human computer integration lab

THE UNIVERSITY OF CHICAGO

what if the “I” in HCI stands for Integration?

pedro lopes

associate prof. in computer science

evolution of computing interfaces

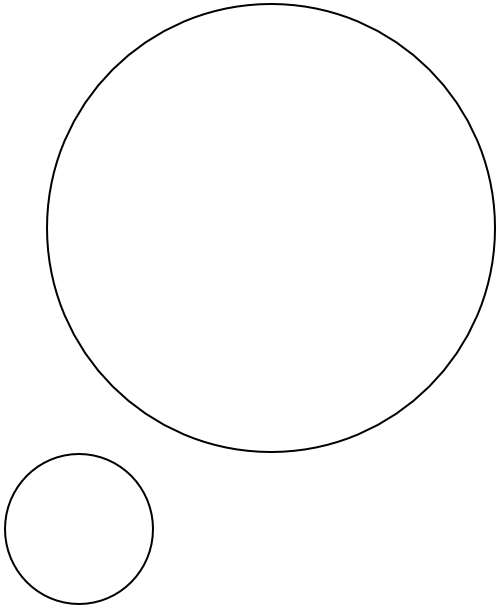
your device

you

mainframe

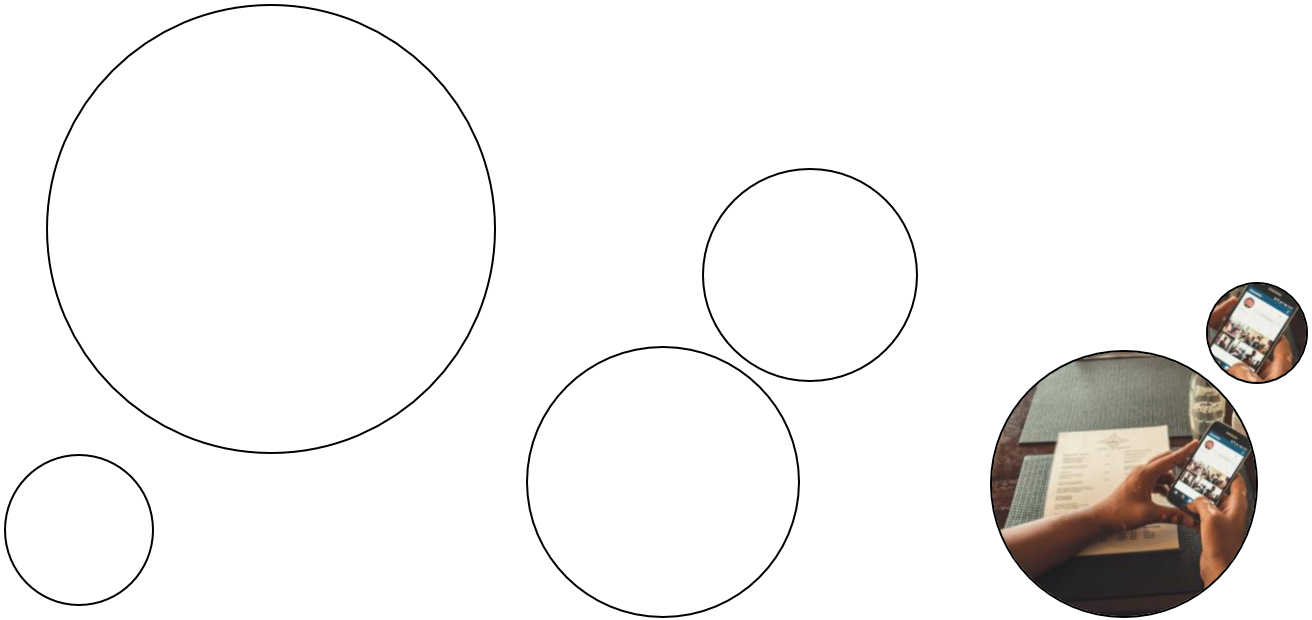
(computers that took up an entire room)

early computers used command line interfaces (CLI)
to enable expert-users to **perform simulations**



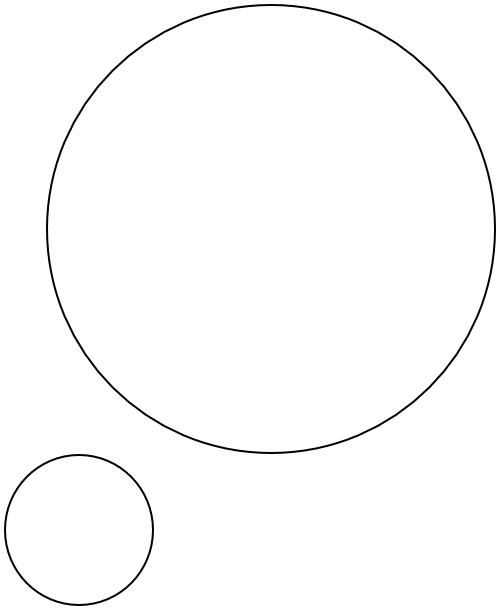
mainframe desktop

in the 80s the desktop’s graphical user interface (GUI) moved computers into **millions of offices & homes**

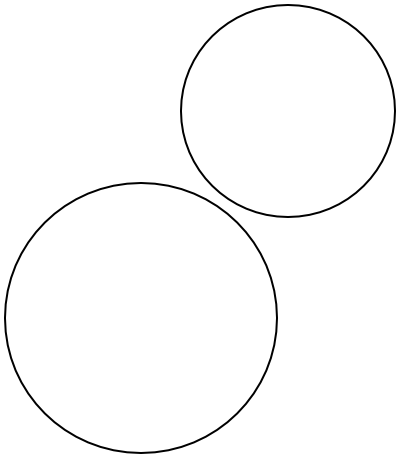


mainframe desktop mobile

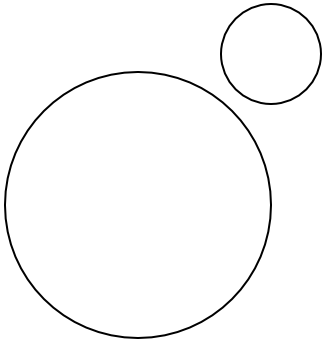
in the 90s, mobile devices moved computing into billions of pockets, accessible **anytime & anywhere**



