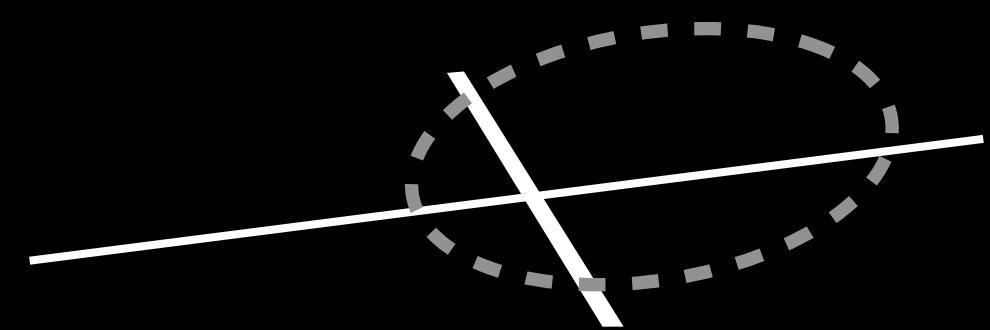
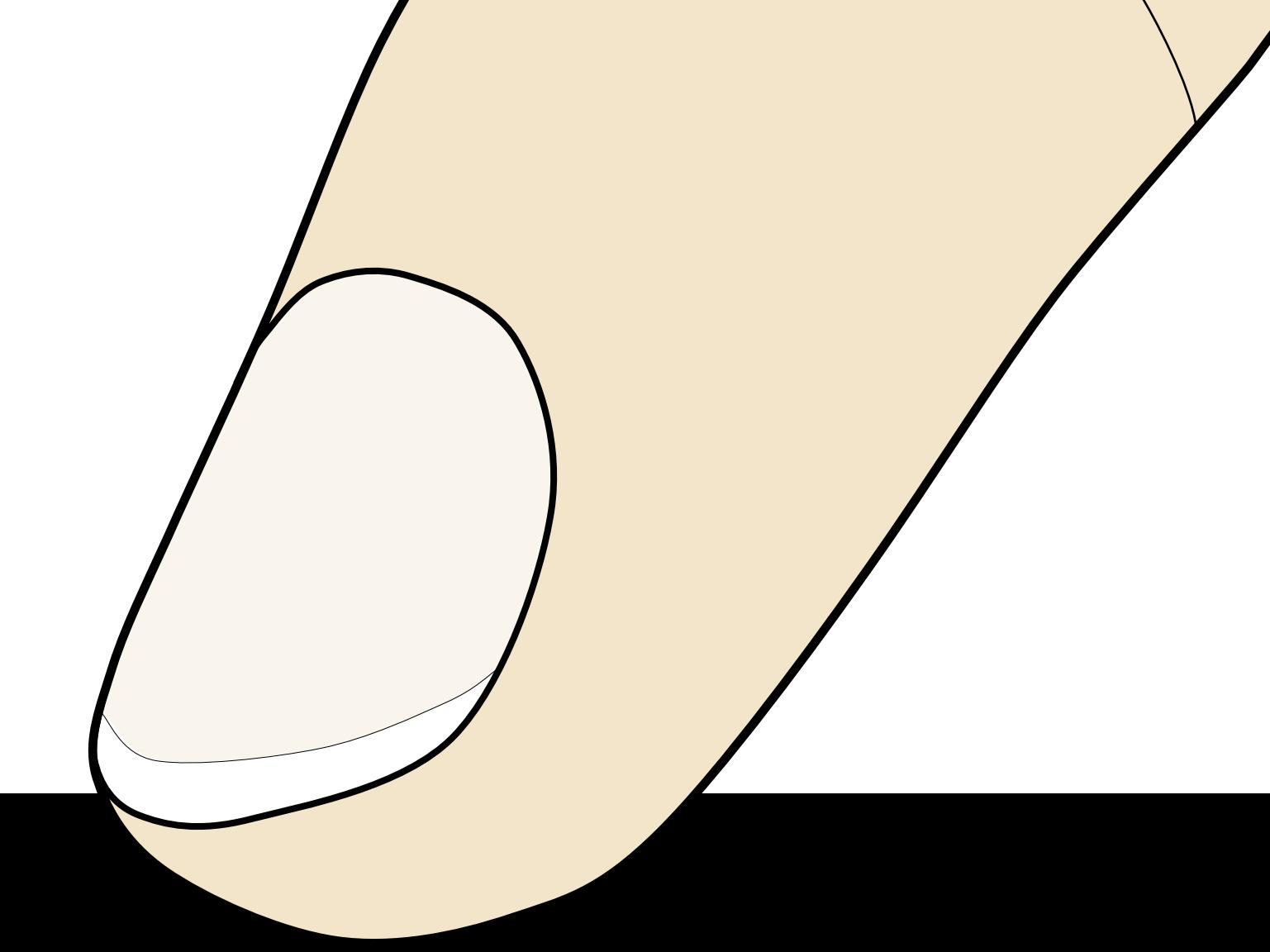


# Touch Input

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



February 11, 2016



Nokia 5800, 2008

hall of fame/hall of shame?



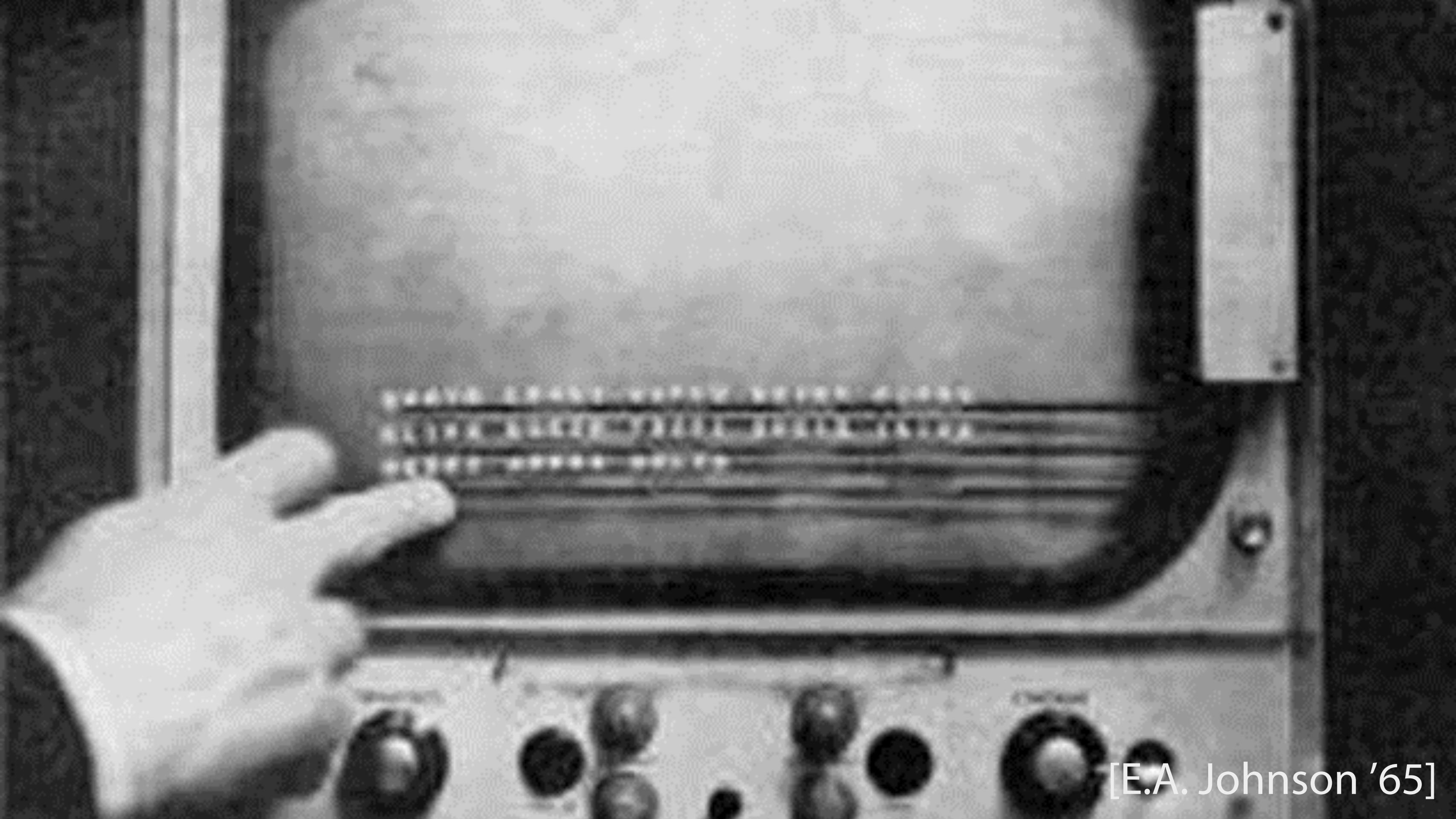
hall of fame/hall of shame?



“we've invented...”



[Lightpen '62]



[E.A. Johnson '65]

[Plato IV '72]

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



Works like magic



IBM Simon, 1992



what was the real novelty here?  
30 second brainstorming

1

Touch technologies

2

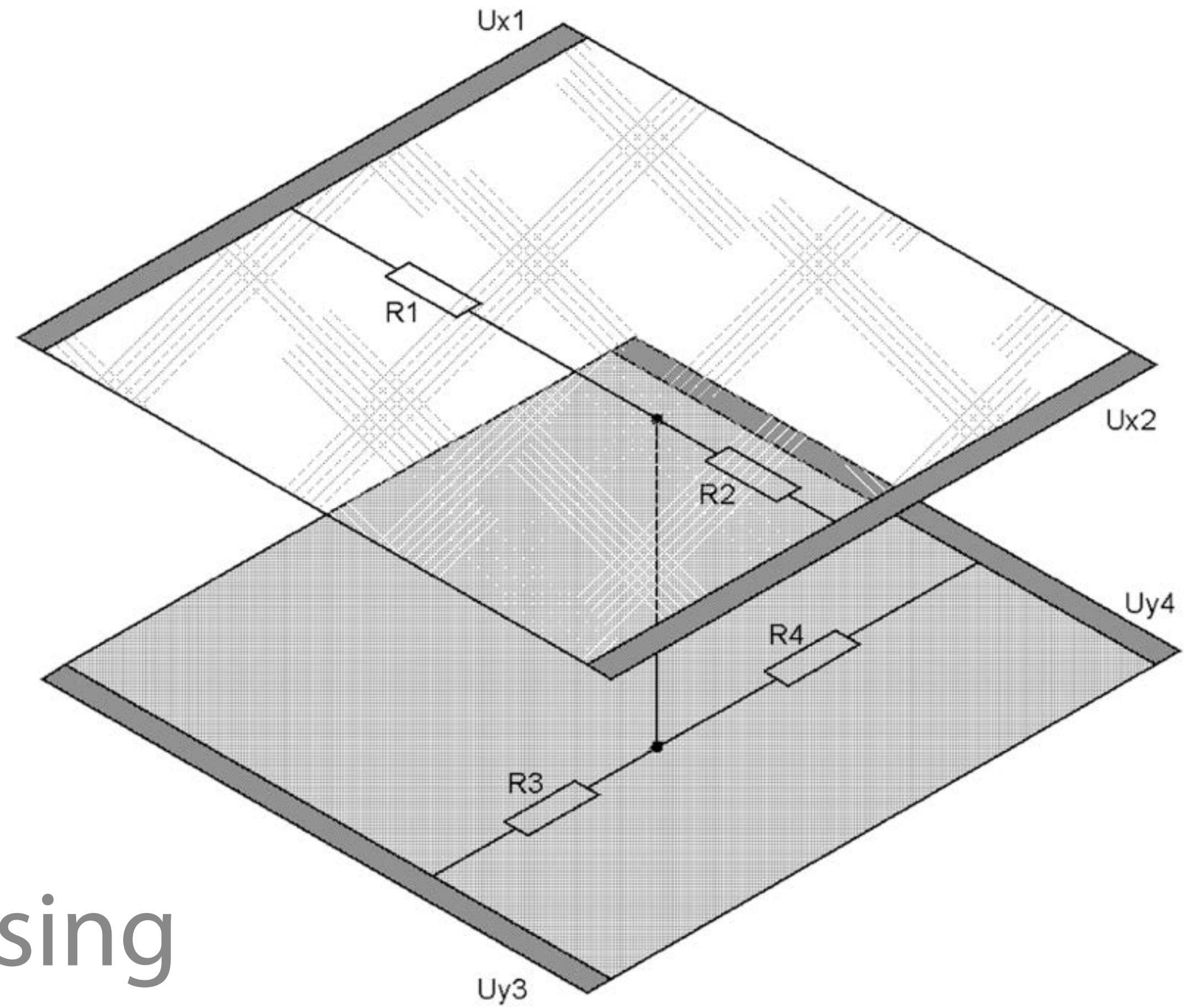
Touch accuracy

# 1

# Touch technologies

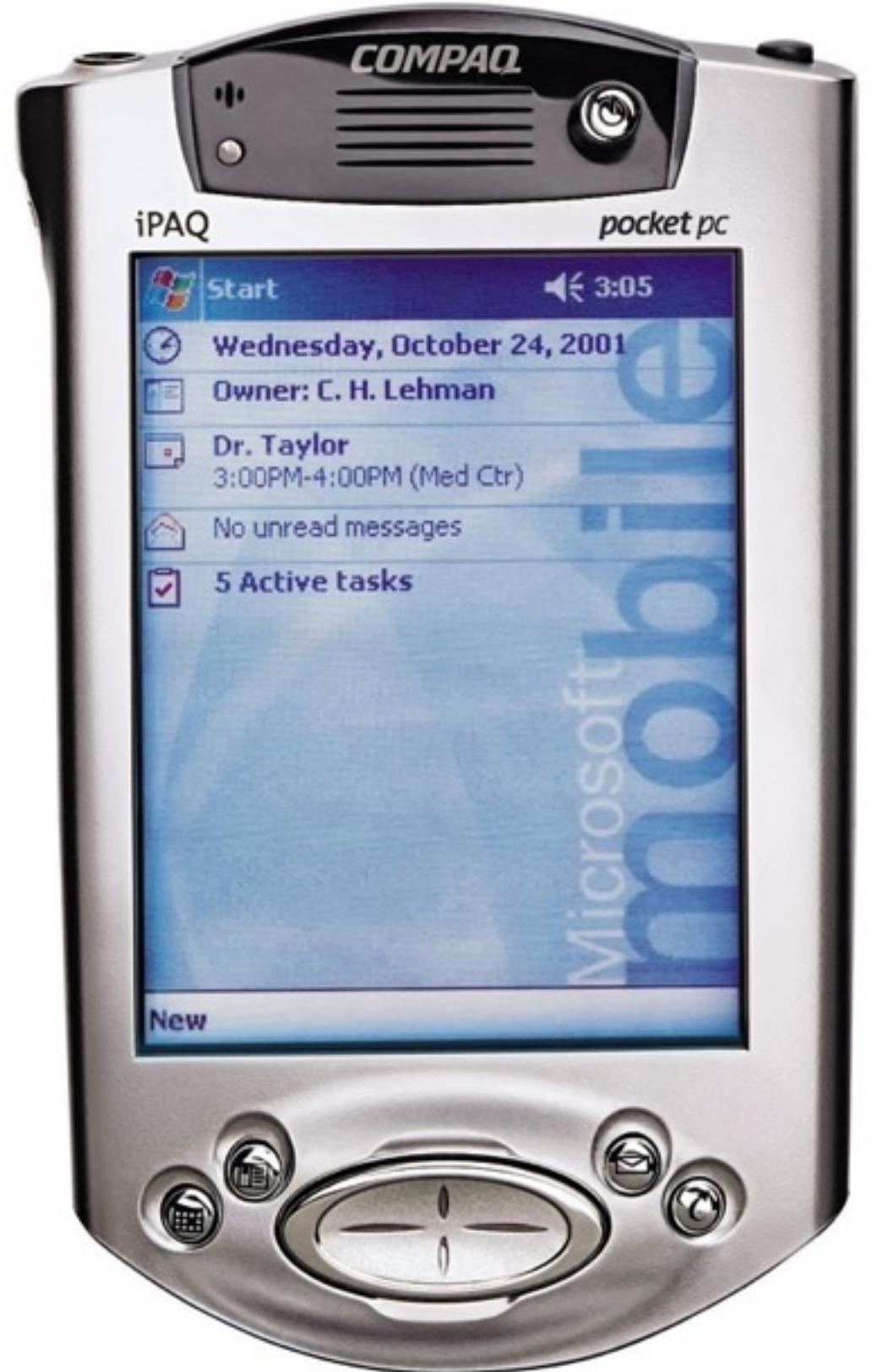
a cursory overview

resistive sensing





Inspiron 7000, 1998



Compaq PDA, 2000



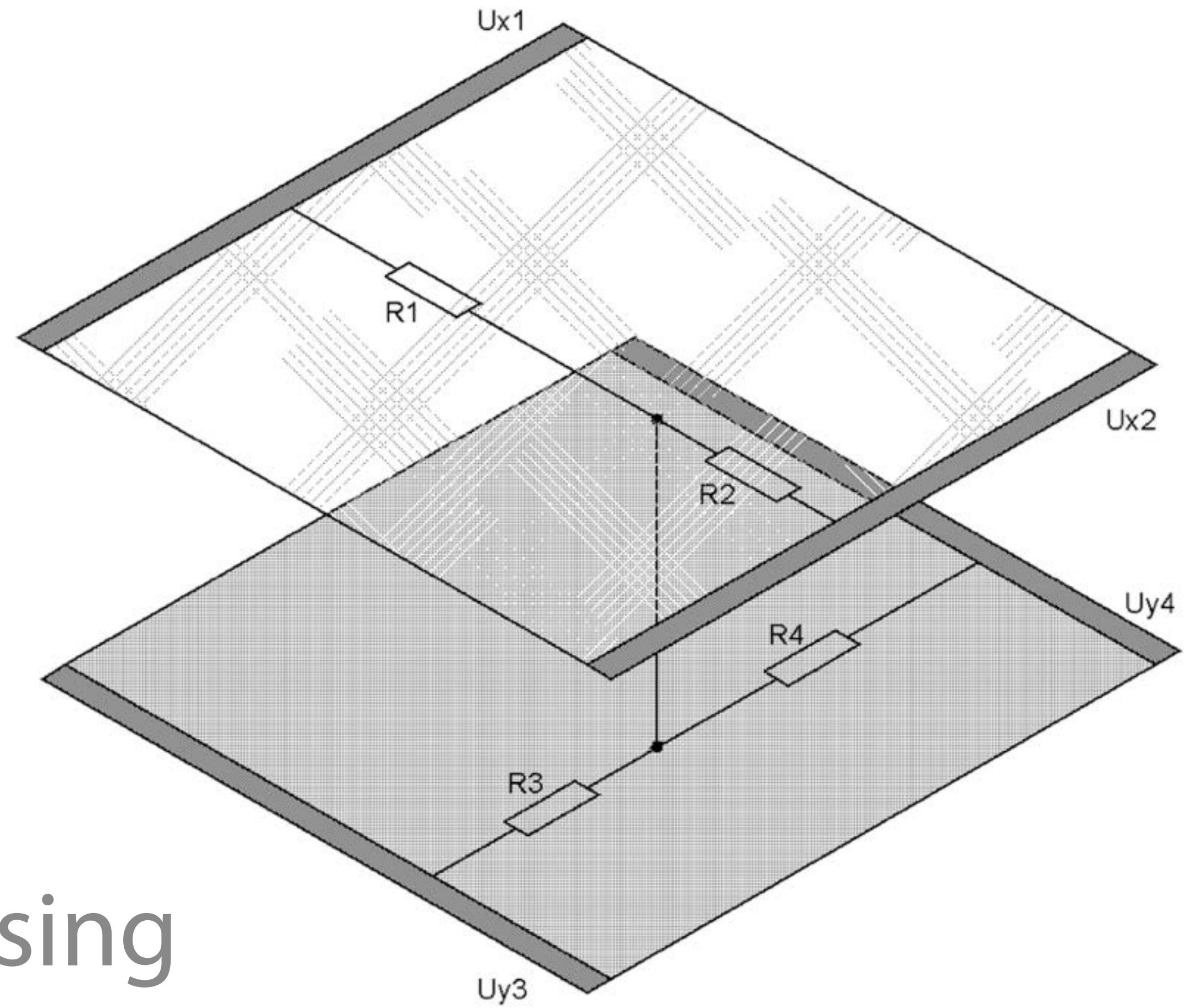
[Matsushita et al., UIST '00]

A black and white photograph showing a close-up of a person's hand interacting with a touch screen. The hand is pressing a button on a dark-colored device, likely a mobile phone or a small tablet. The screen displays a grid pattern, possibly a game or a navigation map. The background is blurred, focusing attention on the hand and the device.

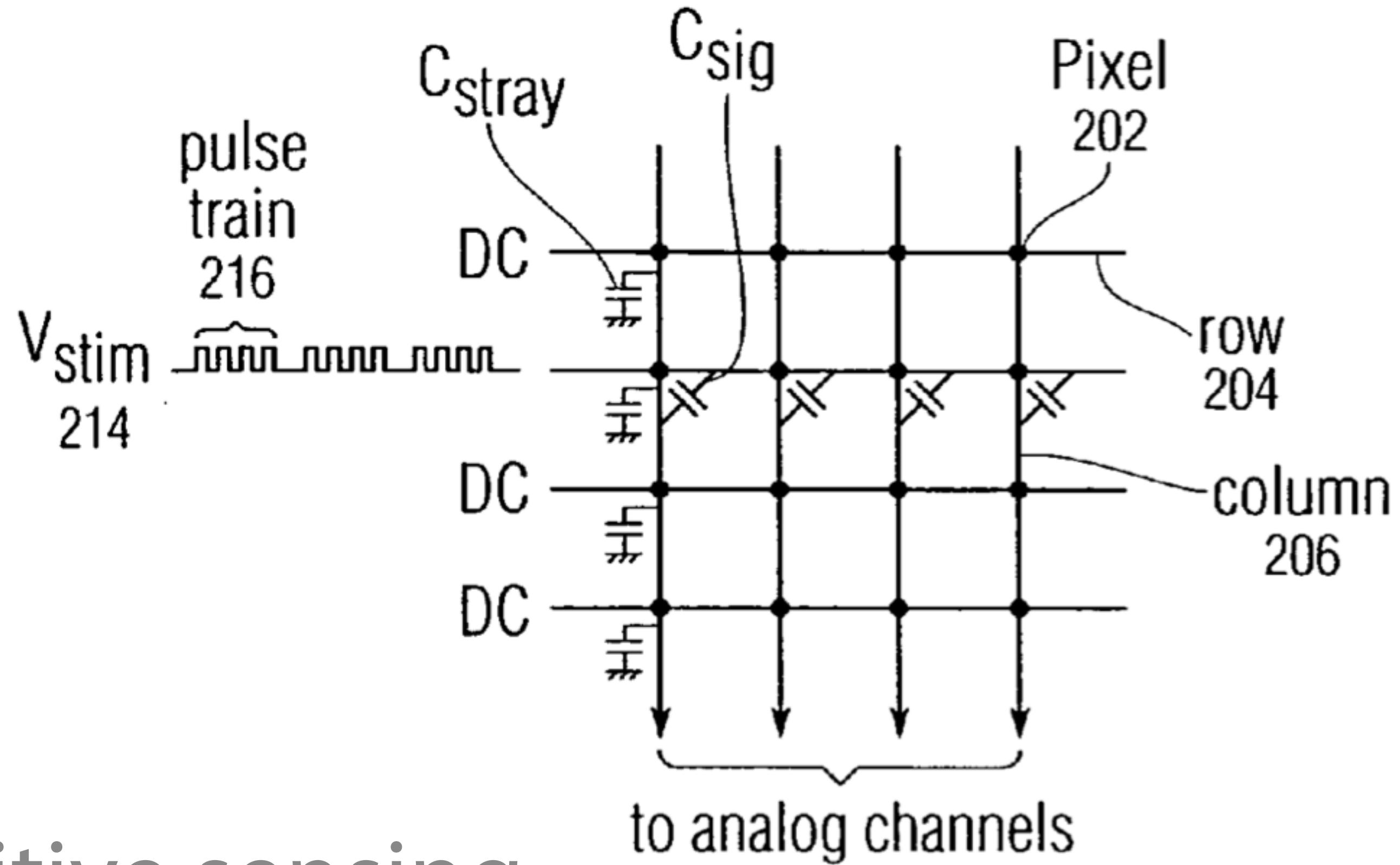
how did they enable dual-touch in a single touch sensor?  
30 second brainstorming

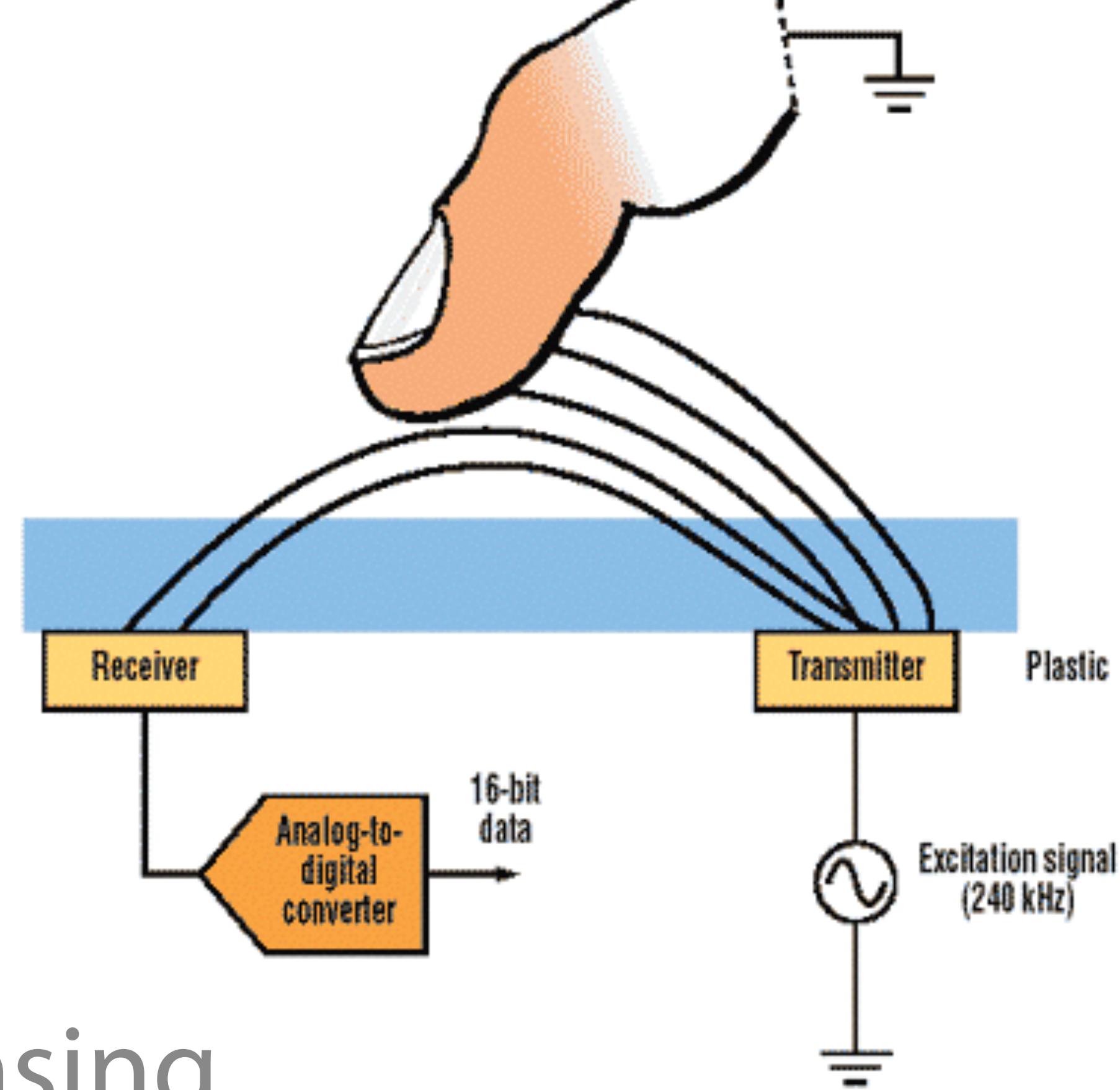
[Matsushita et al., UIST '00]

resistive sensing



capacitive sensing

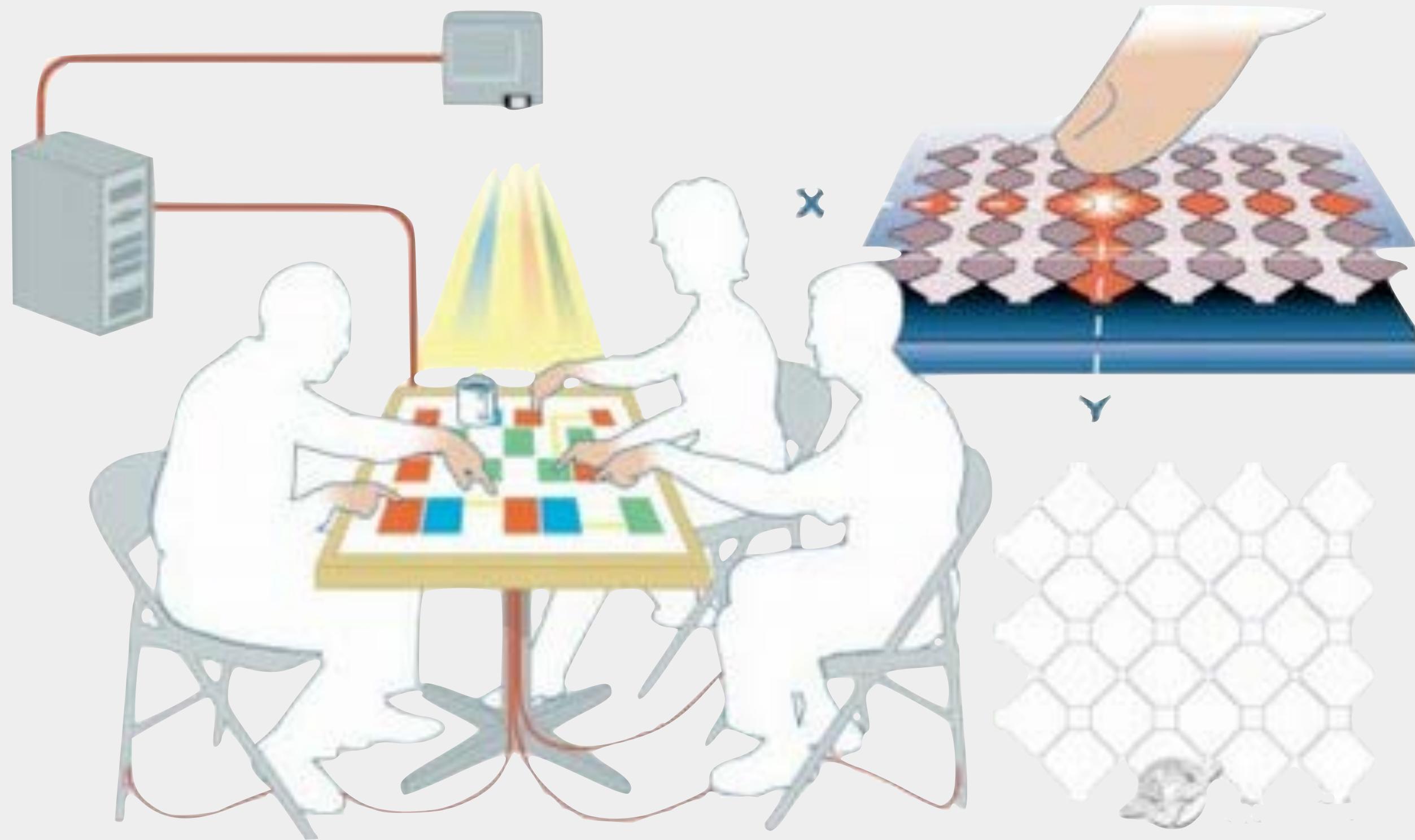




capacitive sensing



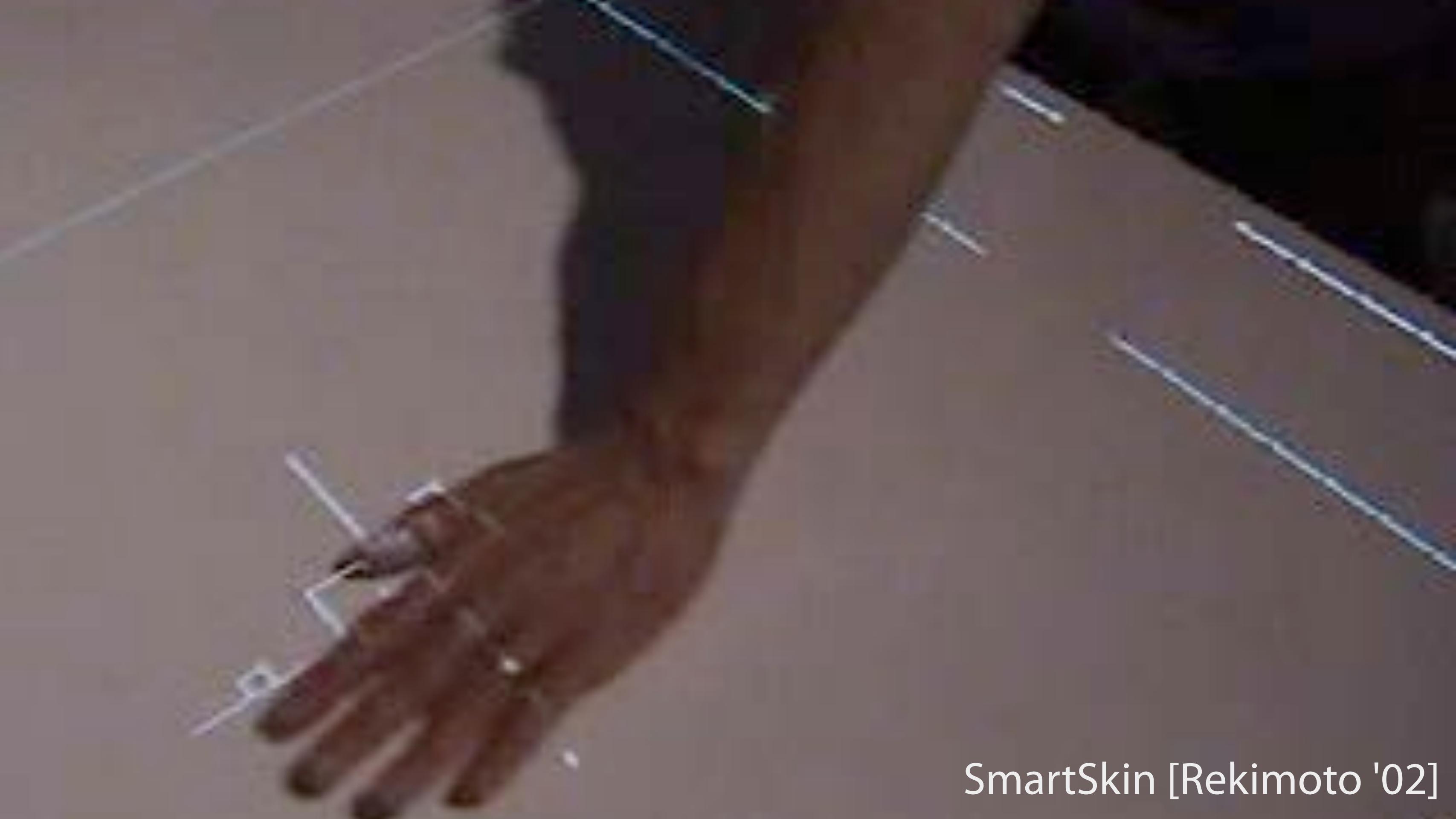
DiamondTouch [Dietz & Leigh '01]



DiamondTouch [Dietz & Leigh '01]



SmartSkin [Rekimoto '02]



SmartSkin [Rekimoto '02]



