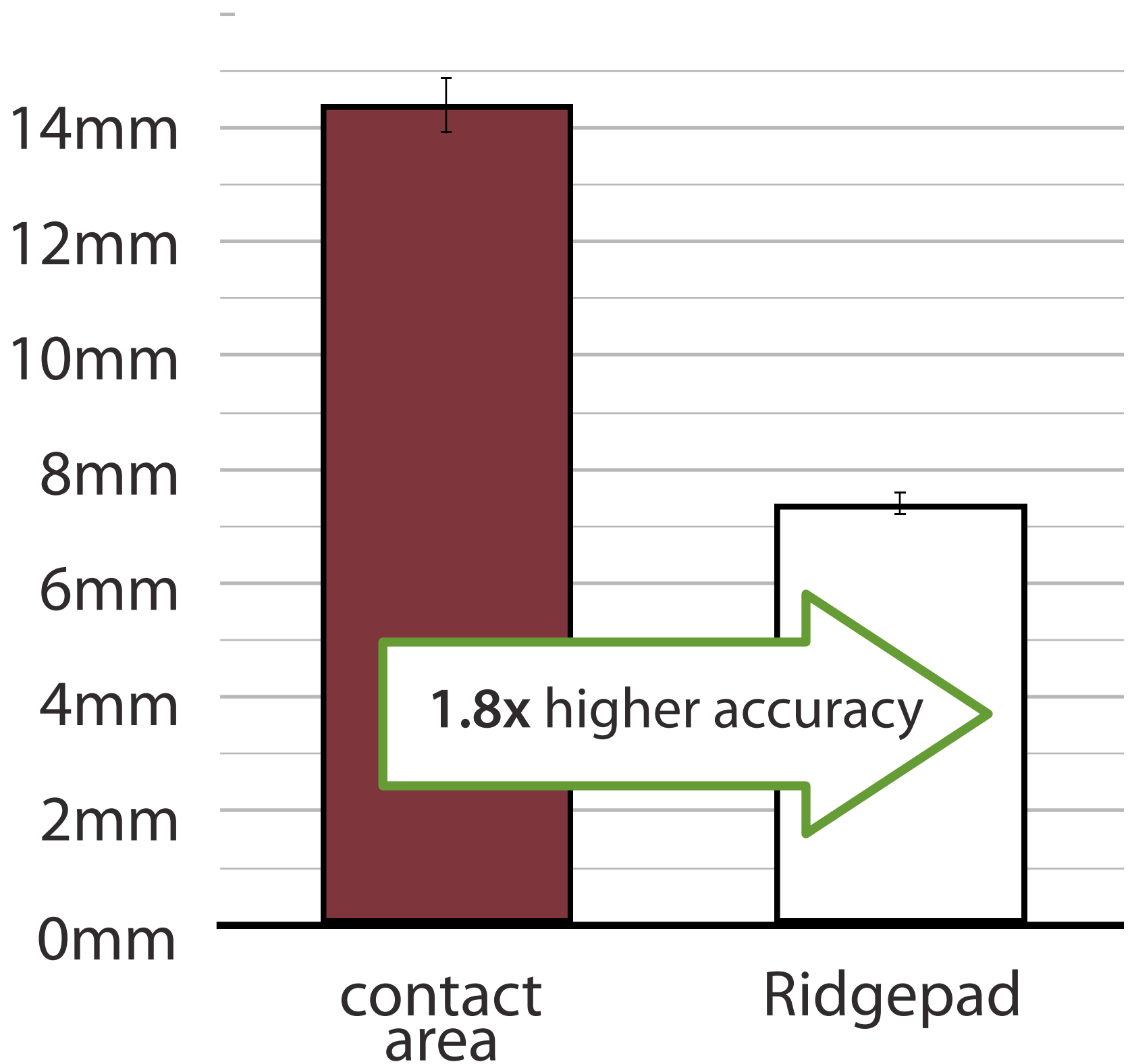


2D contact area
+ **yaw, pitch, roll**
+ **participant ID**

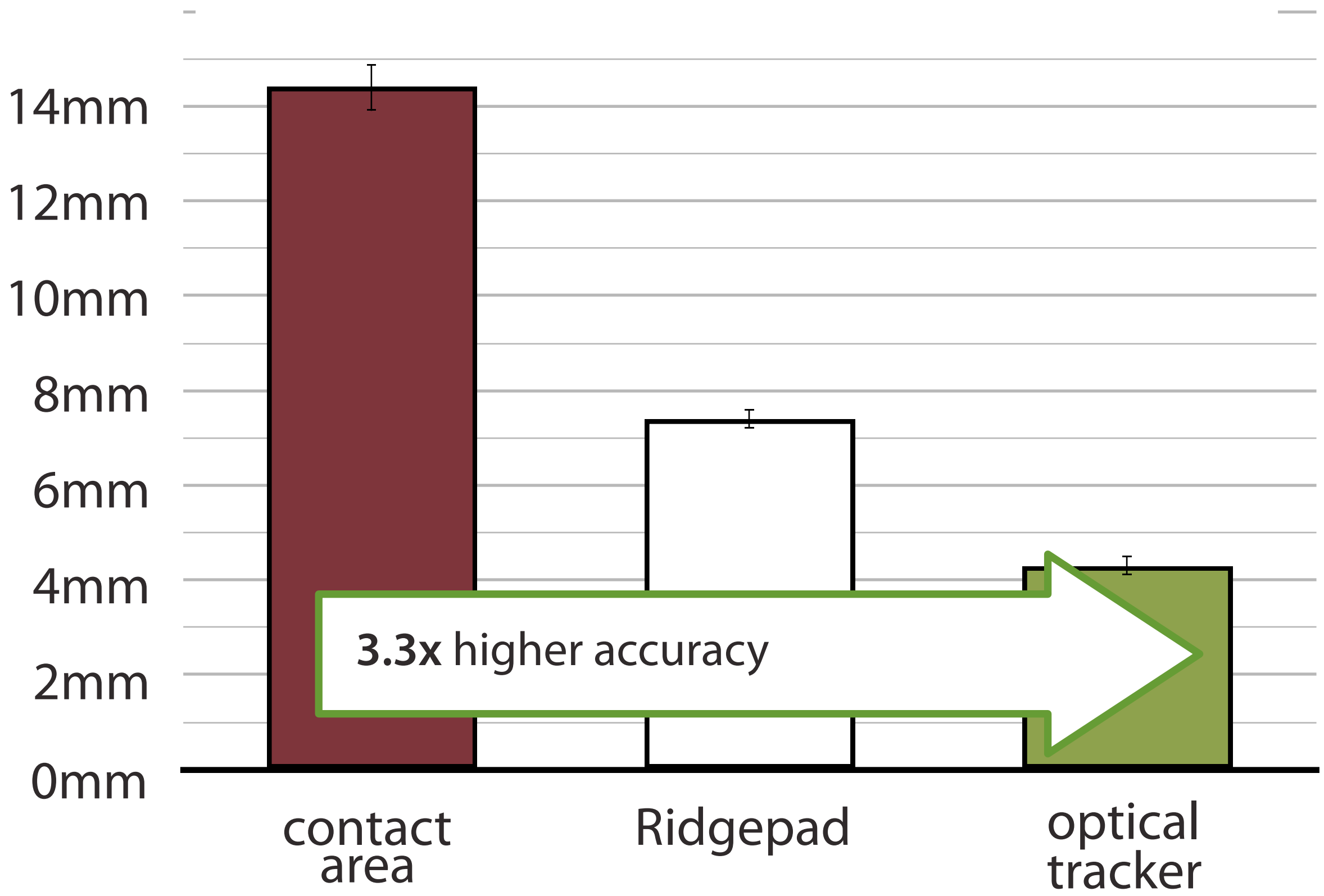


user study