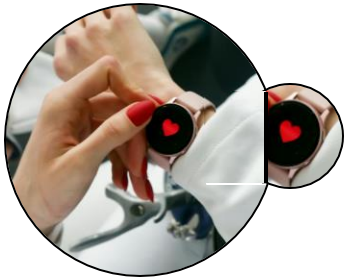
mainframe



desktop

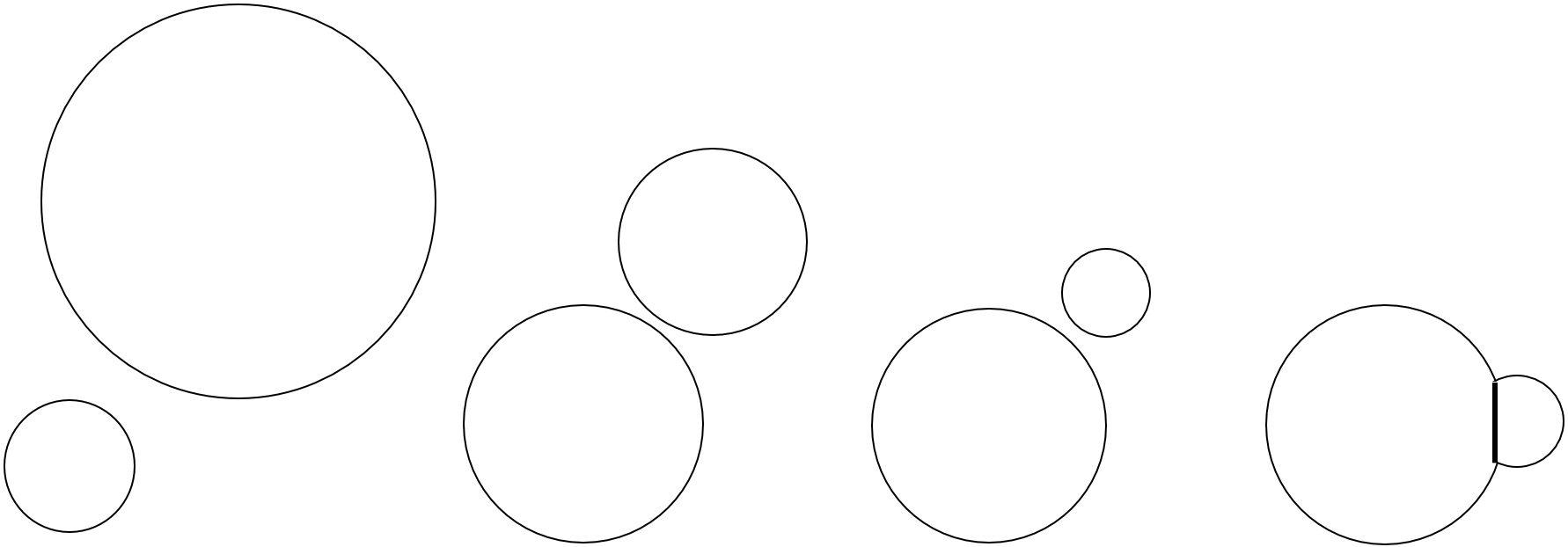


mobile

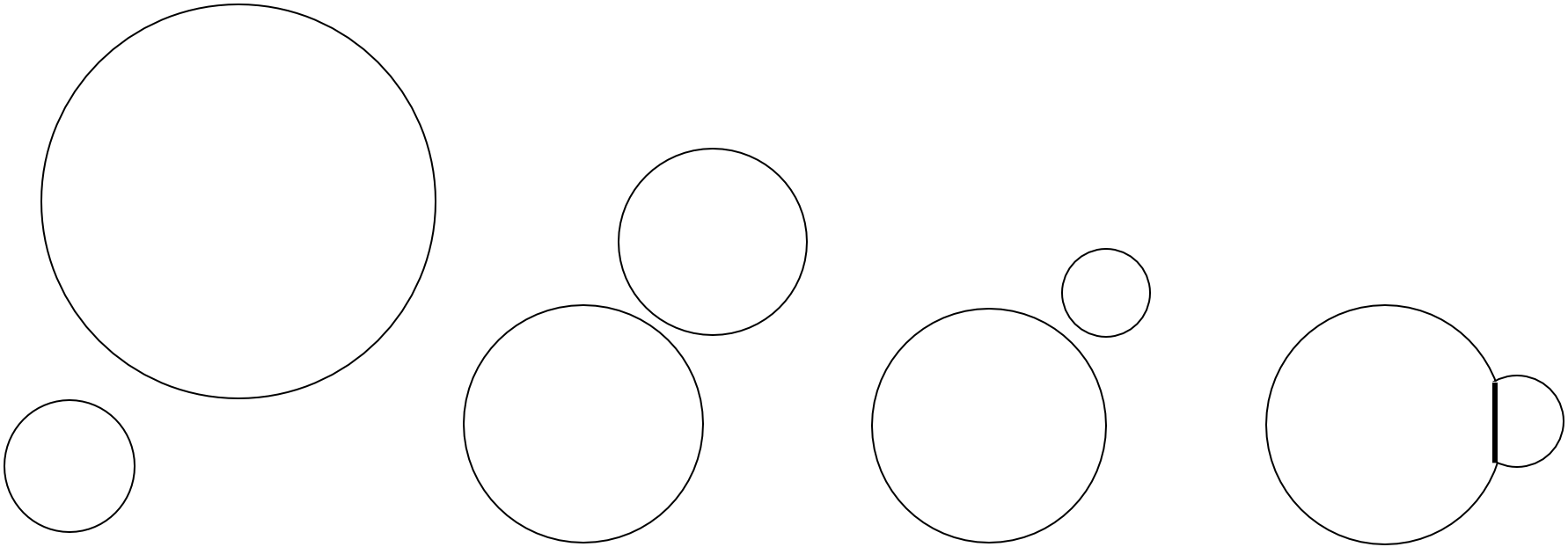


wearable

wearables are in **physical contact with the skin,**
enabling sensing users' physiological signals