Fingerworks, 2005



iPhone 1, 2007



...and it prevailed

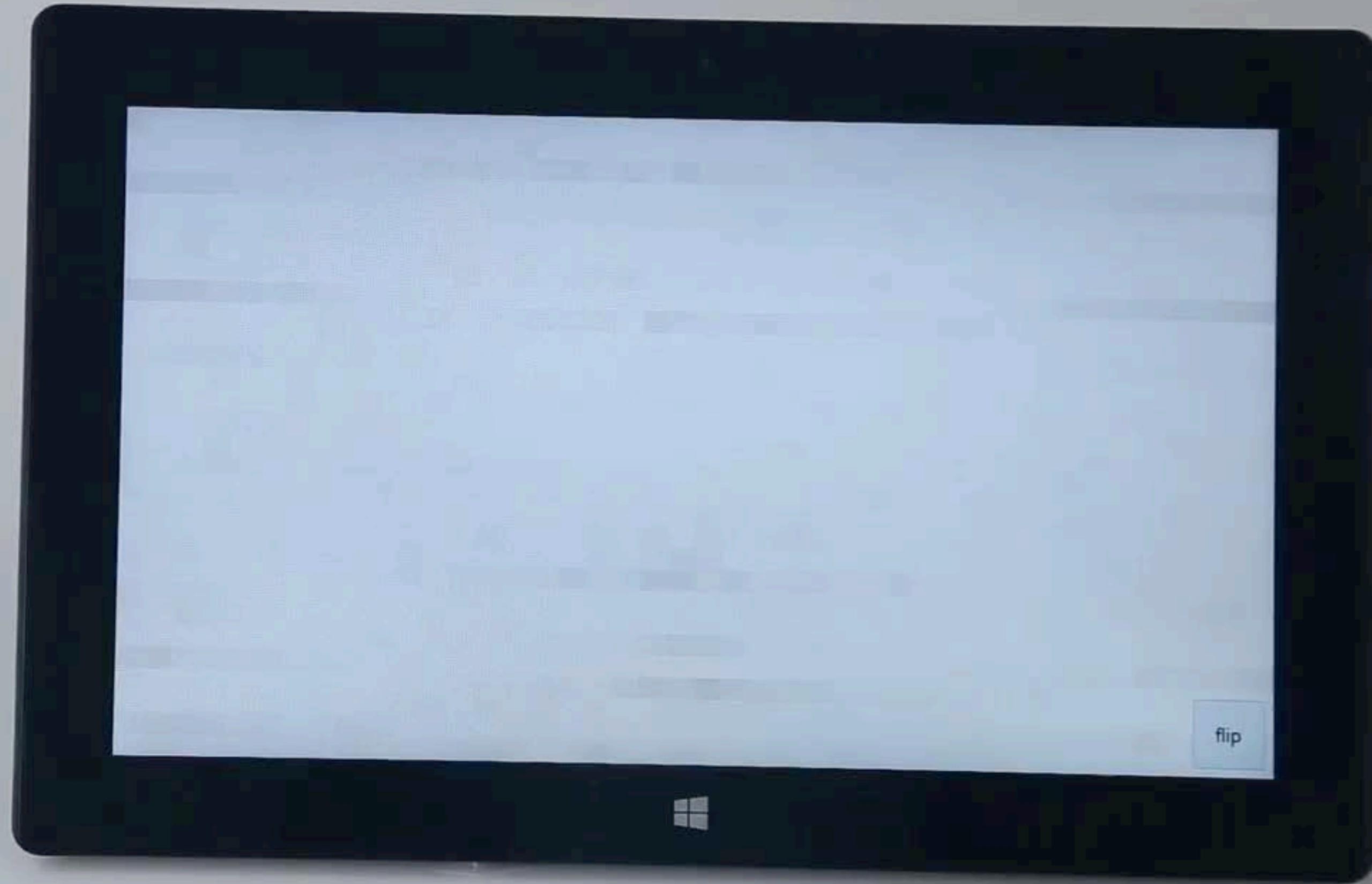
...and it prevailed



# Bodyprint [CHI '15]



# Biometric Touch Sensing [UIST '15]



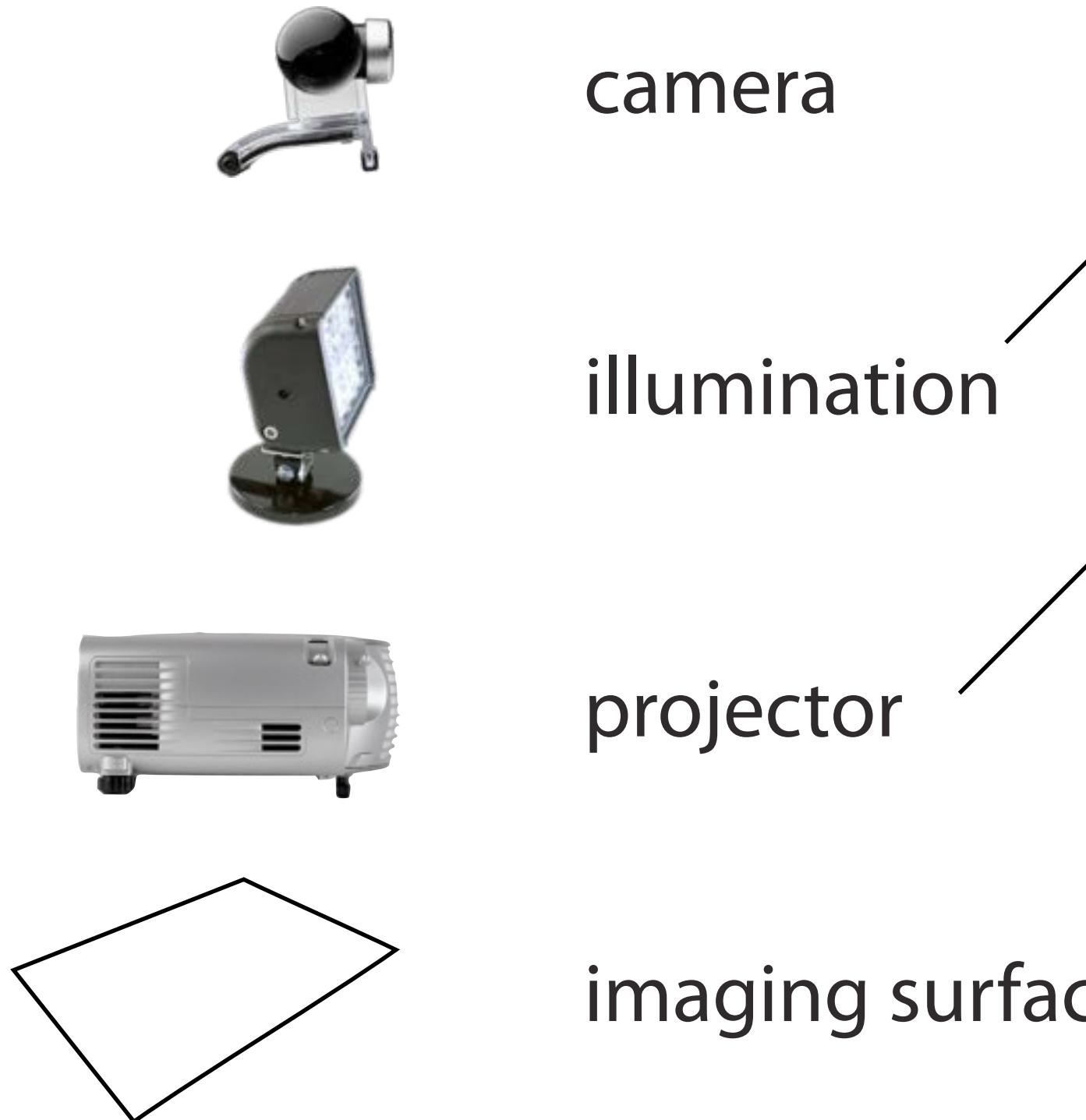
optical touch sensing



# walls & tables



# optical touch sensing



camera

illumination

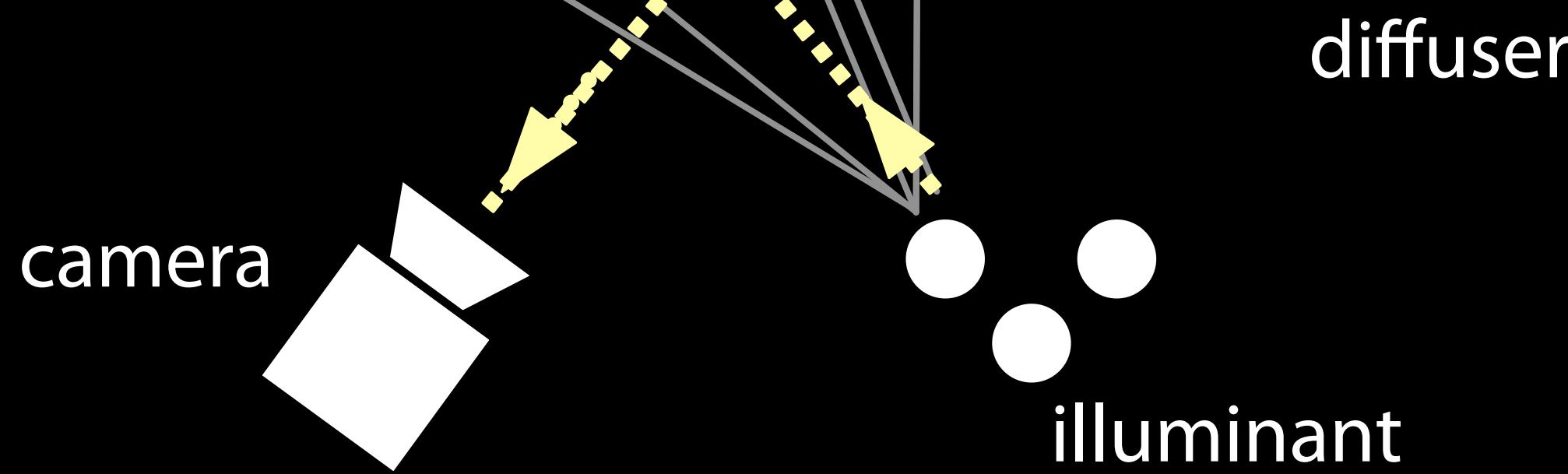
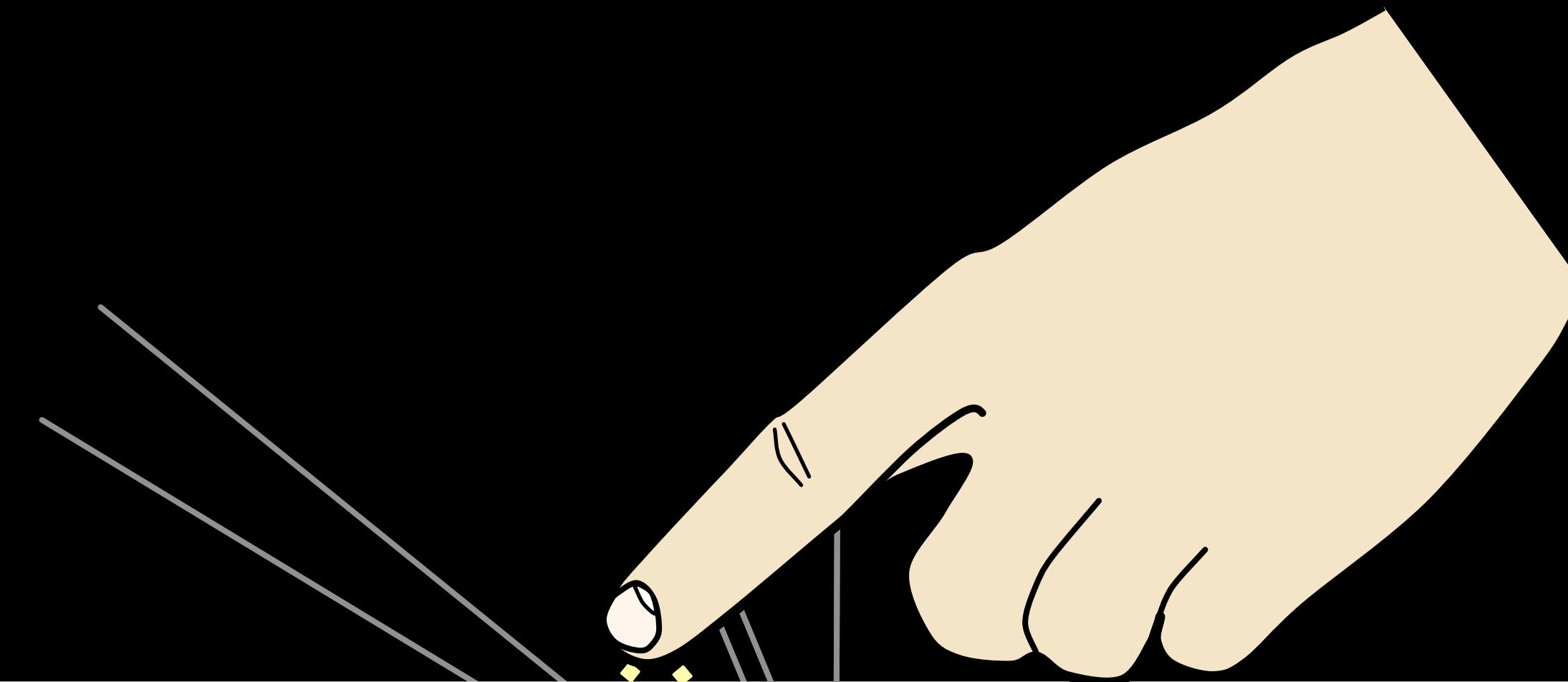
projector

imaging surface

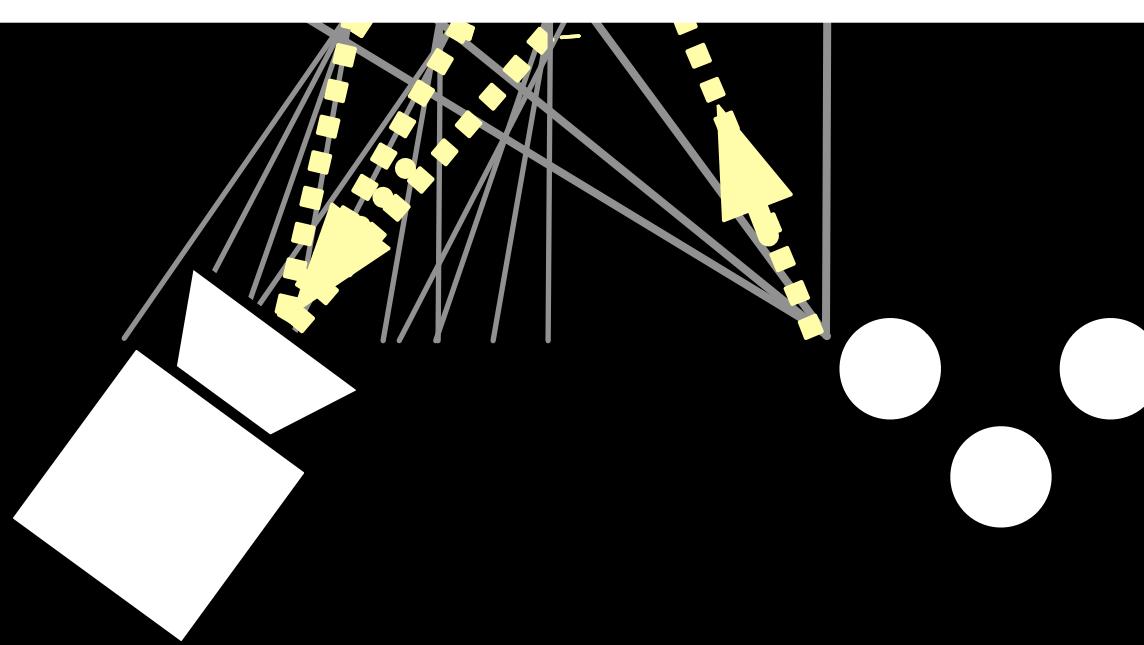
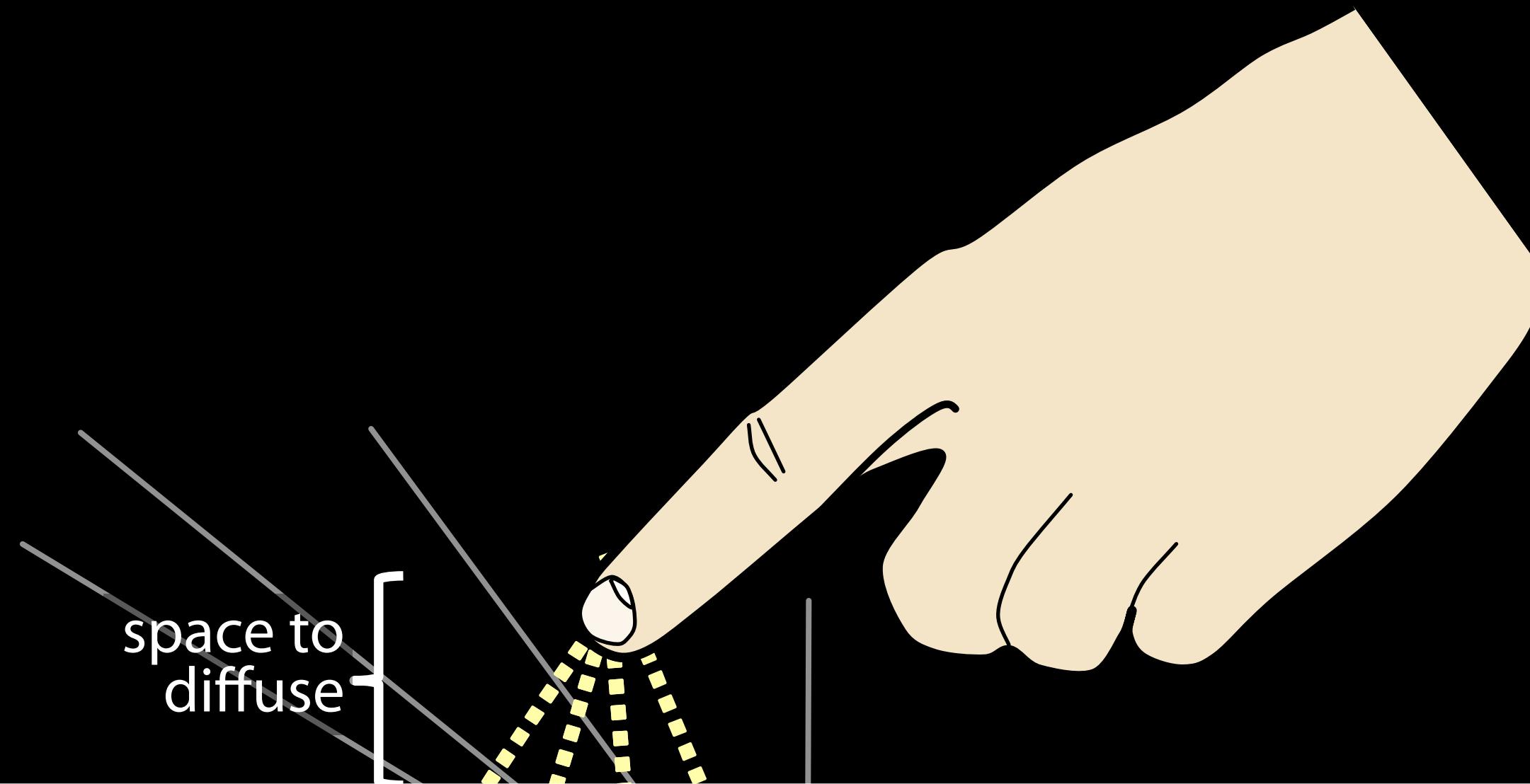
invisible (infrared)

visible

diffuse illumination

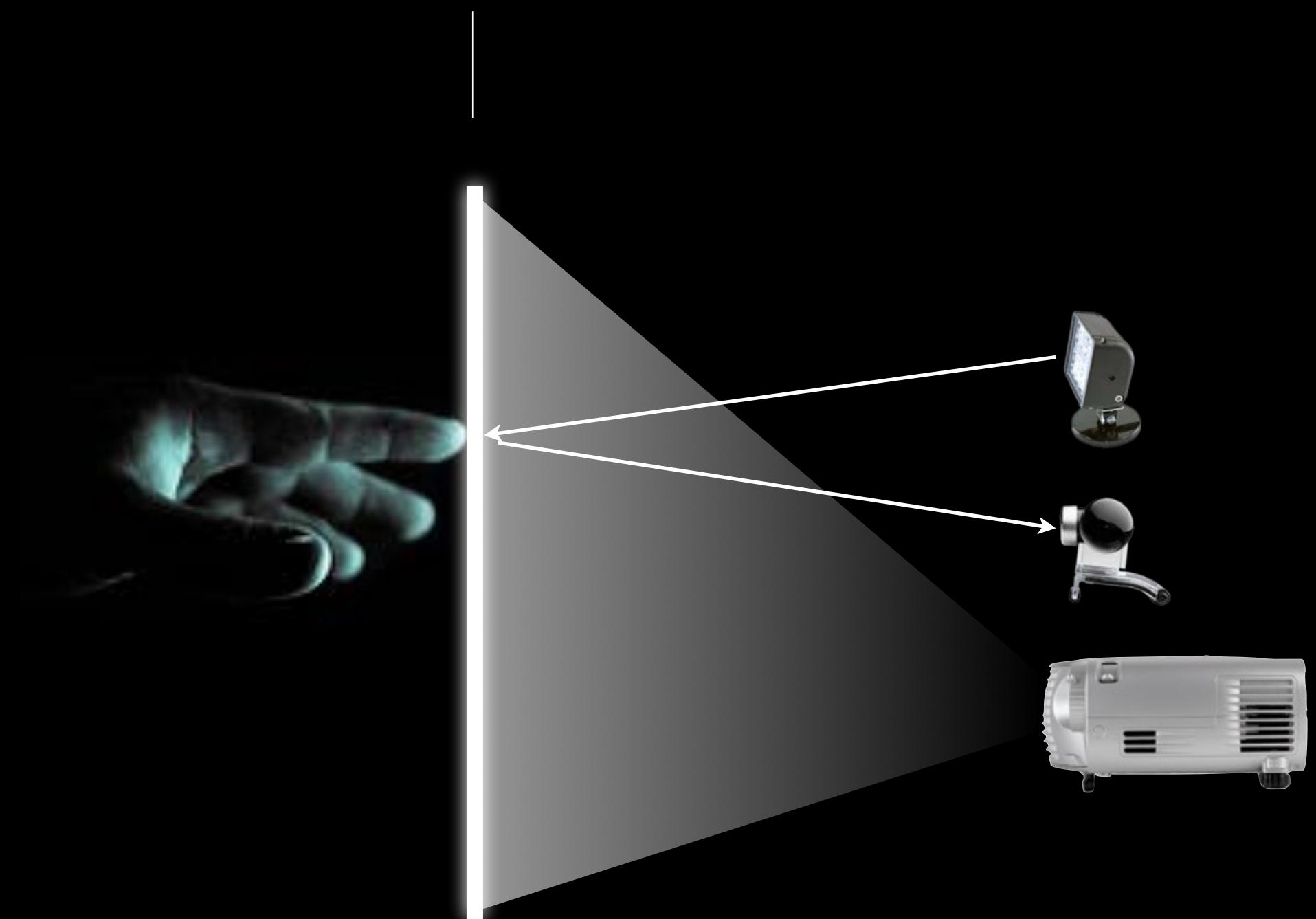




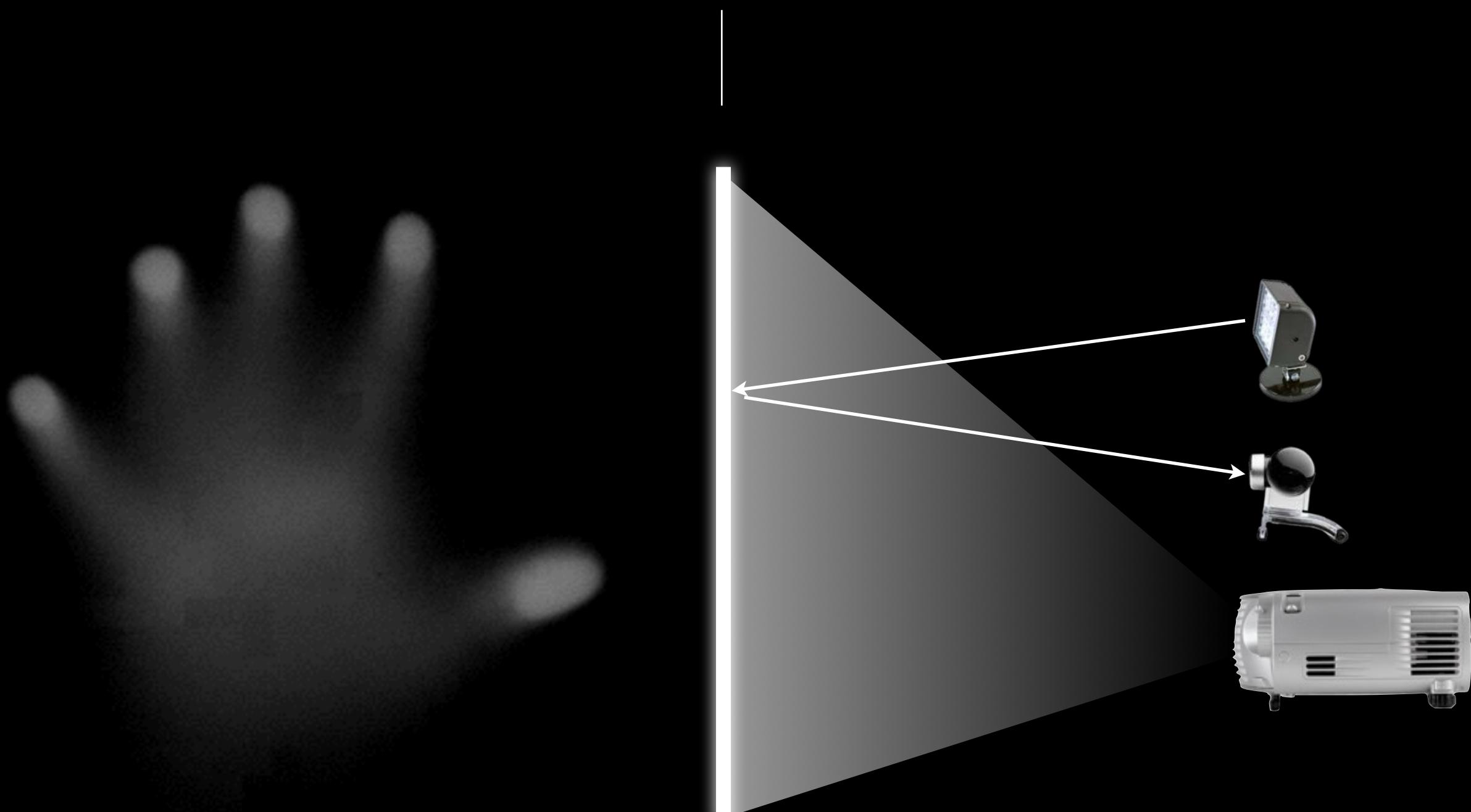


darker and blurry —————

# projection plane



projection plane



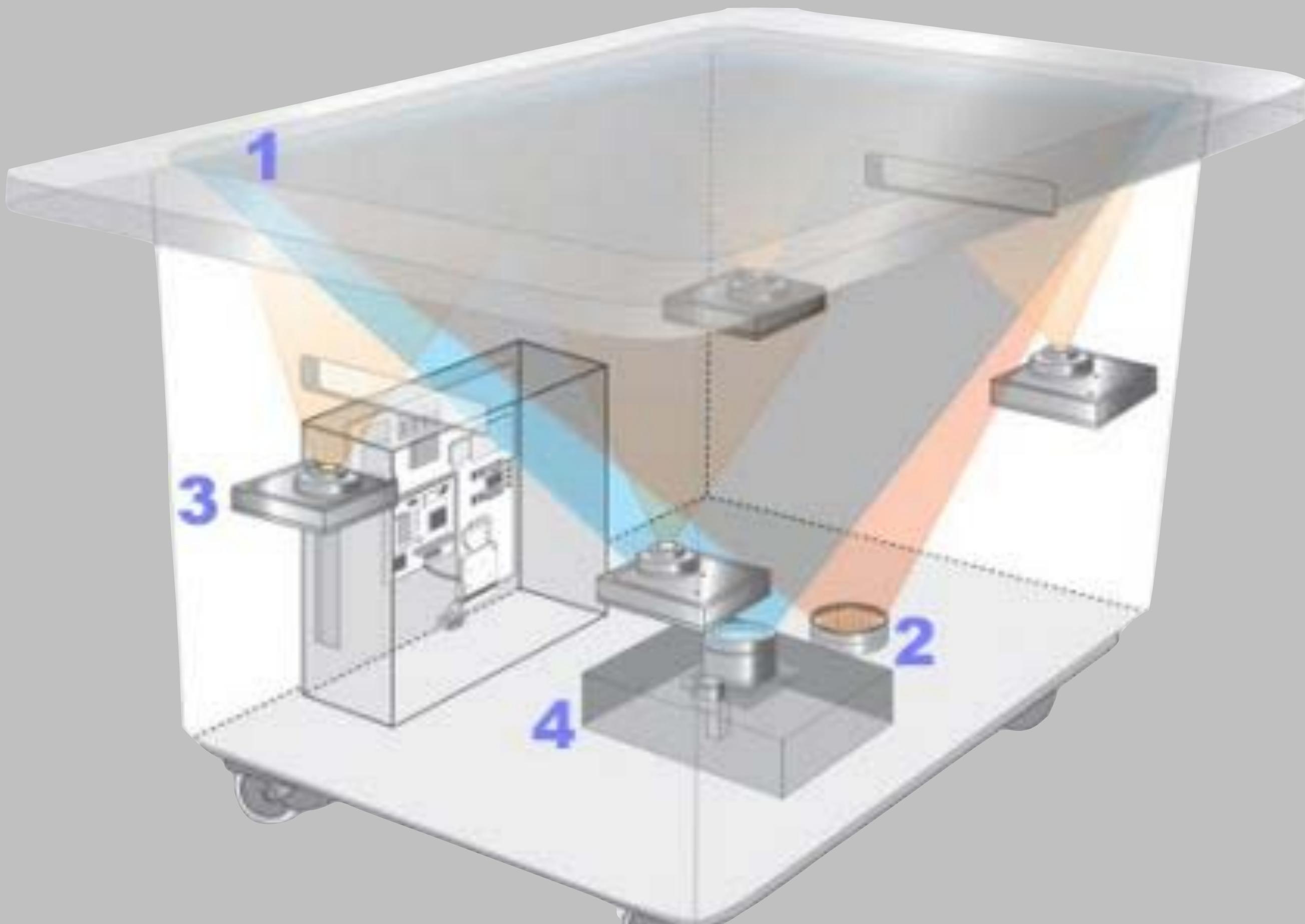
rear DI

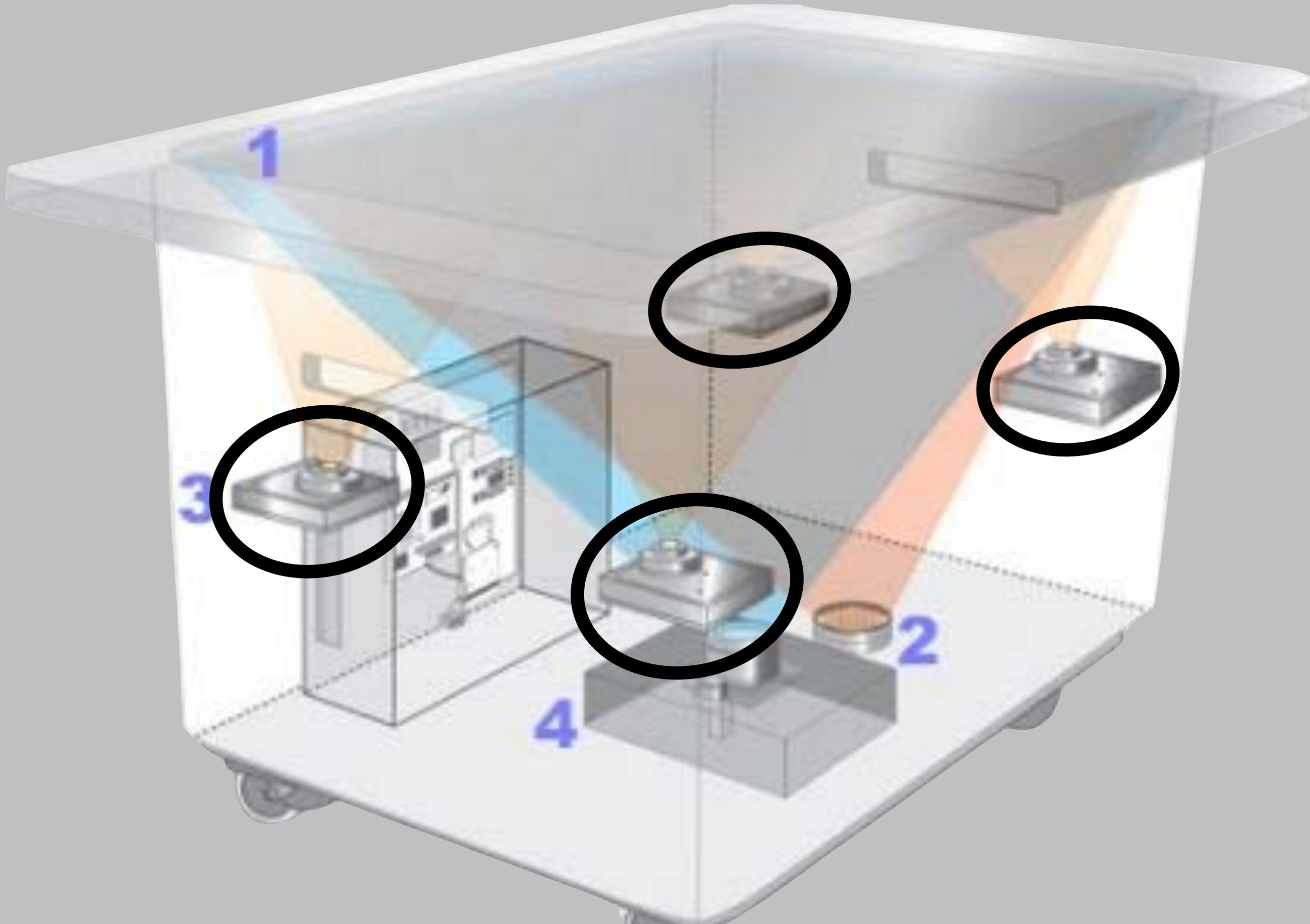


HoloWall [Rekimoto, UIST '97]

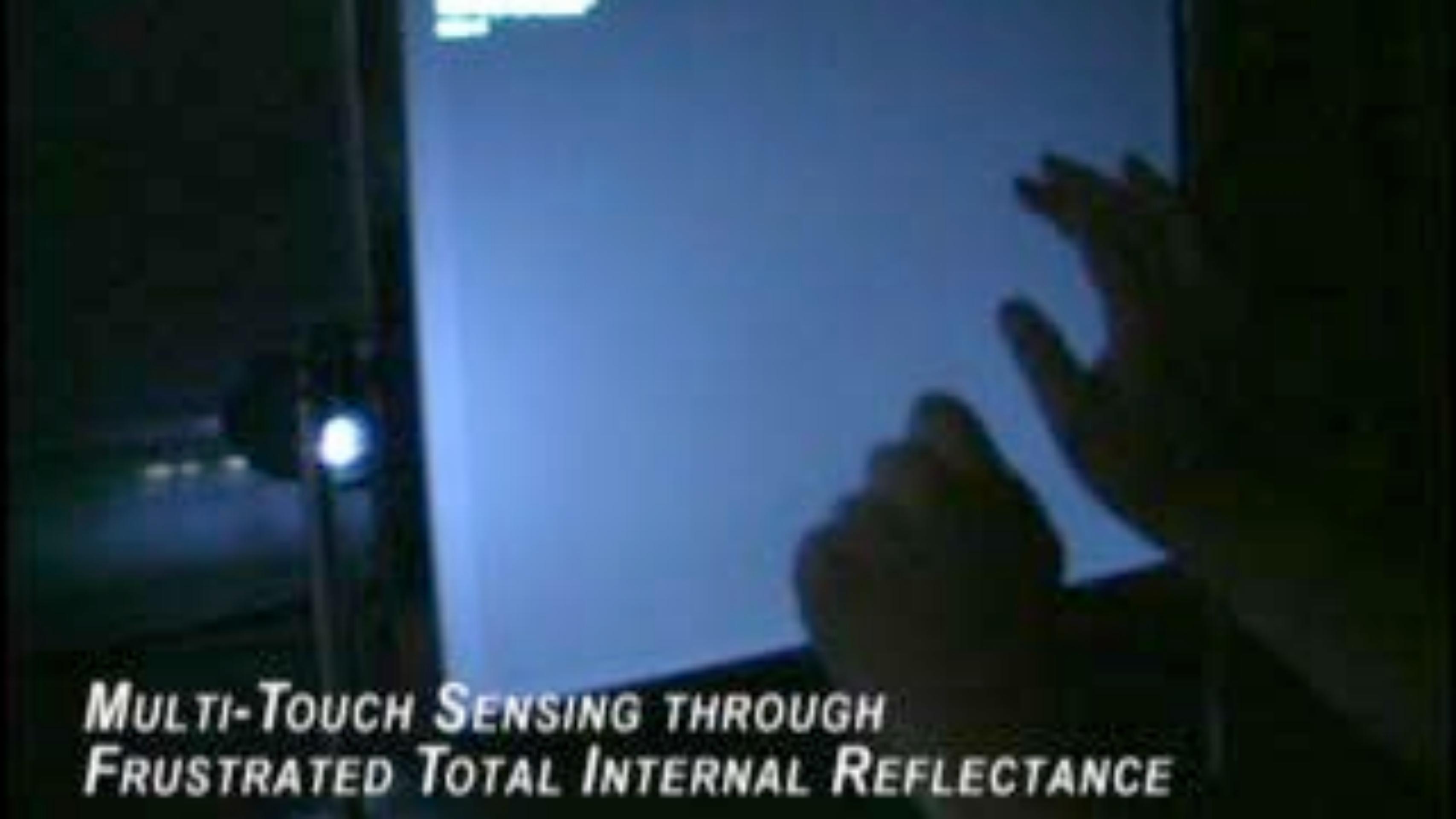


Microsoft Surface, 2008



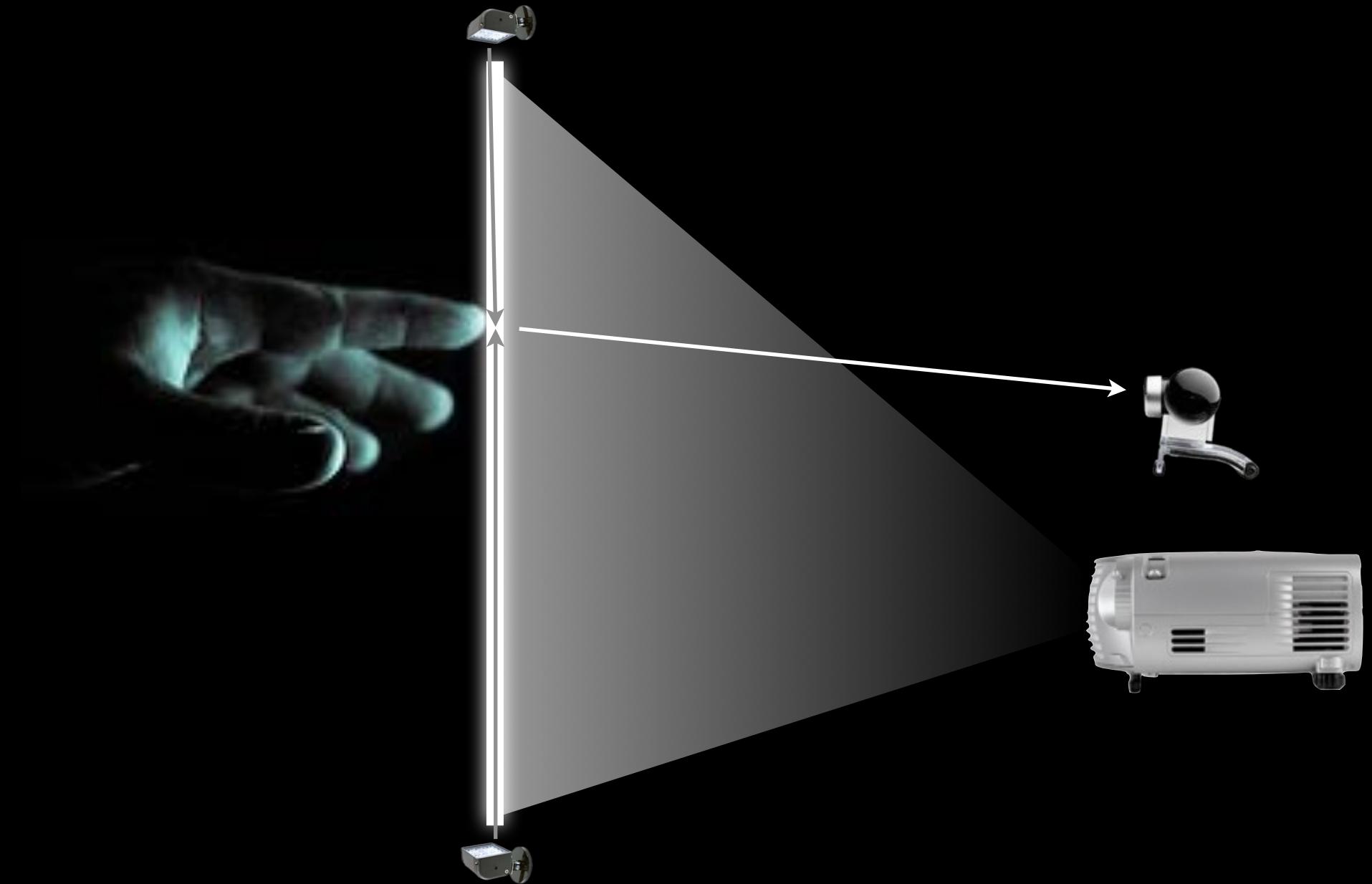


frustrated total internal reflection  
the other camp



# MULTI-TOUCH SENSING THROUGH FRUSTRATED TOTAL INTERNAL REFLECTANCE

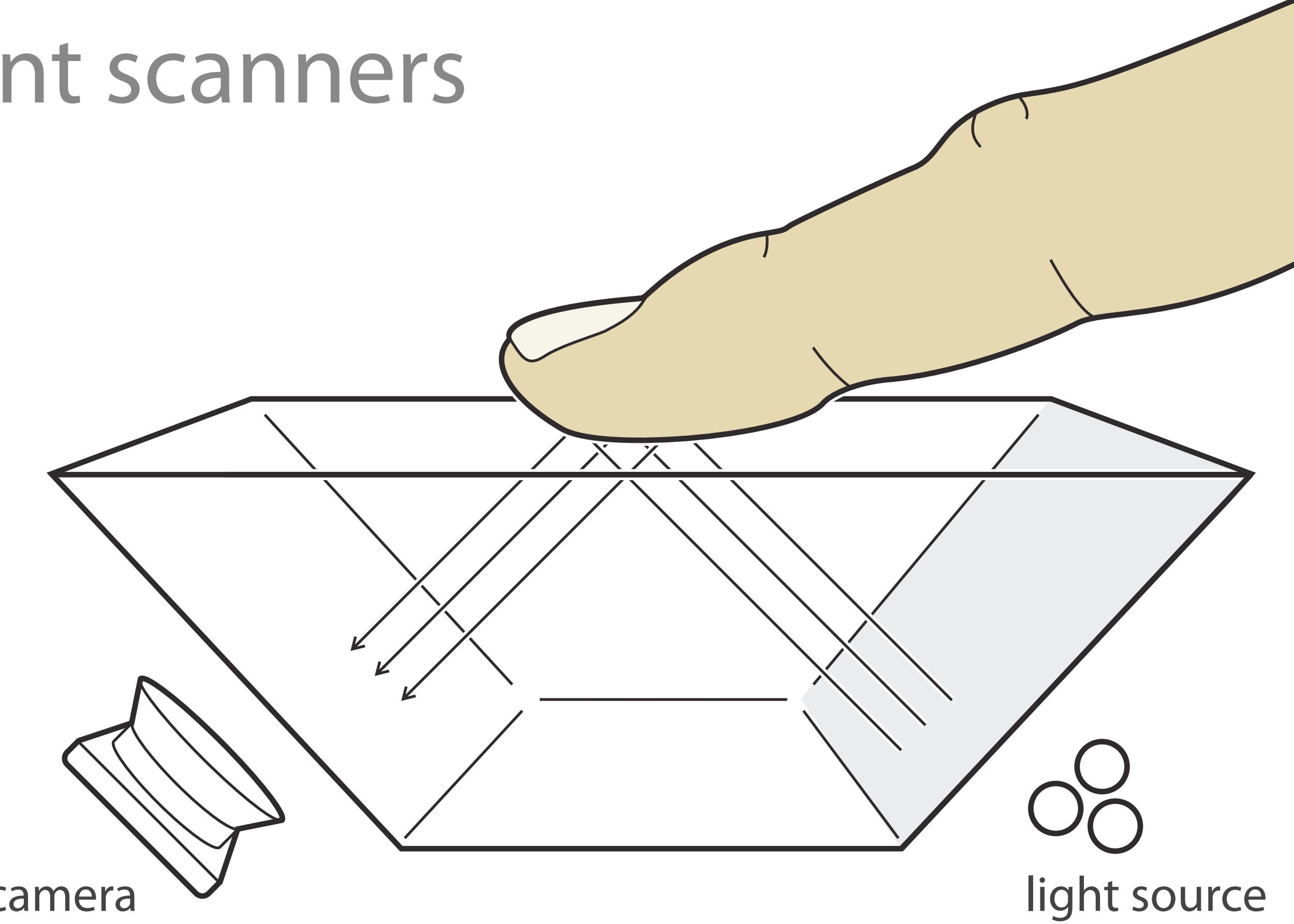
# projection plane

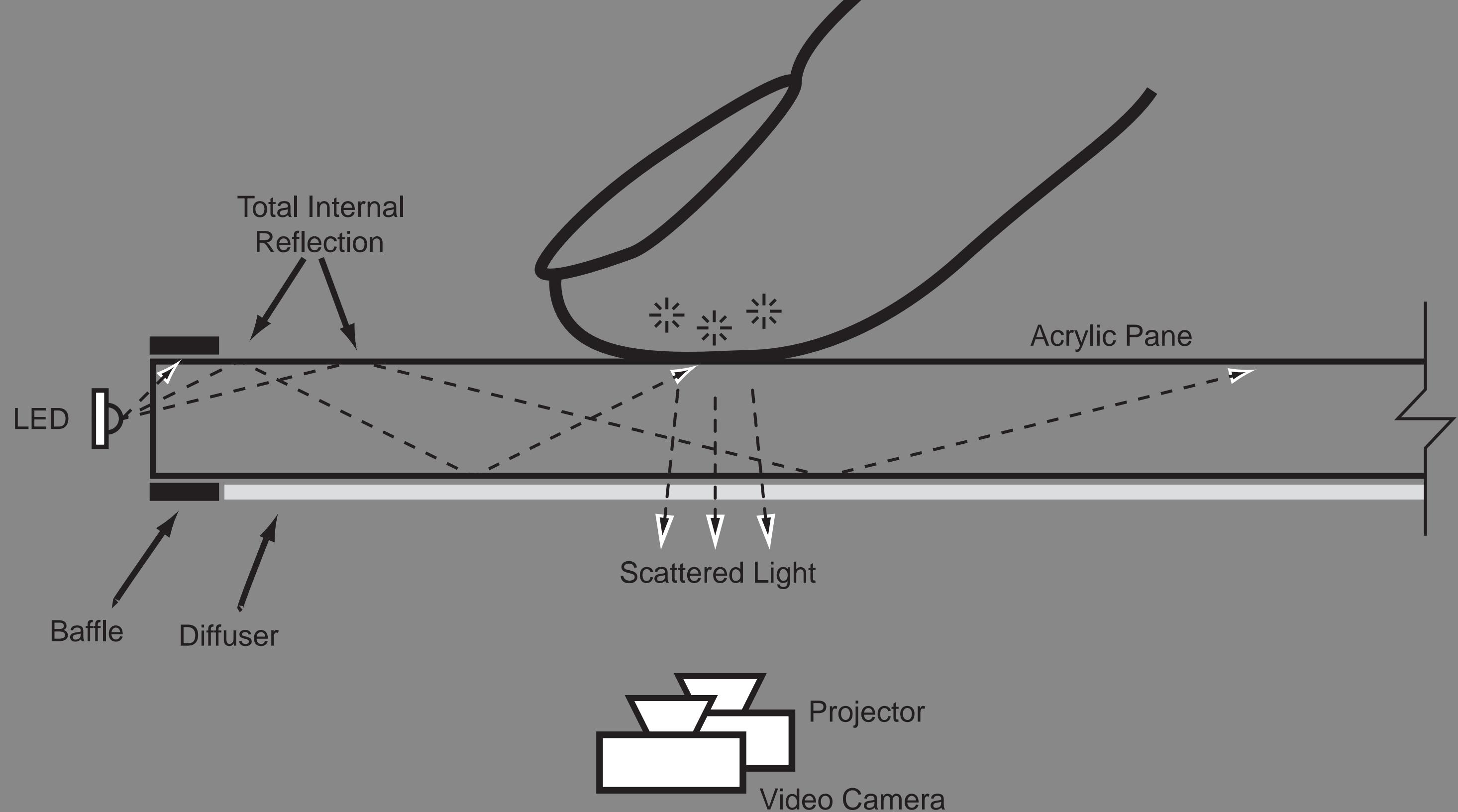


FTIR

[Han, UIST '05]