minimum button size

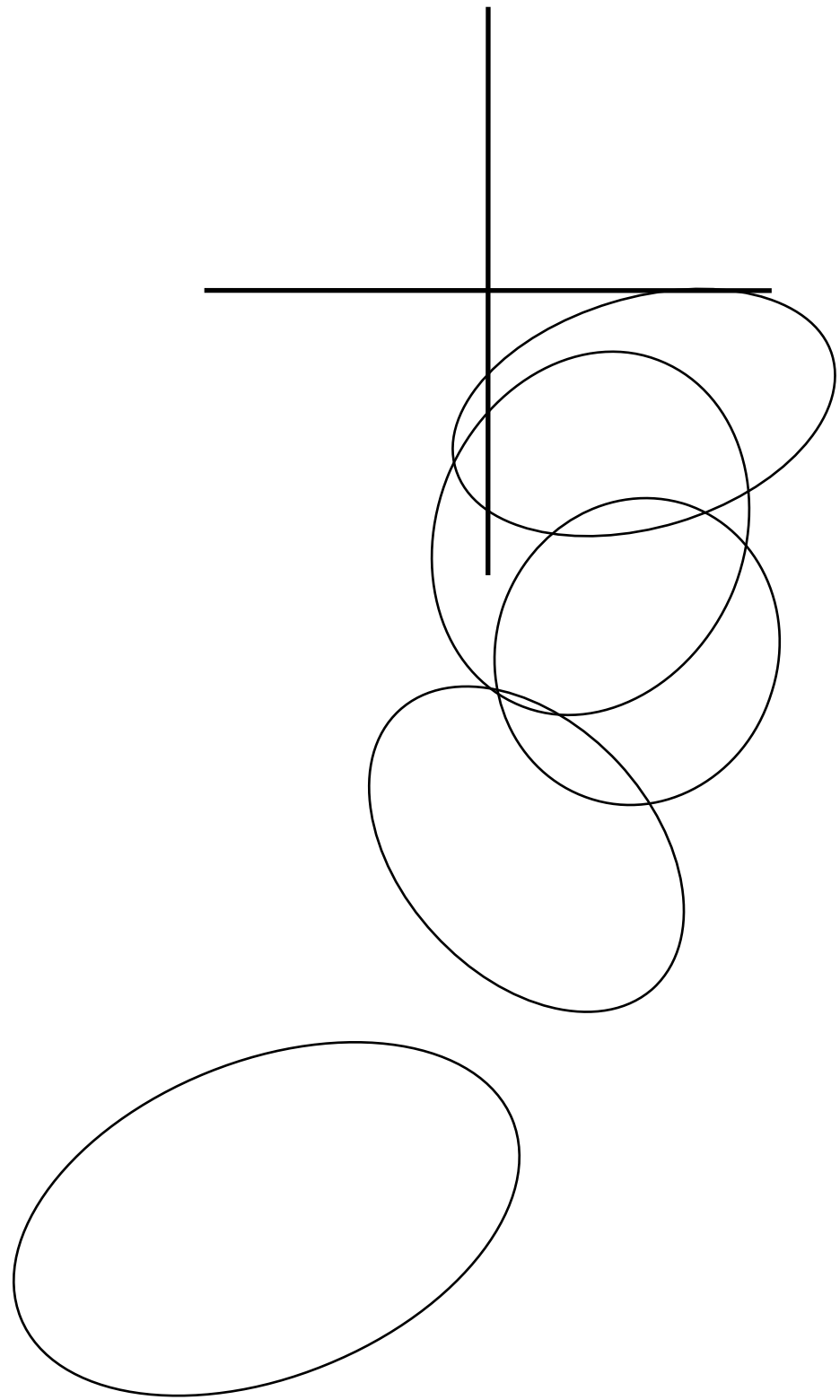


minimum button size



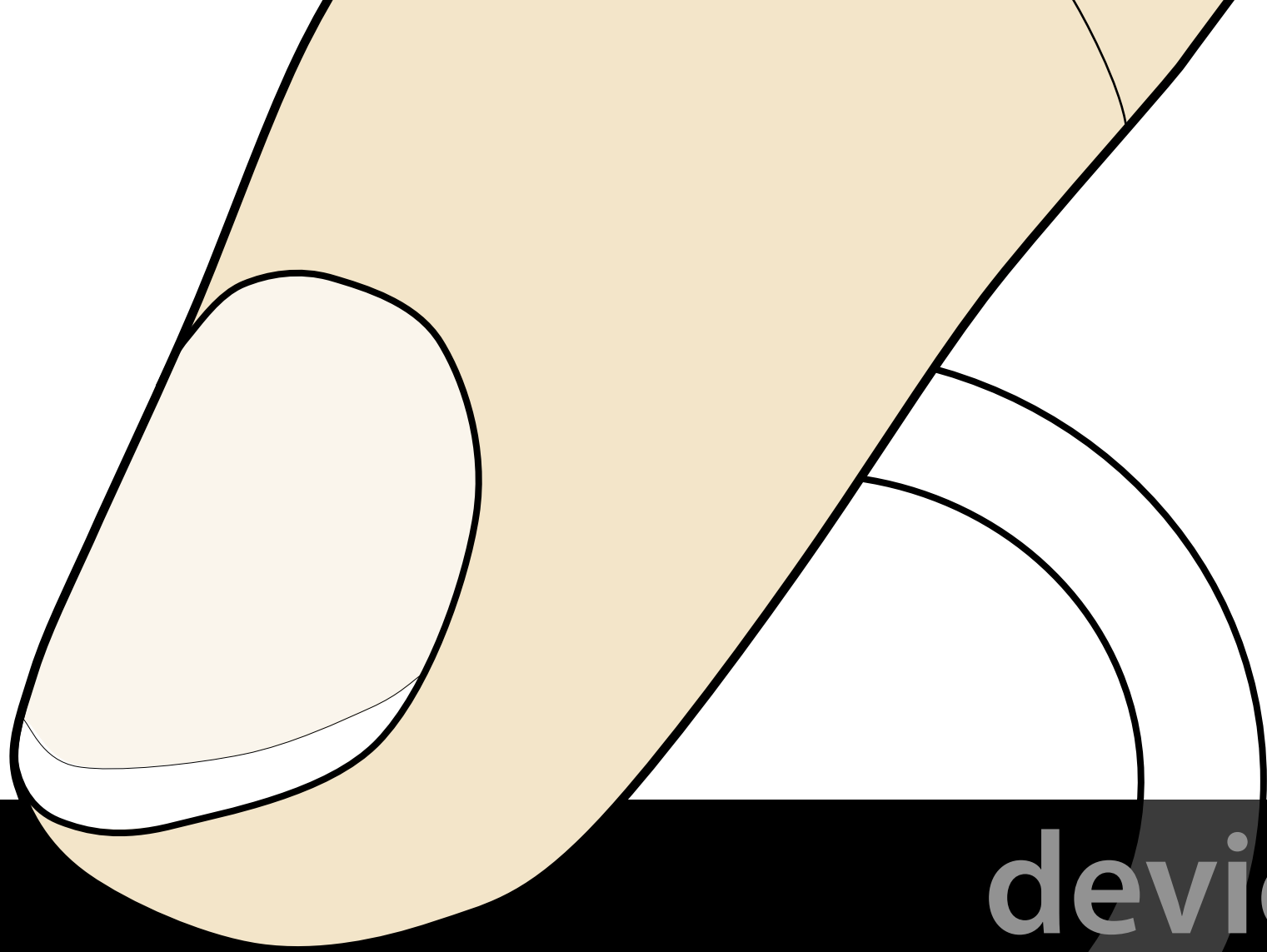
now we're done and touch is accurate.