each evolution-step brought **unique benefits**



each evolution-step brought **unique benefits**

e.g., create interactions **not possible before**

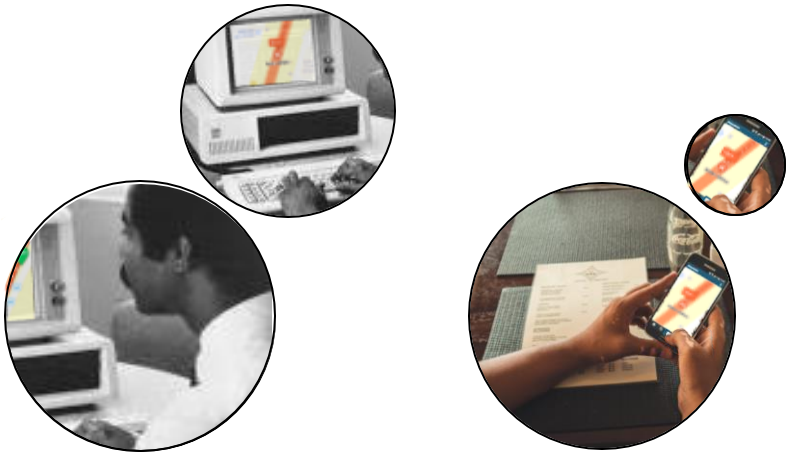
mainframe

desktop → mobile

wearable

each evolution-step brought **unique benefits**

e.g., maps on desktop did not change society

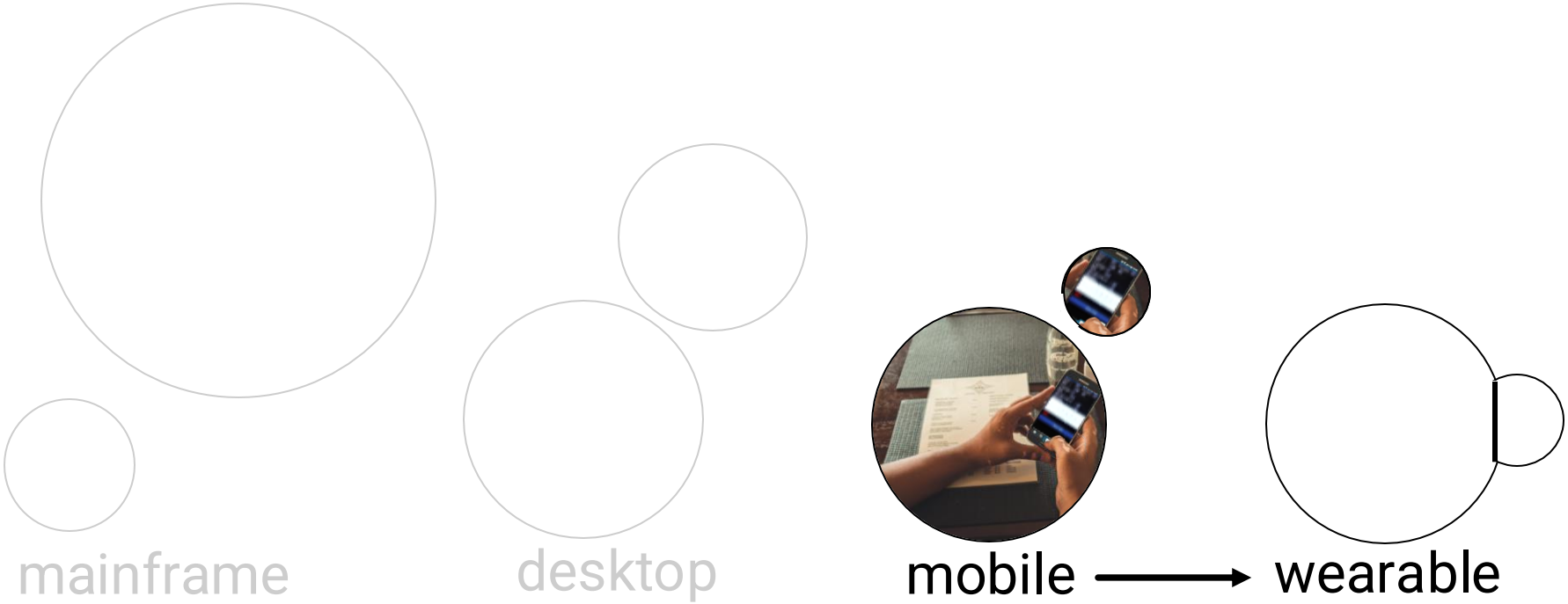


mainframe

desktop ⟶ mobile

wearable

each evolution-step brought **unique benefits**
e.g., maps on desktop did not change society
but mobile **interactive maps on changed us**

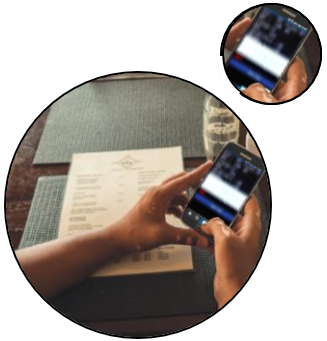


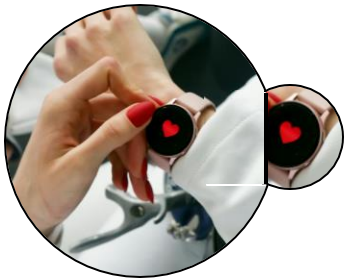
each evolution-step brought **unique benefits**