# fingerprint scanners

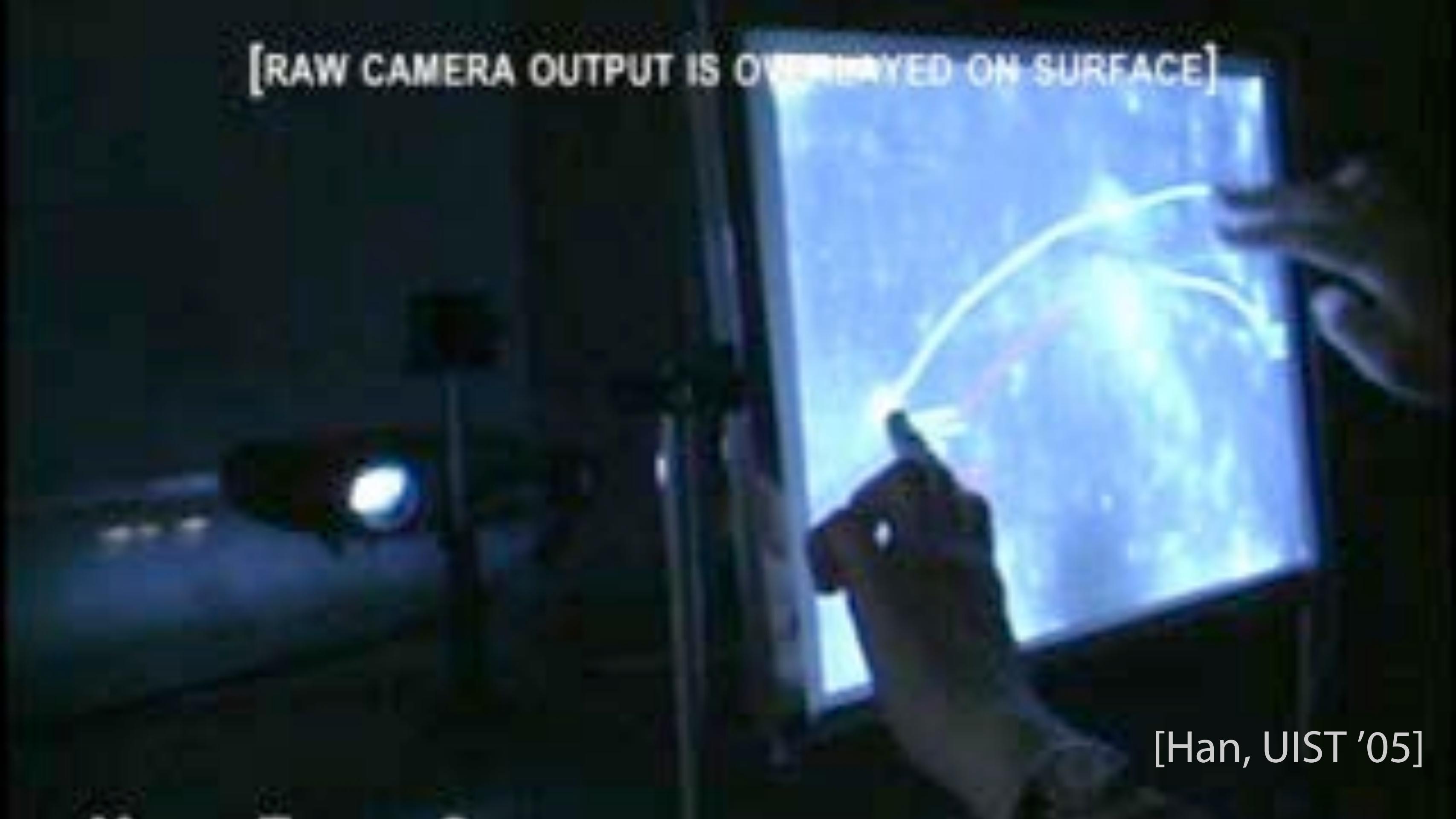




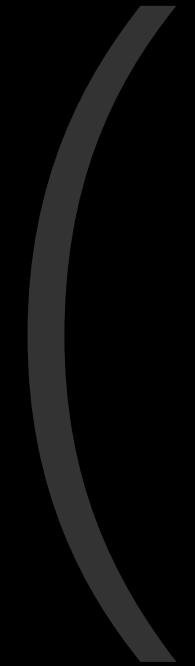
FTIR

[Han, UIST '05]

[RAW CAMERA OUTPUT IS OVERLAYED ON SURFACE]



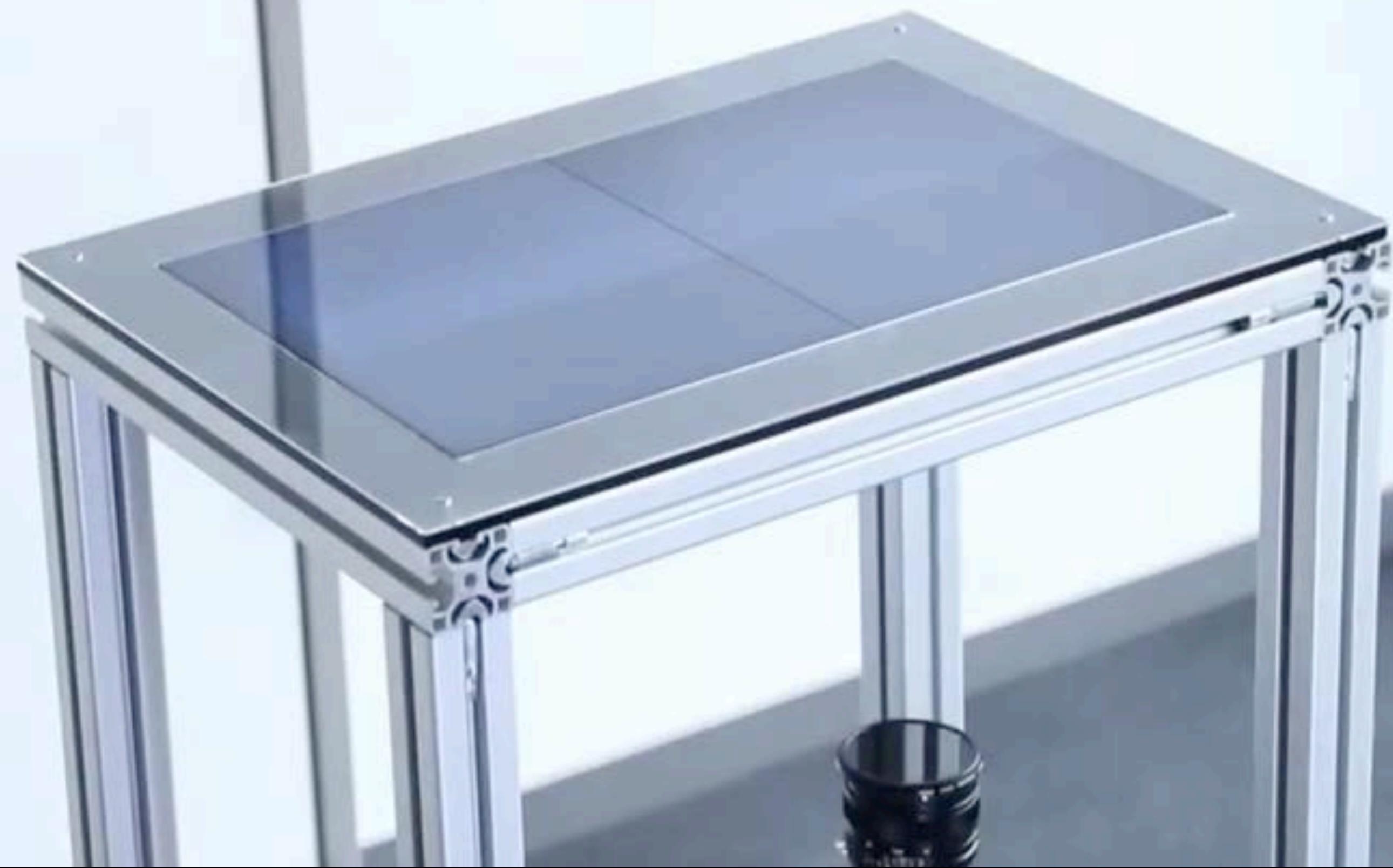
[Han, UIST '05]



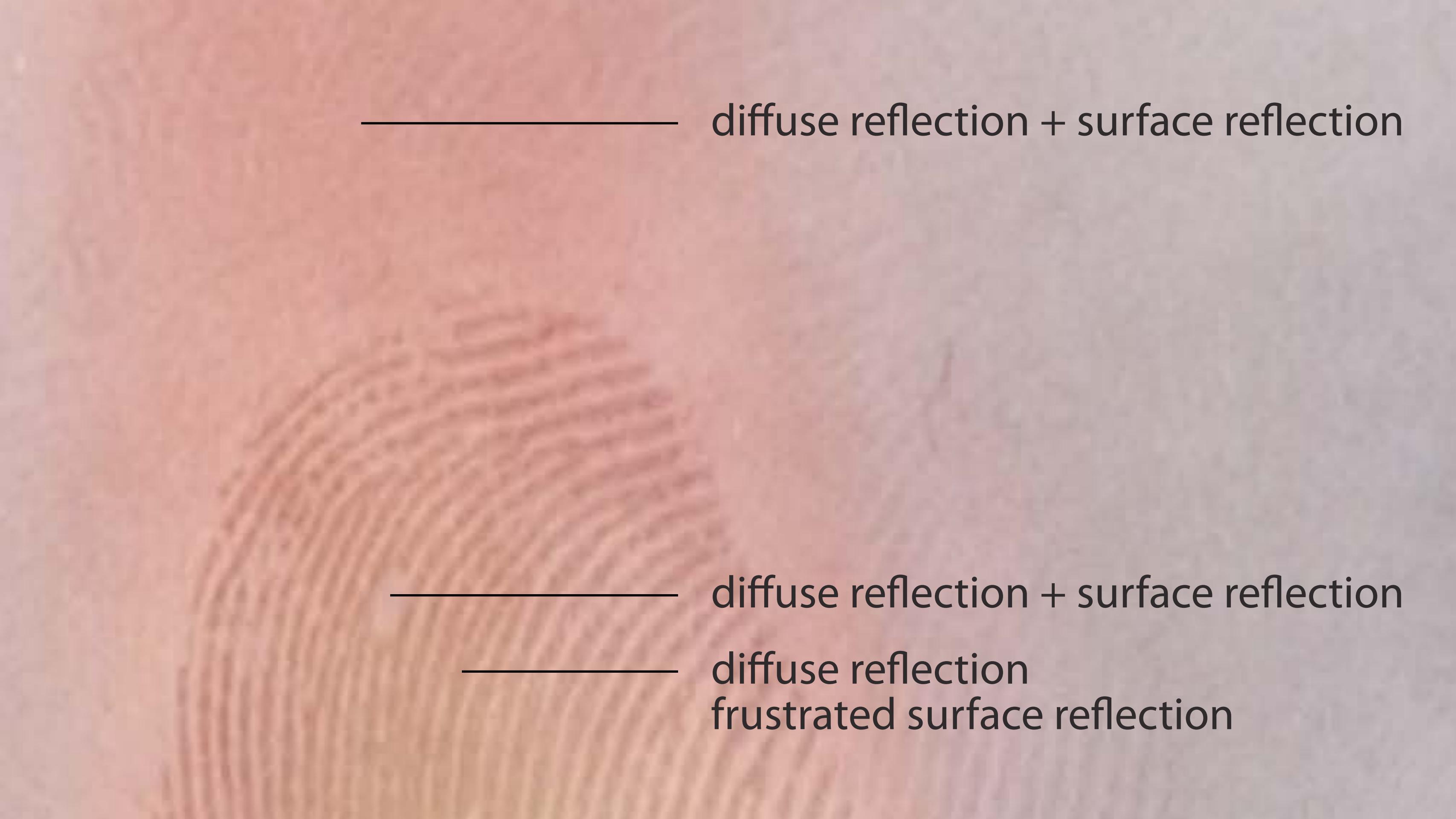
weird mixes  
diffuse illumination + frustrated Fresnel reflection



[Fiberio, UIST '15]







---

diffuse reflection + surface reflection

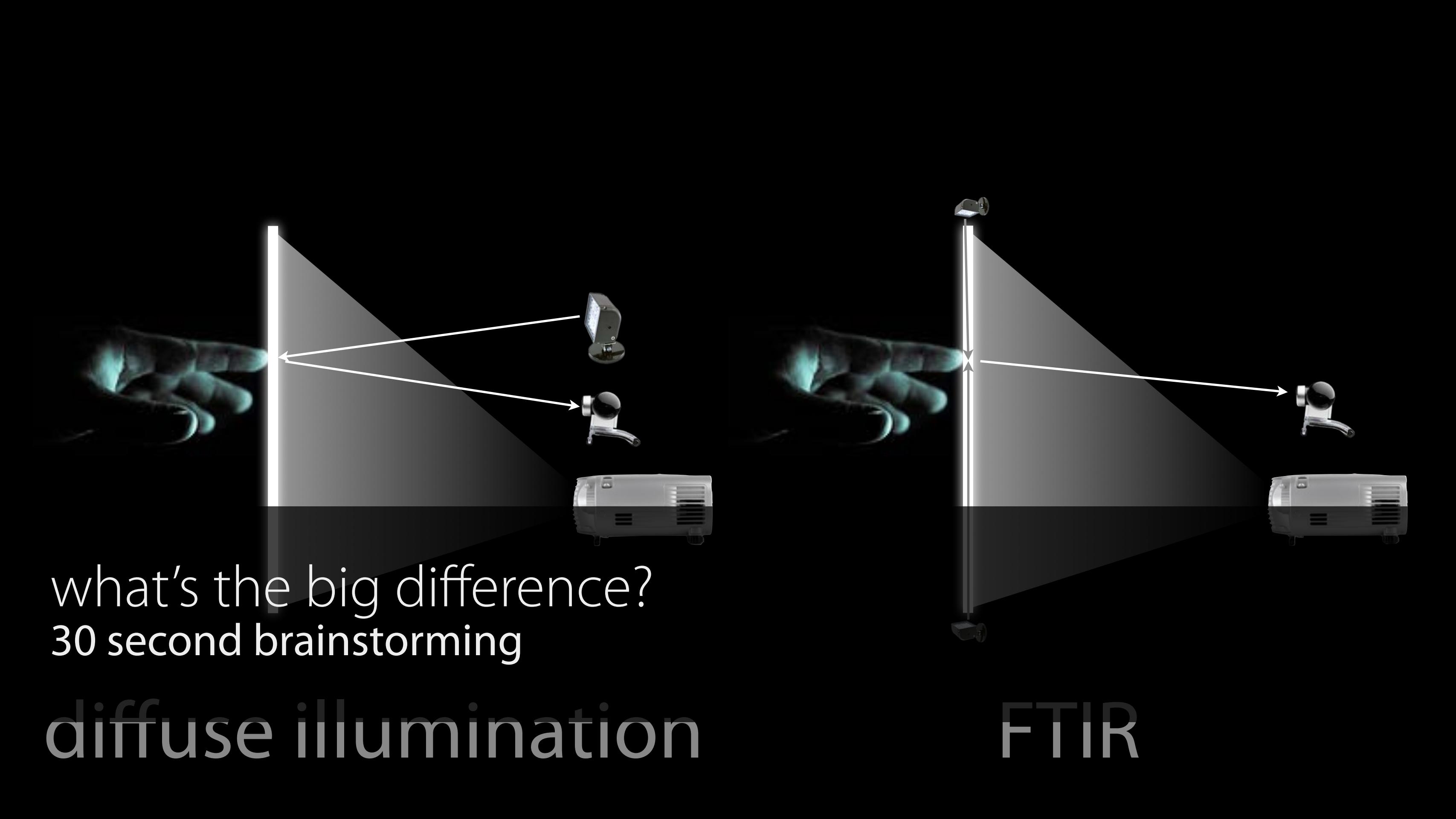
---

diffuse reflection + surface reflection

---

diffuse reflection  
frustrated surface reflection





The diagram illustrates the difference between two types of illumination. On the left, labeled 'diffuse illumination', a hand is shown against a dark background. A vertical light source illuminates the hand from the side, creating a bright, triangular highlight on the wall behind it. Two arrows point from this highlight to two different sensor heads: one with a standard lens and another with a wider-angle lens. Below these is a projector icon. On the right, labeled 'FTIR', a hand is shown against a dark background. A vertical light source illuminates the hand from the side, creating a bright, triangular highlight on the wall behind it. An arrow points from this highlight to a sensor head with a standard lens. Below this is a projector icon.

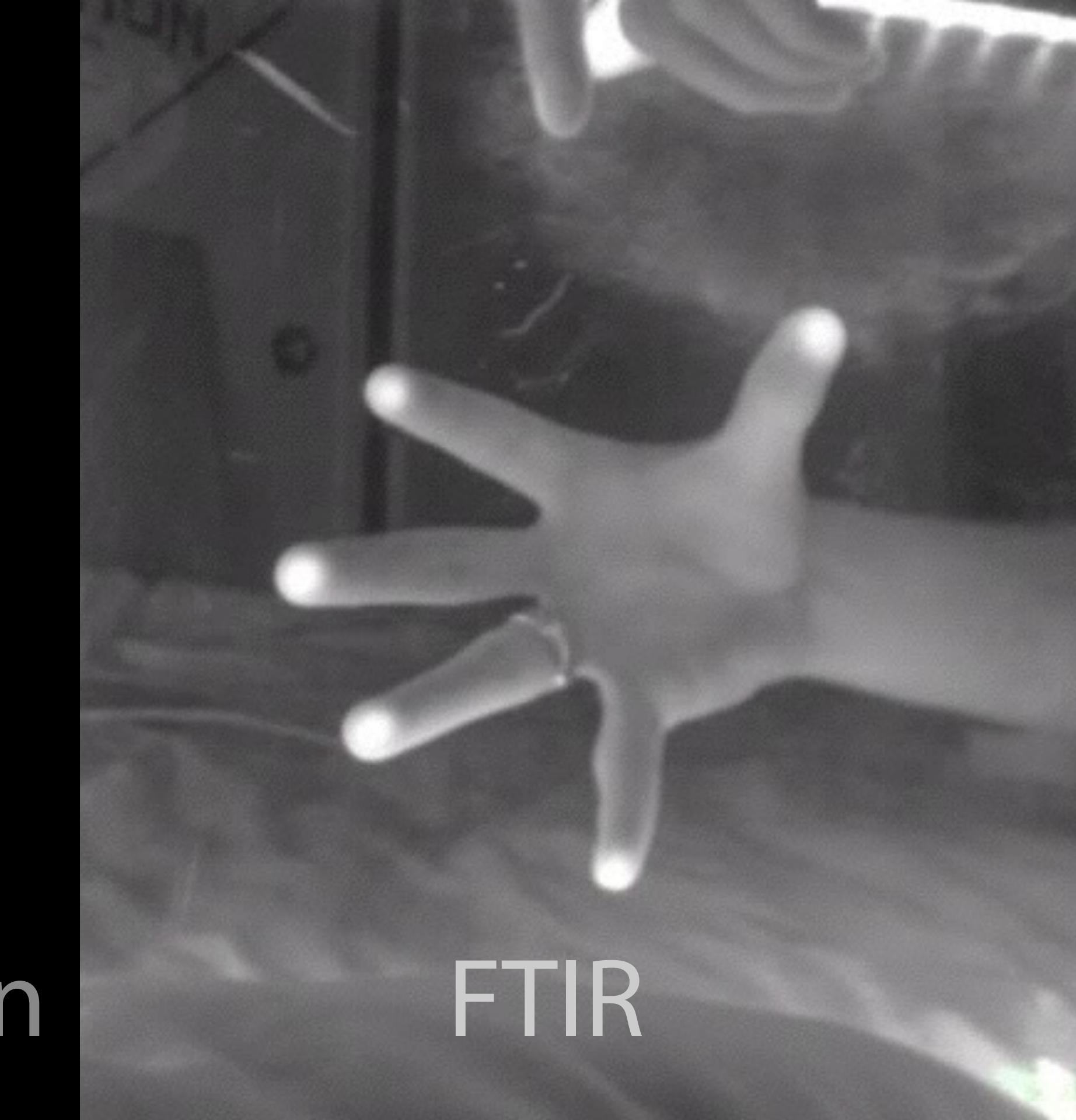
what's the big difference?  
30 second brainstorming

diffuse illumination

FTIR



diffuse illumination

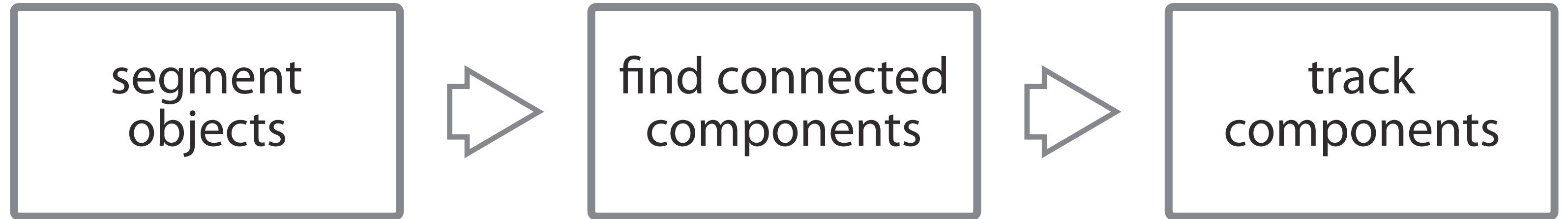


FTIR

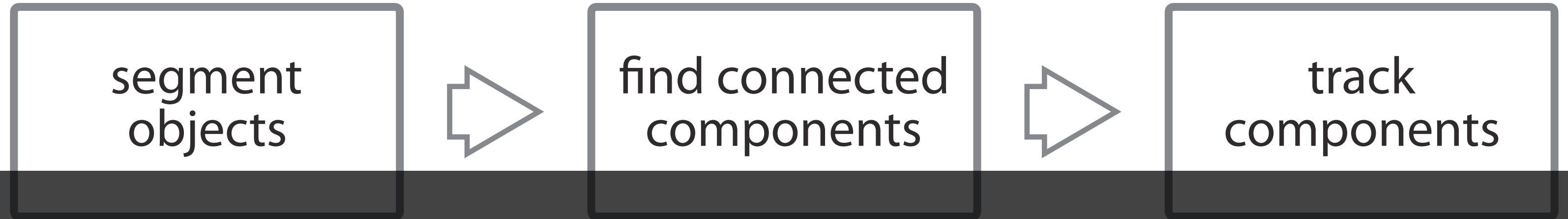
1  
5  
Touch processing



typical processing pipeline



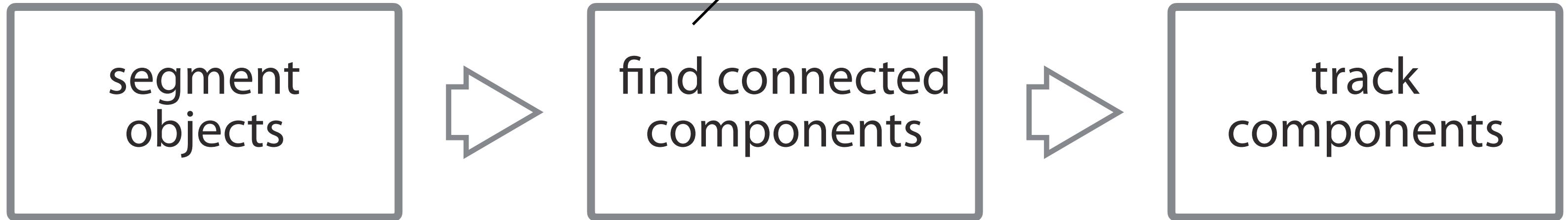
typical processing pipeline



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

typical processing pipeline

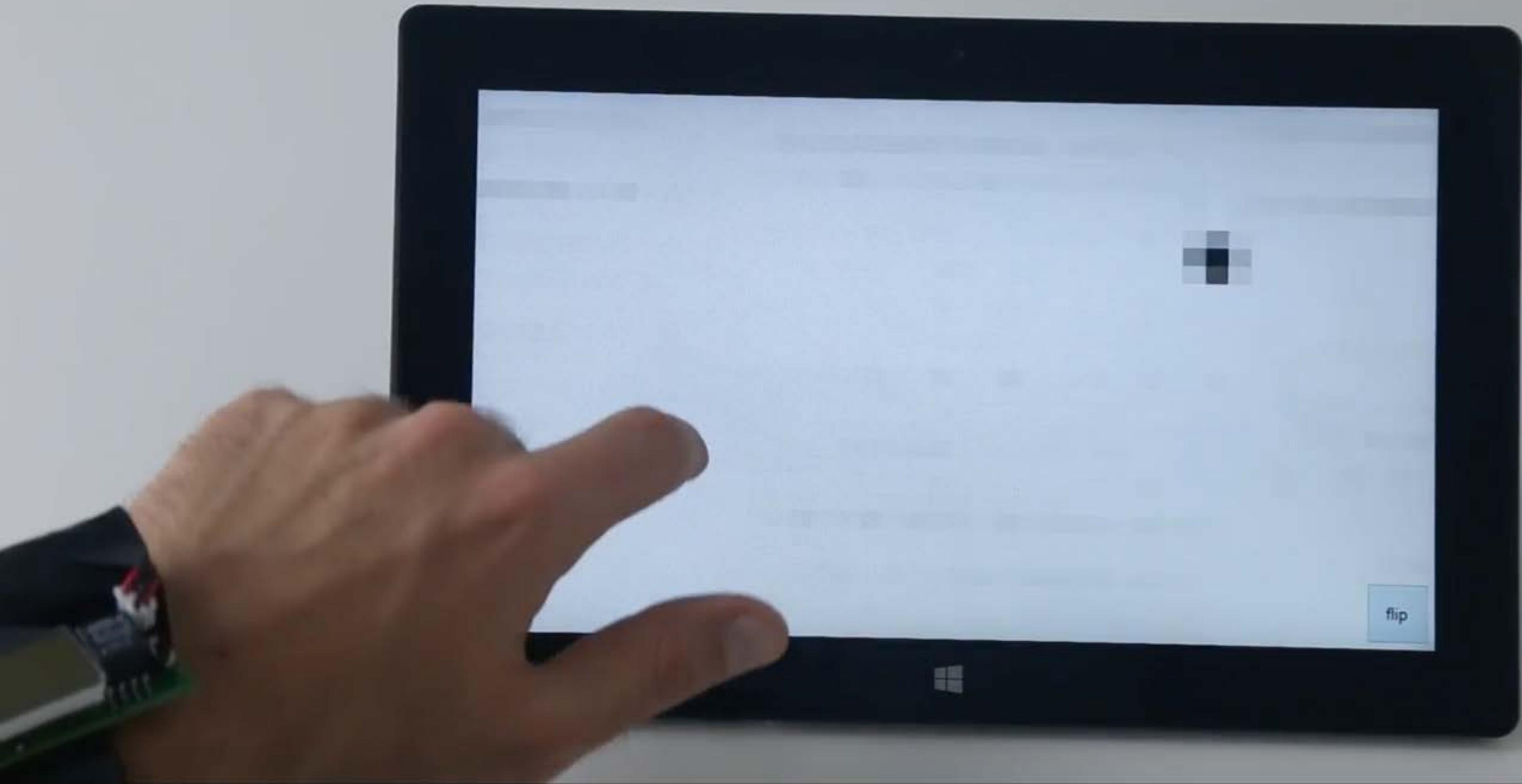
typical processing pipeline



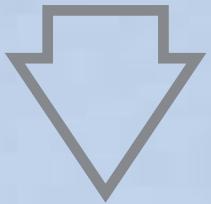


Touch accuracy

# Biometric Touch Sensing [UIST '15]

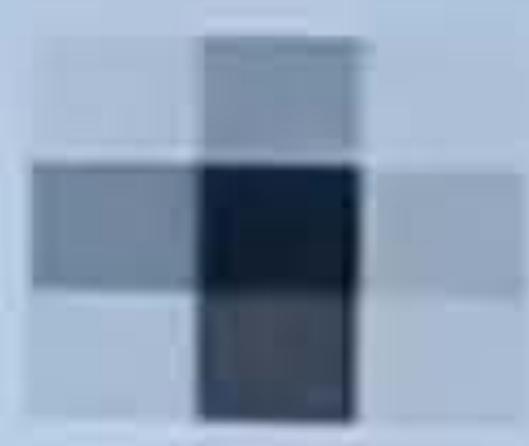


input resolution: 42 x 33 across a 10" display



map to an accurate input location

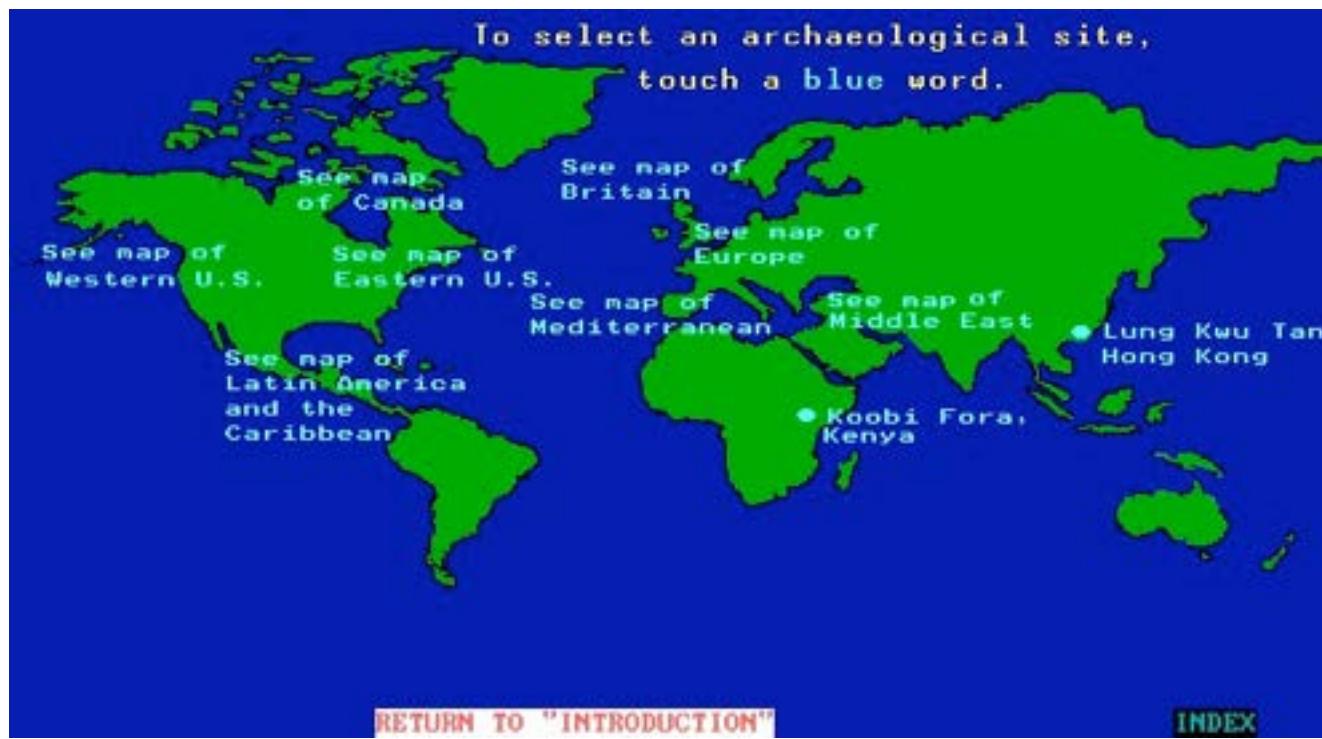
screen resolution: 2,160 x 1,440



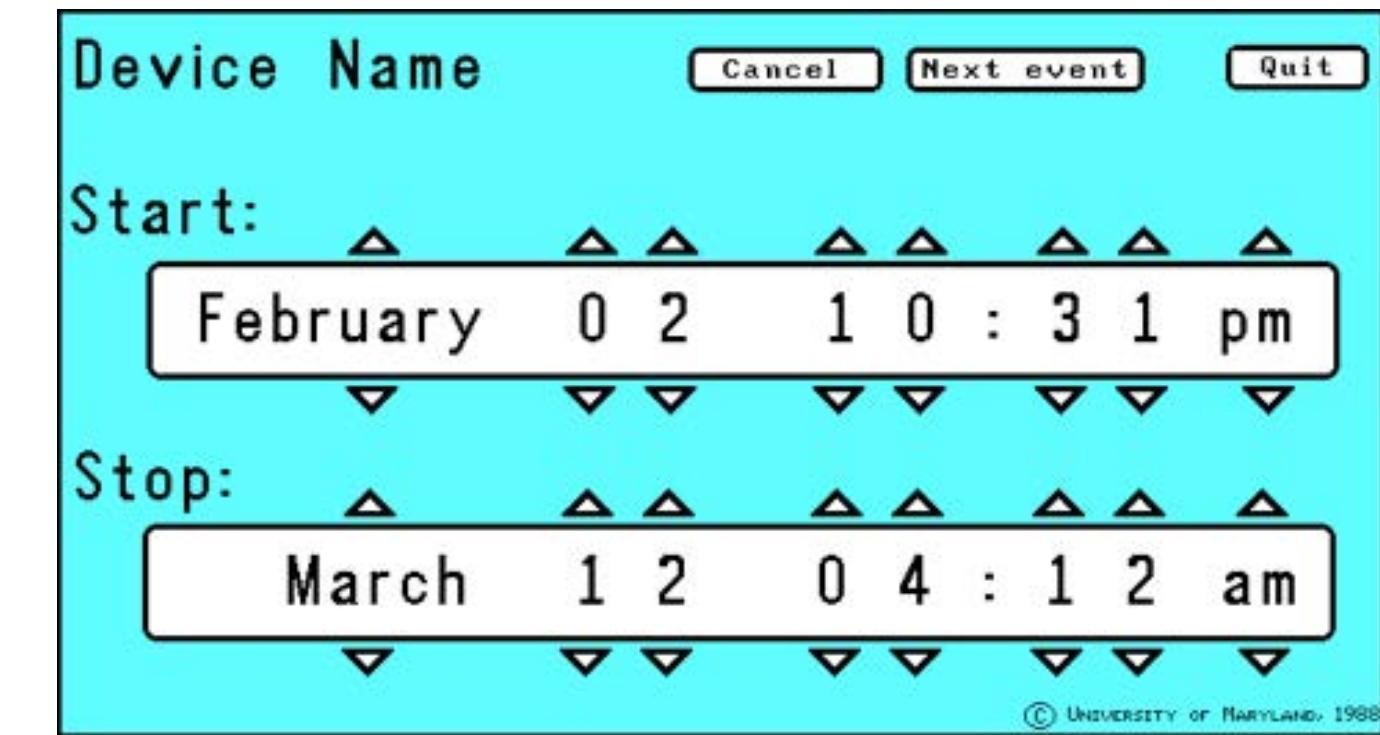
center of gravity



if only it were that easy :-)



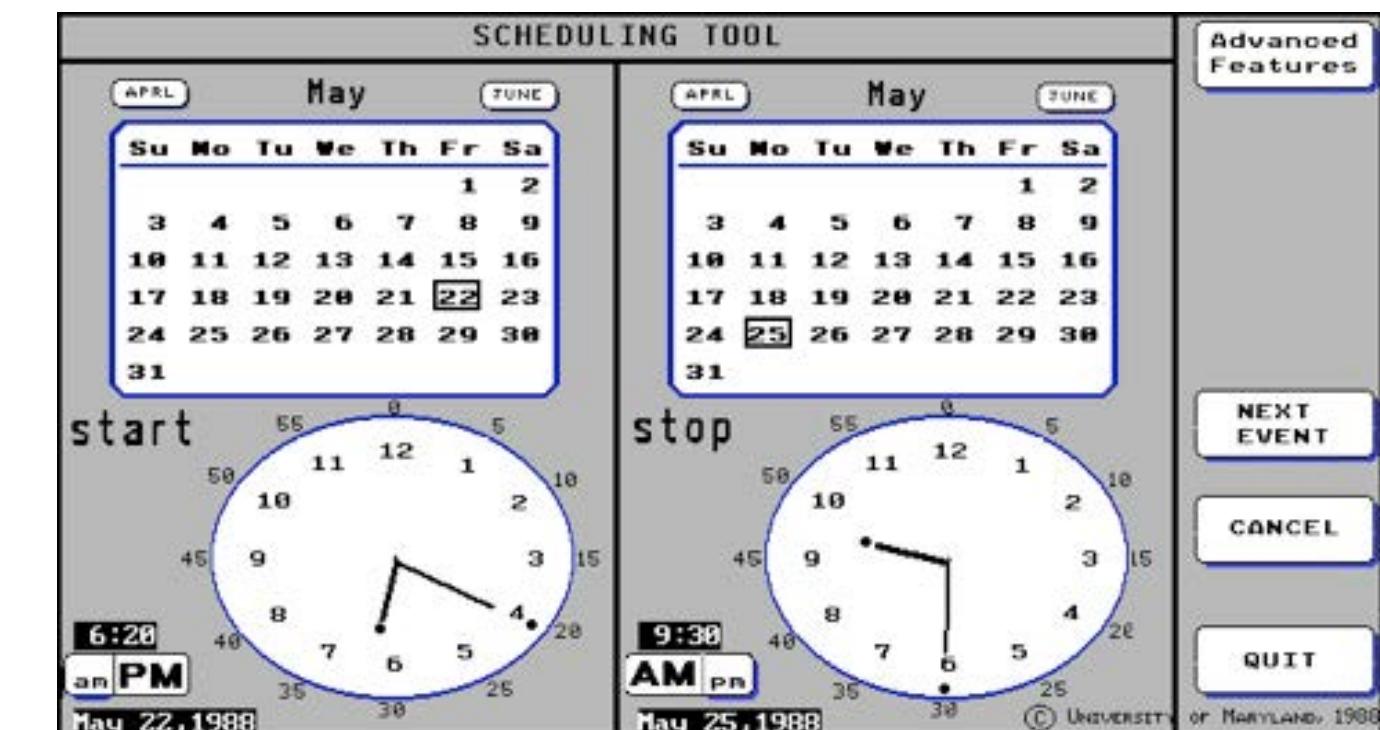
Information Kiosks [Plaisant et al. '88]



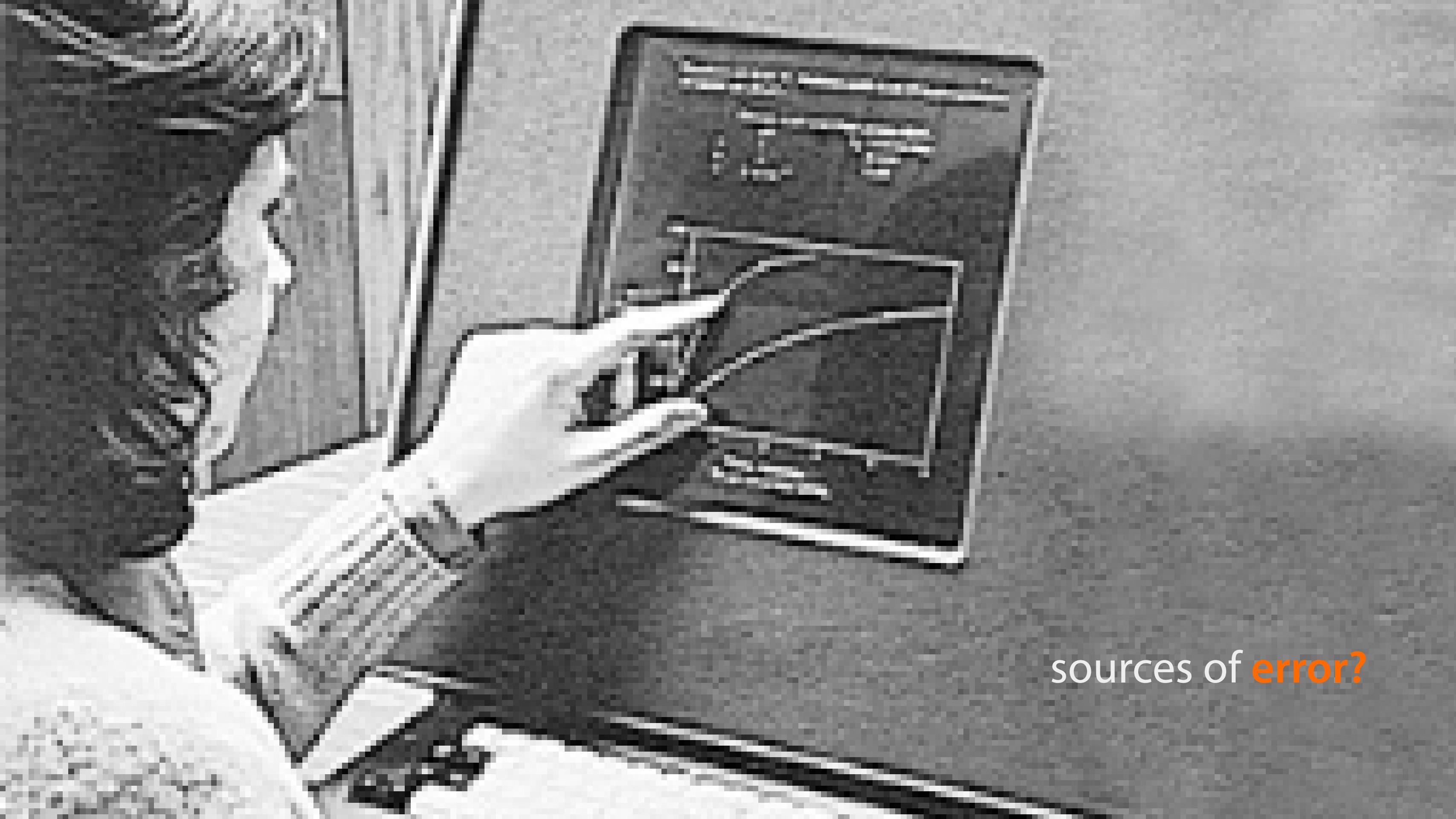
Home Automation [Plaisant et al. '90 and on]