no! there's a **bug** here!
we're still compensating...

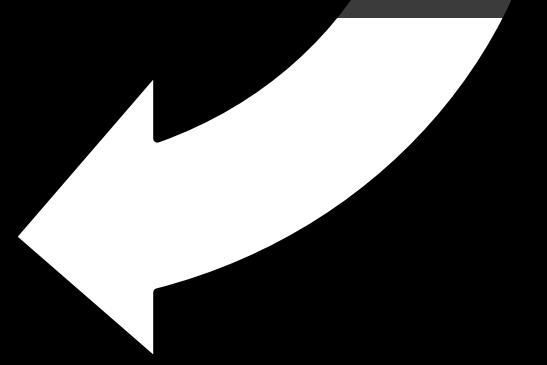


systematic effect

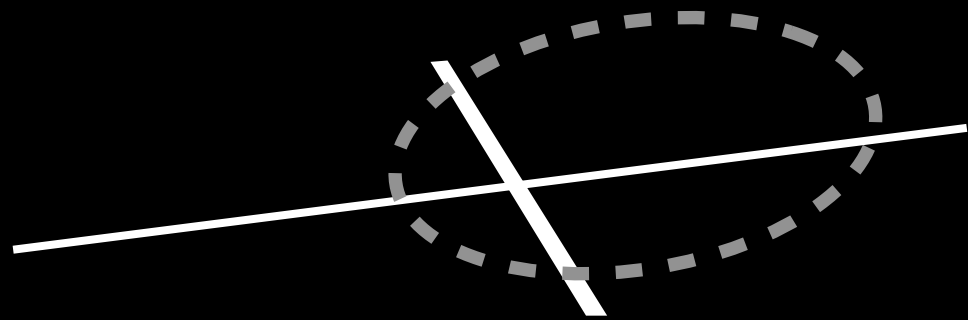
3D



device



2D

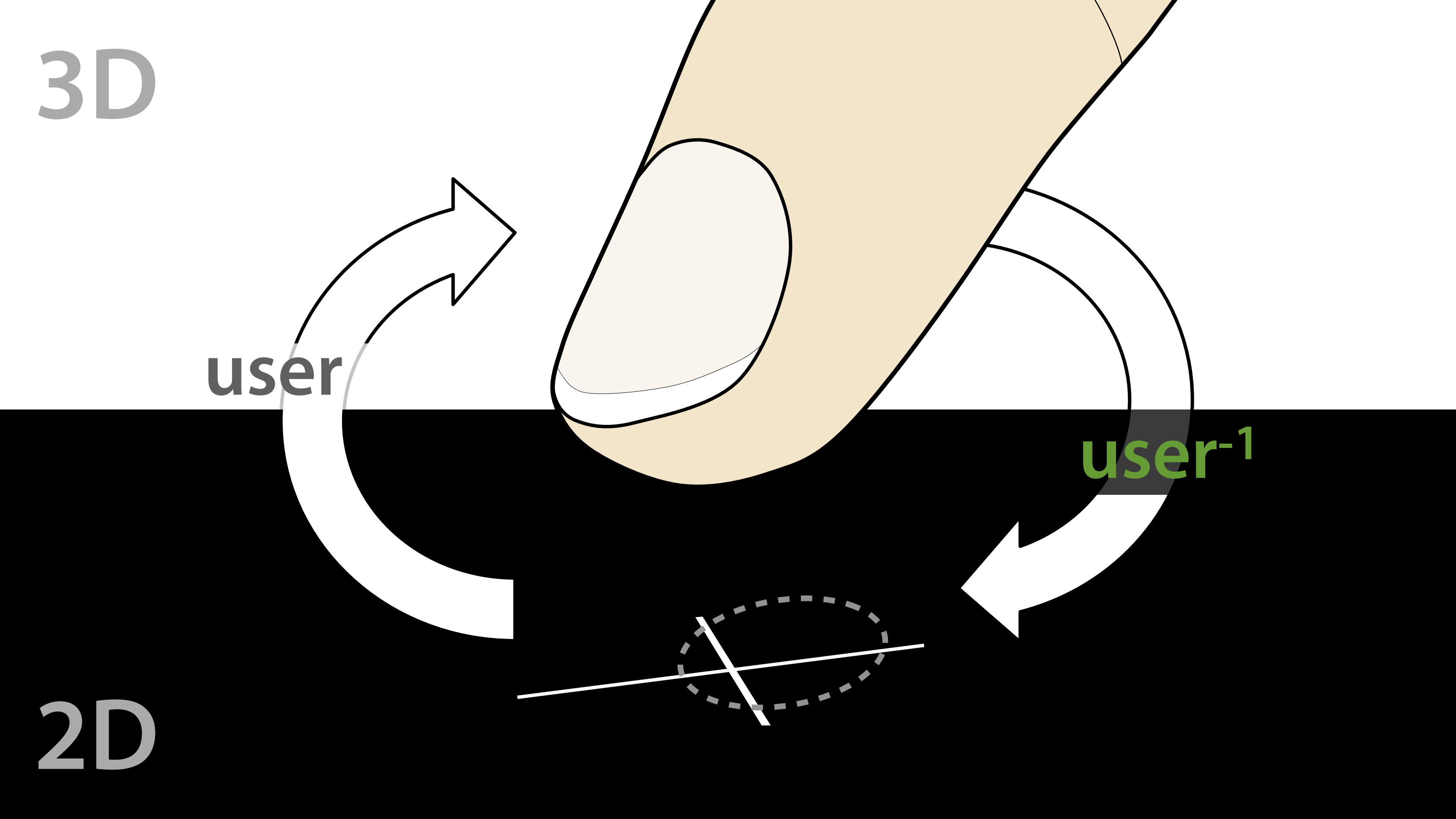


3D

user

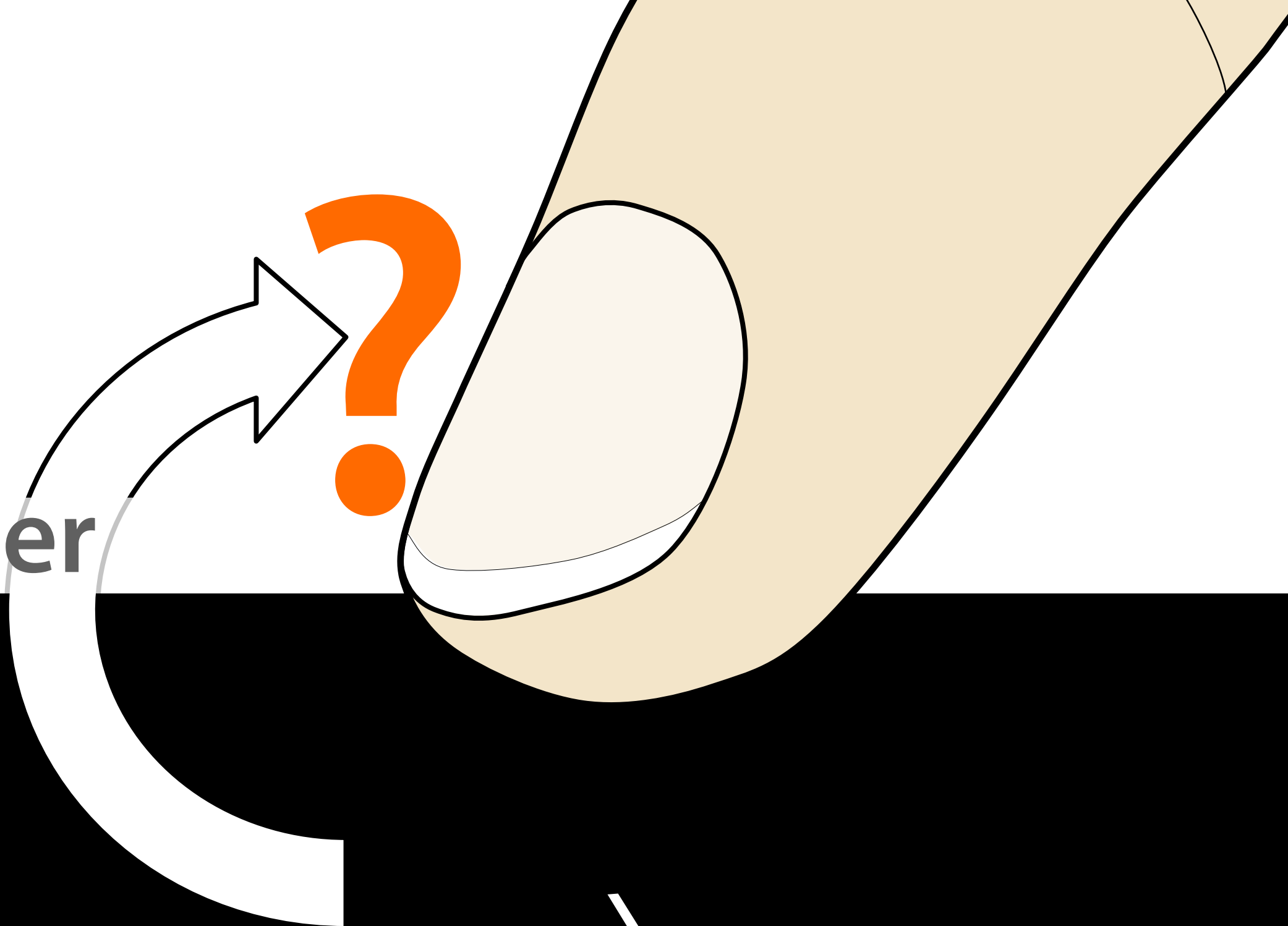
user-1

2D

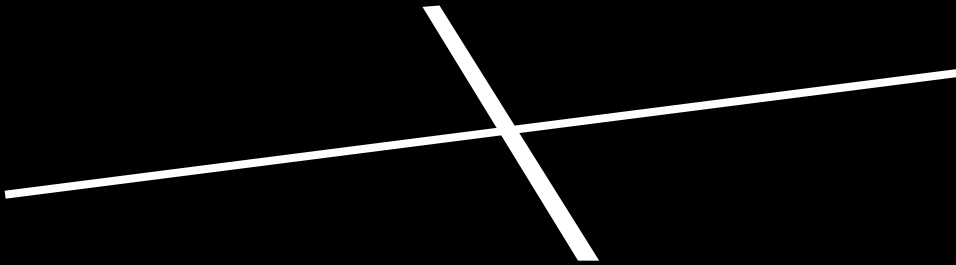


3D

user



2D



A black silhouette of a person with arms raised holding hats, standing on a walkway by a lake under a clear blue sky. The person is holding a hat in each hand, and the background shows a body of water, trees, and a clear blue sky. The text "goal: trying to understand" is overlaid on the image in white.

goal:
trying to understand

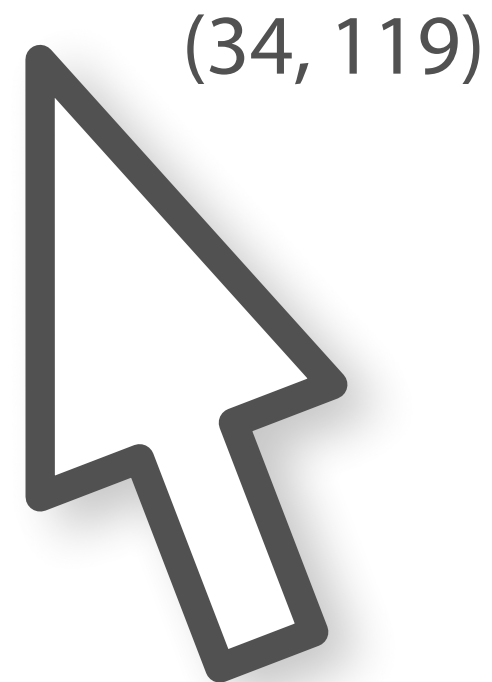
challenge

challenge

we need a **model**

in HCI, models are typically obtained using an **unambiguous** device (e.g., mouse)

1. measure data points
- 2. fit a curve**



but **what** shall we measure?

there are **infinite ways**
how users might map
these crosshairs to 3D



so we had to revert to
basic experimental process...



guess a model

try it out in an experiment

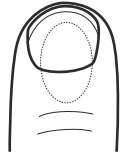







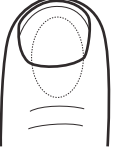







if outcome is bad, **repeat**

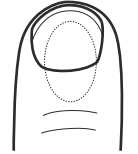
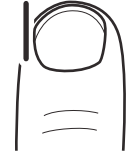






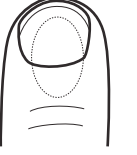







which model?

if it is not
the contact area...