e.g., body-data on mobile was not revolutionary

mainframe

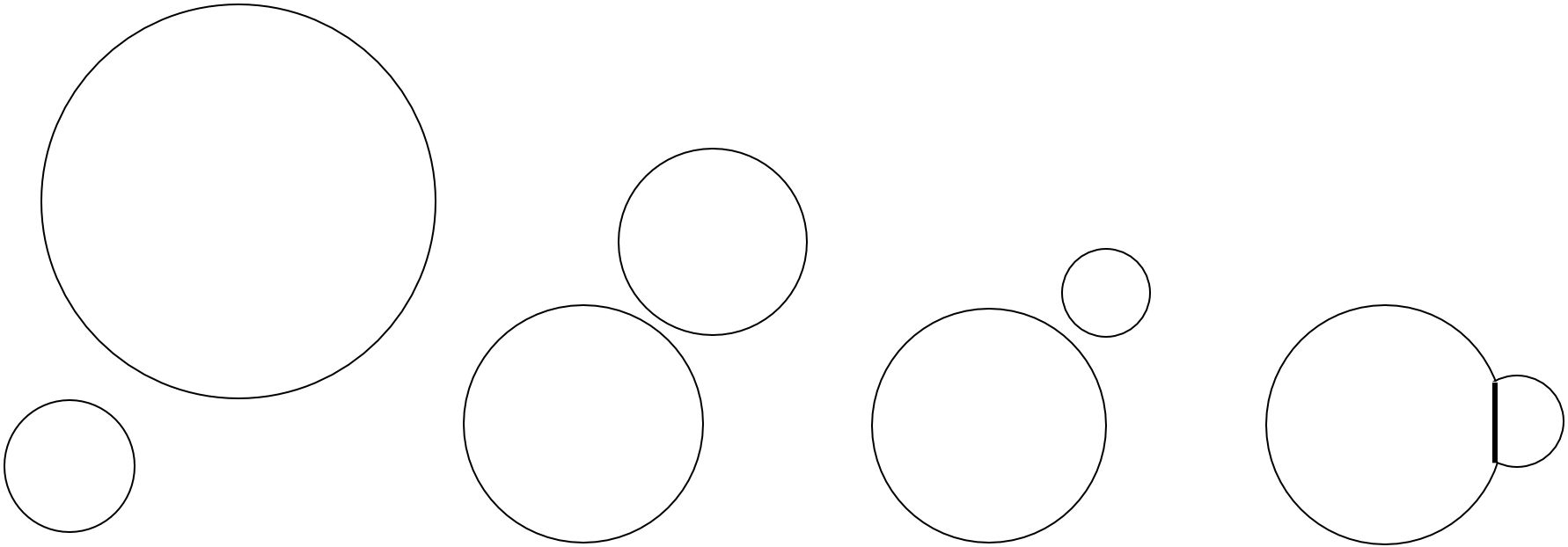
desktop



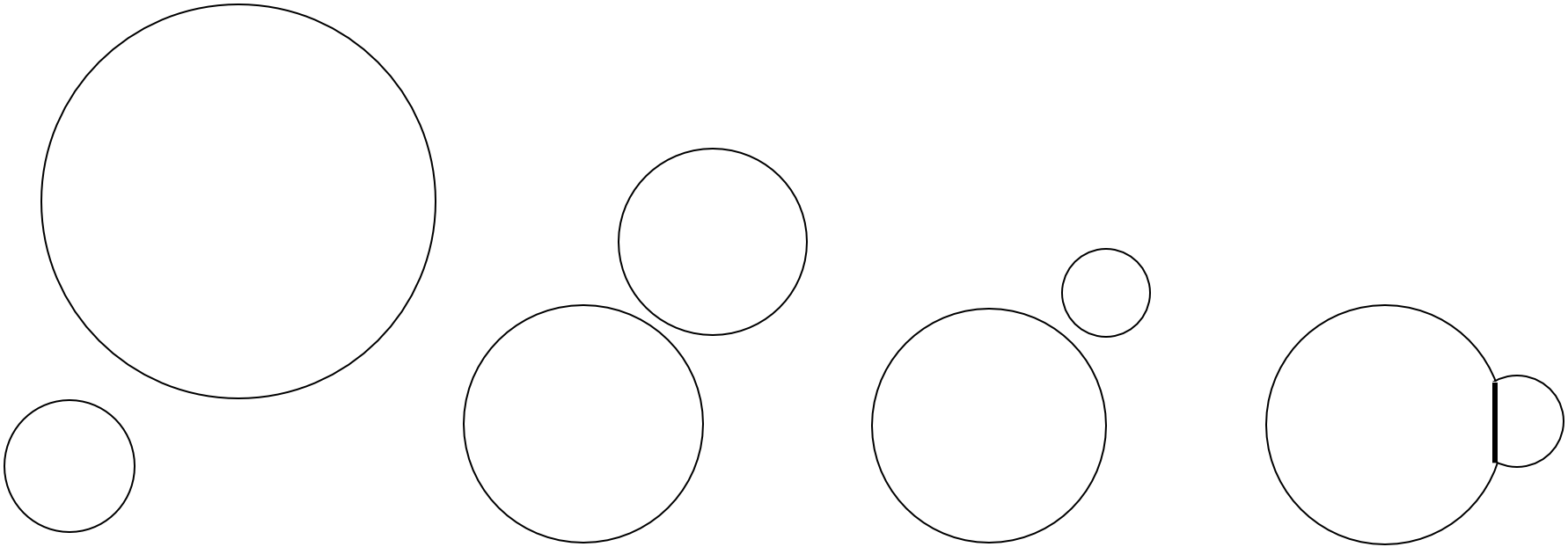


mobile ⟶ wearable

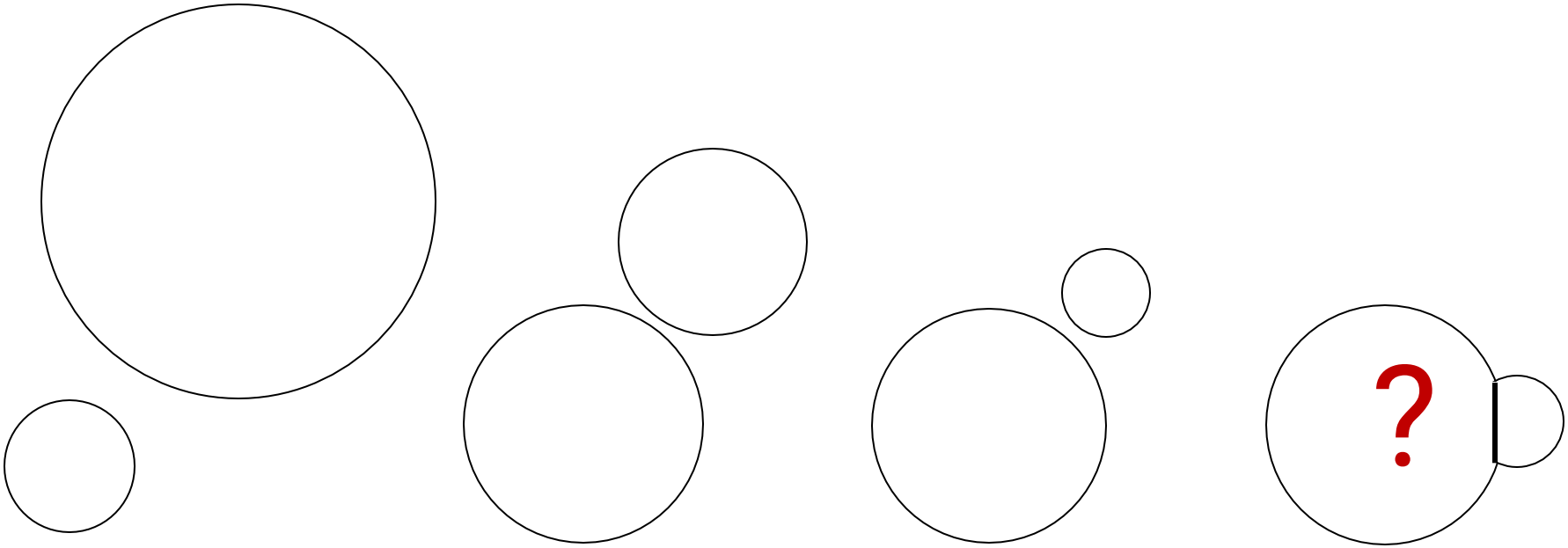
each evolution-step brought **unique benefits**
e.g., body-data on mobile was not revolutionary
but it in a **wearable** it created **a new movement**



if each evolution-step of computer interfaces **proved useful**



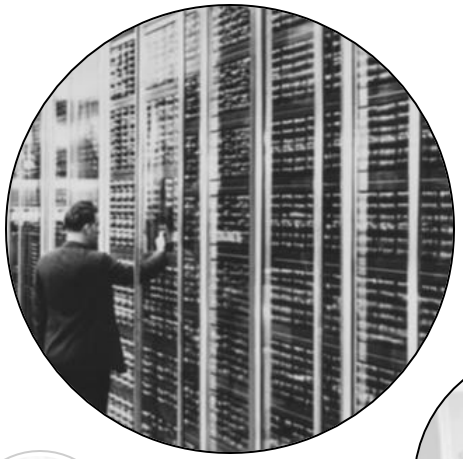
if each evolution-step of computer interfaces **proved useful**