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”

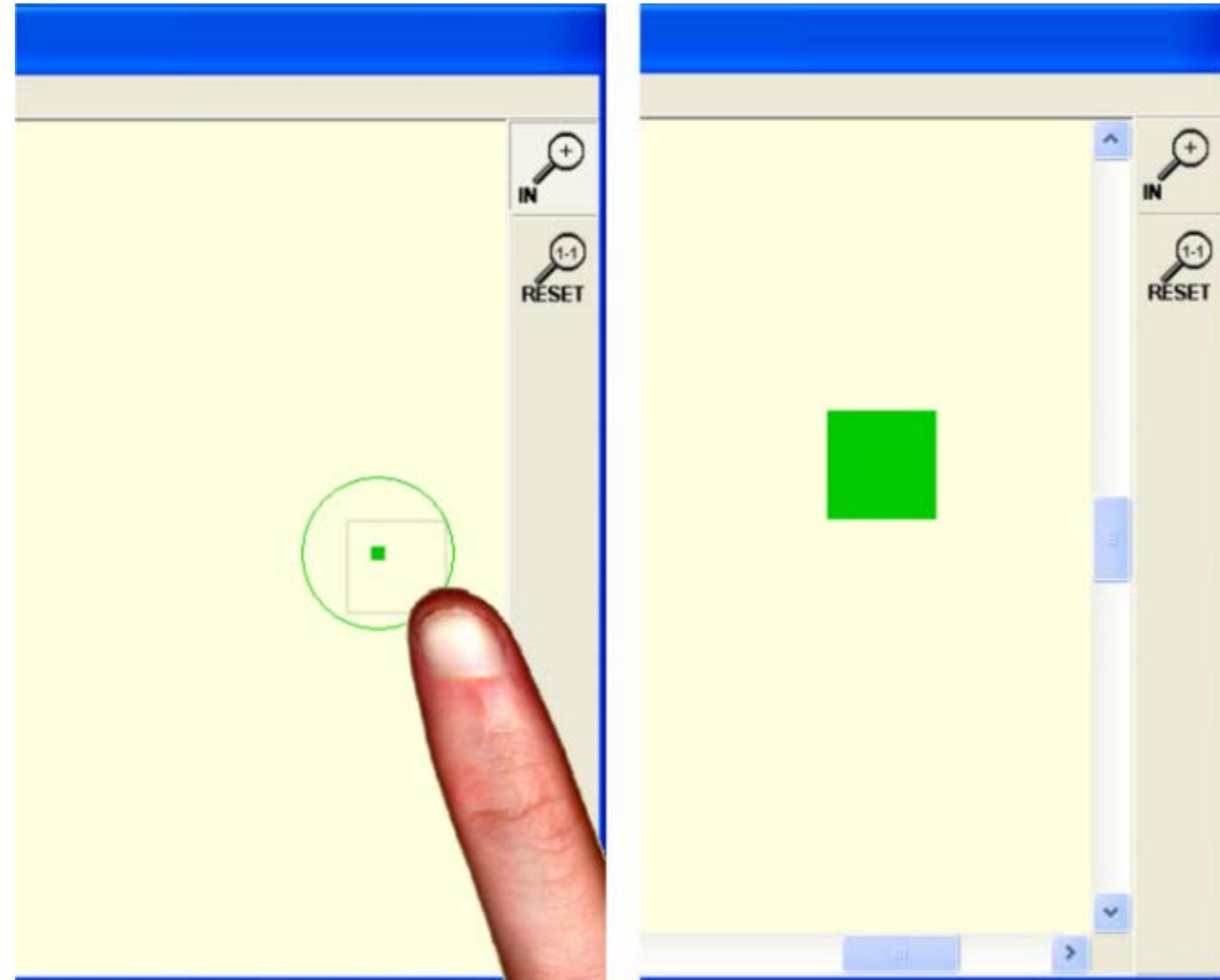
“fatigue in arm motion”

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

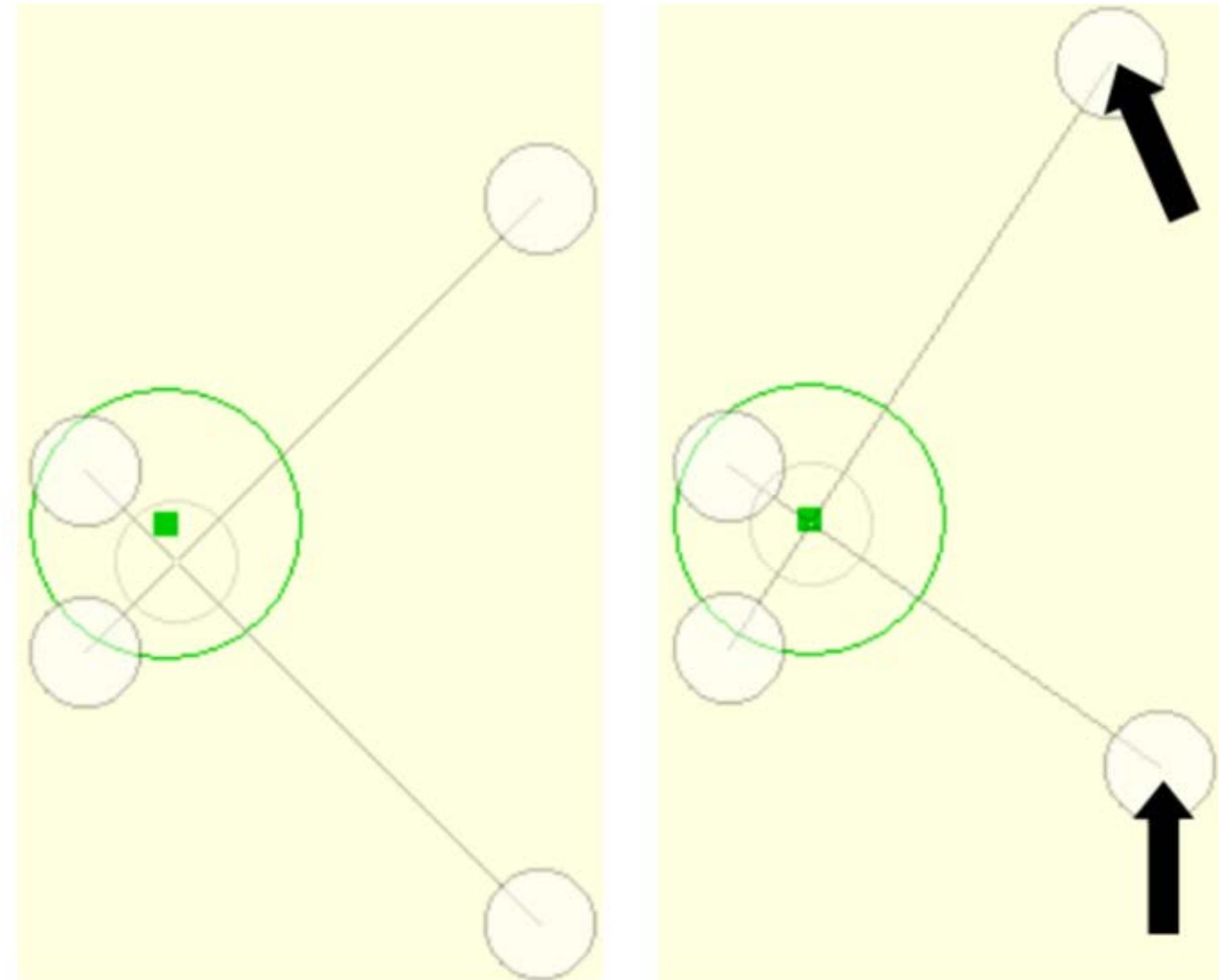
strategies: touch-down, first-contact, lift-off + **offset cursor**

[Potter et al. CHI '88]

okay, let's use cursors then...



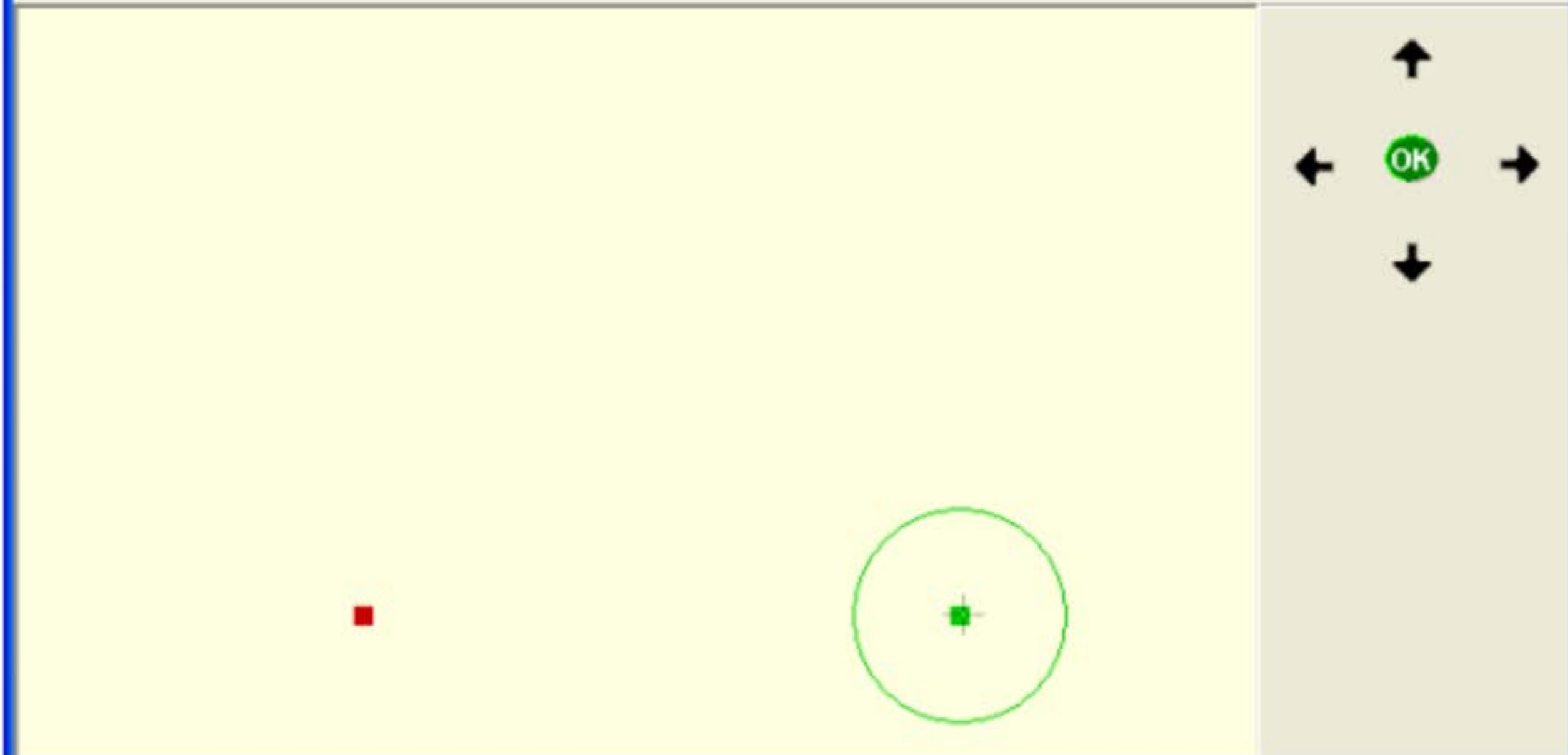
High precision touch screen interaction  
[Albinsson and Zhai, CHI '03]



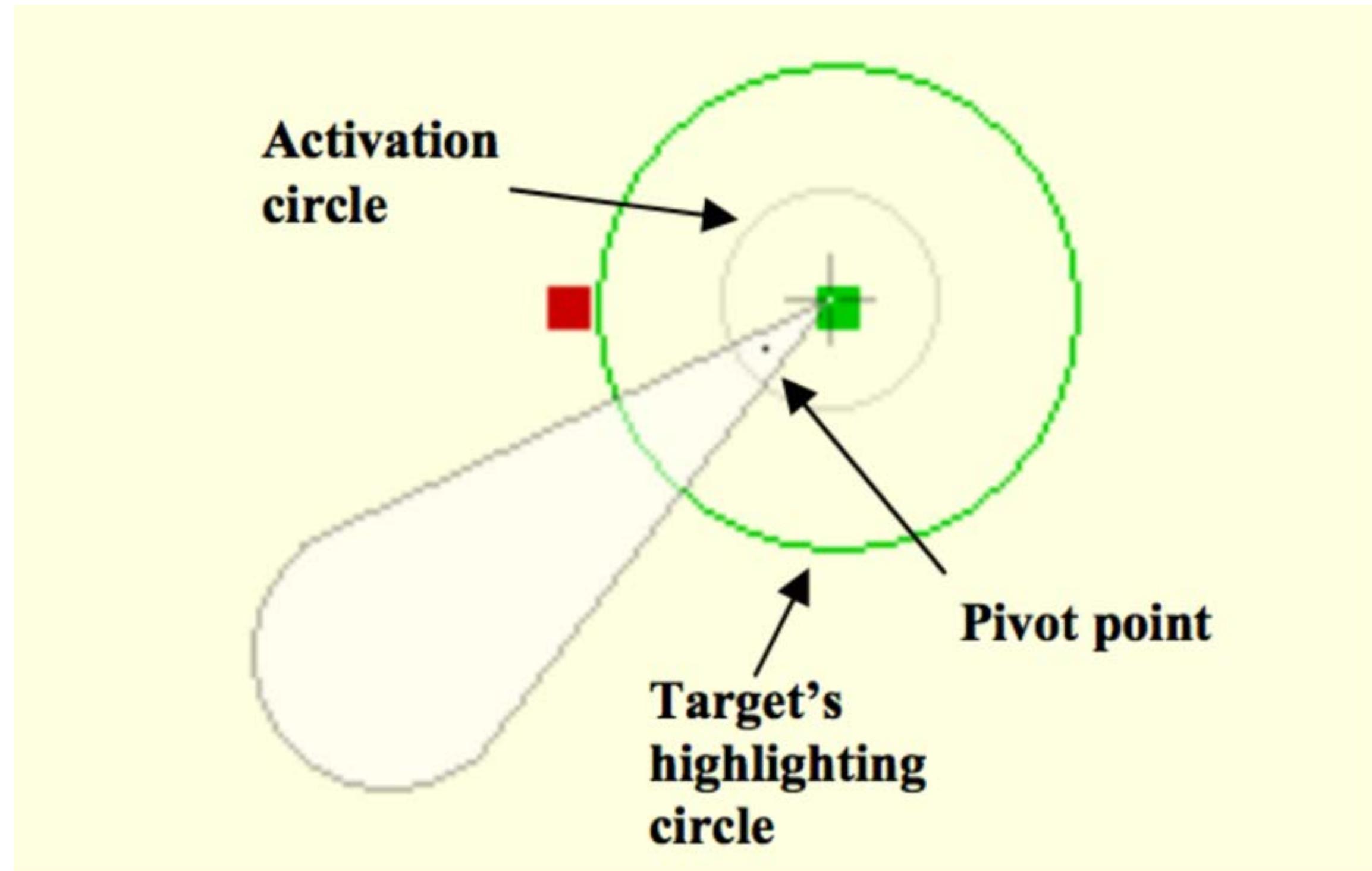
High precision touch screen interaction  
[Albinsson and Zhai, CHI '03]

# Touch Screen Pointing Test

Experiment Settings



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



# High precision touch screen interaction

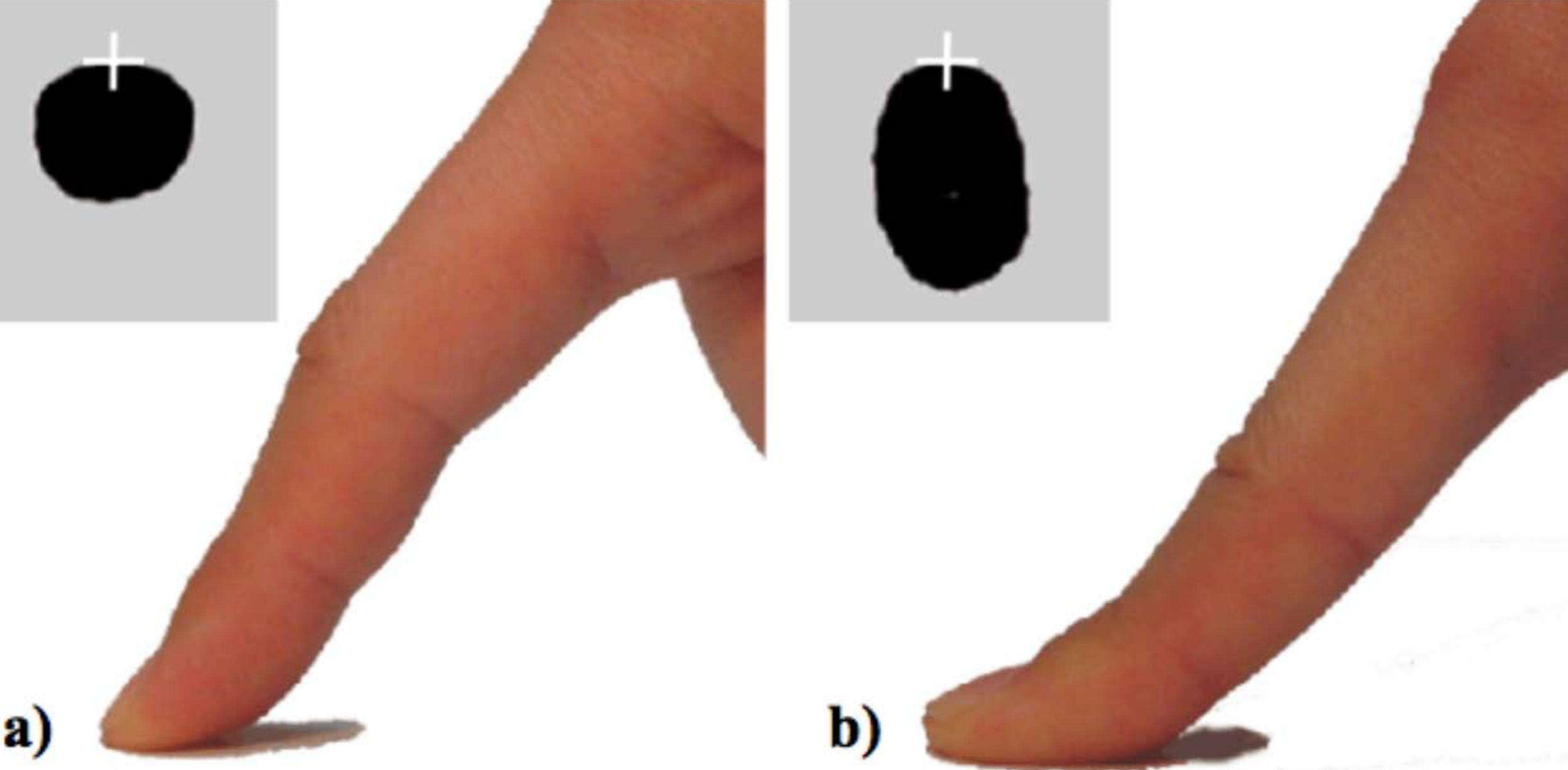
[Albinsson and Zhai, CHI '03]

# Precise Selection Techniques

[Benko et al., CHI '06]

# Precise Selection Techniques

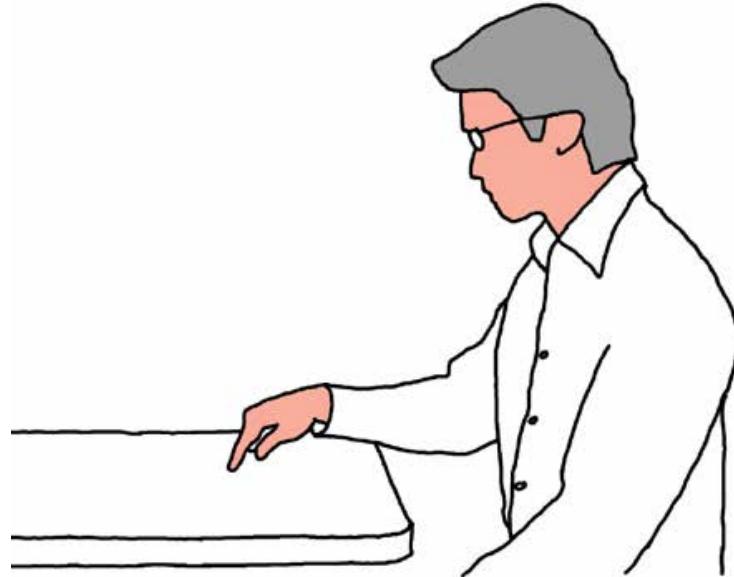
[Benko et al., CHI '06]



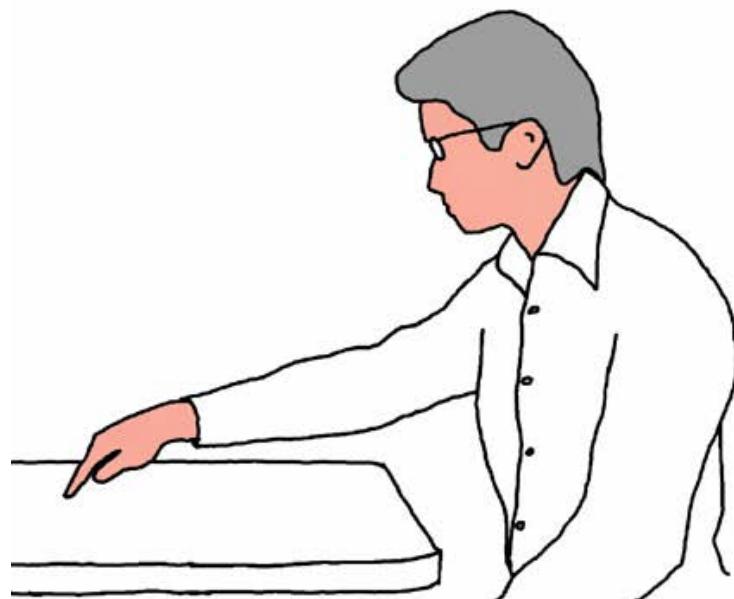
# Precise Selection Techniques

[Benko et al., CHI '06]

vertical finger pitch

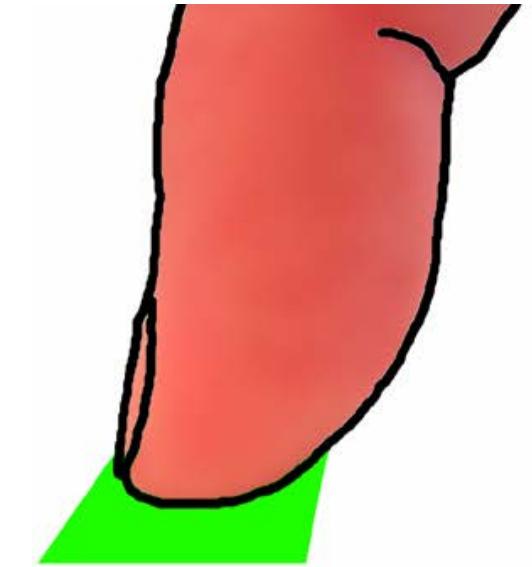


flat finger pitch

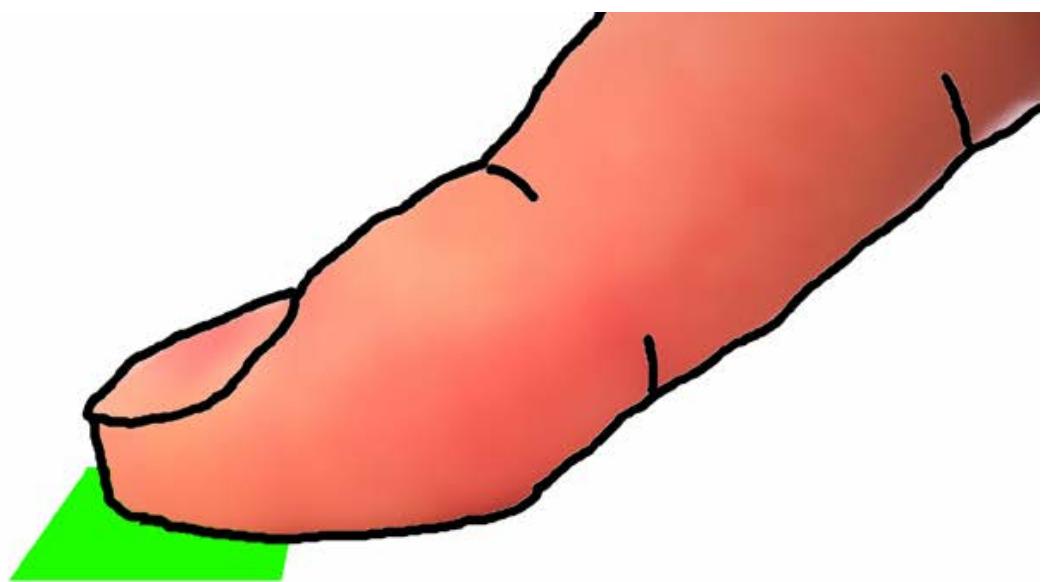


Direct-touch vs. mouse input

[Forlines et al., CHI '07]



contact area



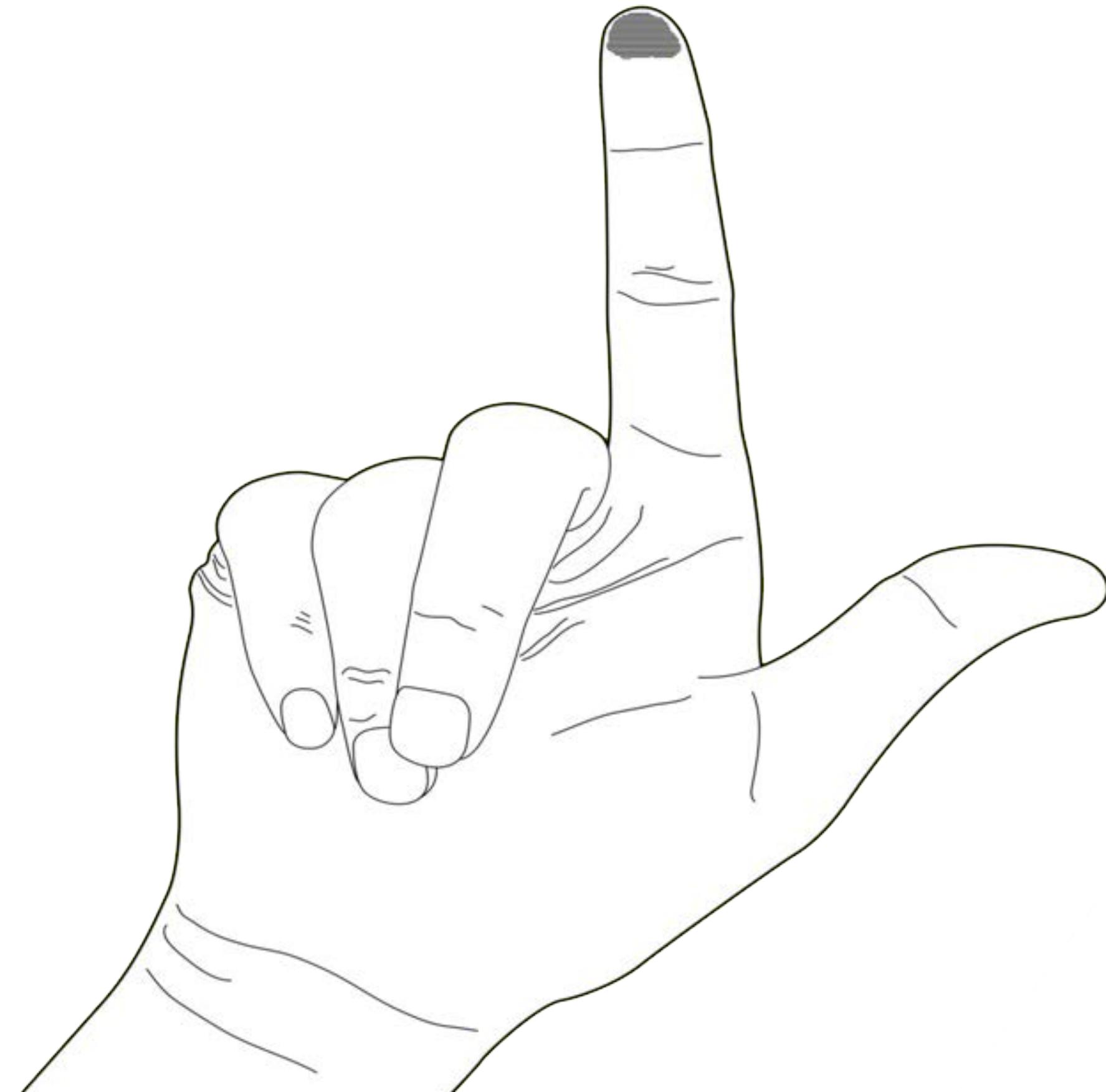
the culprit:

the **fat-finger** problem

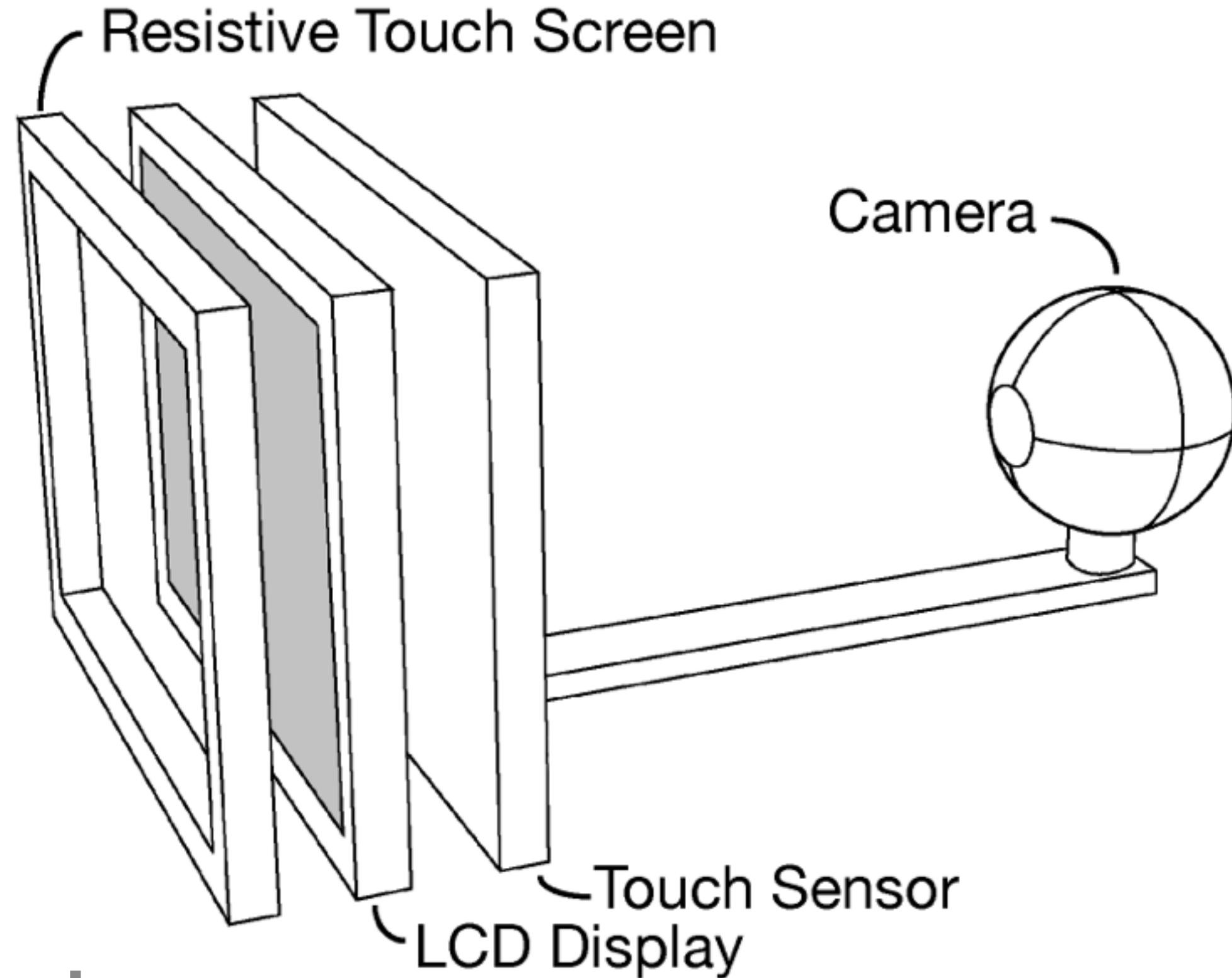
fat finger



**fat finger**

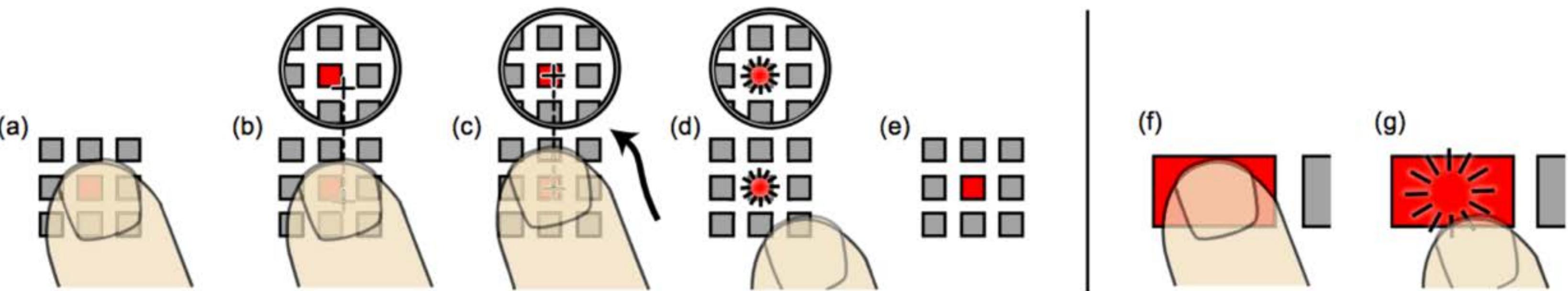


# LucidTouch



[Wigdor et al., CHI '07]





# Shift

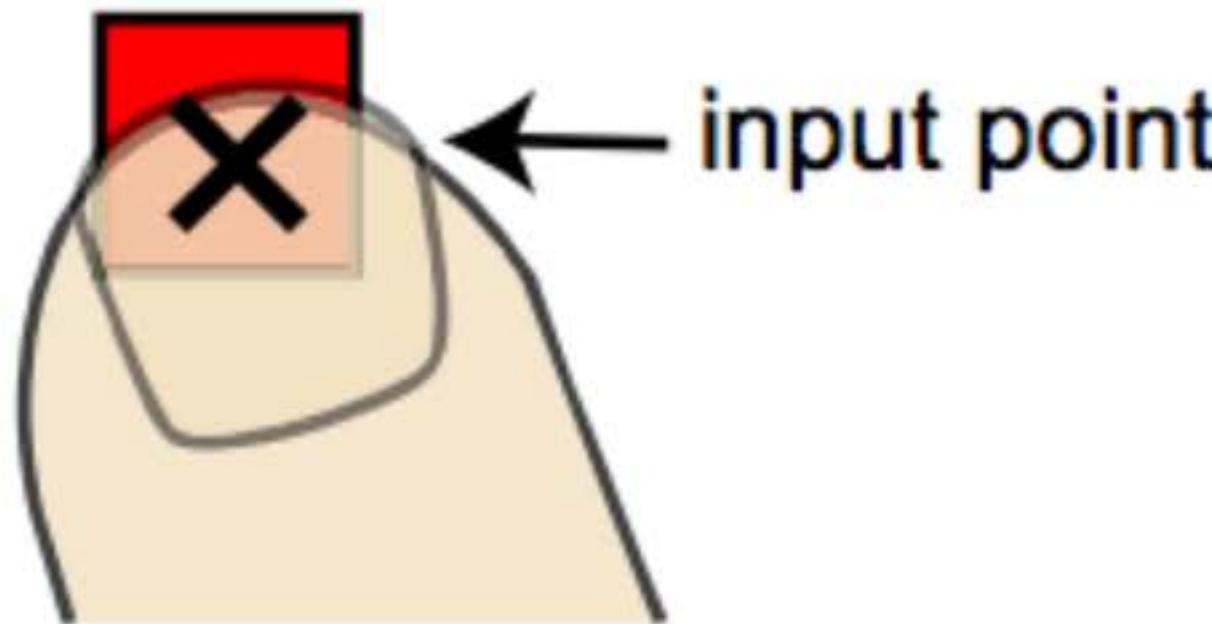
[Vogel and Baudisch, CHI '07]

why did you read this paper?  
30 second brainstorming

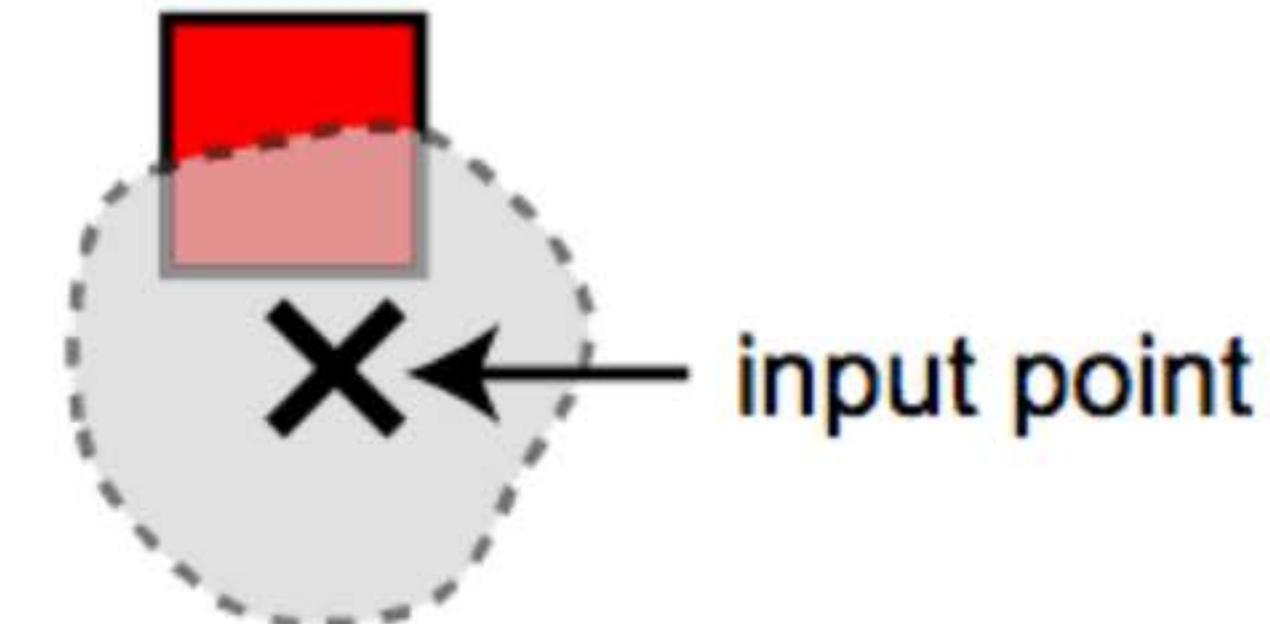
Shift

[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!



# which link am I selecting?

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

المرجع

Bahasa Indonesia

Bahasa Melayu

Български

Català

Česky

Dansk

Deutsch

Eesti

Ελληνικά

Español

Esperanto

Euskara

فارسی

Français

Galego

한국어

עברית

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, Madras had a population of 76,530 making it the second largest city in the Madras Presidency, next only to Madras?