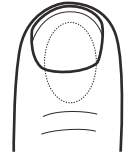
















**creating models
using visual features**

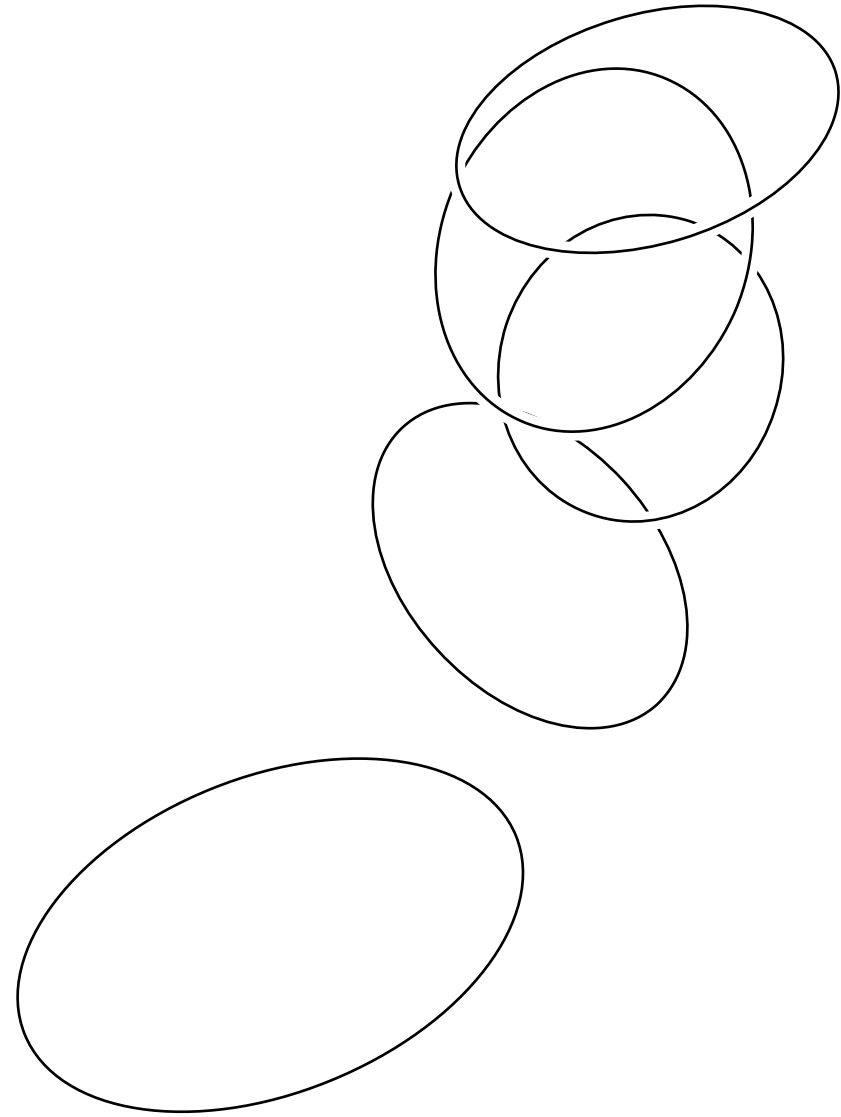
								
								
								
								
								
								
								
								
								