imagine the **value we could derive** from …

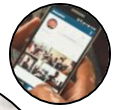


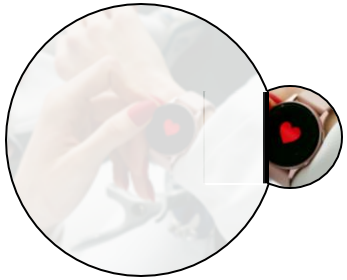
mainframe desktop mobile wearable

if each evolution-step of computer interfaces **proved useful**
imagine the **value we could derive** from **the next-gen interface**


what **drives** this evolution?
?
mainframe
desktop
mobile
wearable
what’s next?





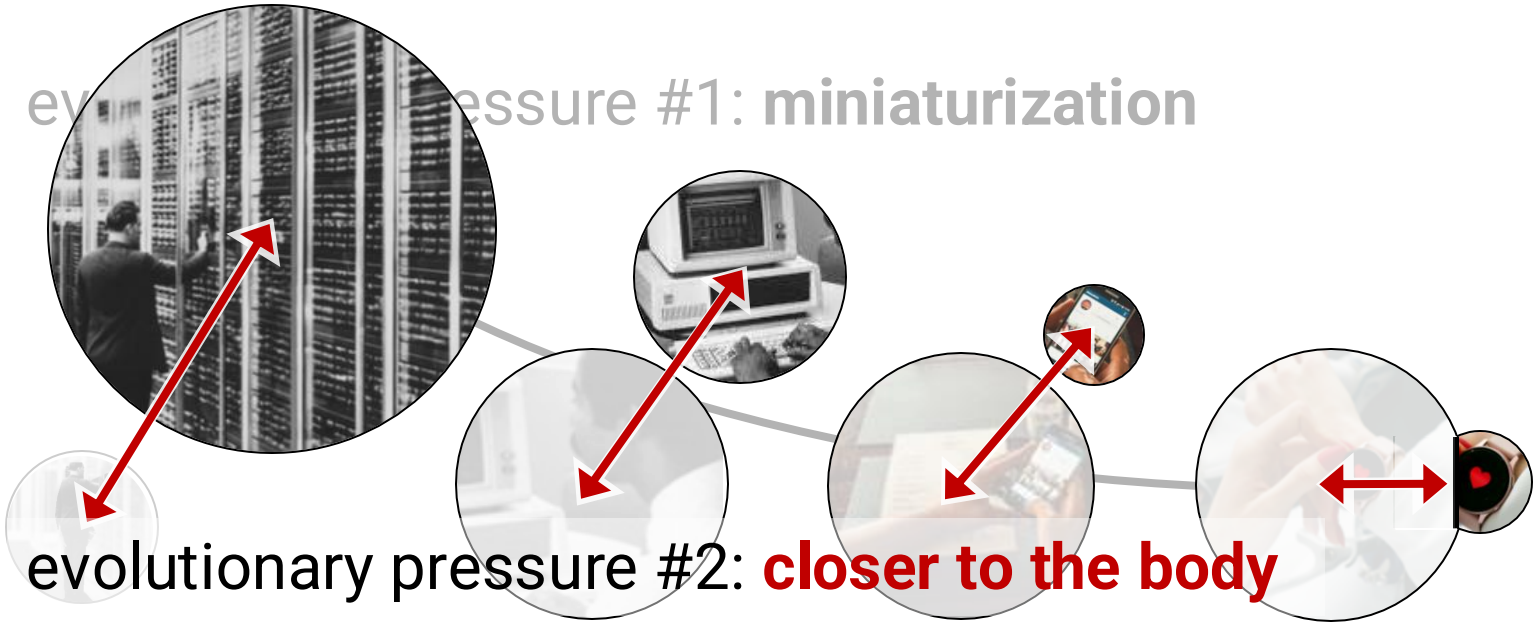


?

mainframe desktop mobile wearable what’s next?

evolutionary pressure #1: **miniaturization**

mainframe desktop mobile wearable what's next?