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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

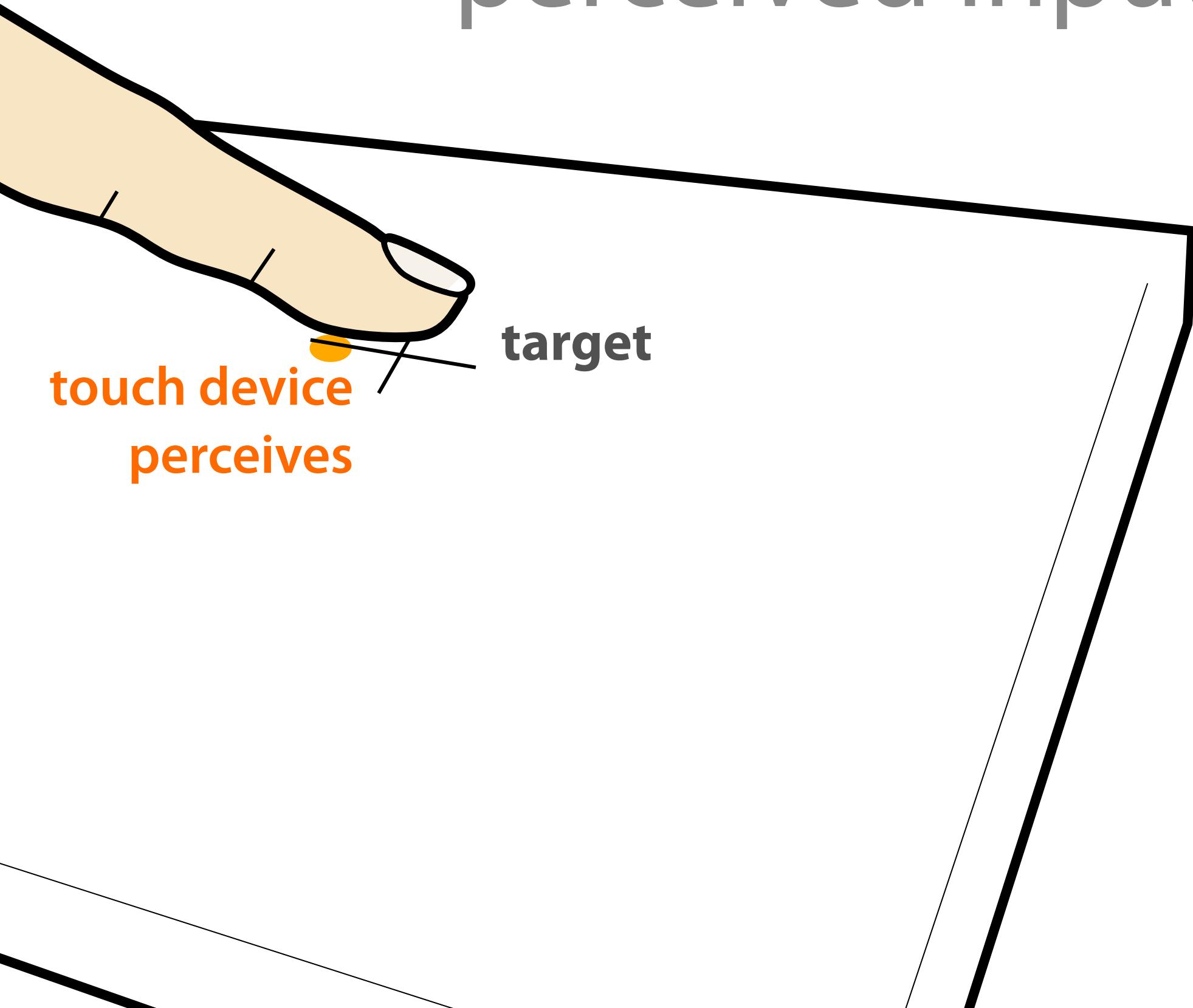
no fat finger  
problem

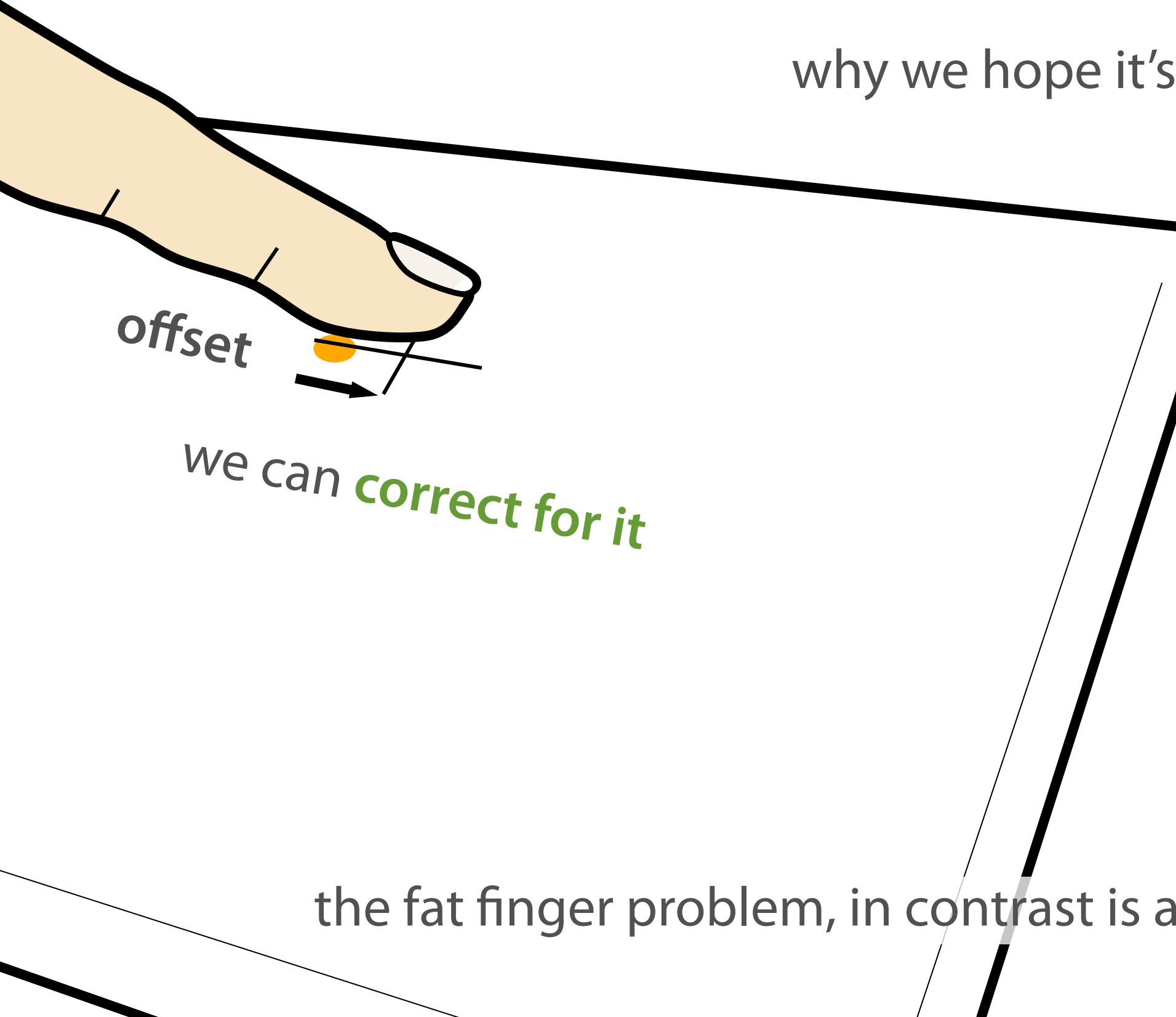
instead, almost all observed targeting error comes from

# perceived input point

problem

# perceived input point problem





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

offset

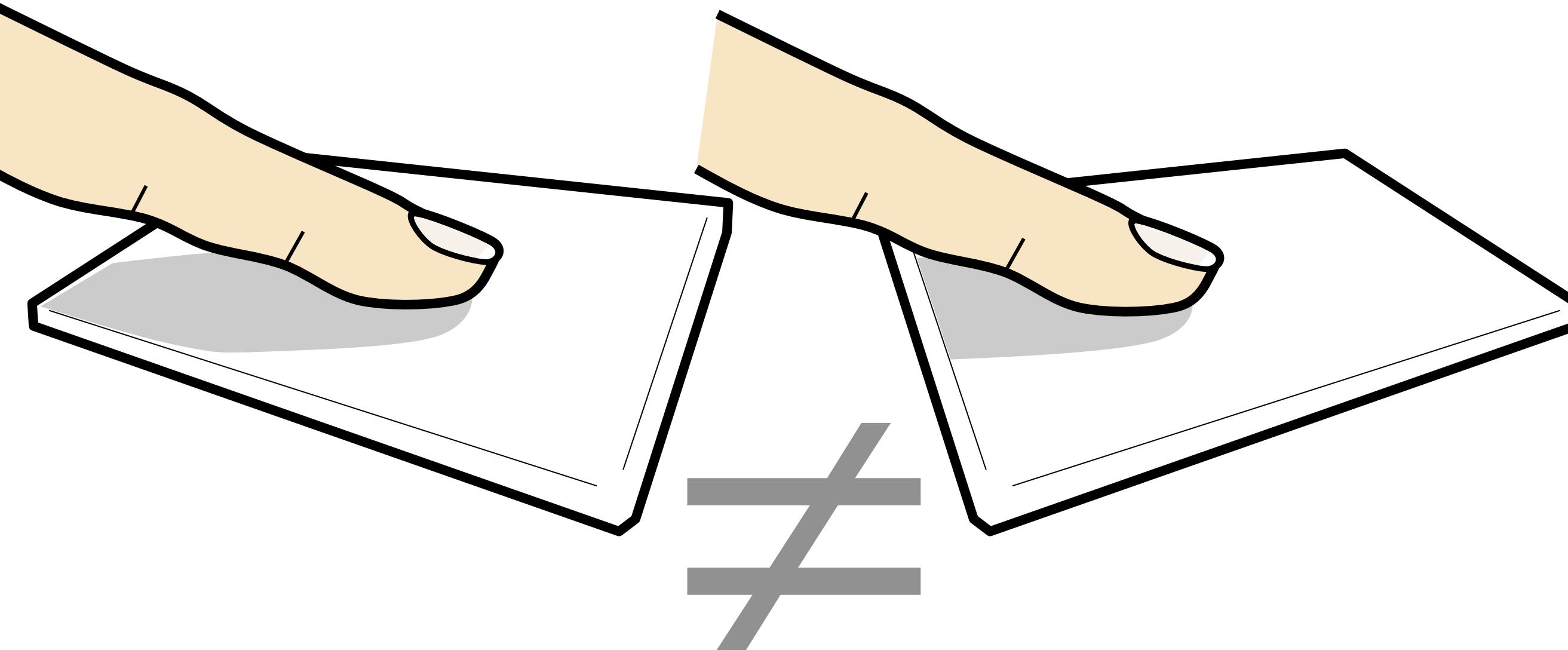
*we can correct for it*

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

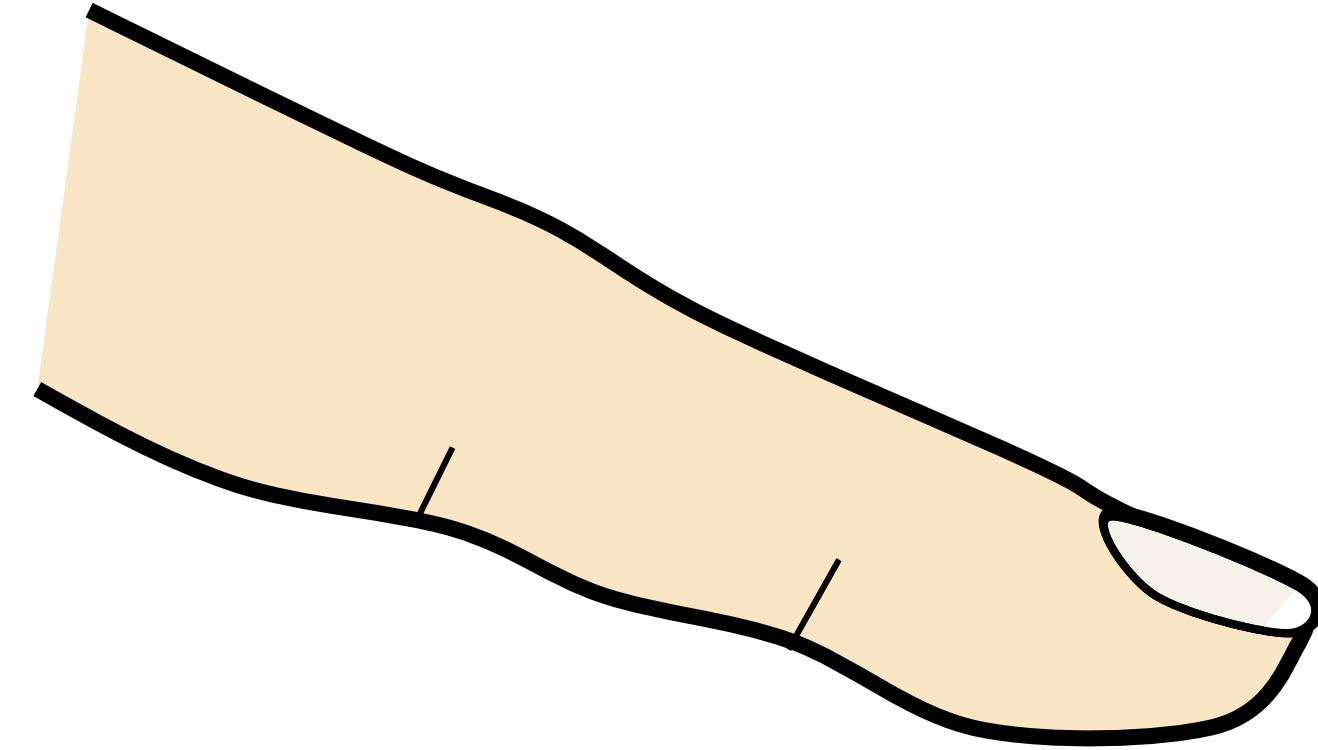
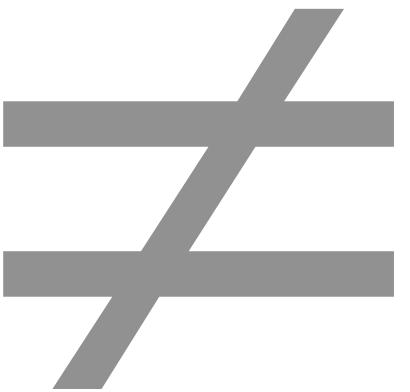
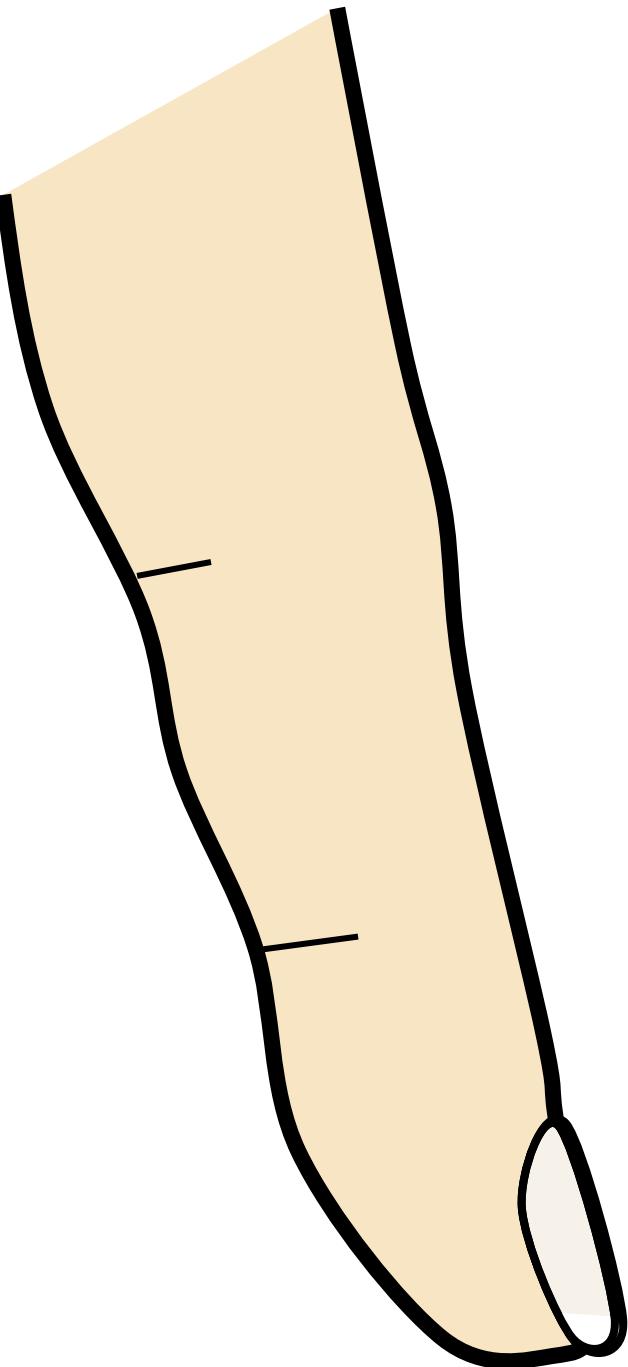
# our main hypothesis

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

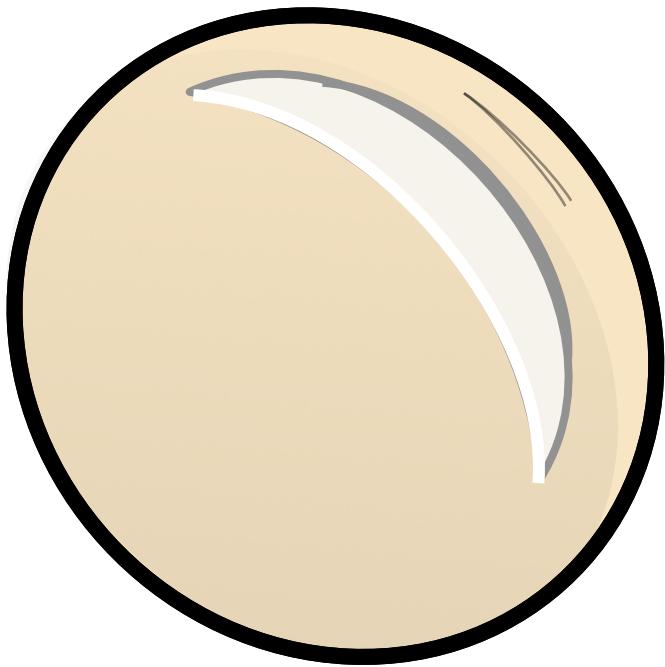
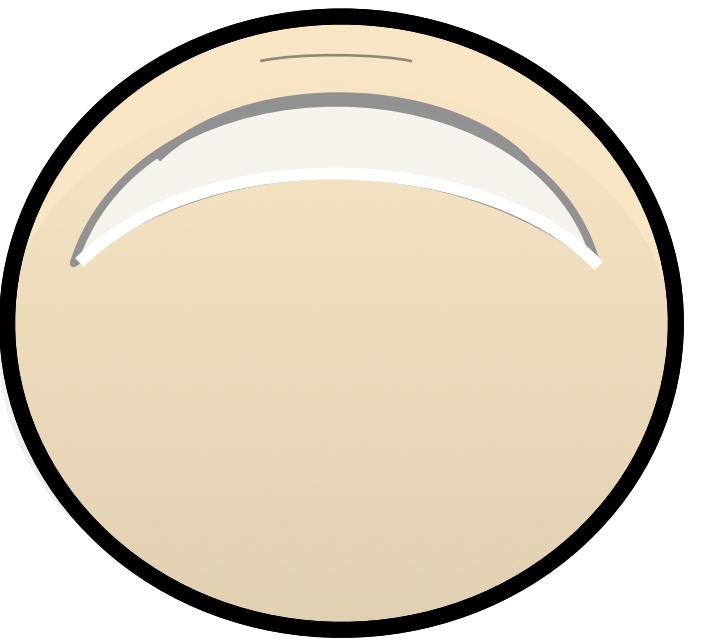
# 1 yaw



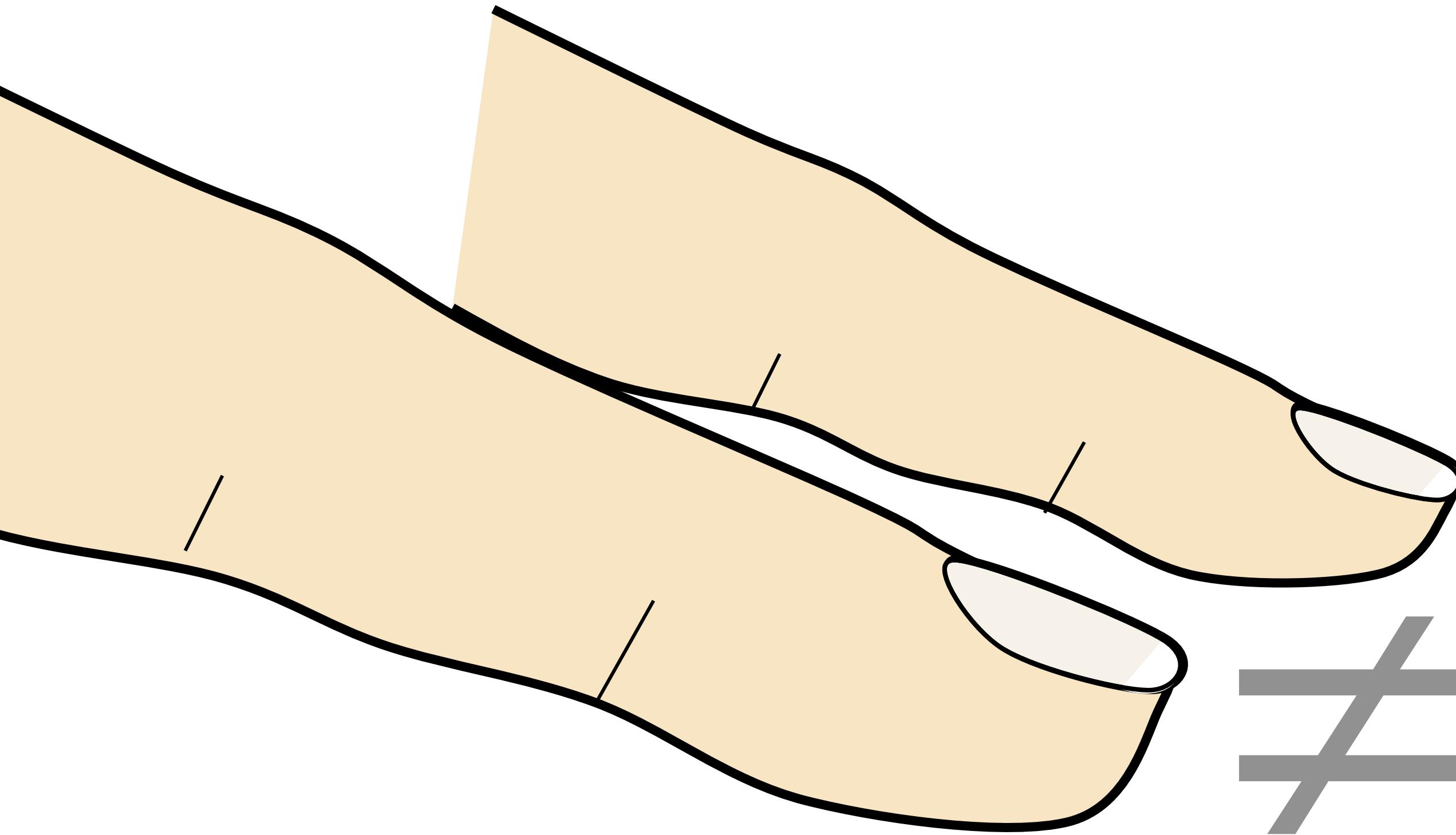
2 pitch



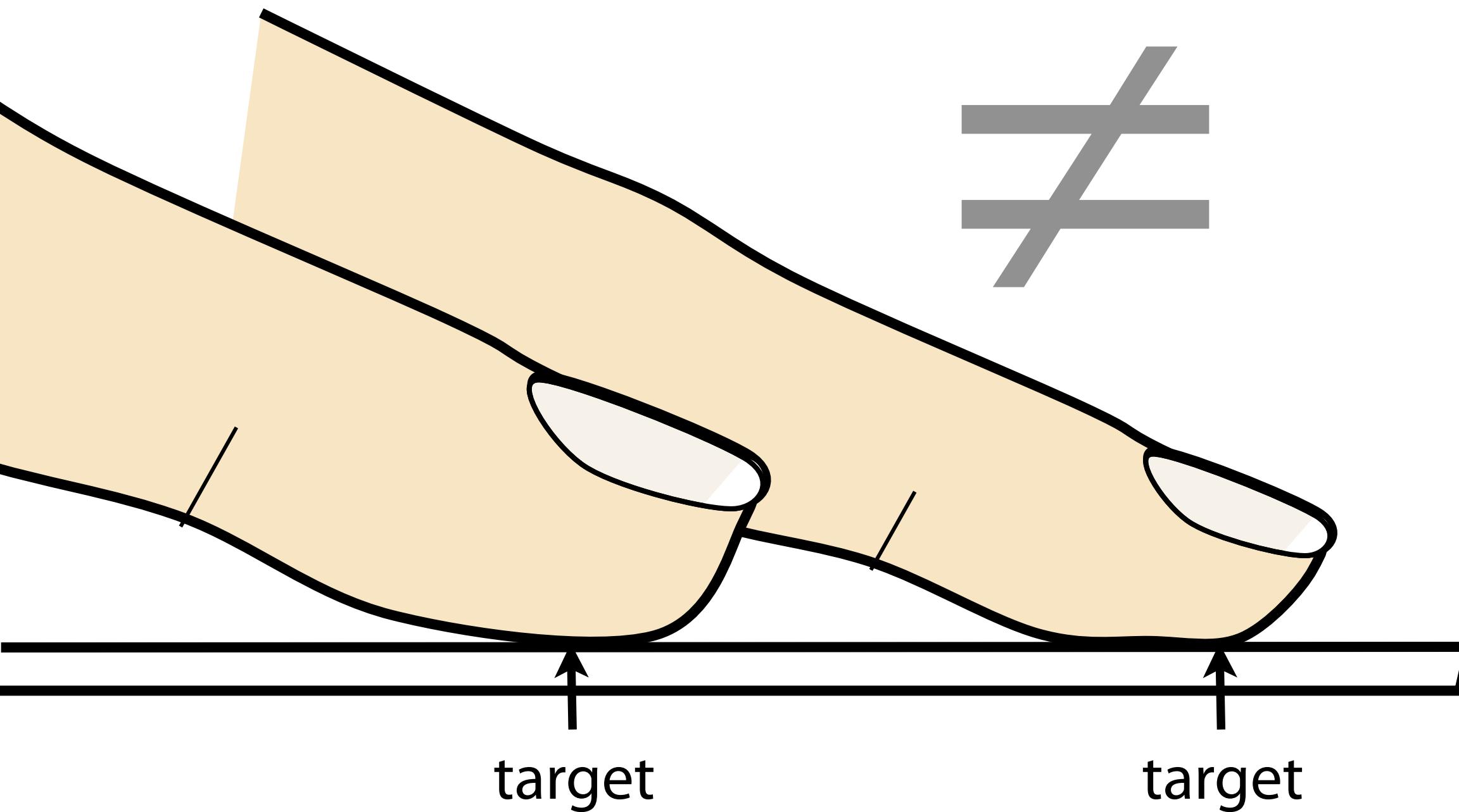
3 roll



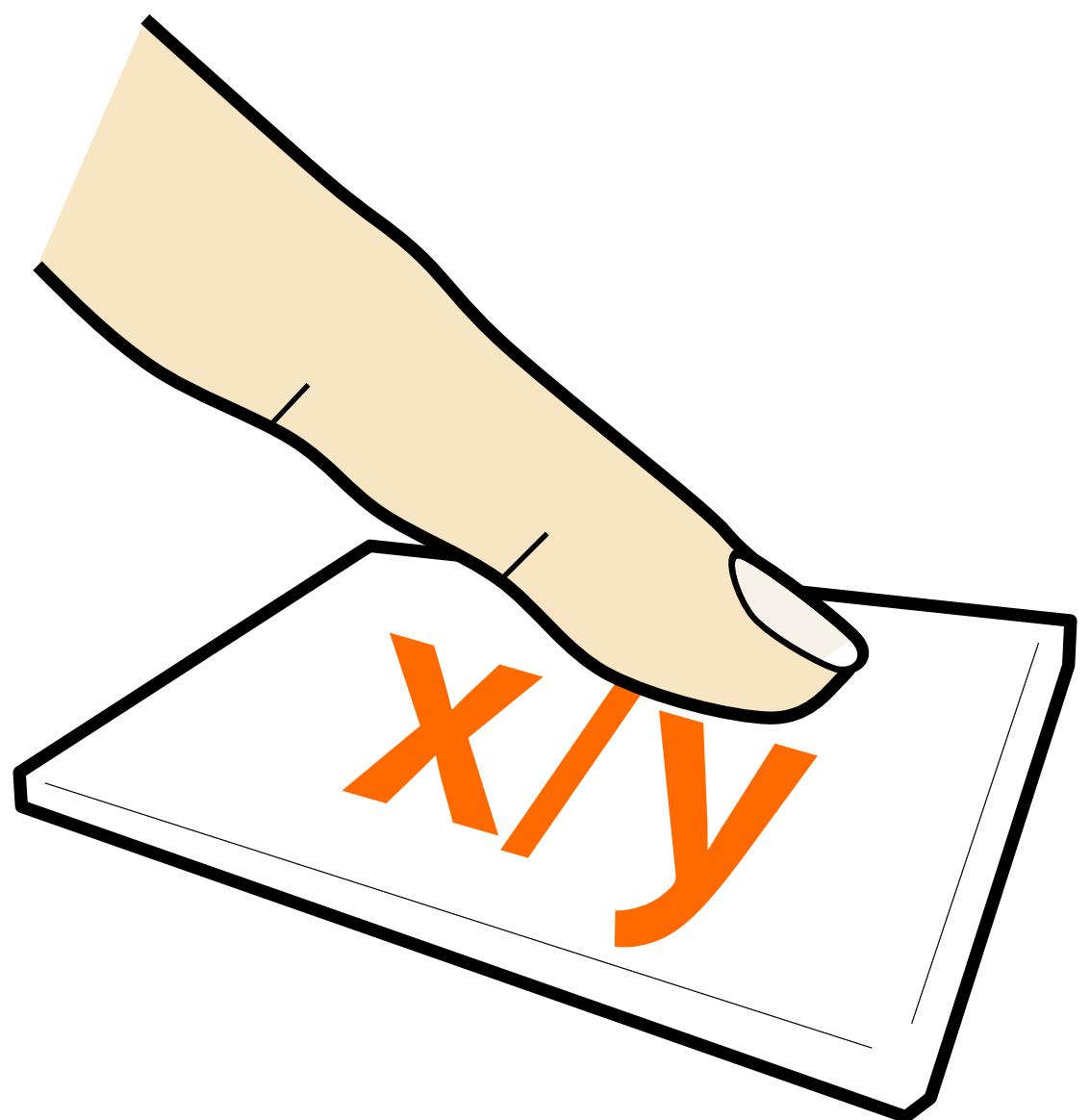
# 4 users: finger shape



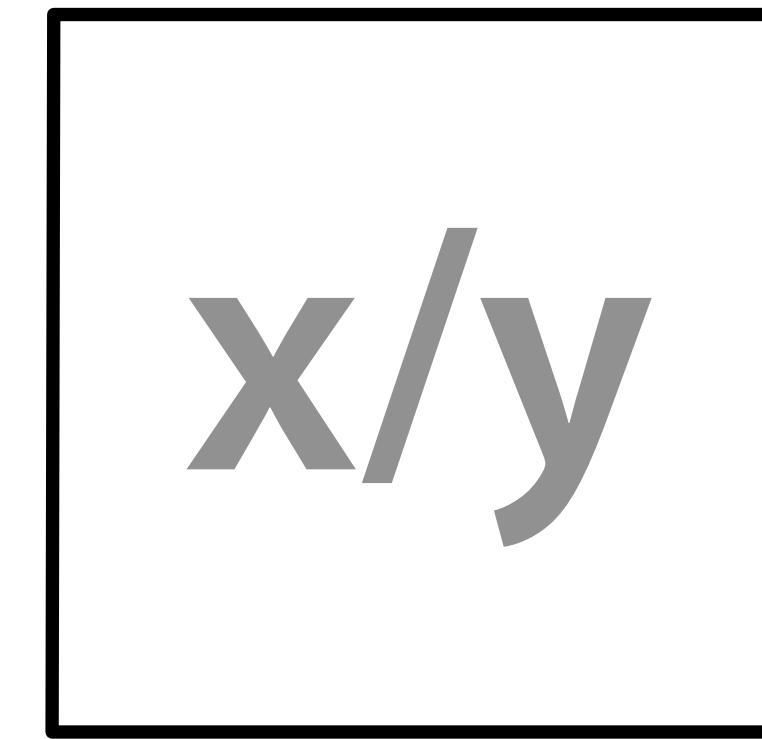
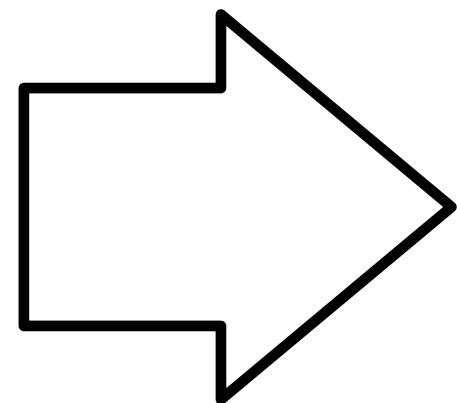
# 4 users: mental model



# current model

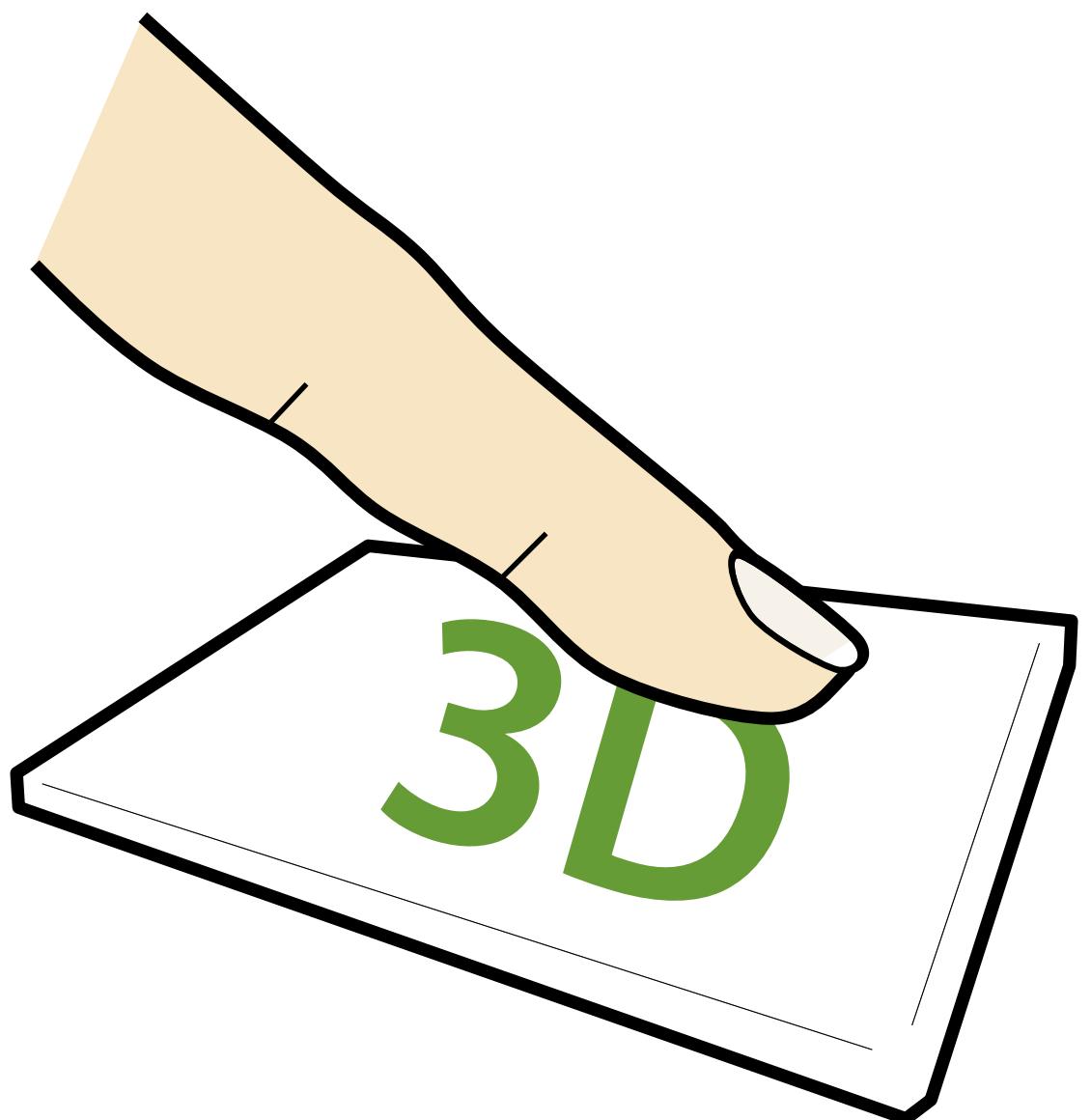


center of contact area

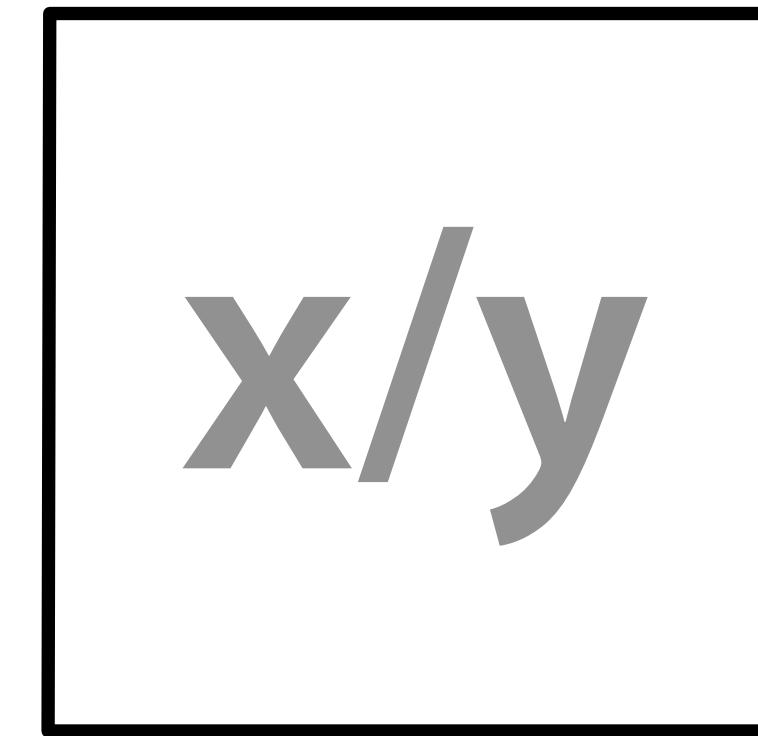
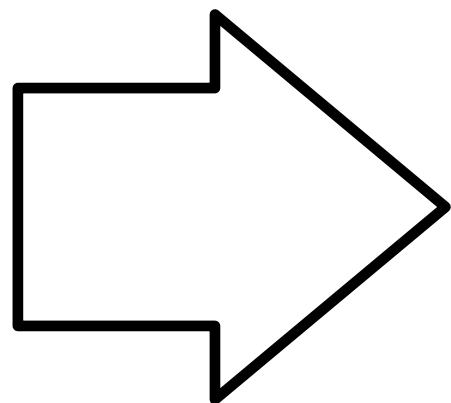