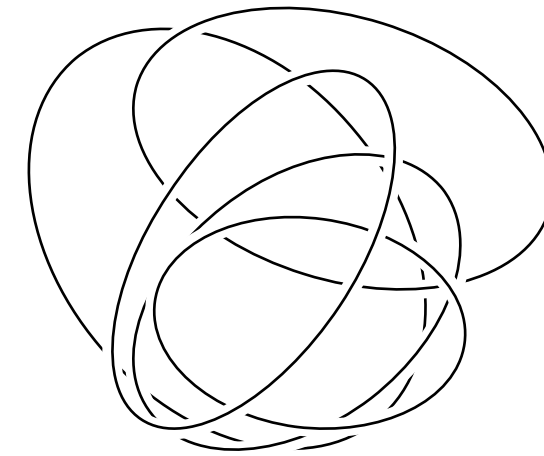
7x7

evaluating the models



bad model
large error offsets

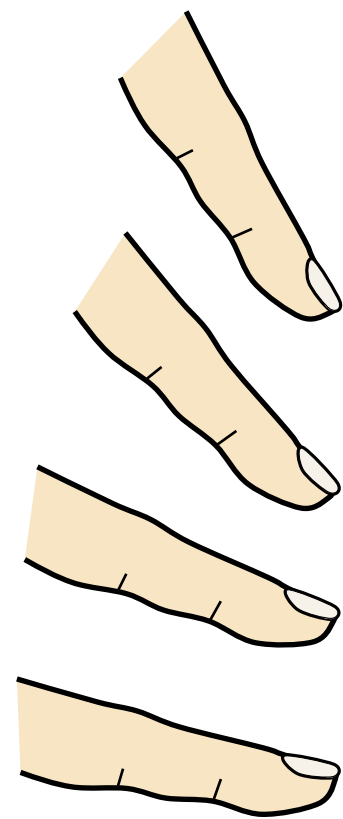


good model
small error offsets

3 user studies



independent variables



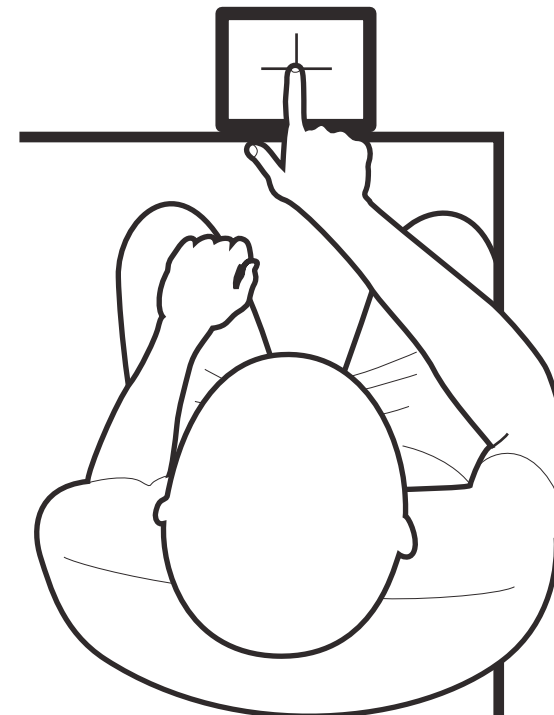
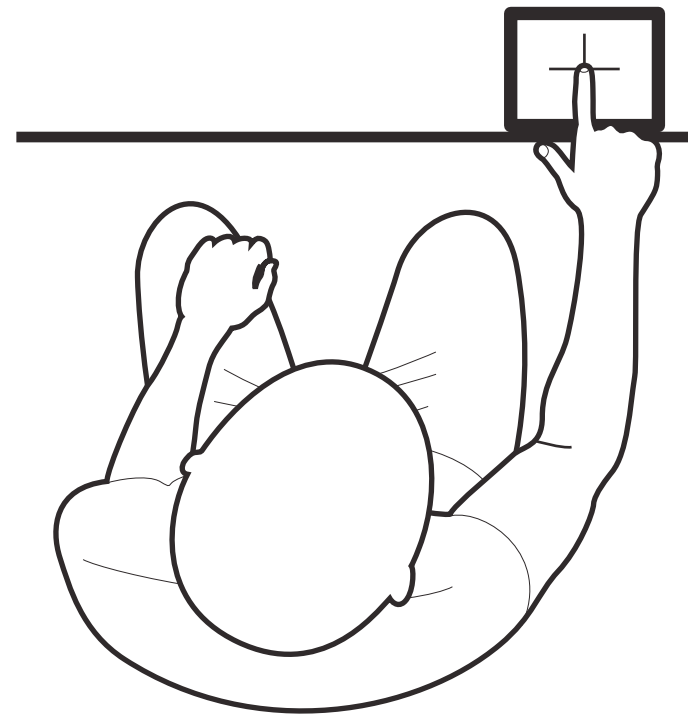
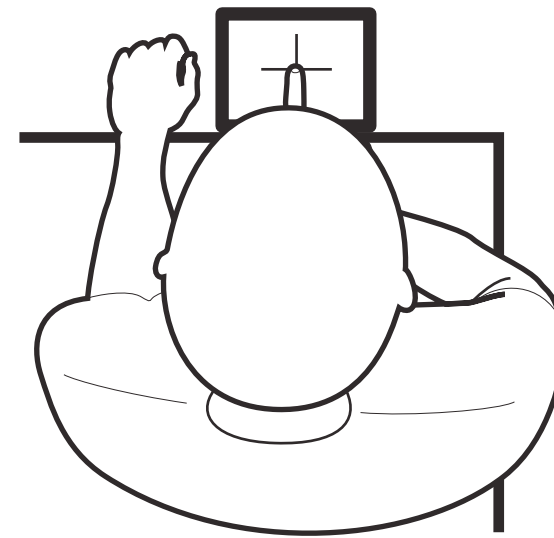
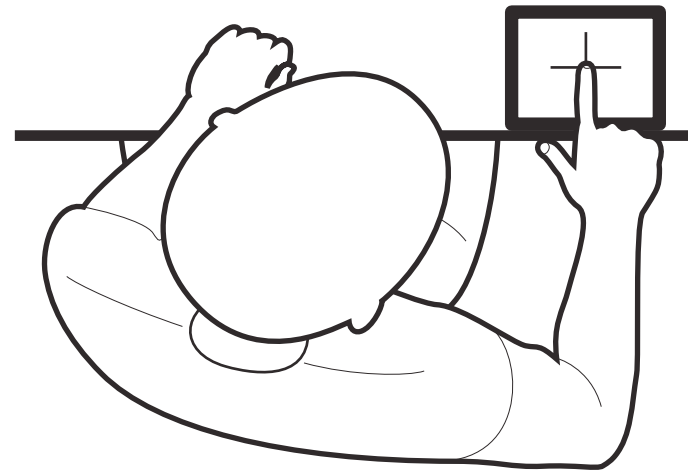
pitch

roll



65°		X			
45°	X	X	X	X	X
25°		X			
15°	X	X	X	X	X

...and head position



study design

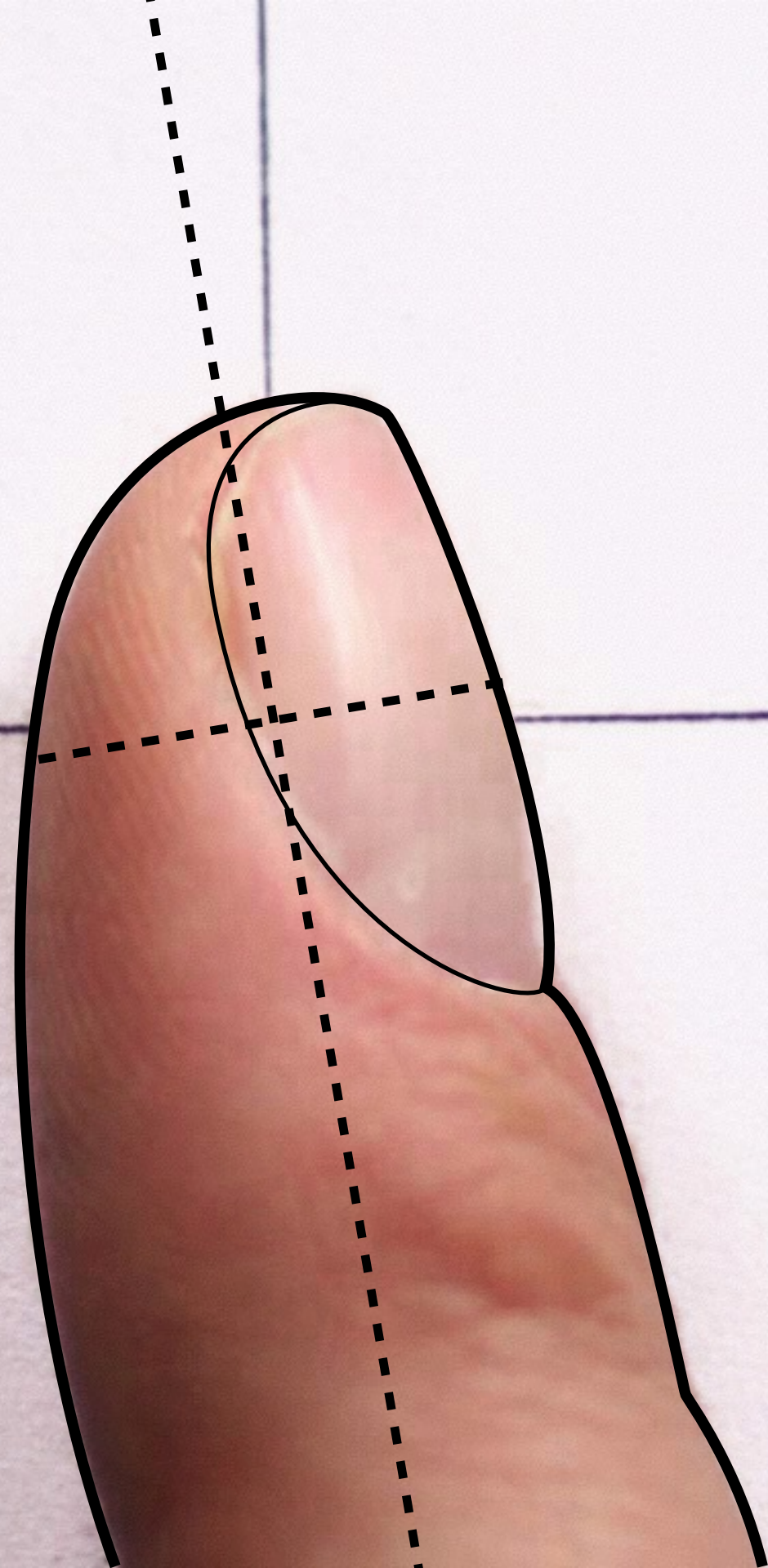
6 combinations of finger angles (pitch, roll)
× 4 head positions
× 2 blocks
× 4 repetitions