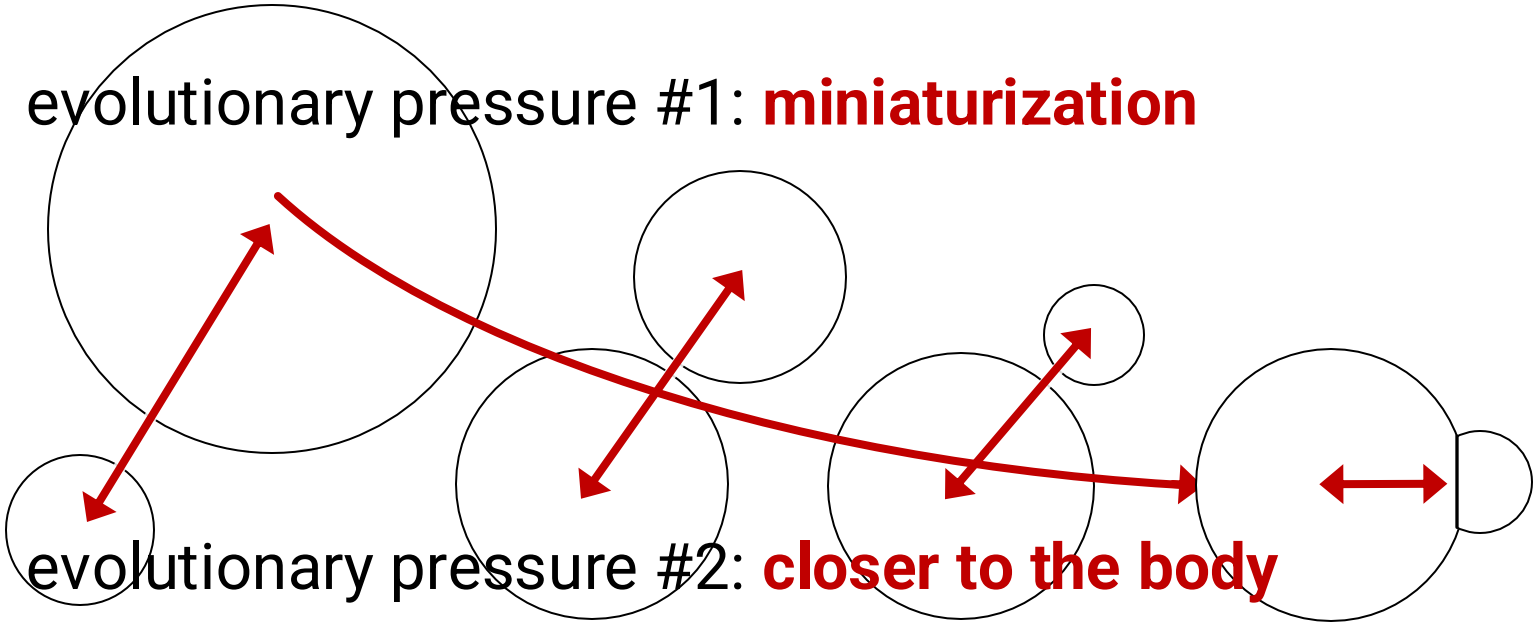
ev essure #1: **miniaturization**

evolutionary pressure #2: **closer to the body**

?

mainframe desktop mobile wearable what's next?

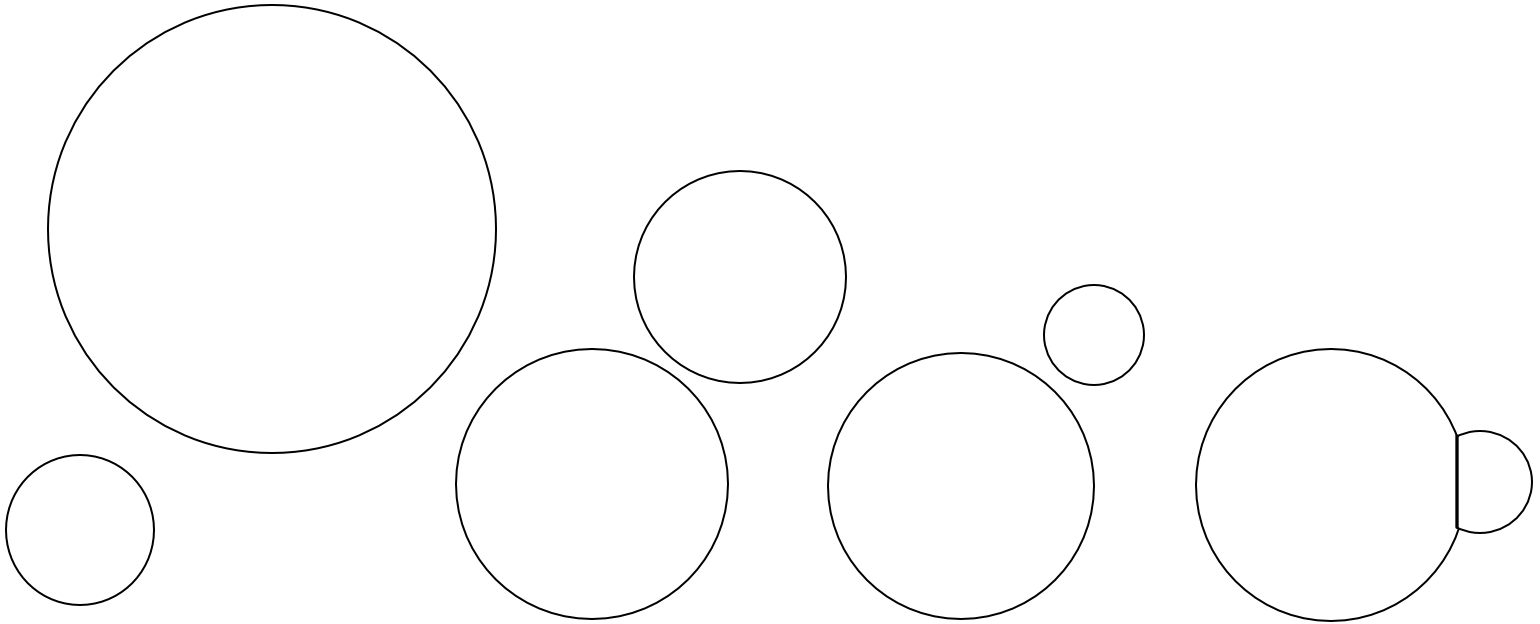
evolutionary pressure #1: **miniaturization**