2D screen

# we propose



sensing the finger in 3D

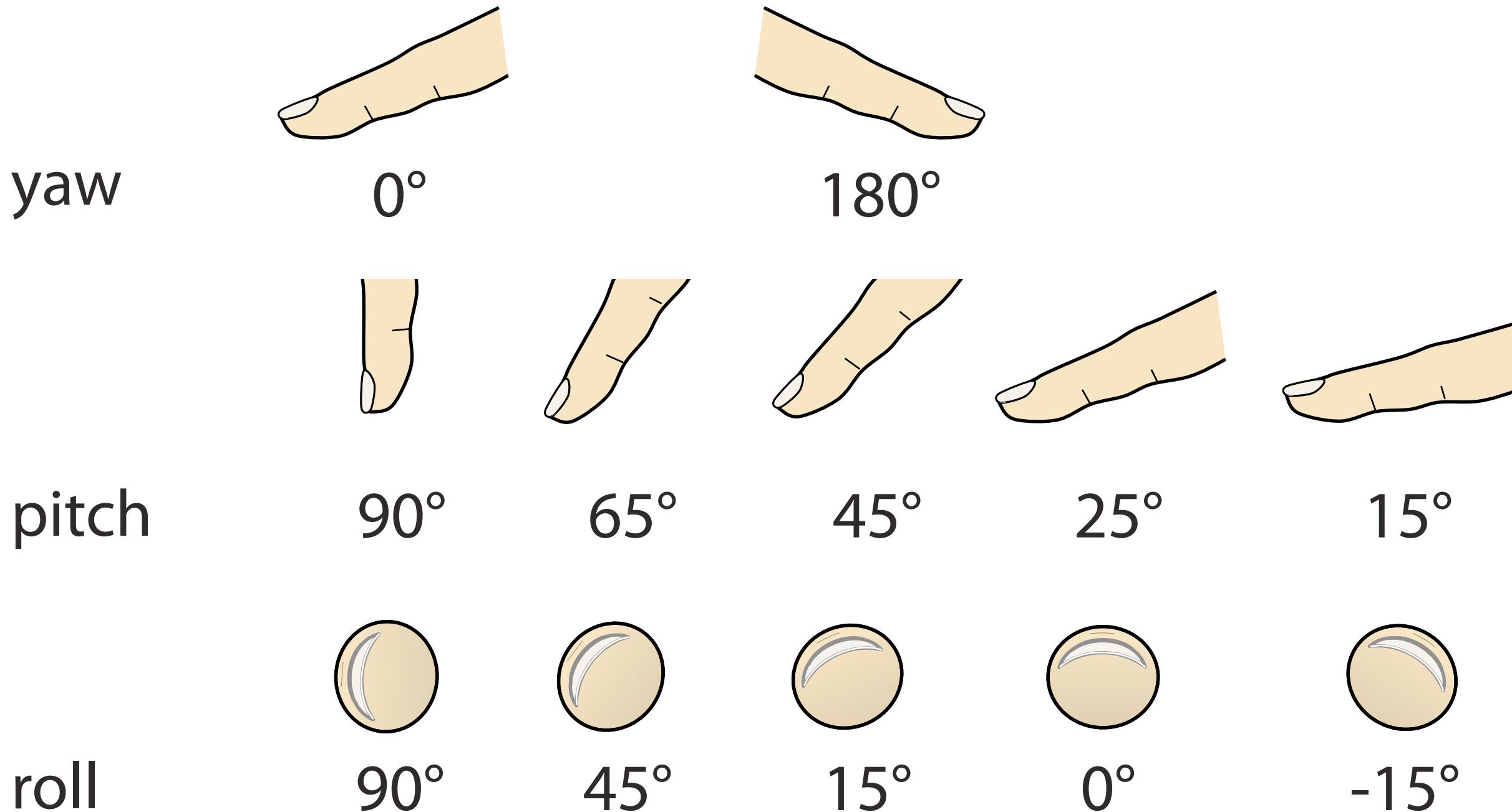


2D screen

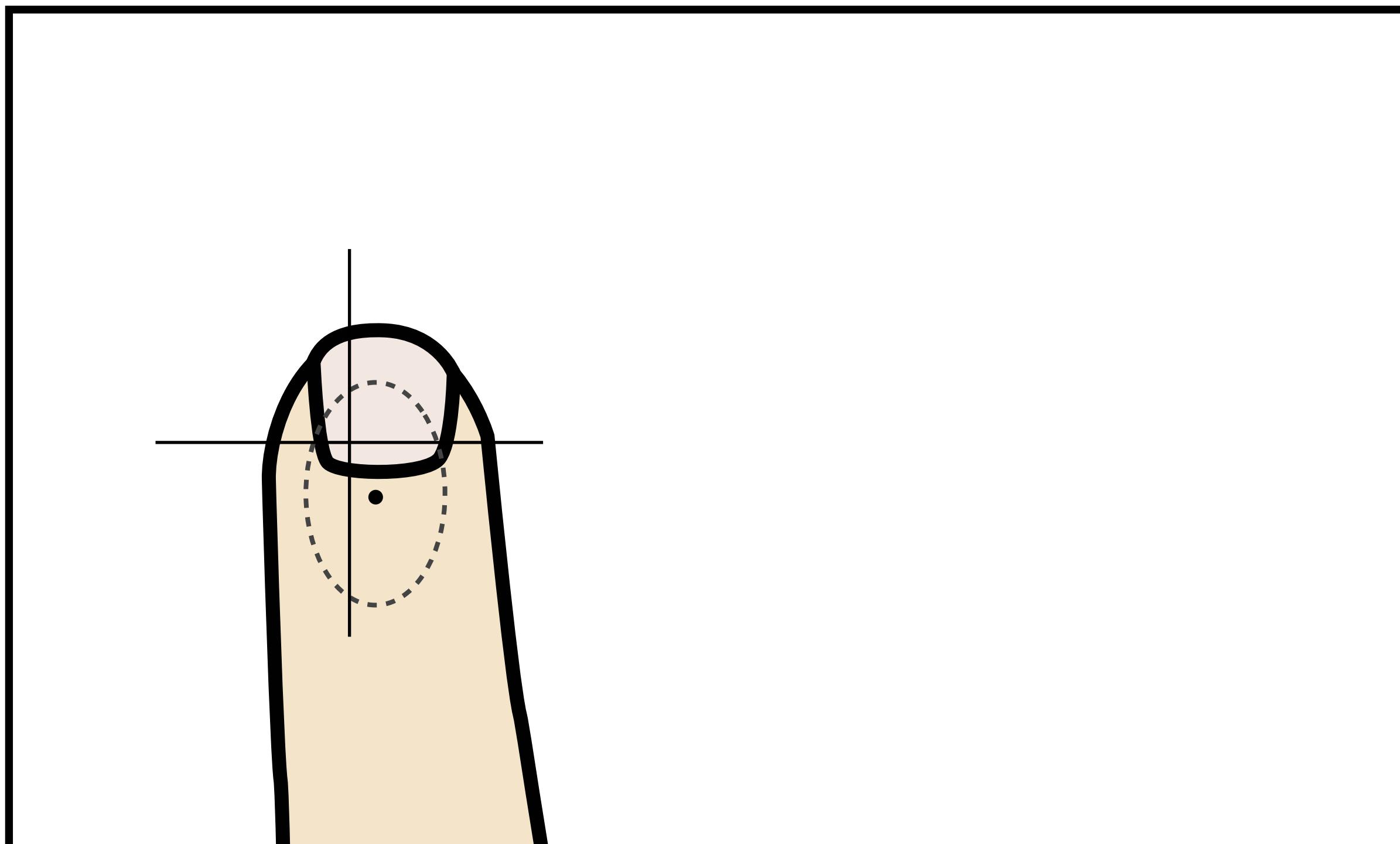


user study

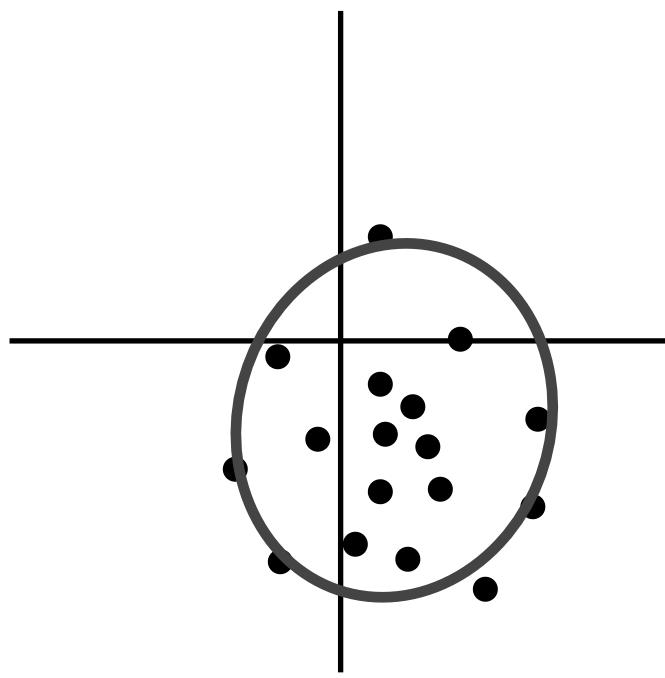
# independent variables



# error metric

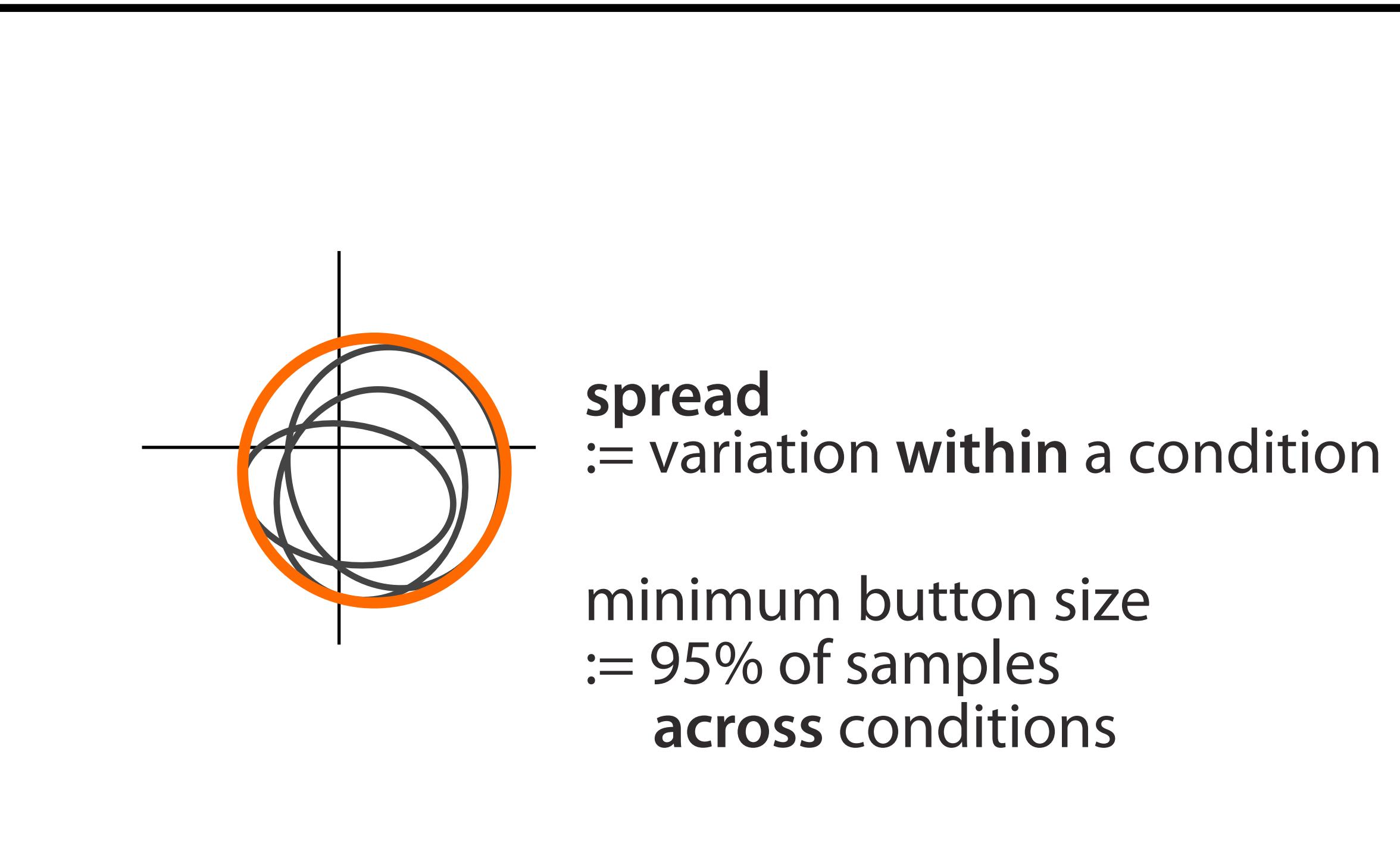


# error metric



**spread**  
:= variation within a condition

# error metric

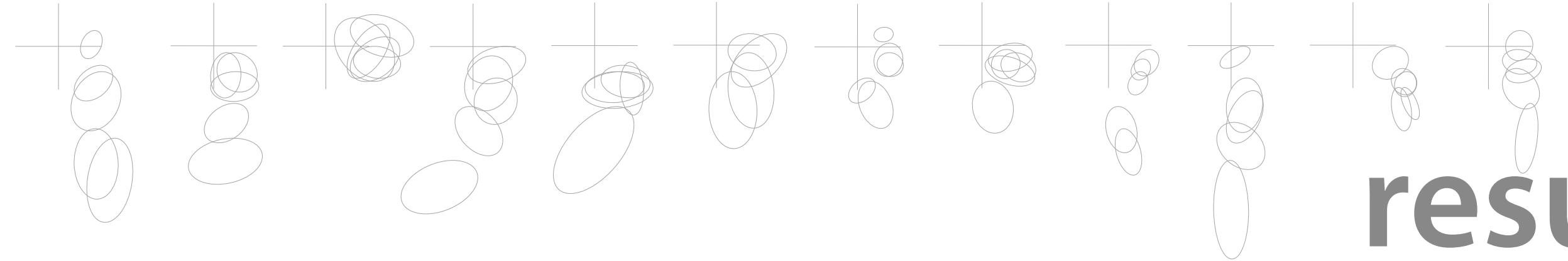
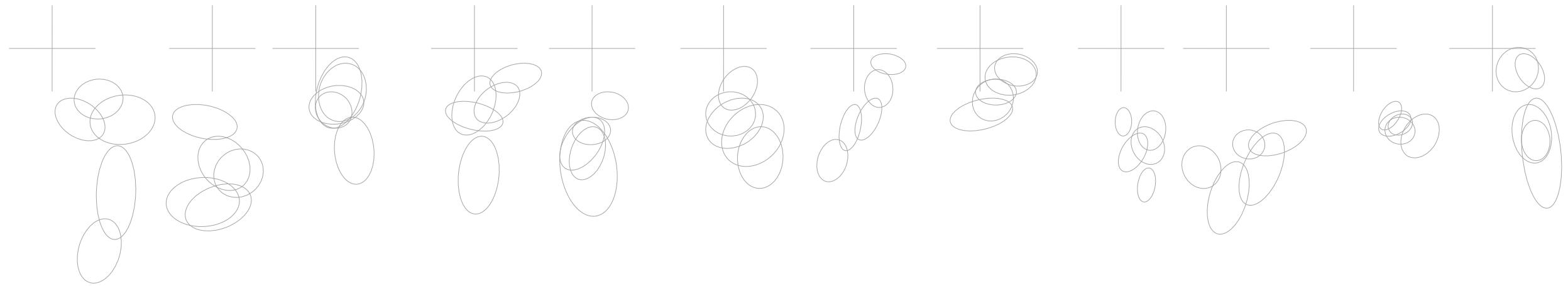


# study design

2 yaw  
× 2 sessions (pitch, roll)  
× 5 angles  
× 6 repetitions per angle  
× 5 blocks

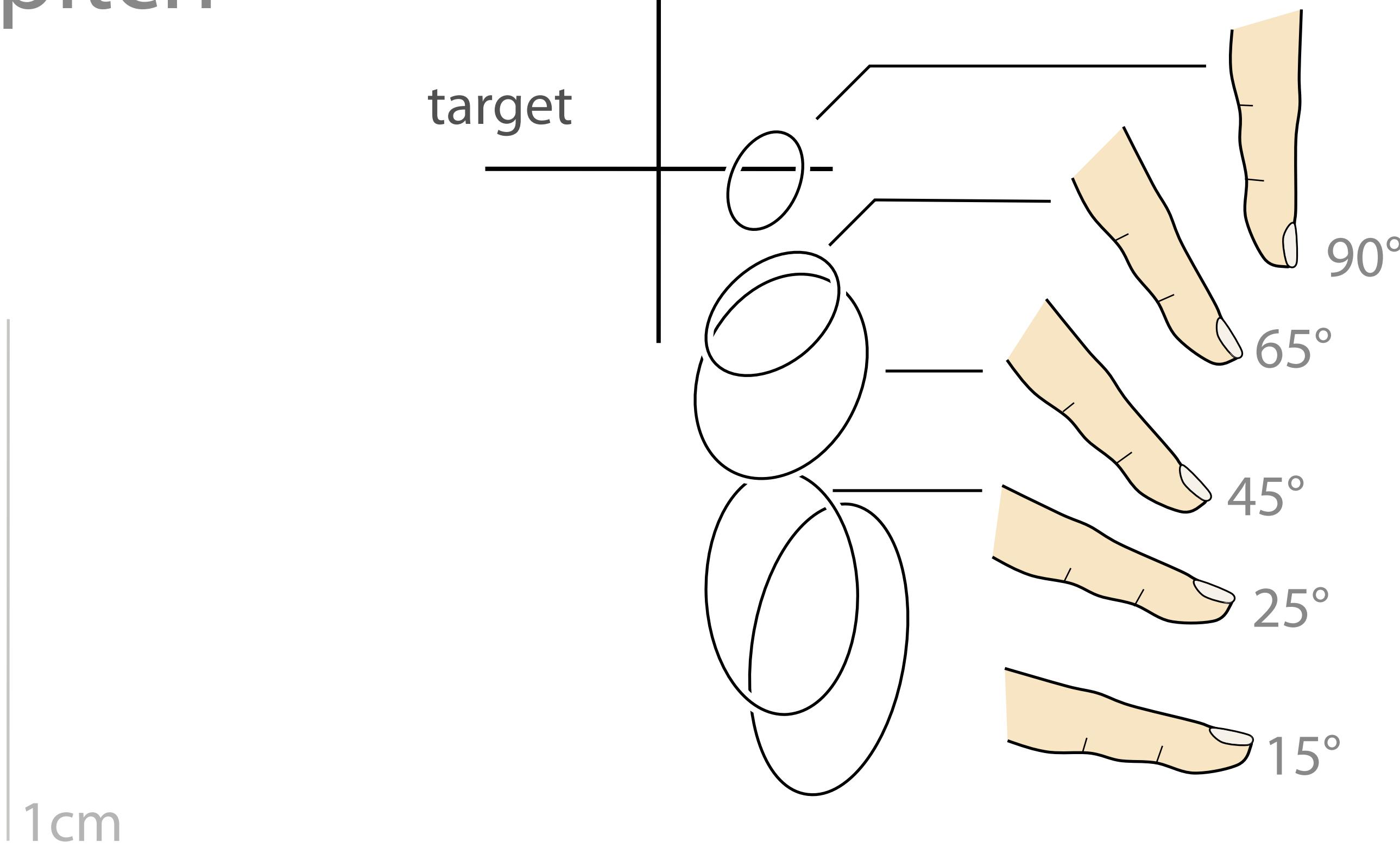
= 600 trials / participant

12 participants

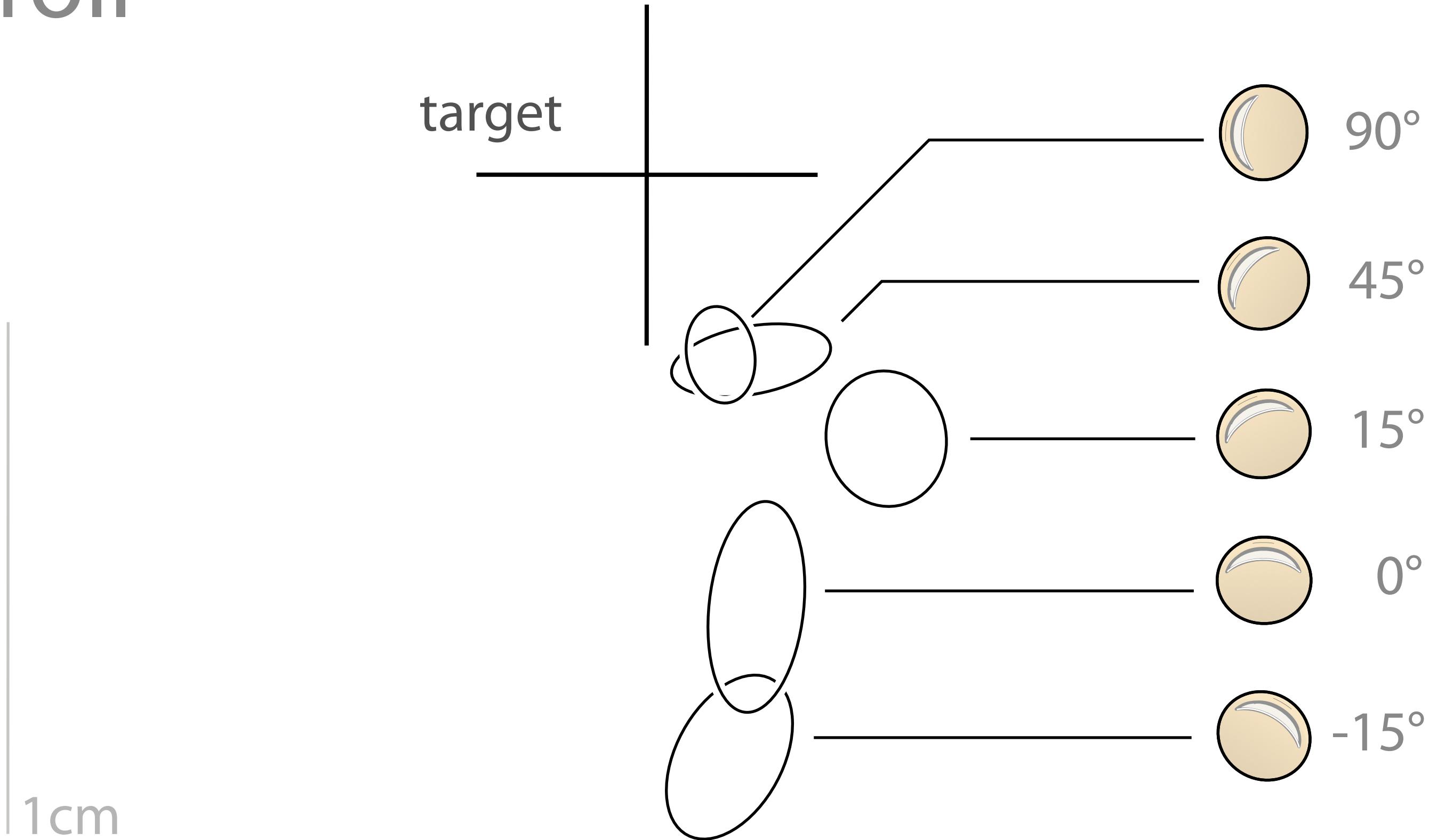


**results**

pitch

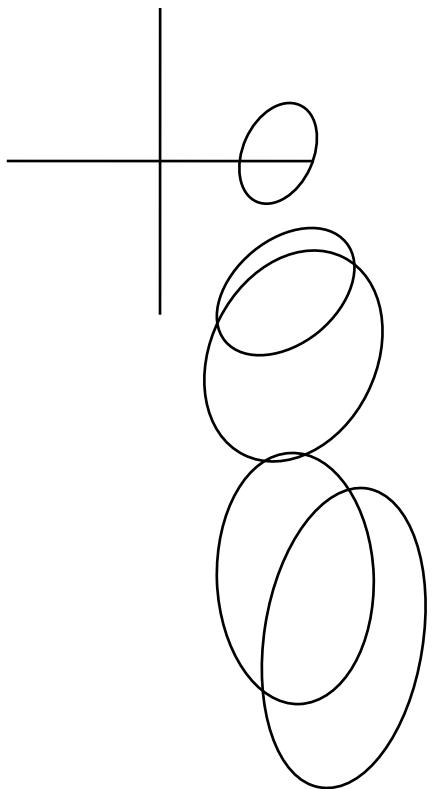


roll

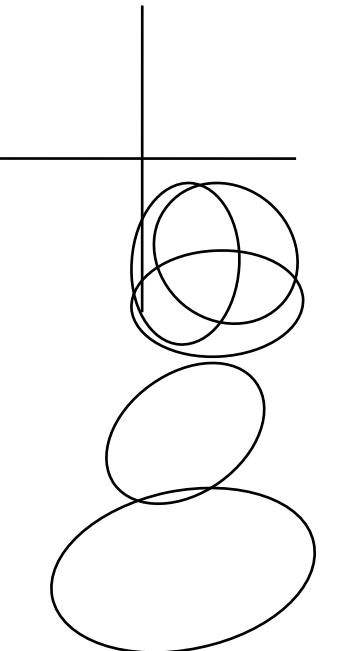


user

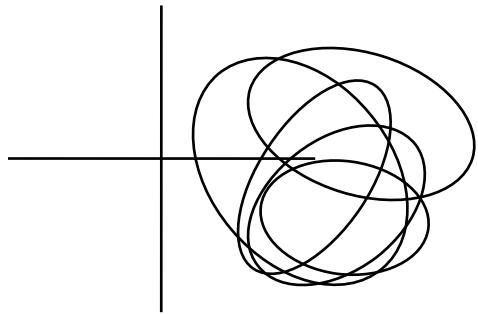
#1



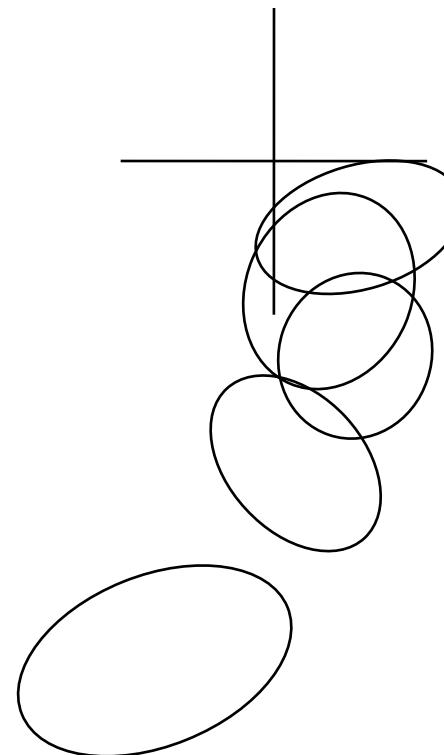
#2



#3



#4

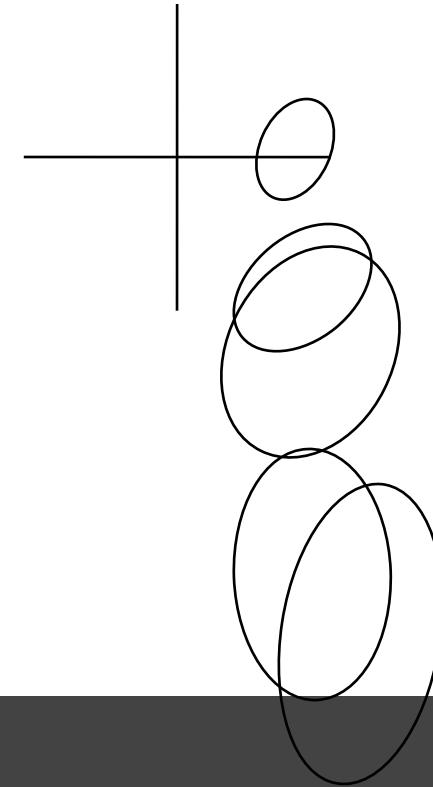


pitch

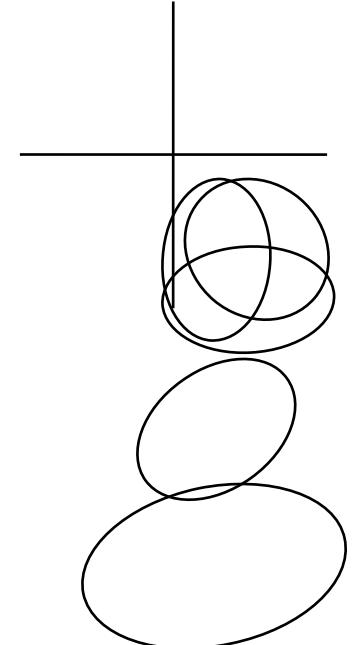
1cm

# user

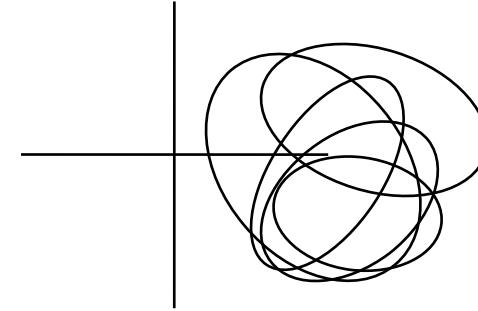
#1



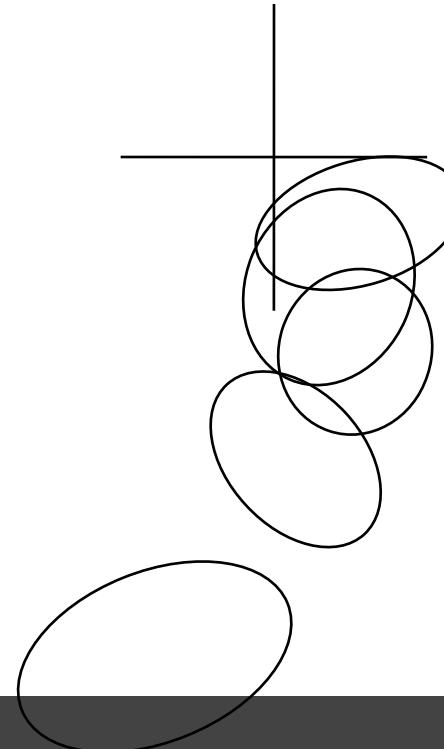
#2



#3



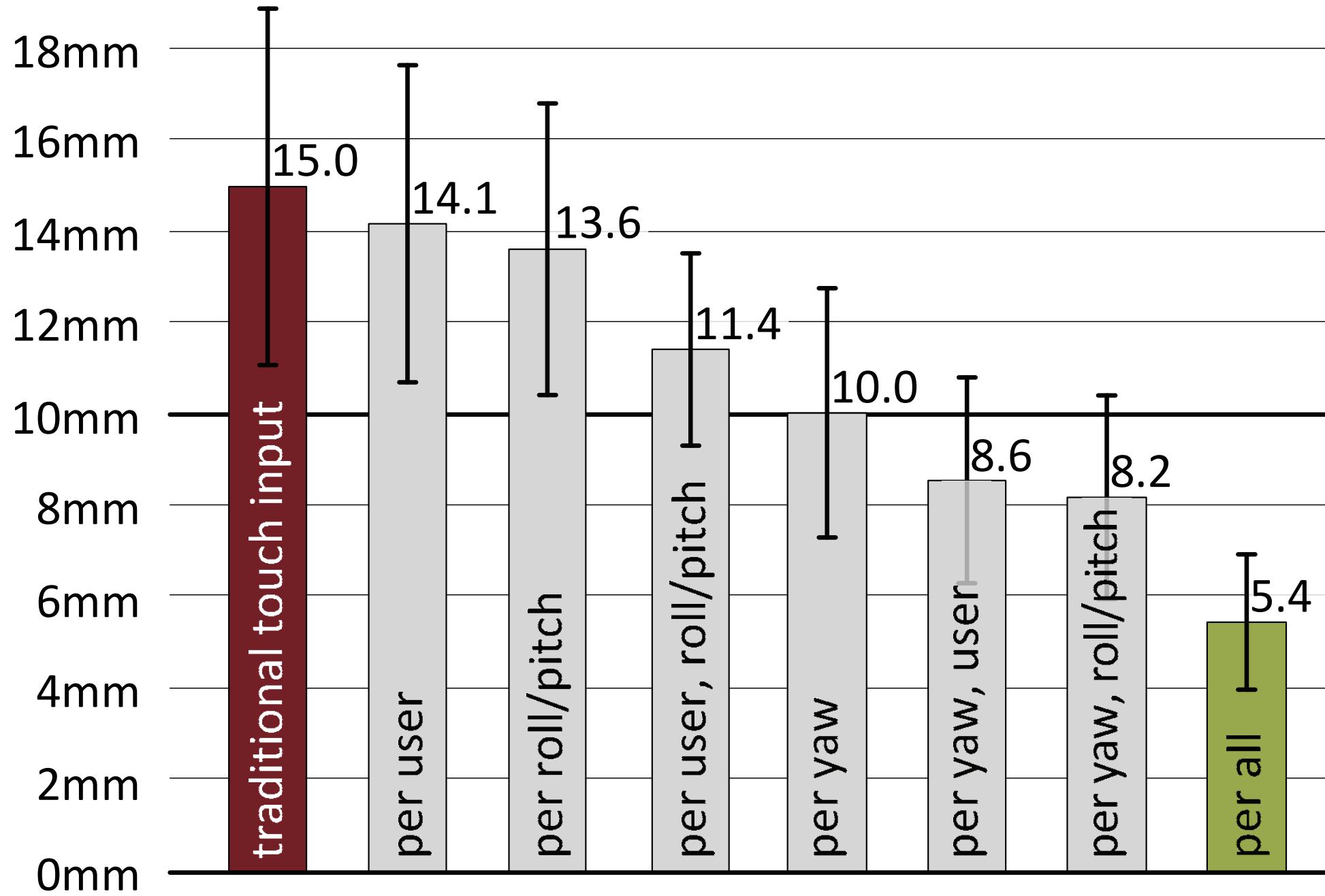
#4



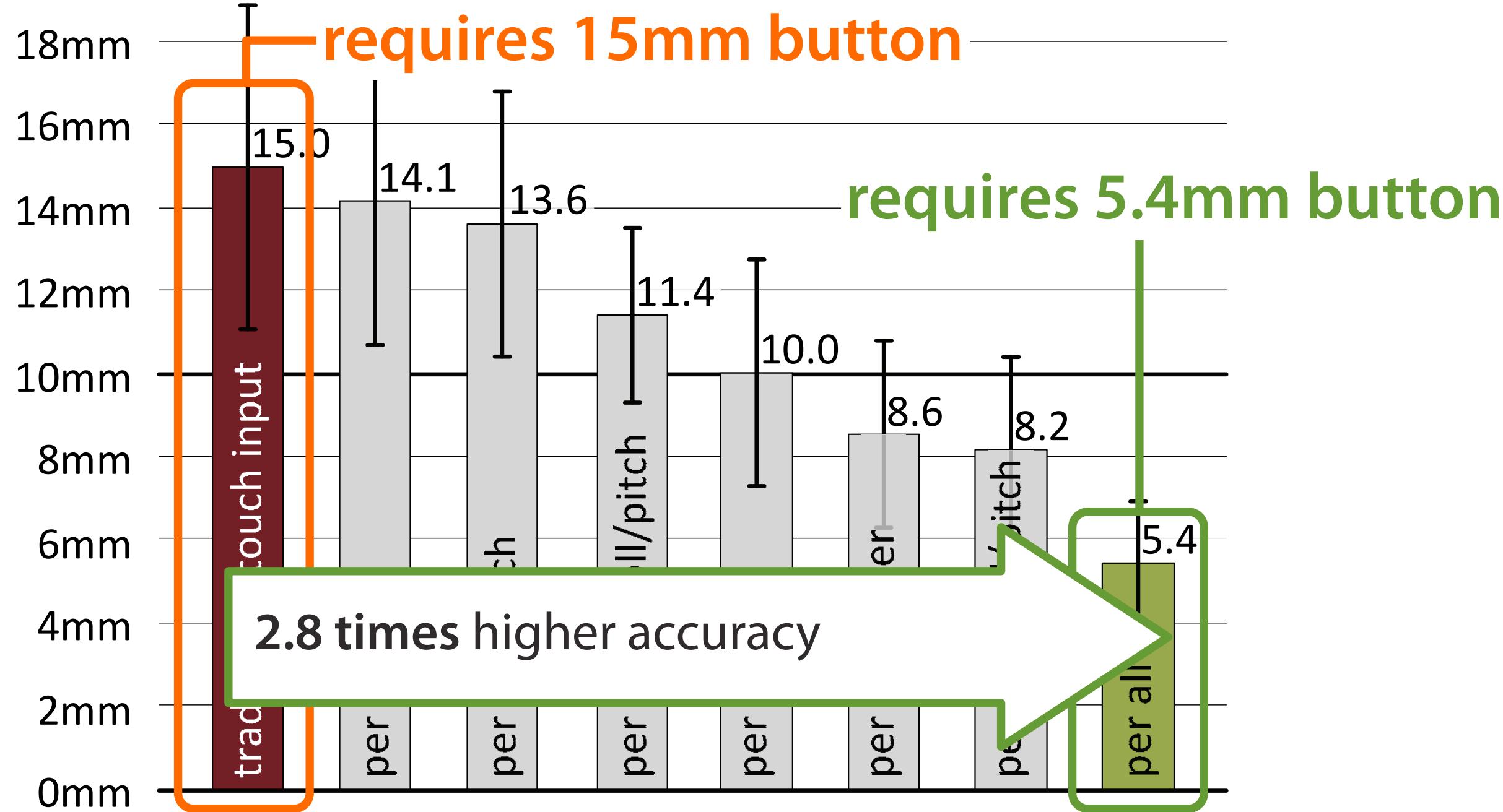
which user is the most accurate?  
30 second brainstorming  
pitch

1cm

# minimum button size



# minimum button size



can we make this real?

# Ridgepad

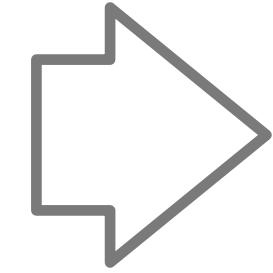
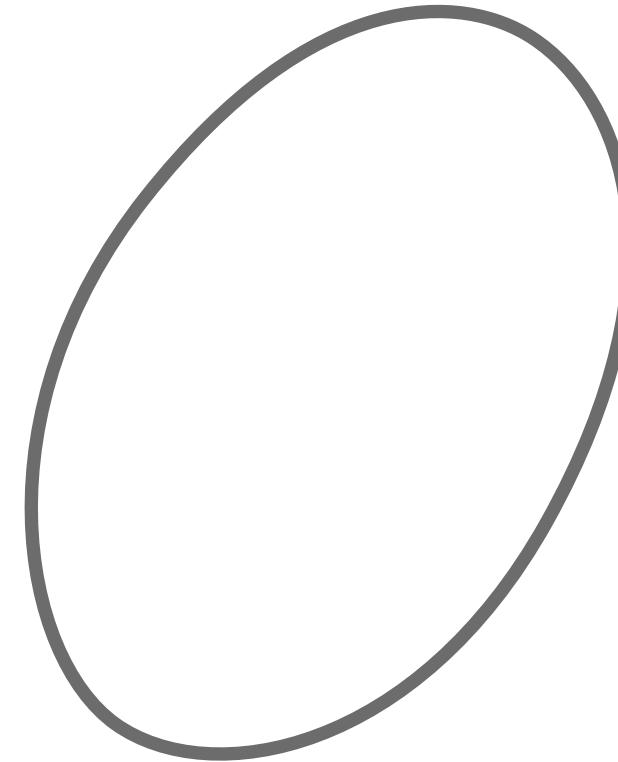
optical fingerprint scanner