=192 trials / participant

30 + 12 + 12 participants



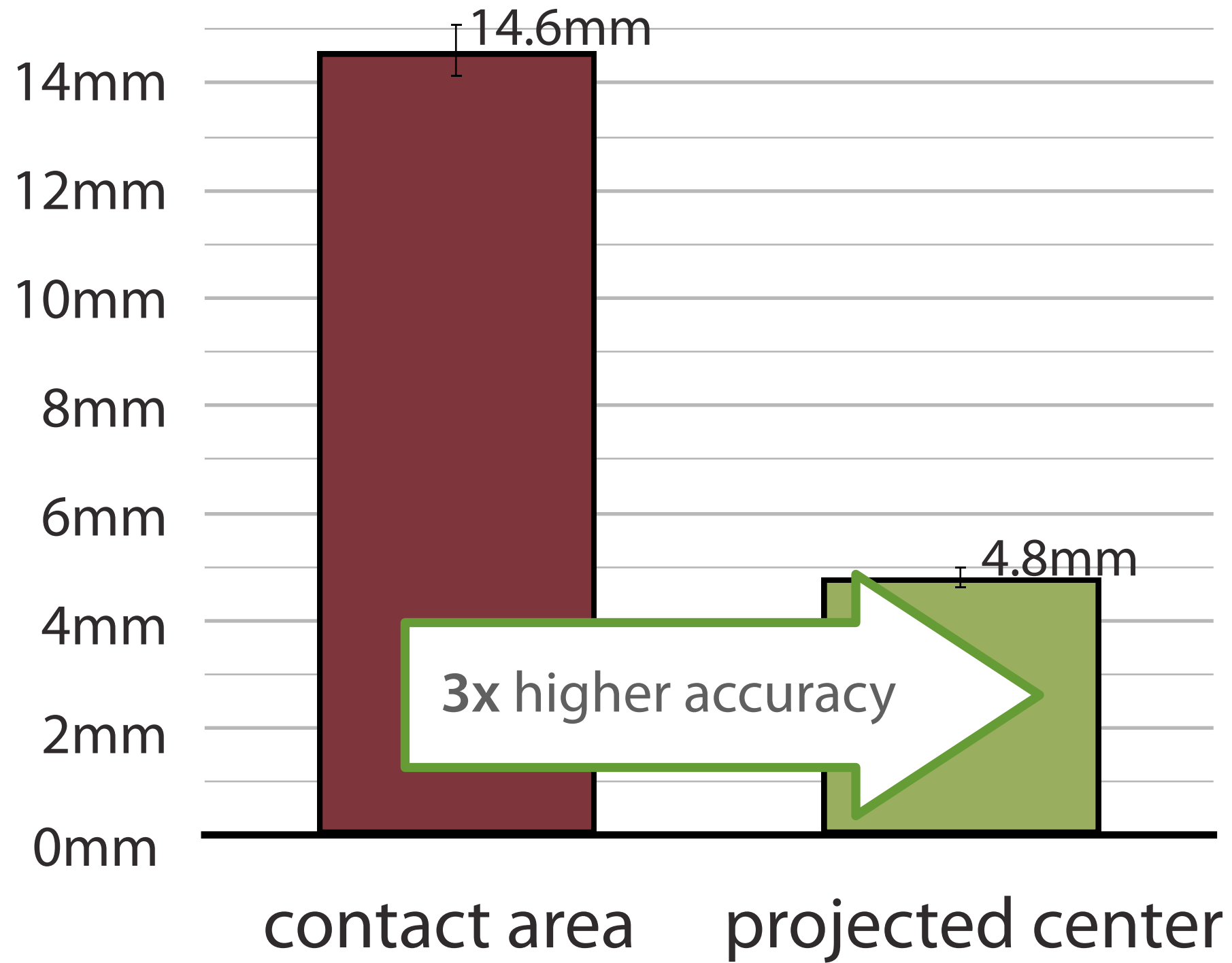
results



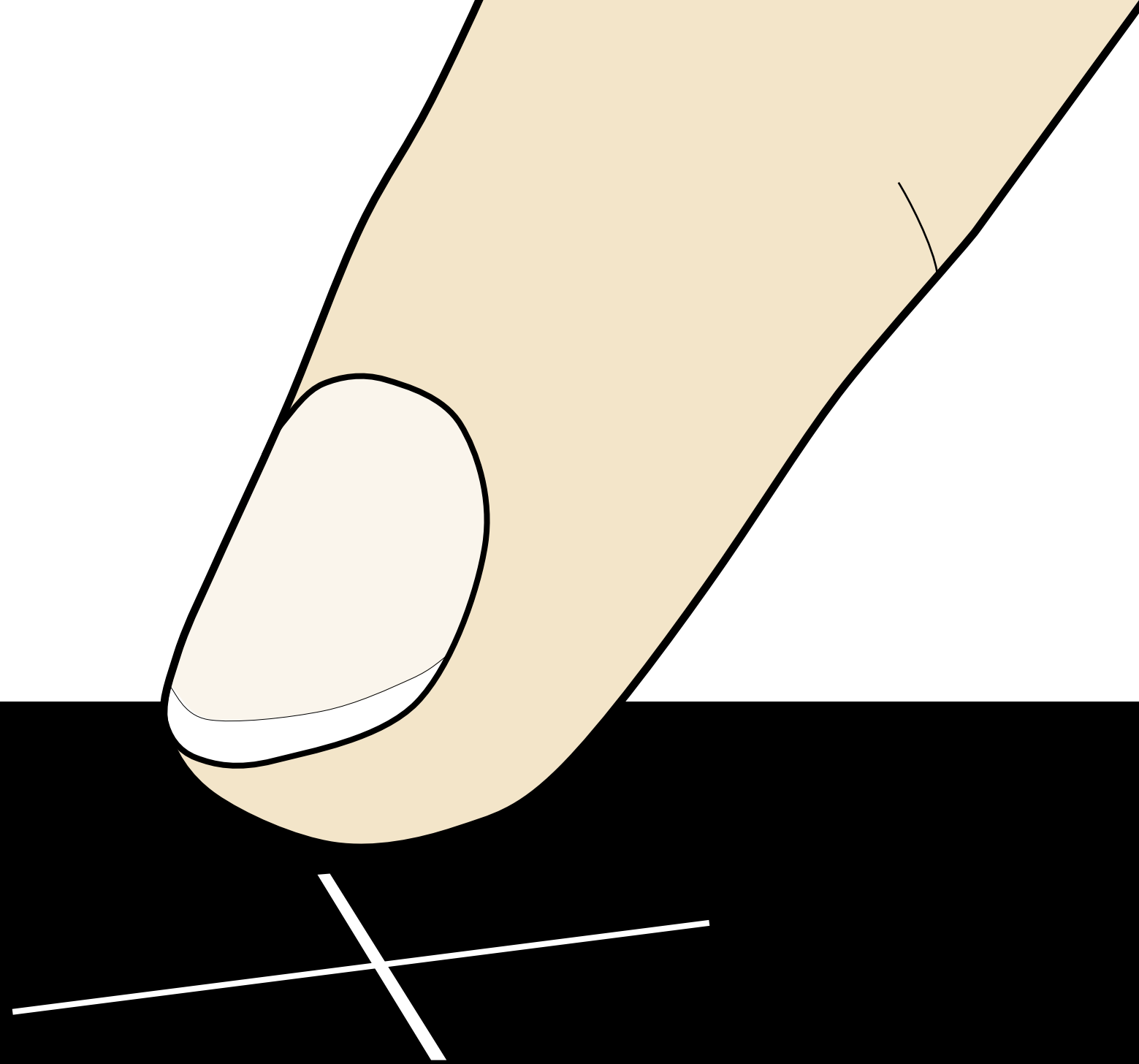
projected center model



minimum button size



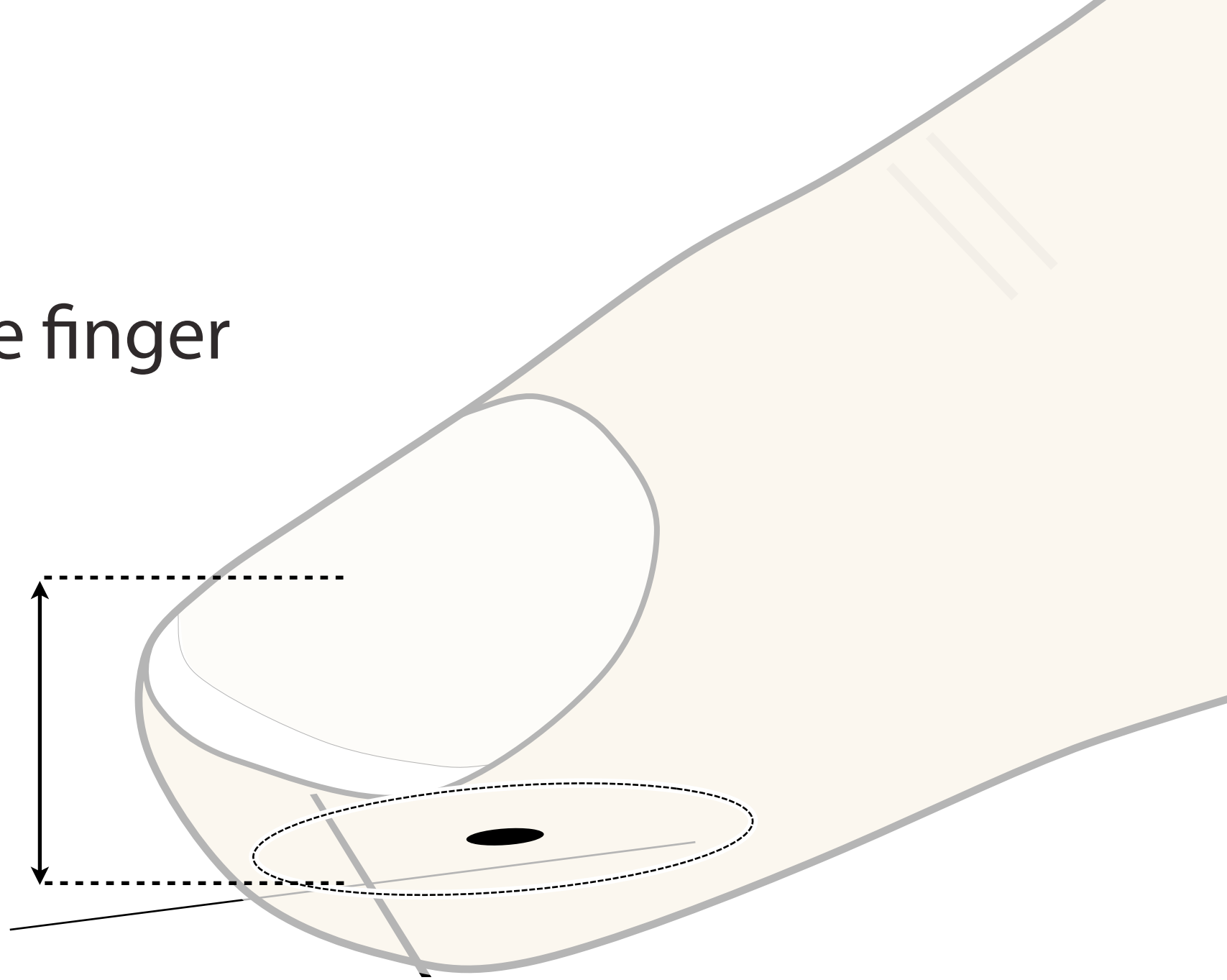
main insight



touch input is a **3D operation**

users target using
features **on top** of the finger

parallax



current devices sense
features **at the bottom** of finger