evolutionary pressure #2: **closer to the body**

?

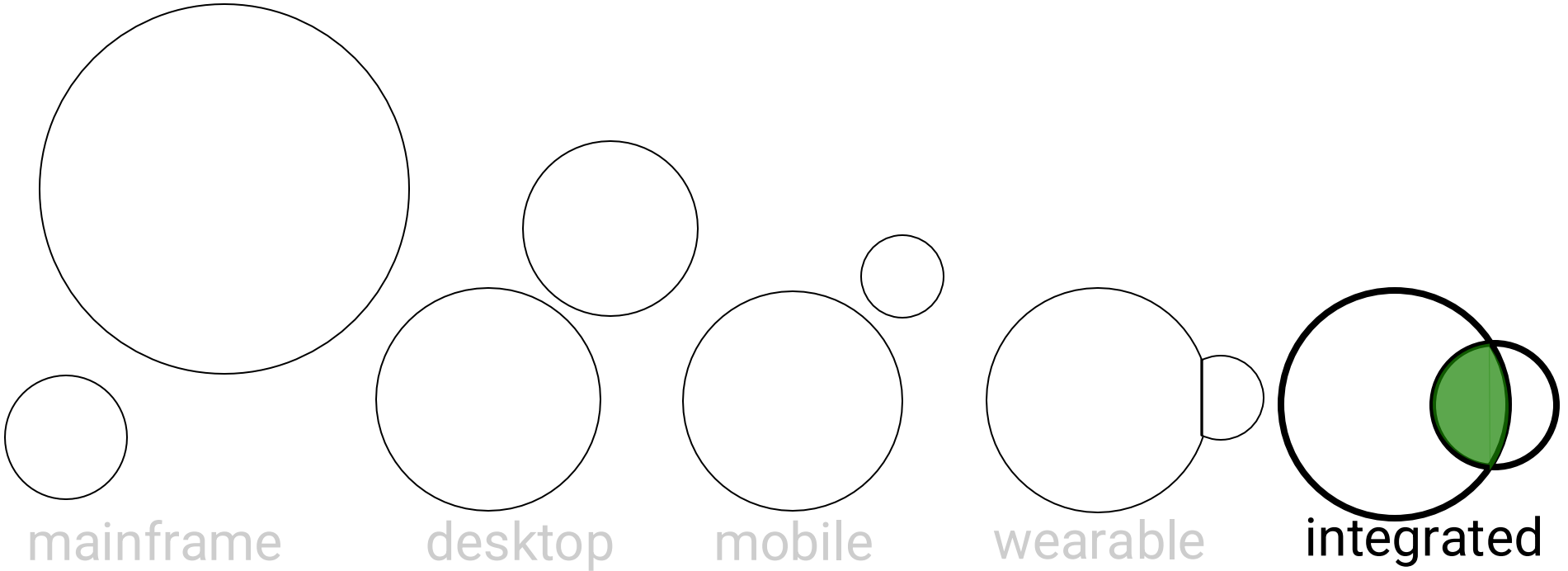
mainframe desktop mobile wearable what's next?