500 dpi

1600 × 1500 pixels



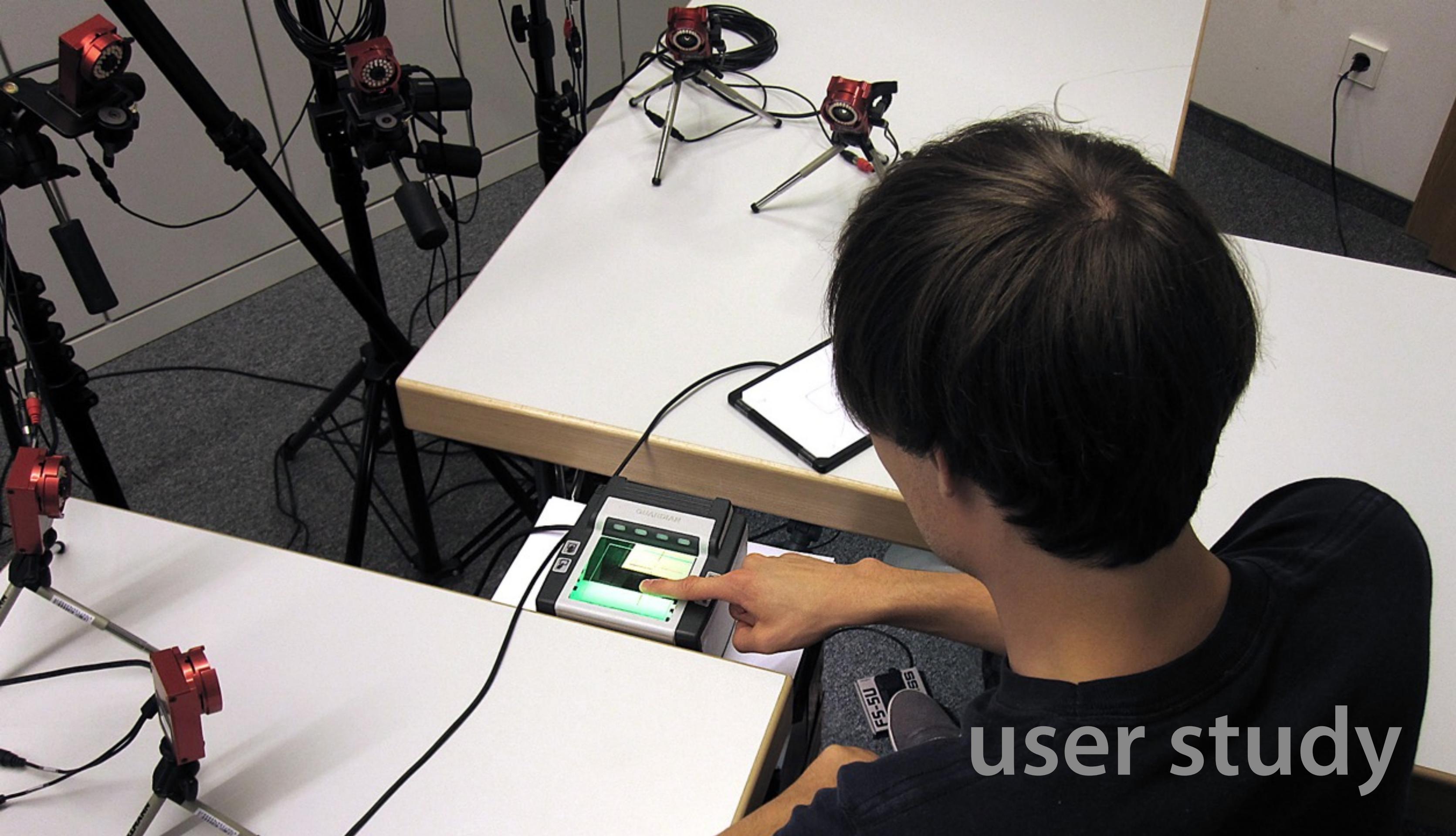
# touchpad vs. fingerprint scanner



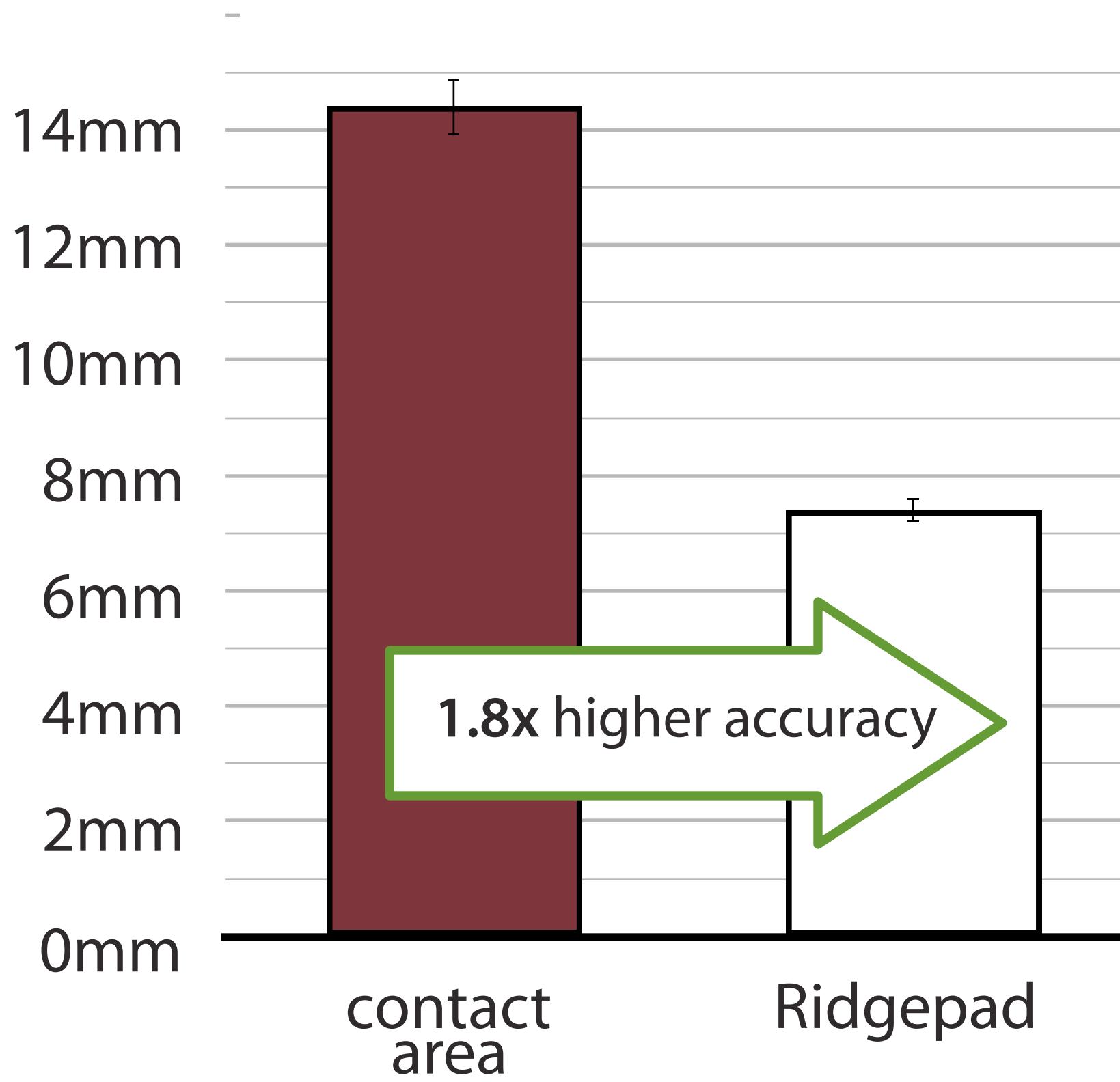
2D contact area

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

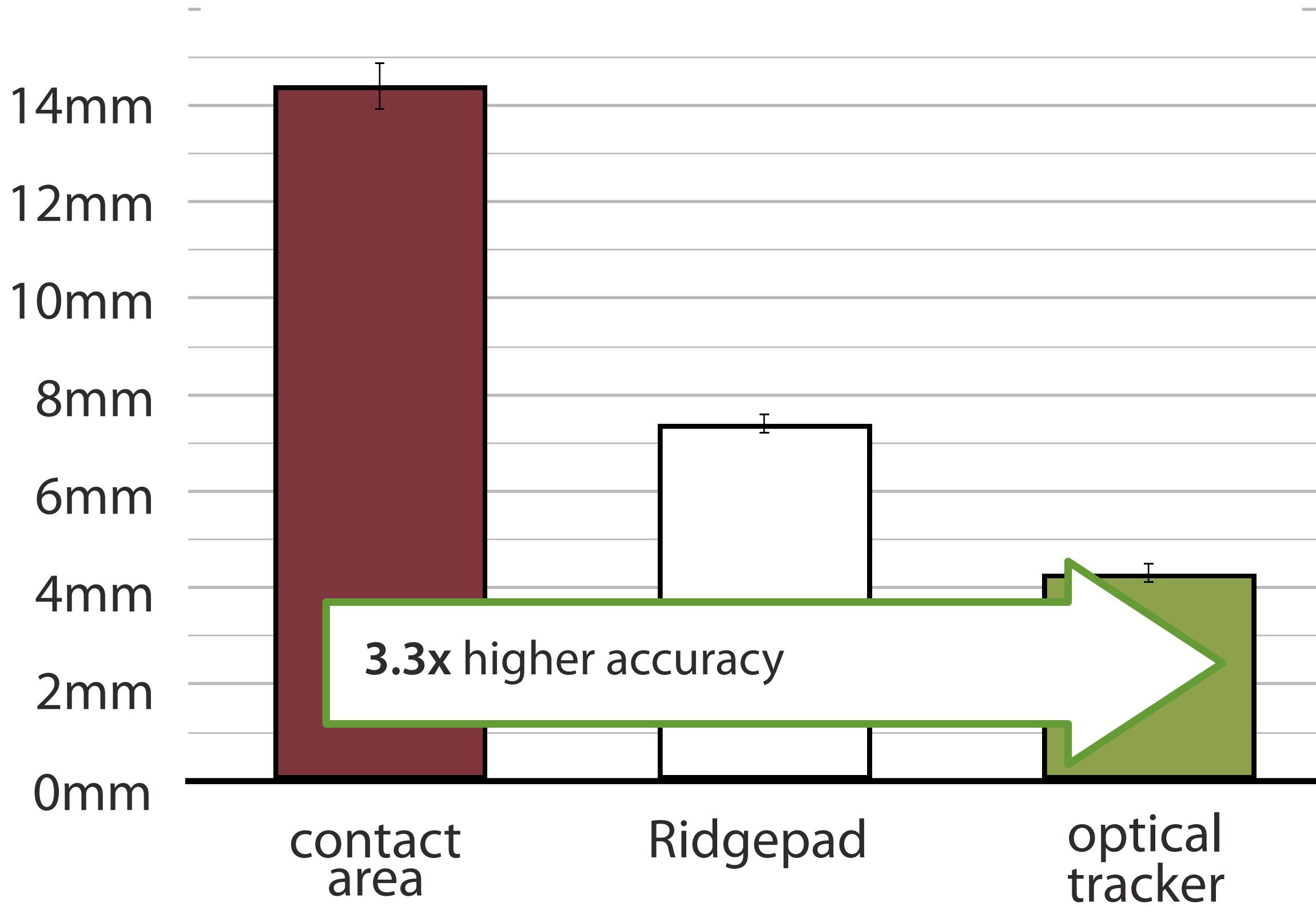
user study



# minimum button size

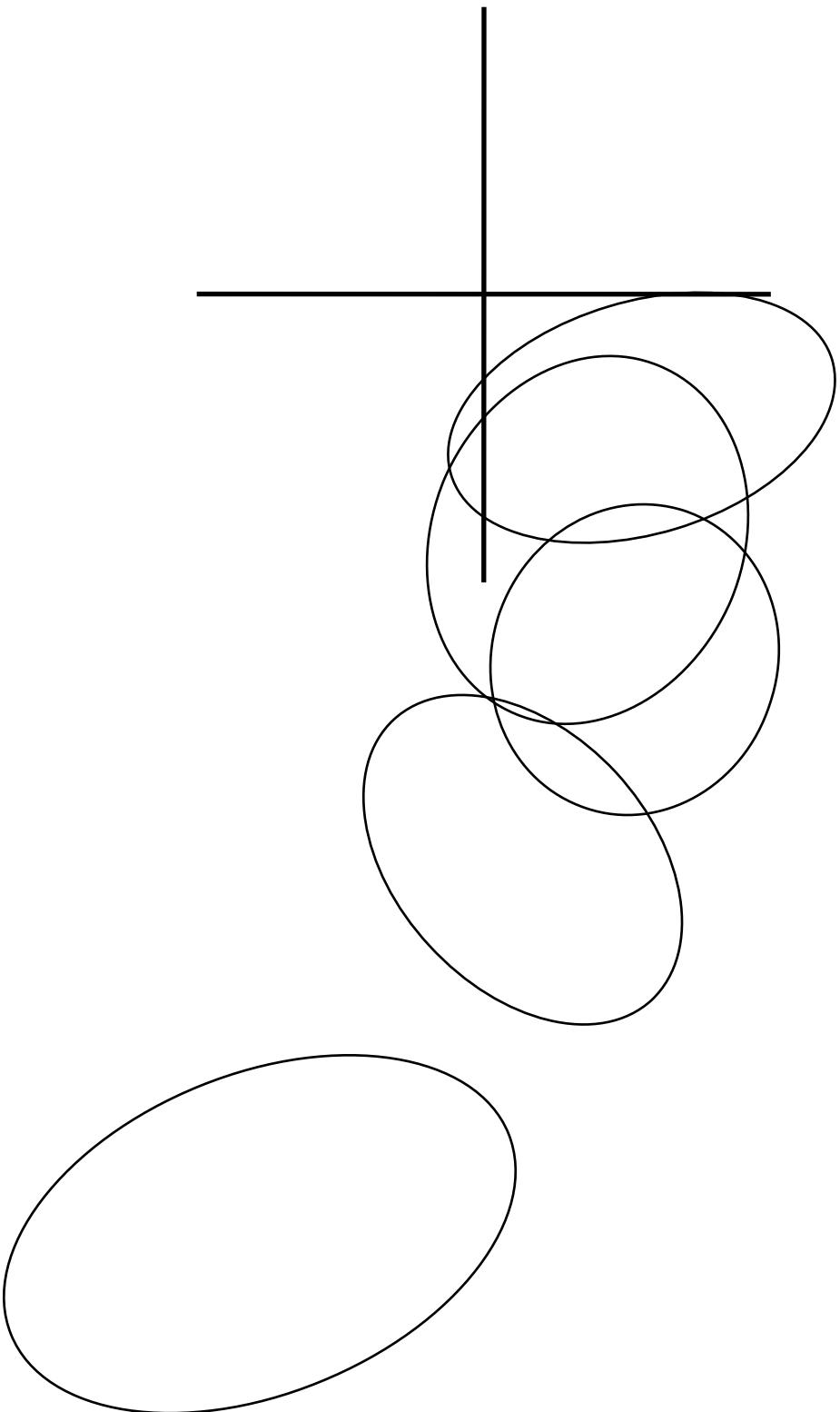


# minimum button size



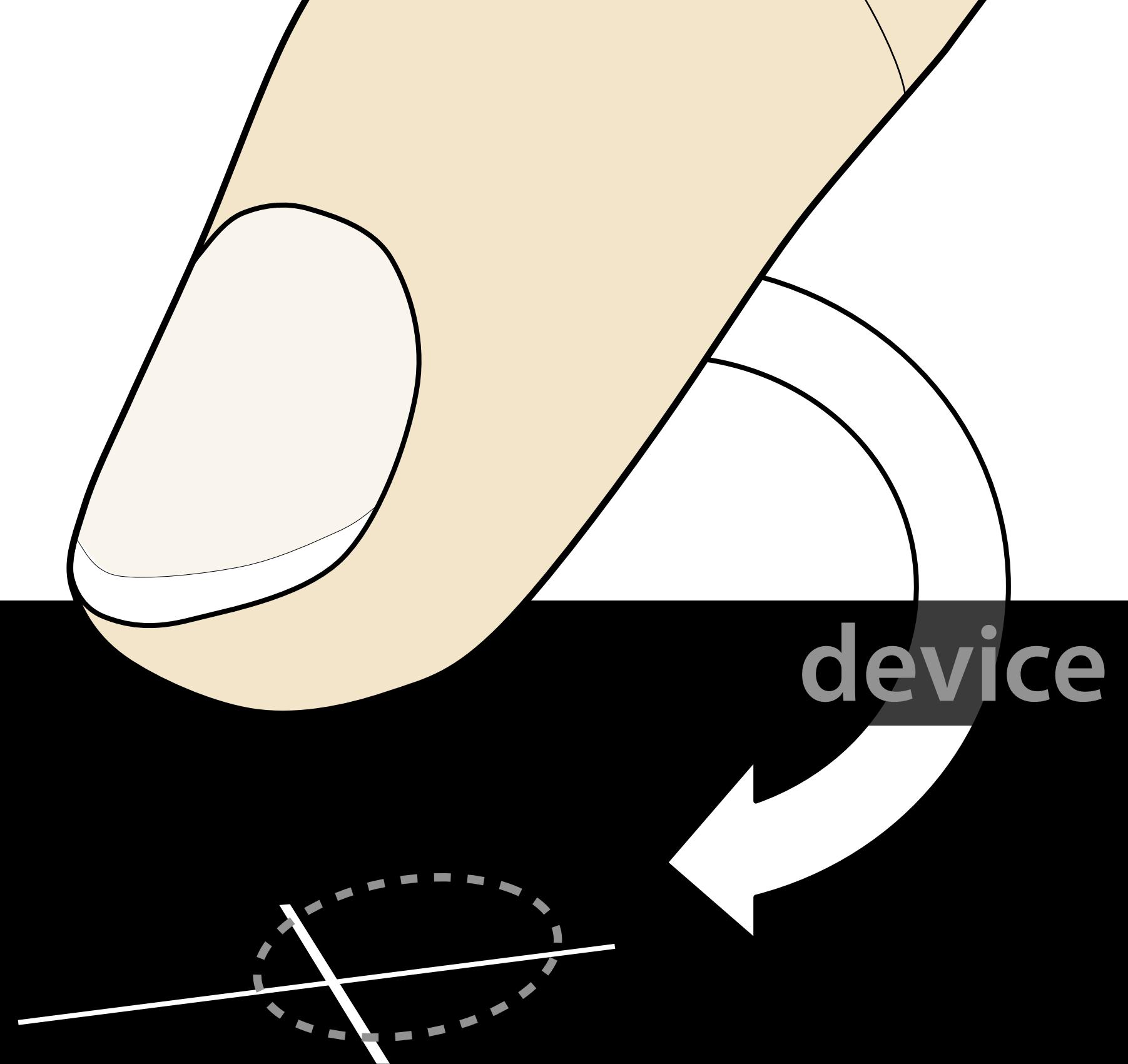
now we're done and touch is accurate.

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



**systematic effect**

3D



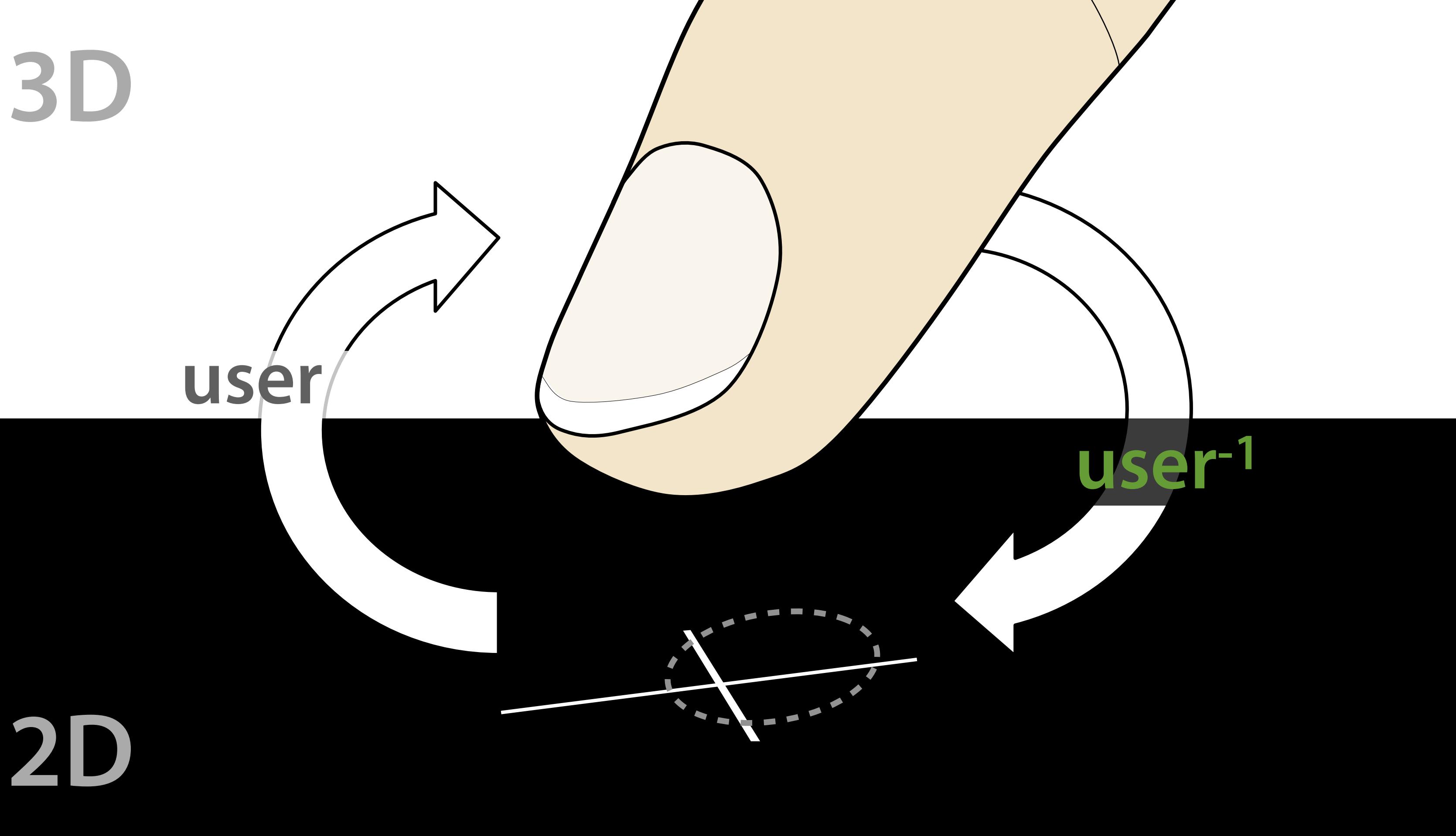
2D

3D

user

2D

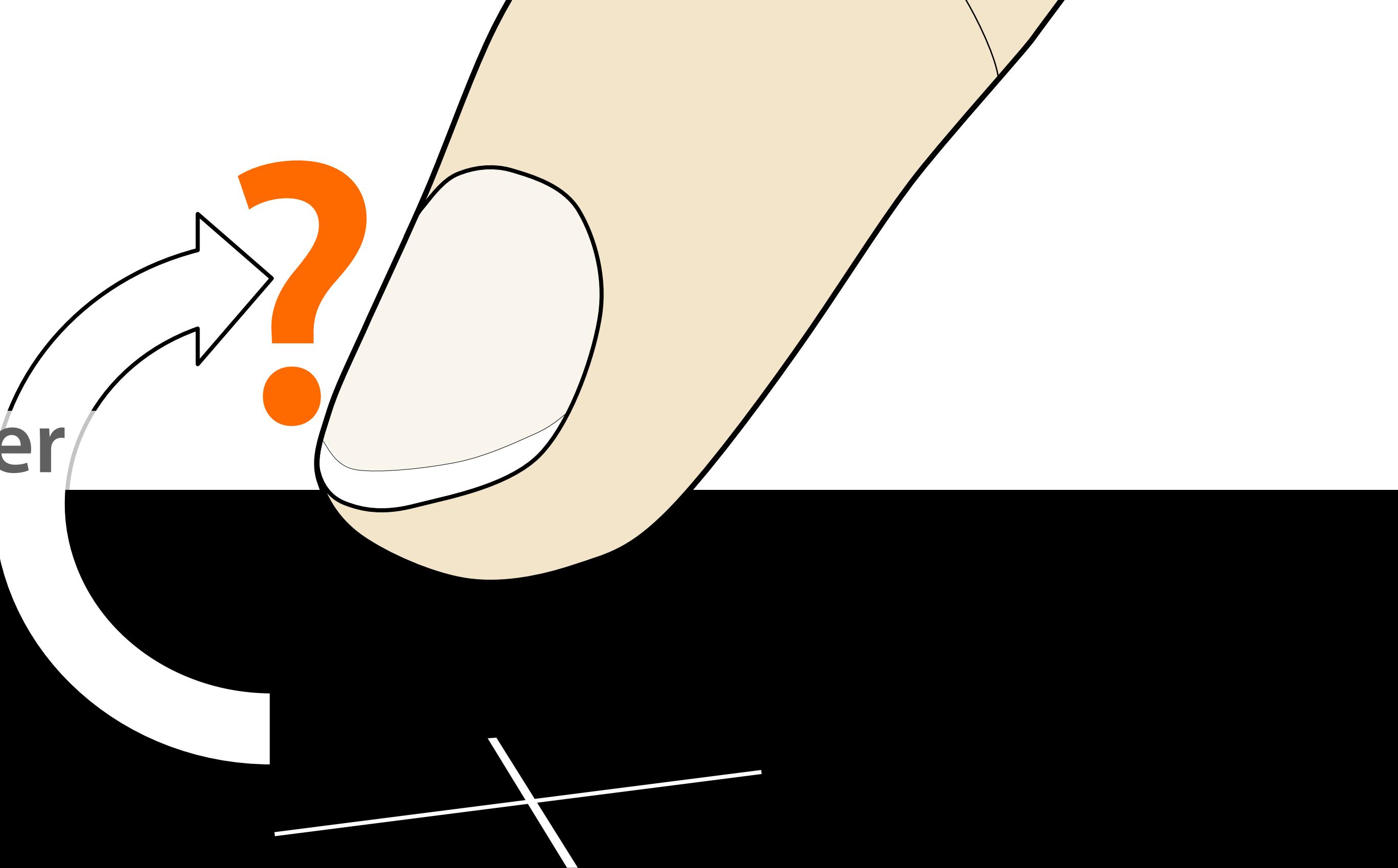
user<sup>-1</sup>



3D

user

2D





goal:  
trying to understand

challenge

# challenge

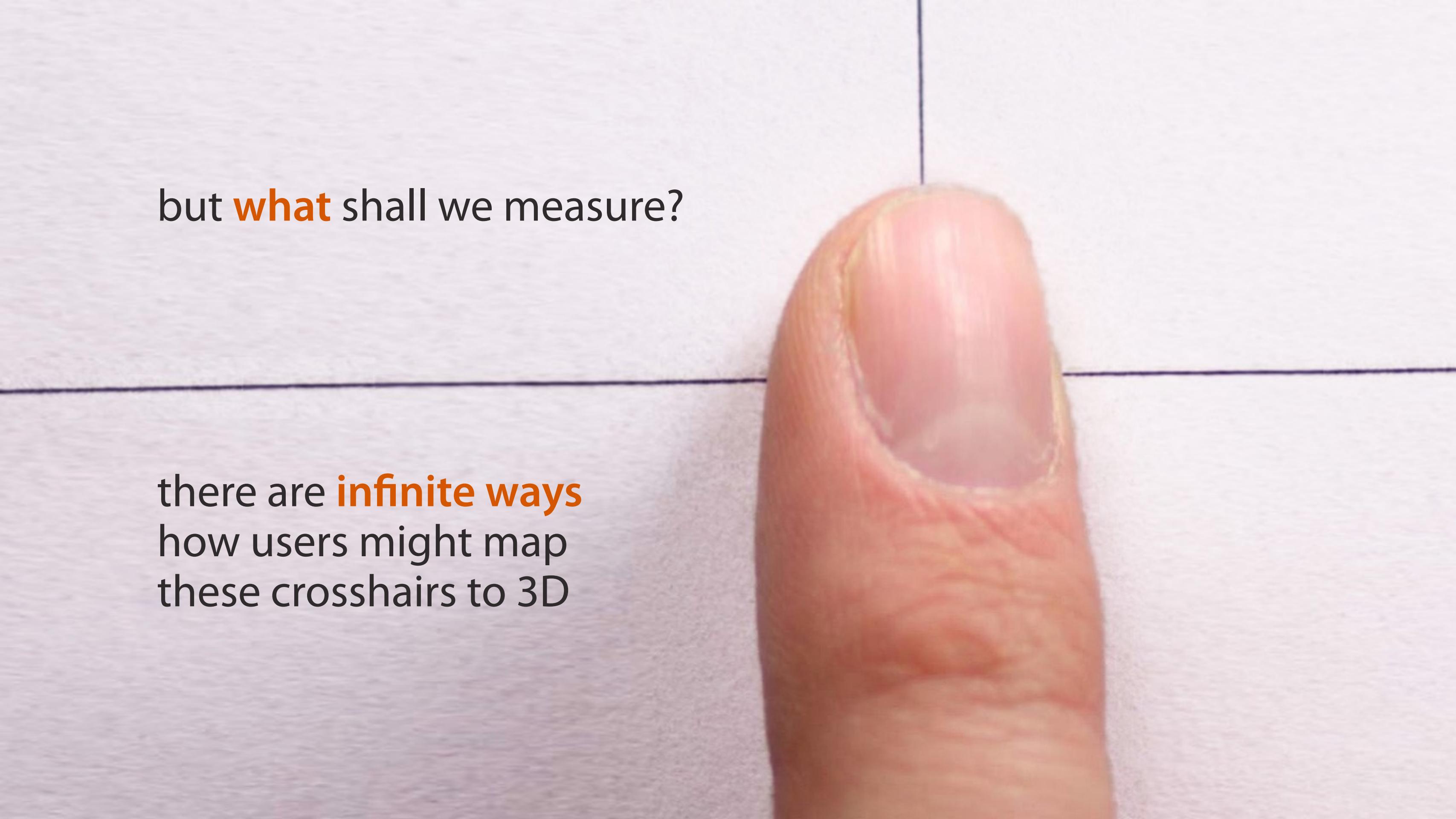
we need a **model**

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

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



(34, 119)



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**

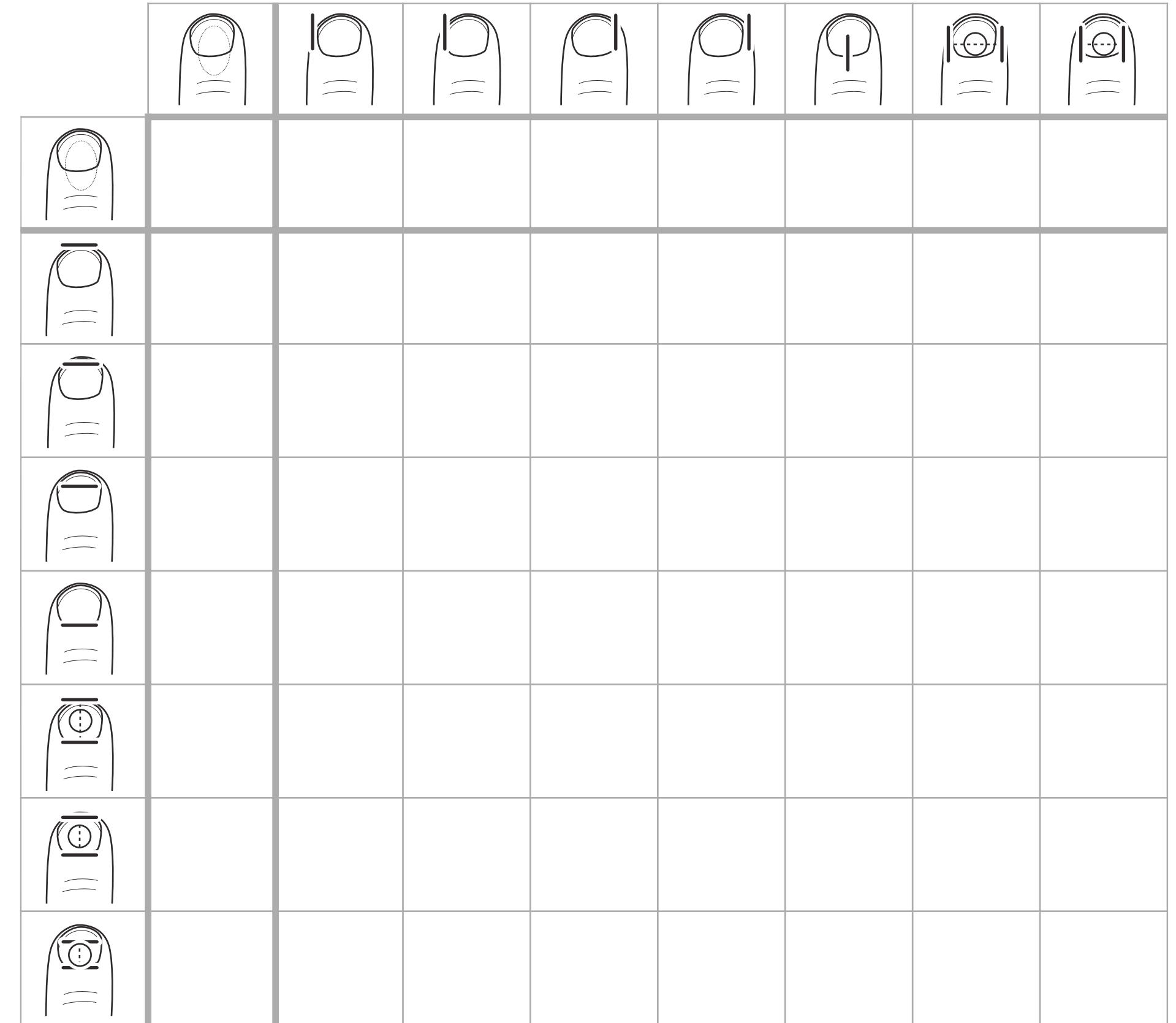
**if outcome is bad, repeat**

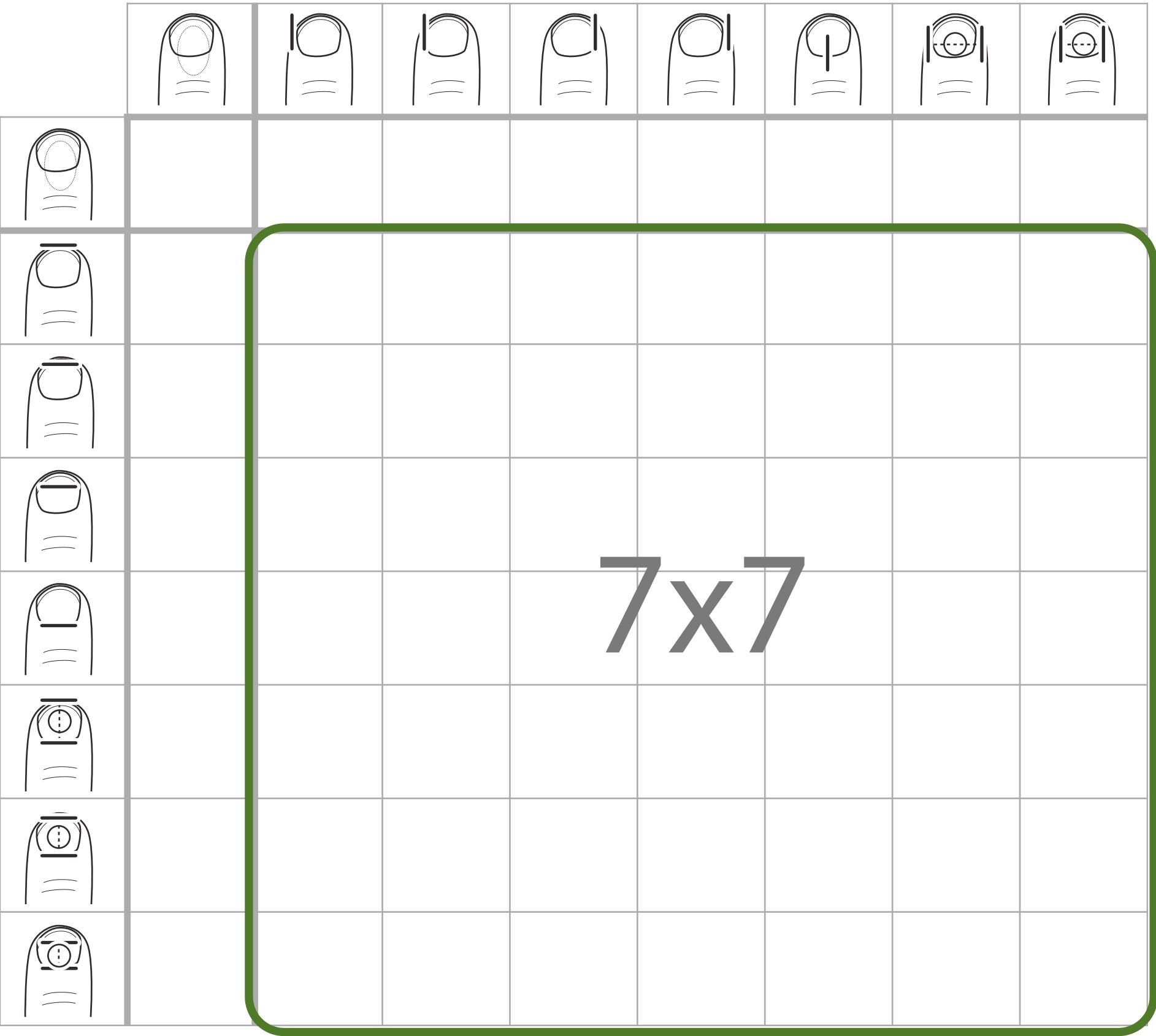
# which model?

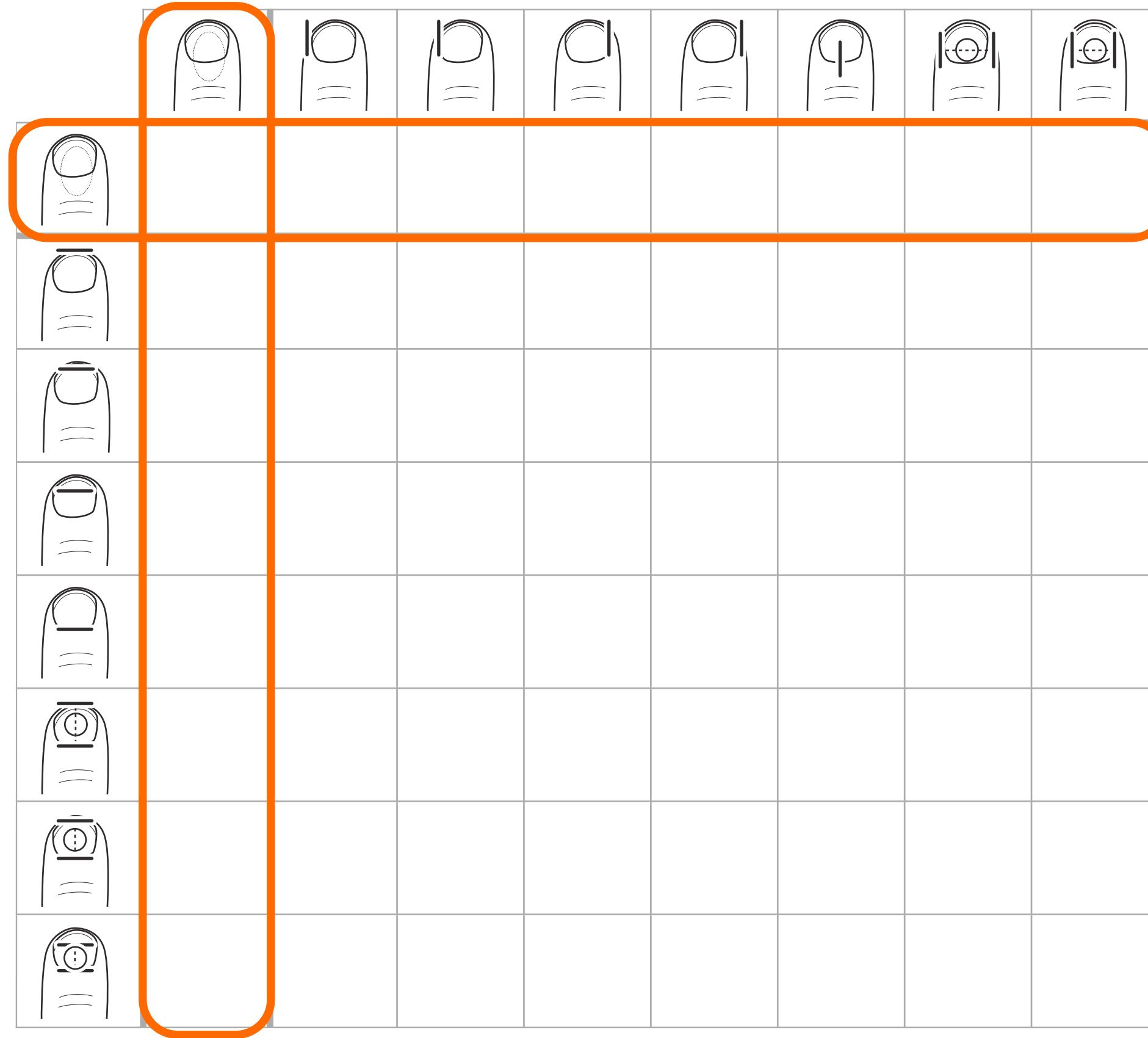
if it is not  
the contact area...