now we have **two options...**

1) We implement users' **mental models**



Imaginary Phone [UIST '11]

2) We **compensate** for errors

Ridgepad

reconstructs the finger in 3D

input-only

not real-time





[Fiberio, UIST '15]

1

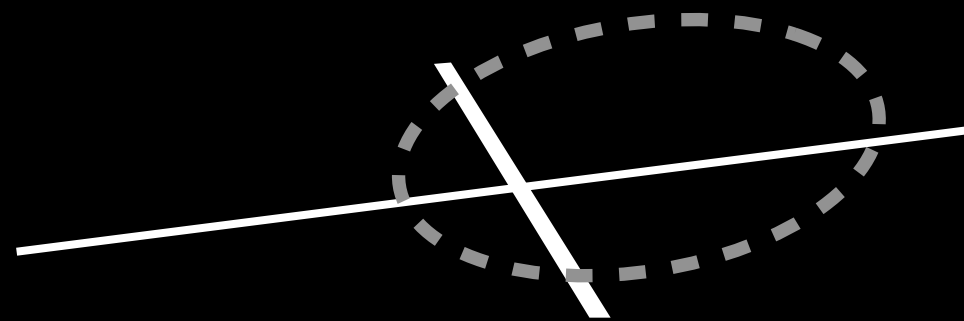
Touch technologies

2

Touch accuracy

Touch Input

CSE 510
Christian Holz
Microsoft Research
<http://www.christianholz.net>



February 11, 2016