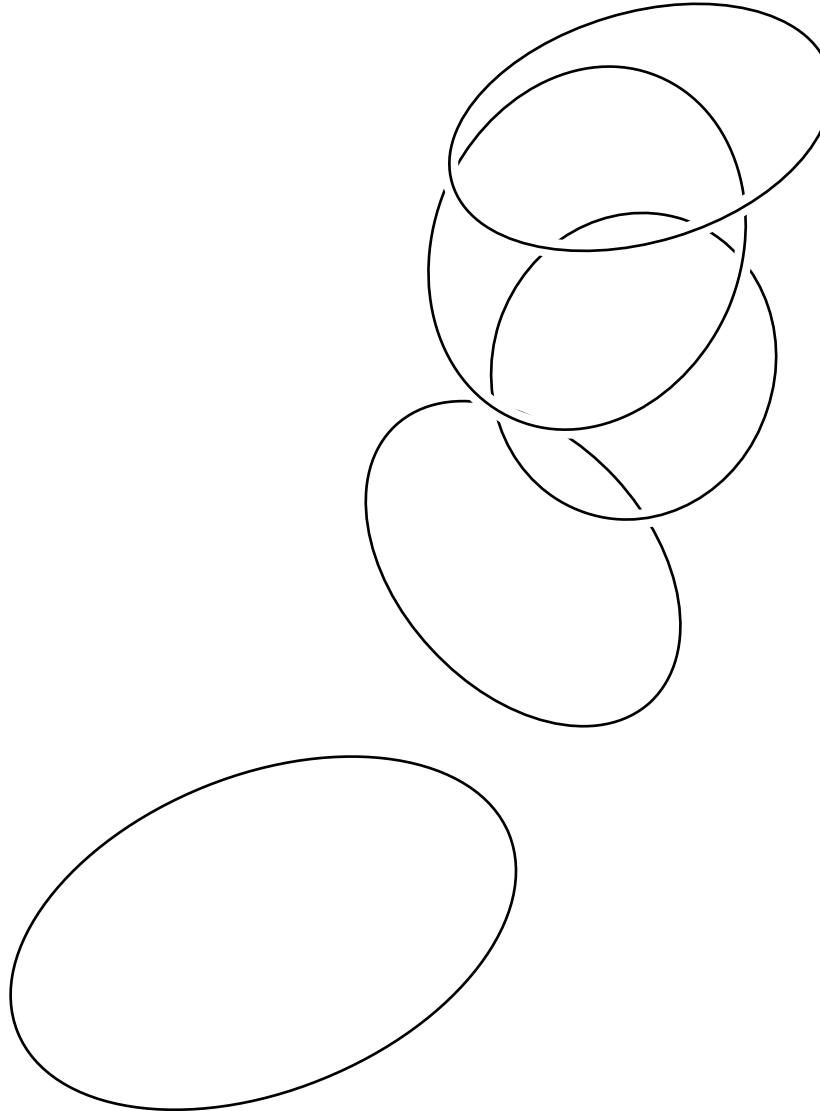
creating models  
using visual features



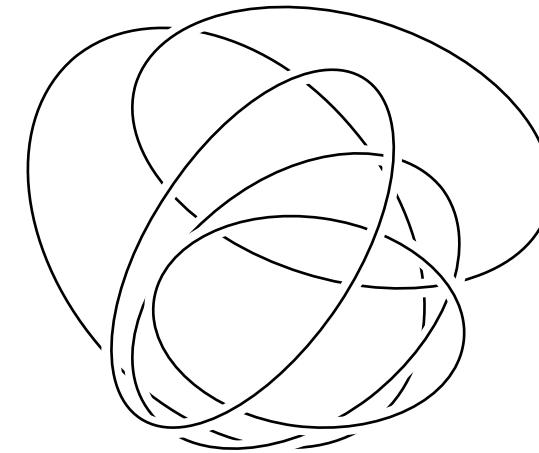




# evaluating the models



**bad** model  
large error offsets

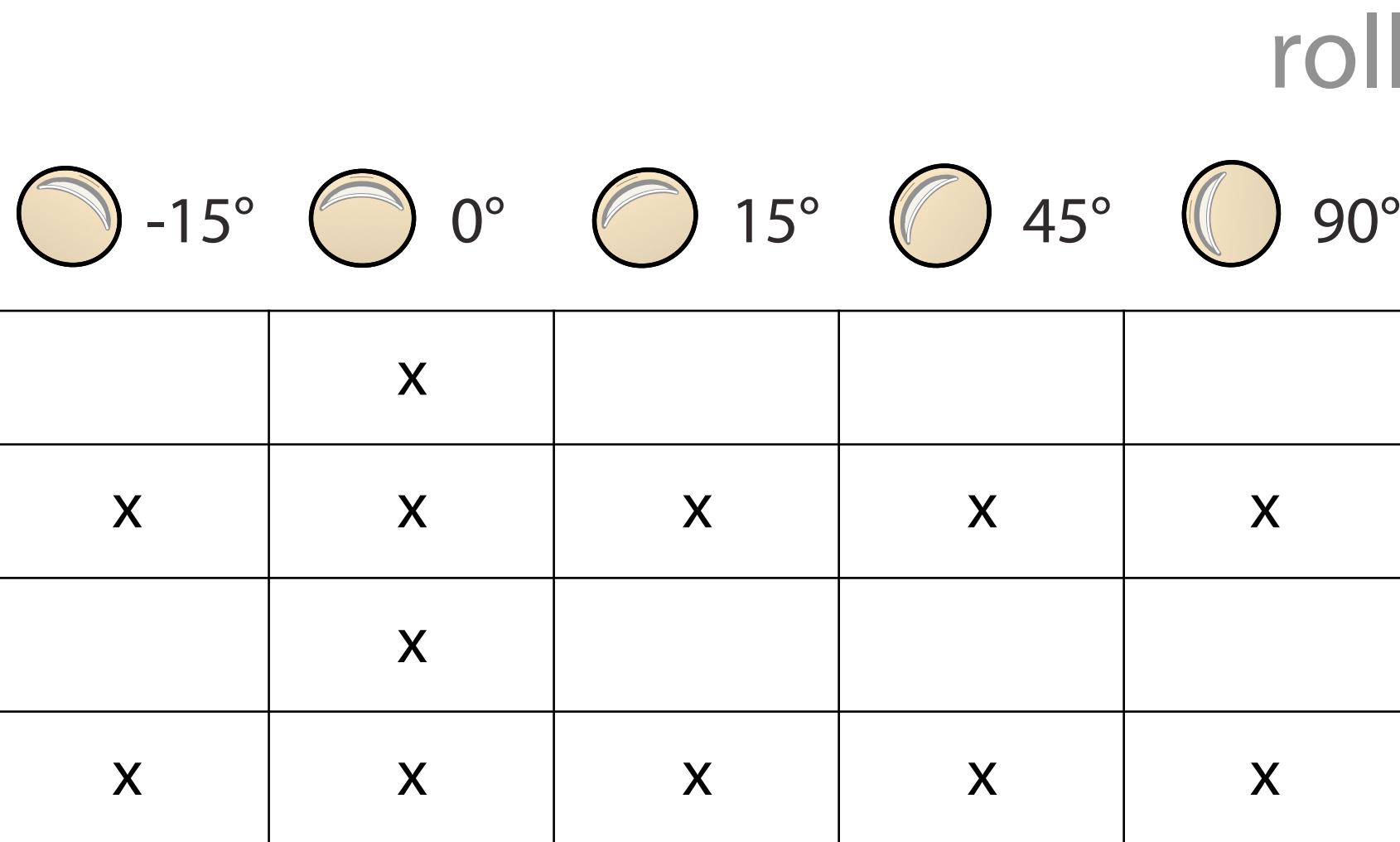
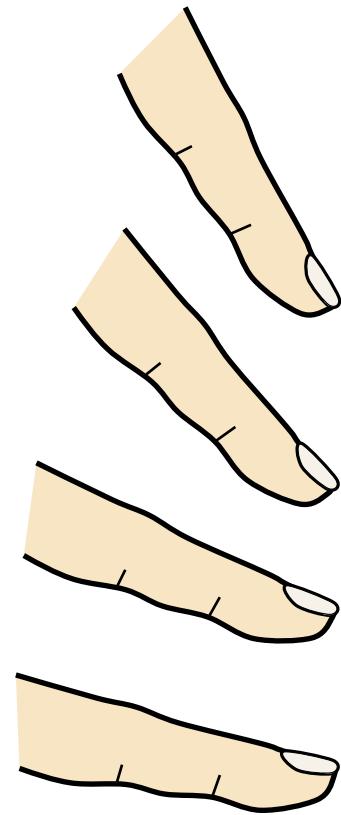


**good** model  
small error offsets

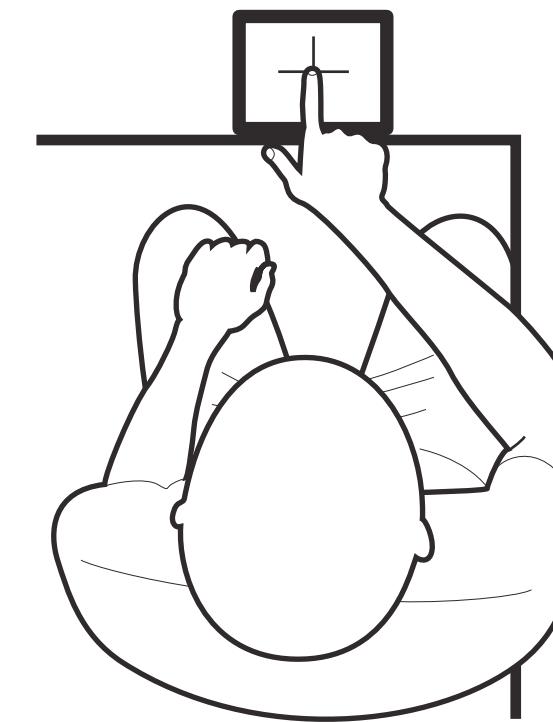
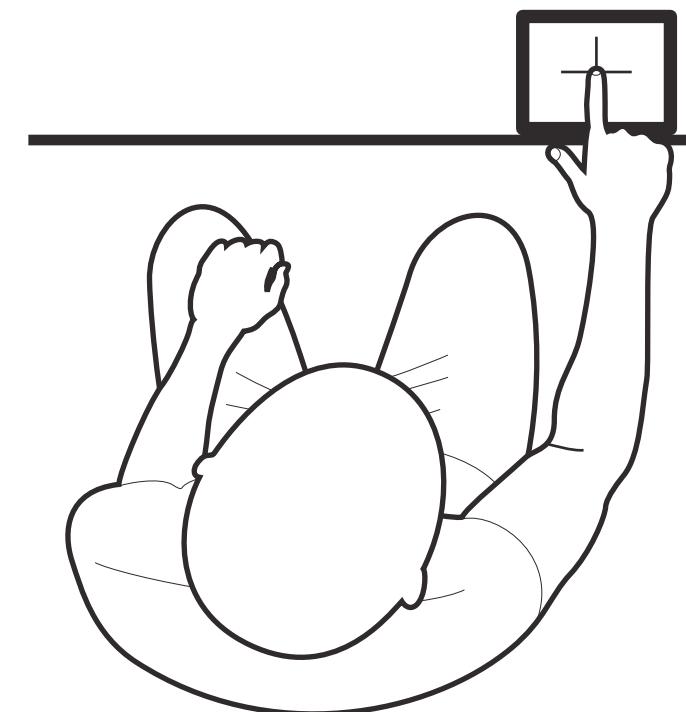
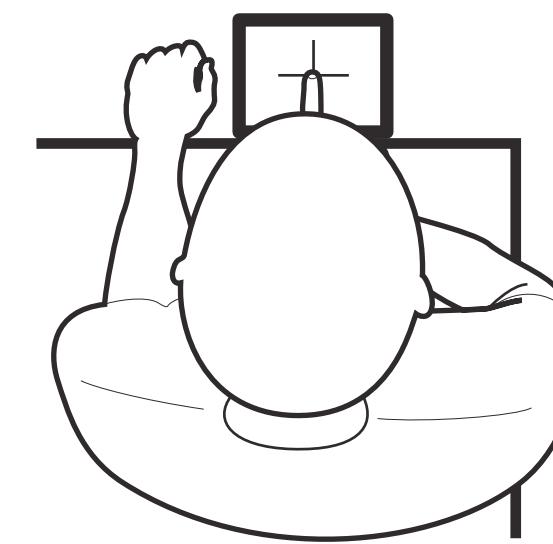
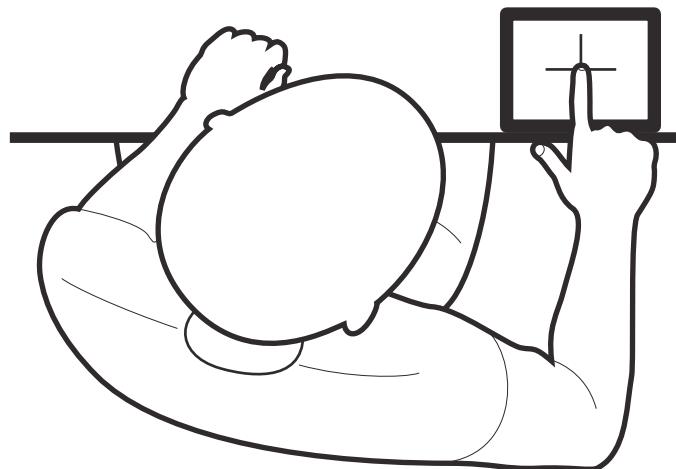
3 user studies



# independent variables



# ...and head position



# study design

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

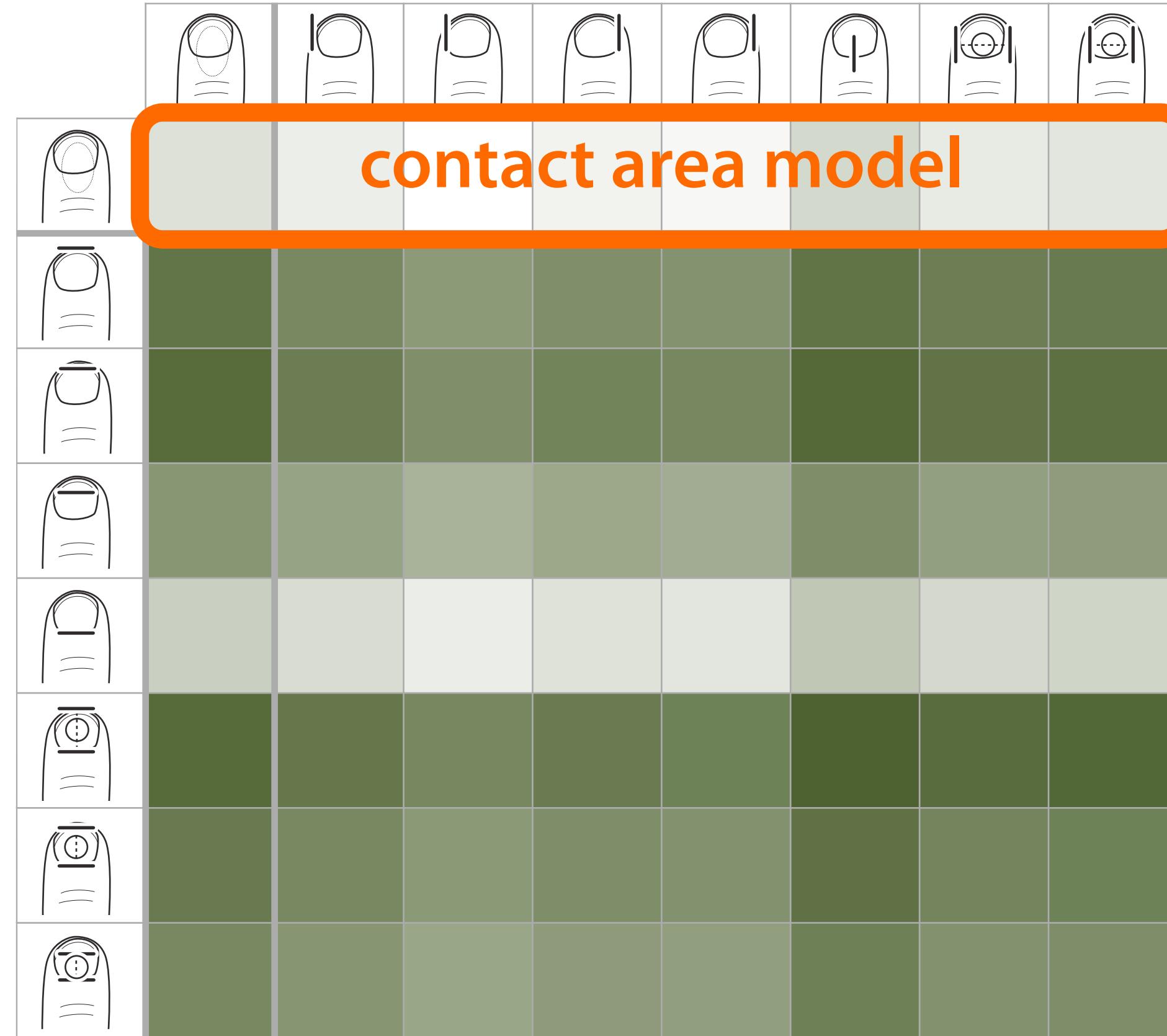
=192 trials / participant

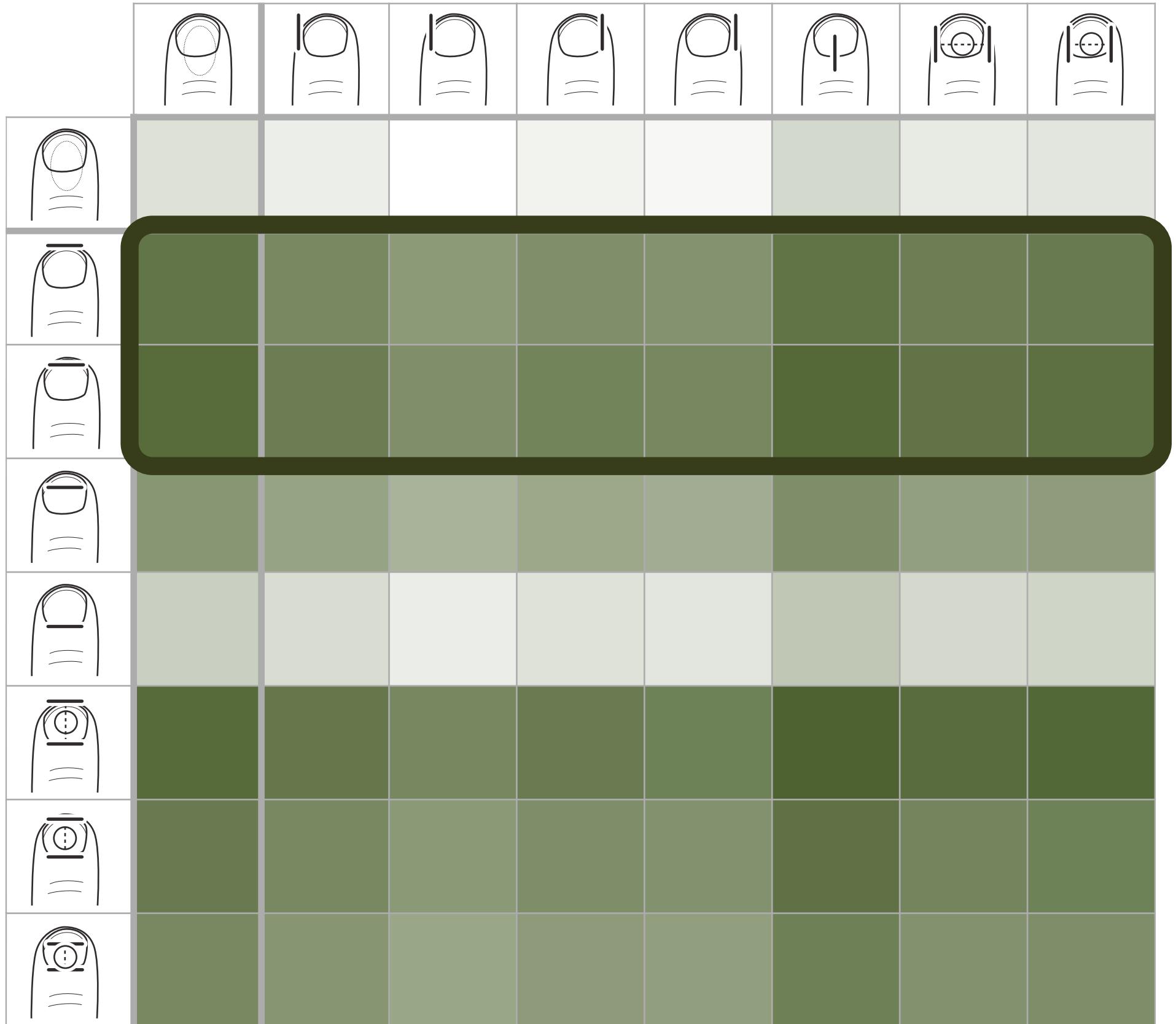
30 + 12 + 12 participants

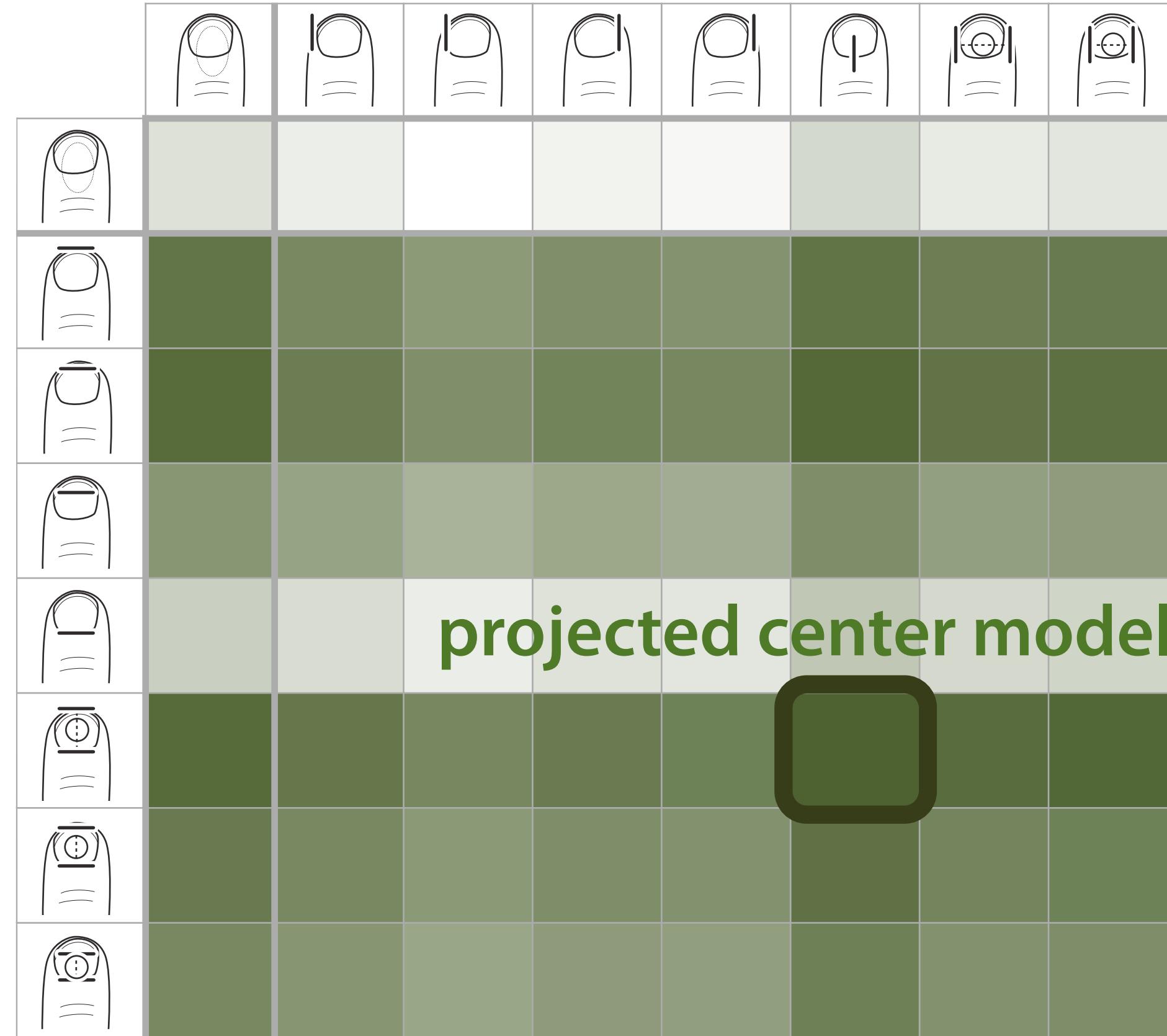


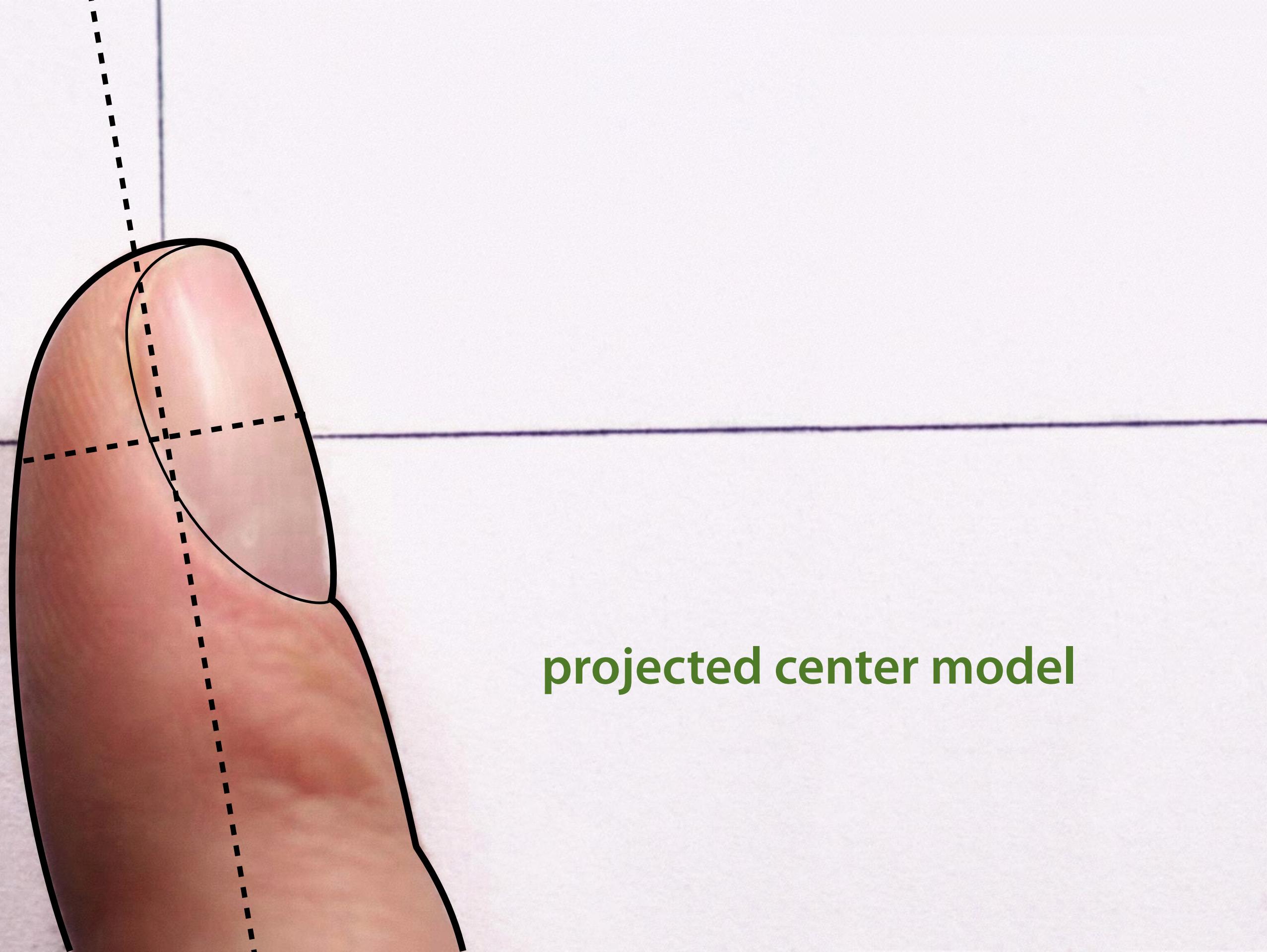
# results

	1	2	3	4	5	6	7	8
1								
2								
3								
4								
5								
6								
7								
8								





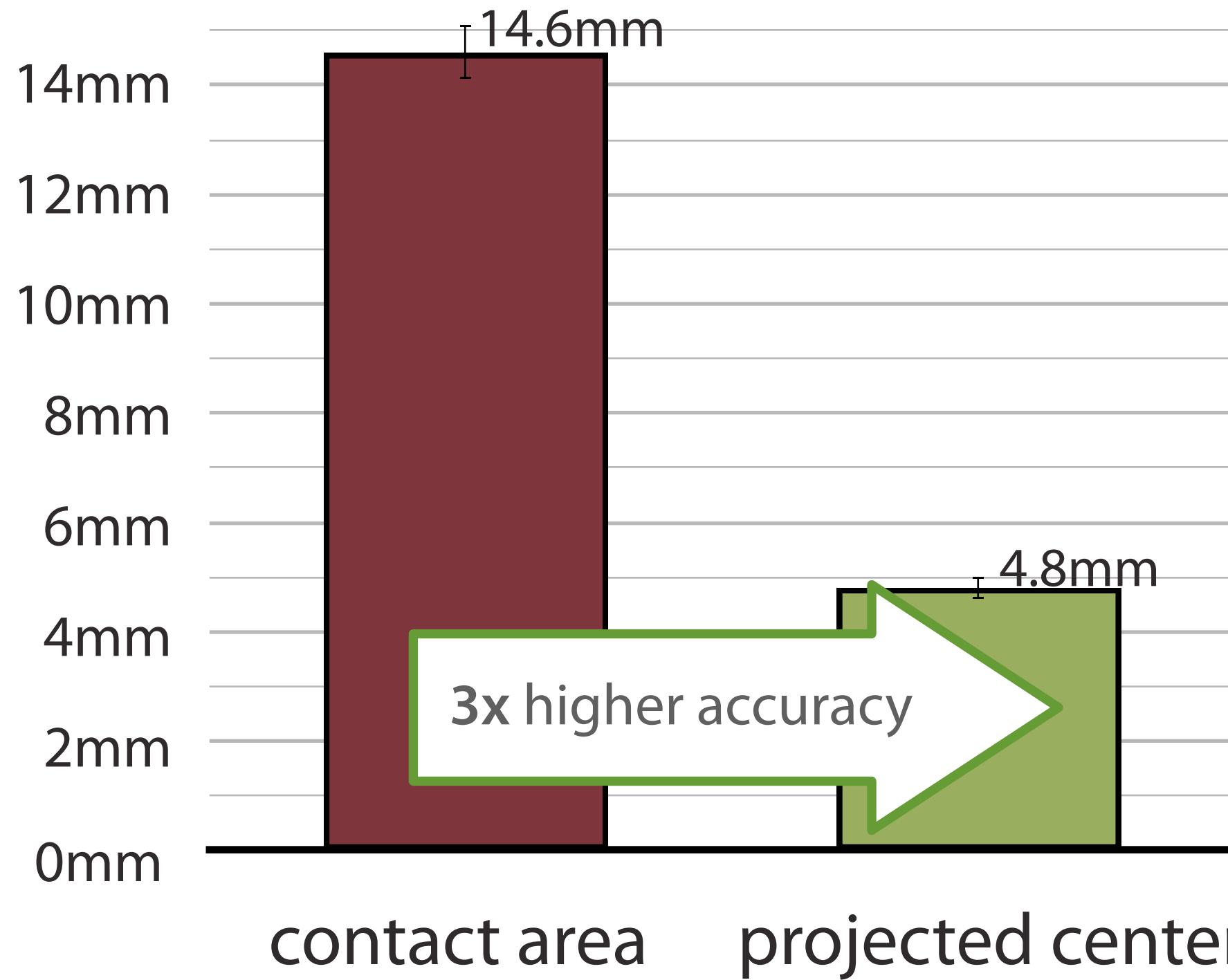




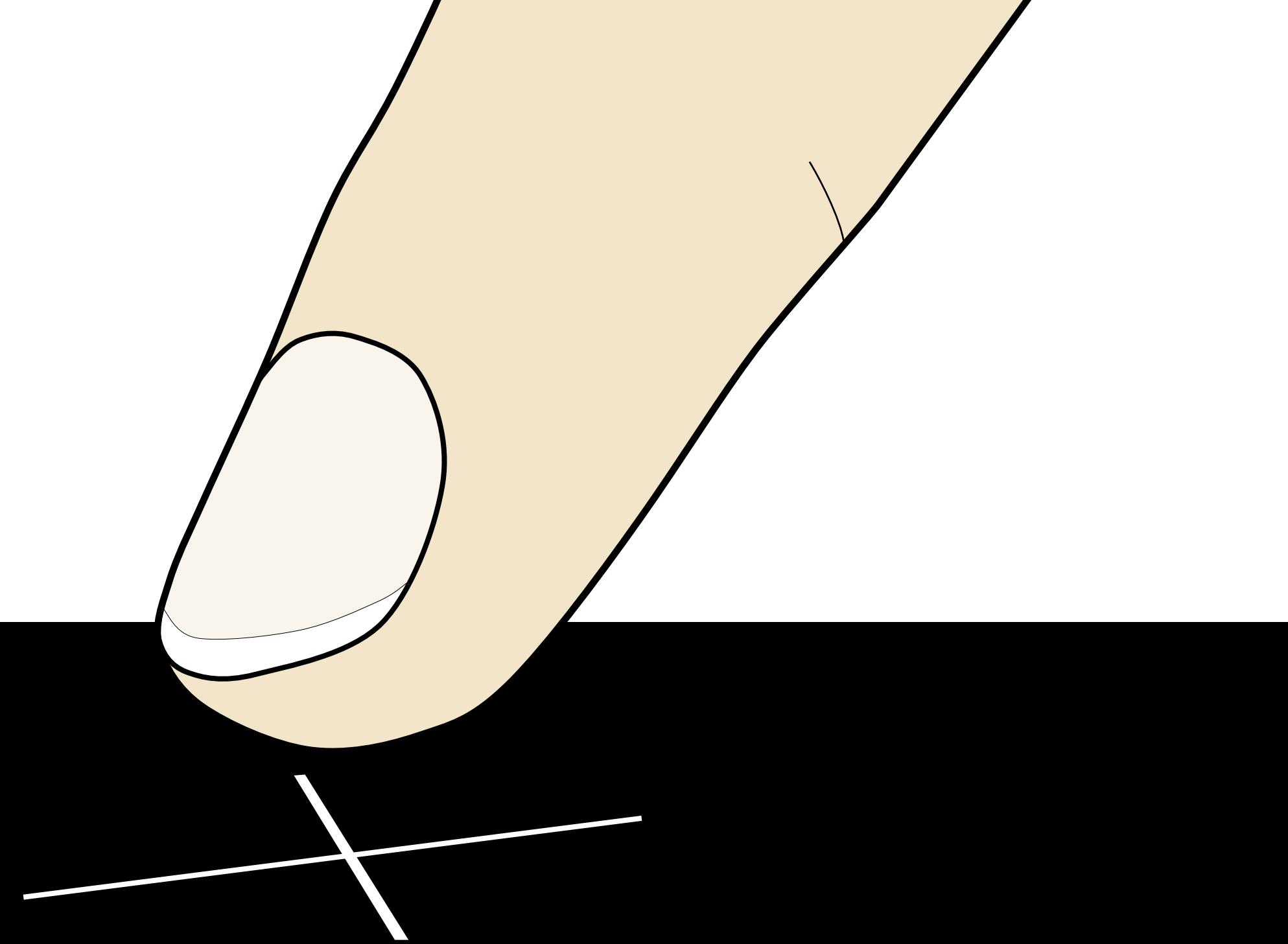
**projected center model**



# minimum button size



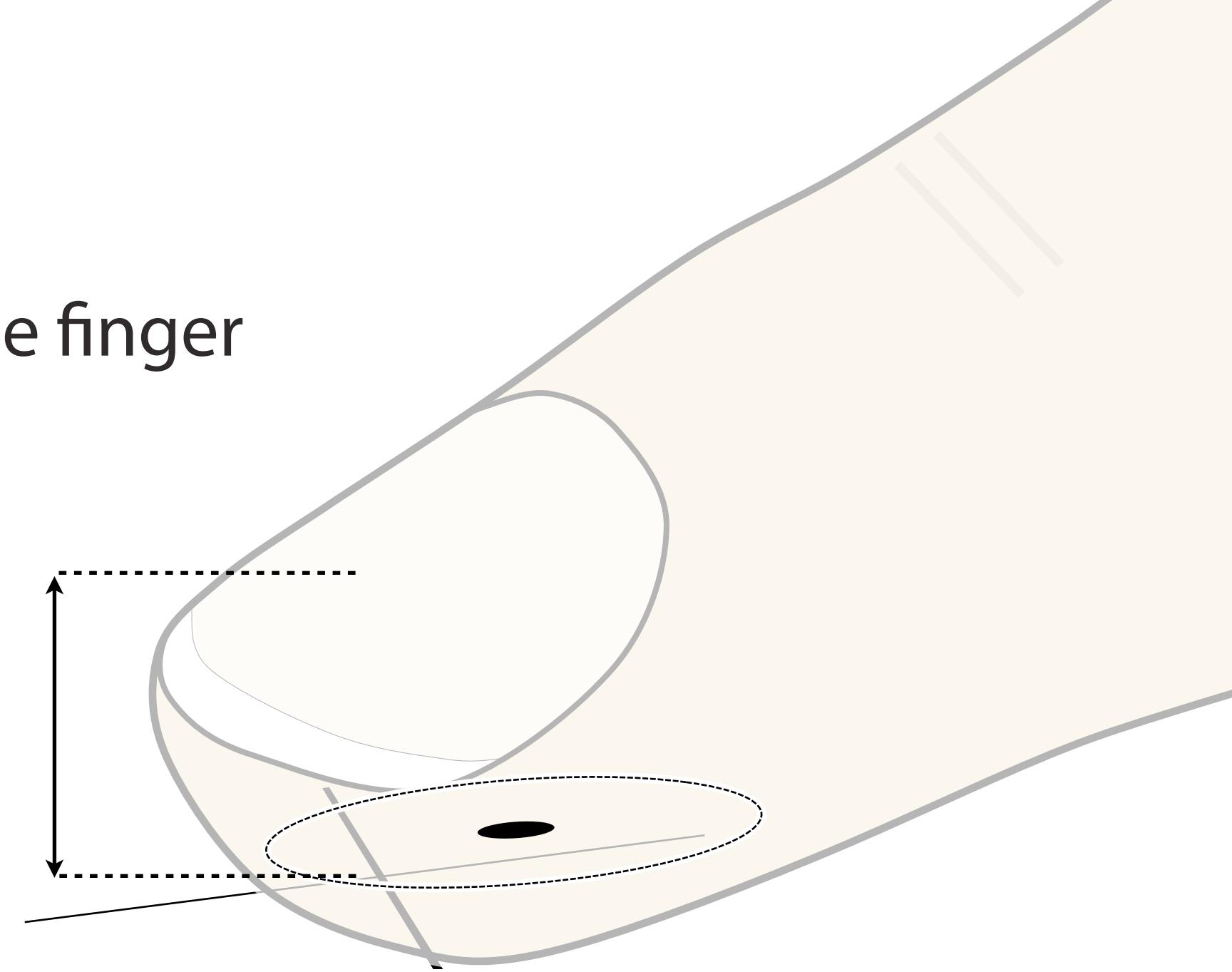
# main insight



touch input is a **3D operation**

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

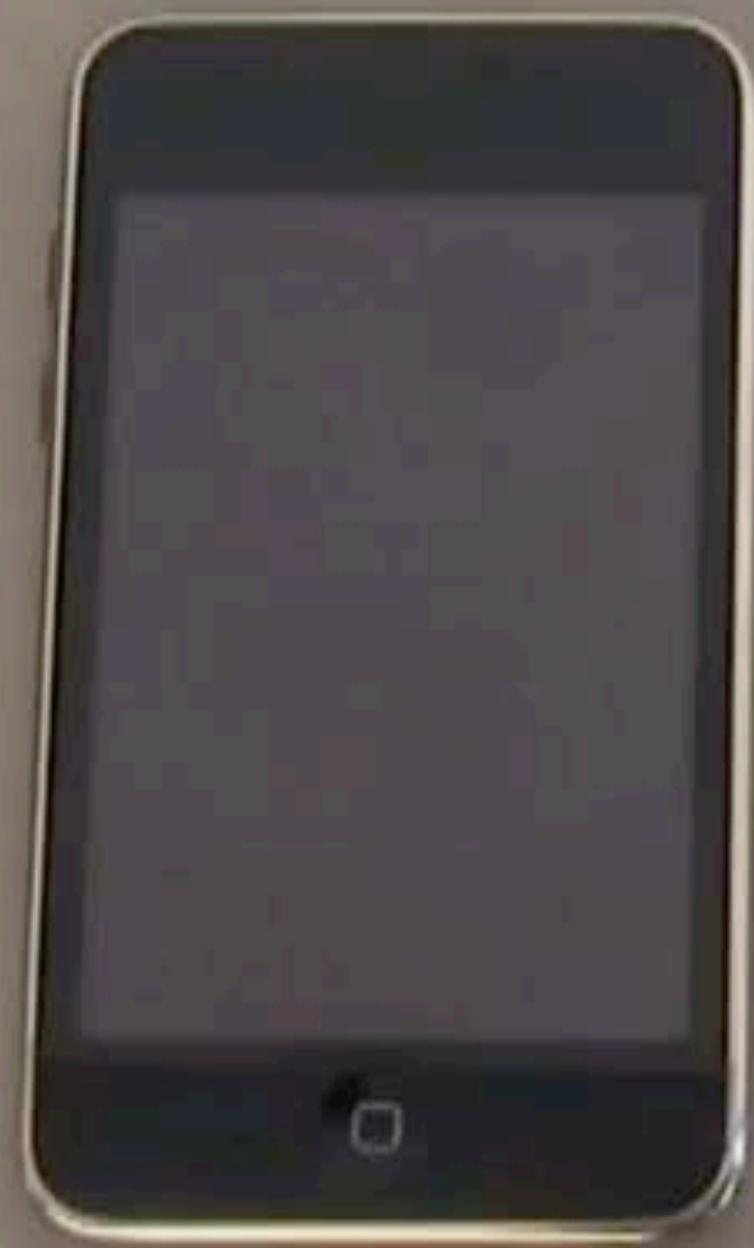
parallax



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

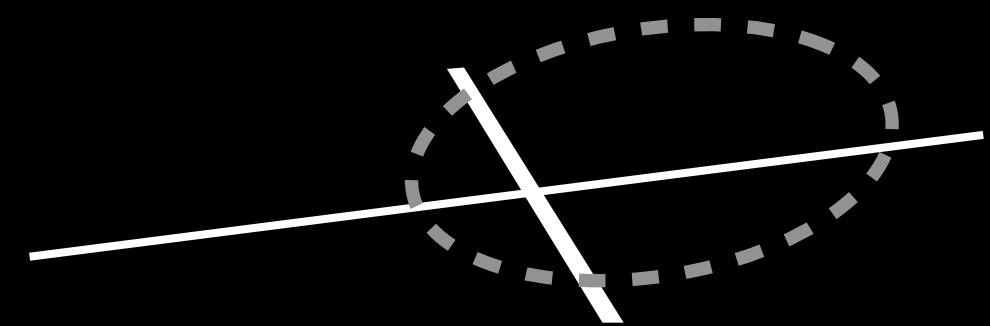
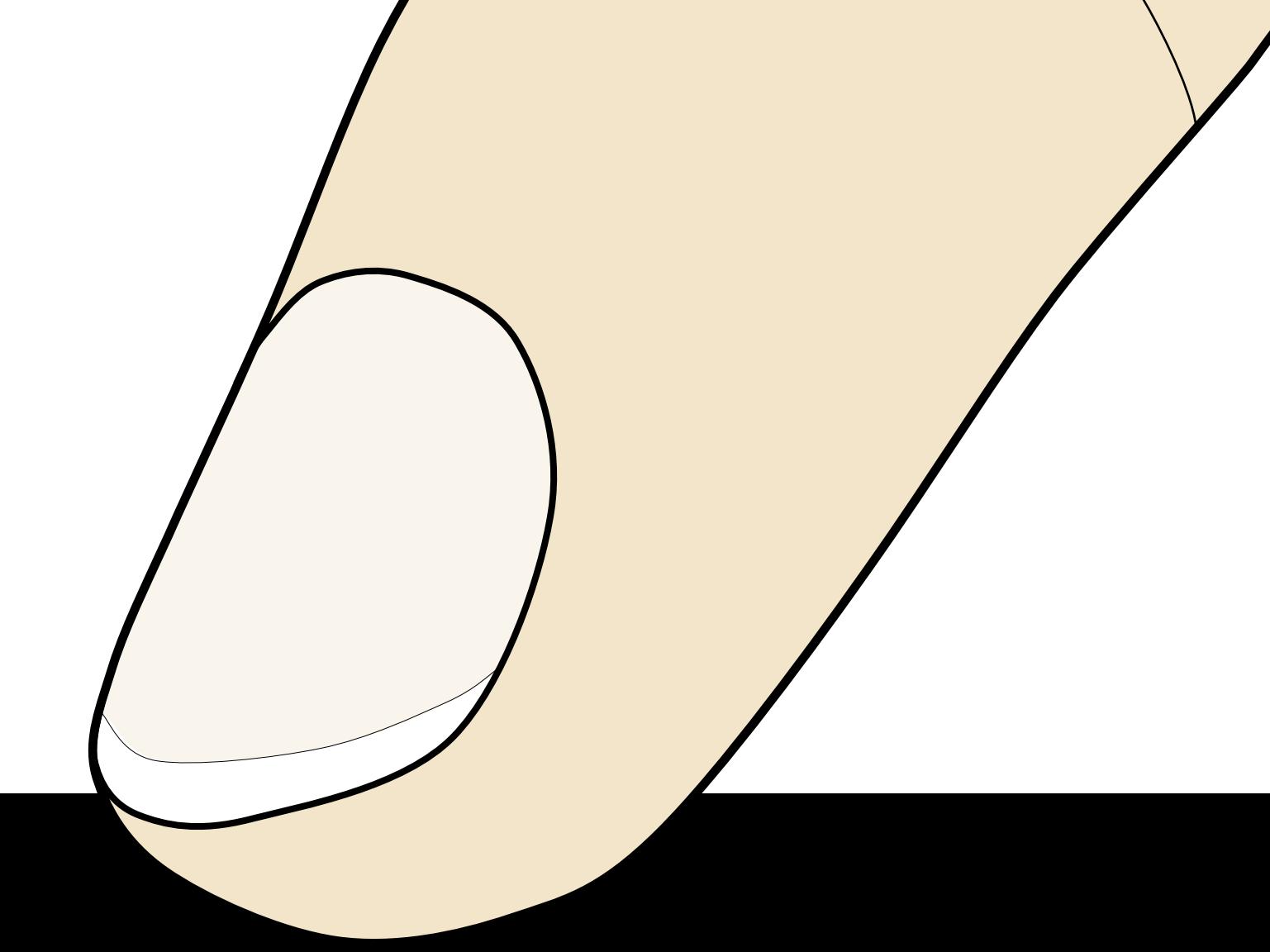
Touch technologies

2

Touch accuracy

# Touch Input

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



February 11, 2016