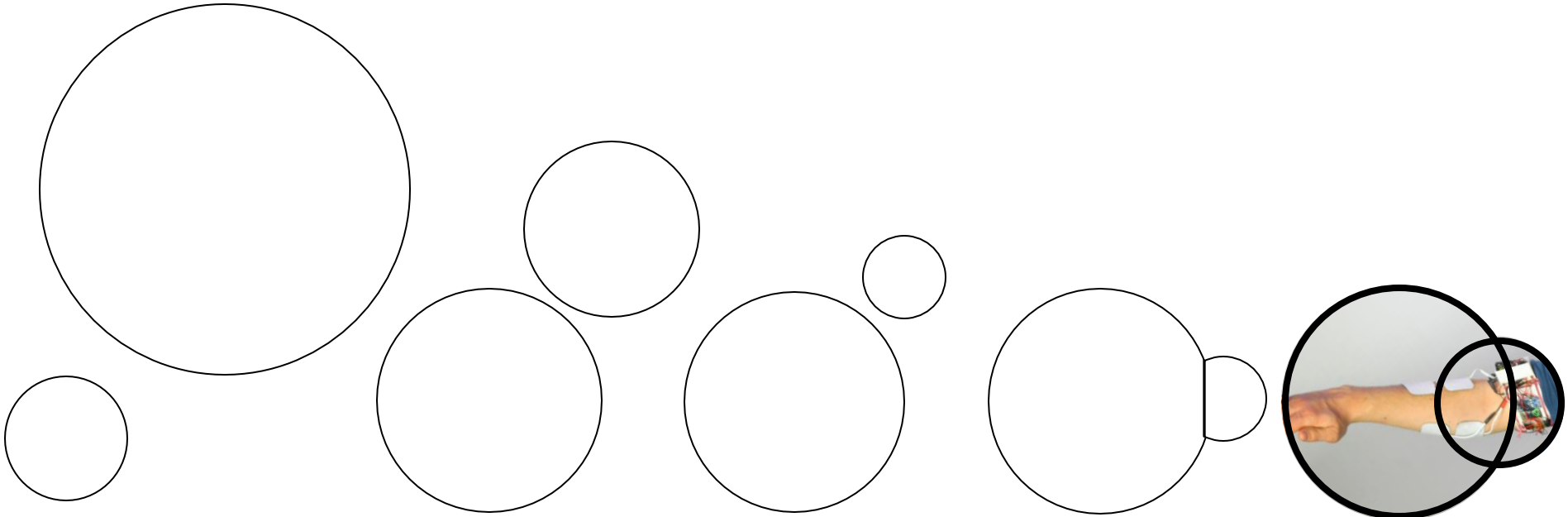


mainframe desktop mobile wearable

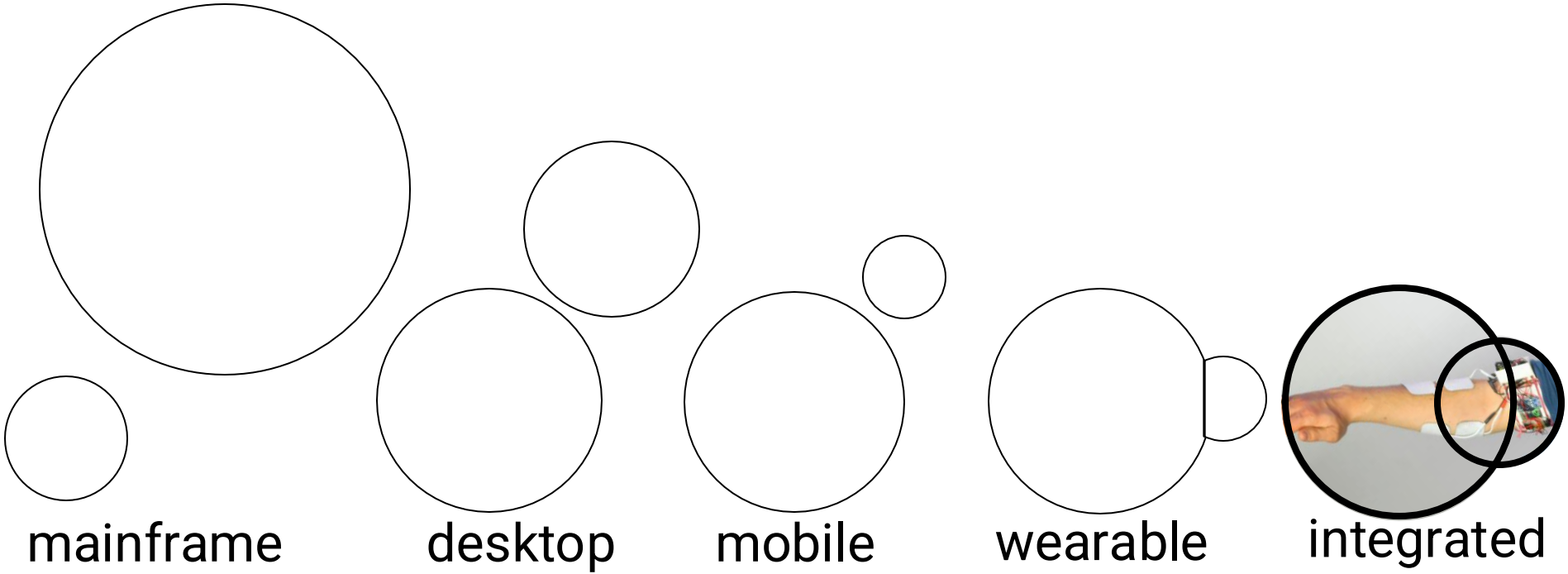
?

what’s next?

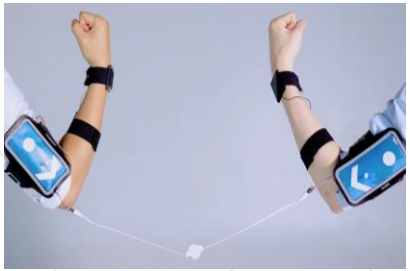

mainframe
desktop
mobile
wearable
integrated


mainframe
desktop
mobile
wearable
integrated

new system by Romain Nith & Yun Ho
https://arxiv.org/abs/2505.10648

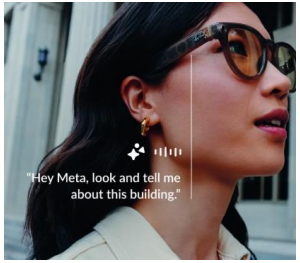

mainframe
desktop
mobile
wearable
integrated

Nishida & Suzuki, 2017, CHI



humane's AI pin

meta's AI glasses



S. Imbrie with a touch-implant
Bensmaia/Greenspon et al. nature comm.

NFC/RFID implants

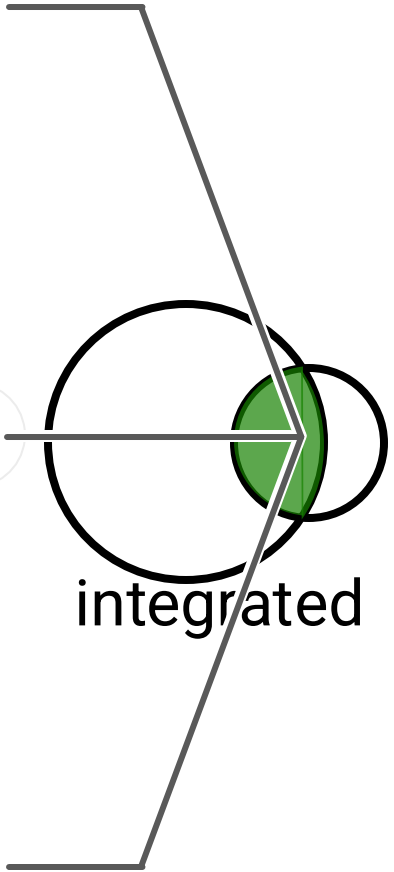
teslasuit

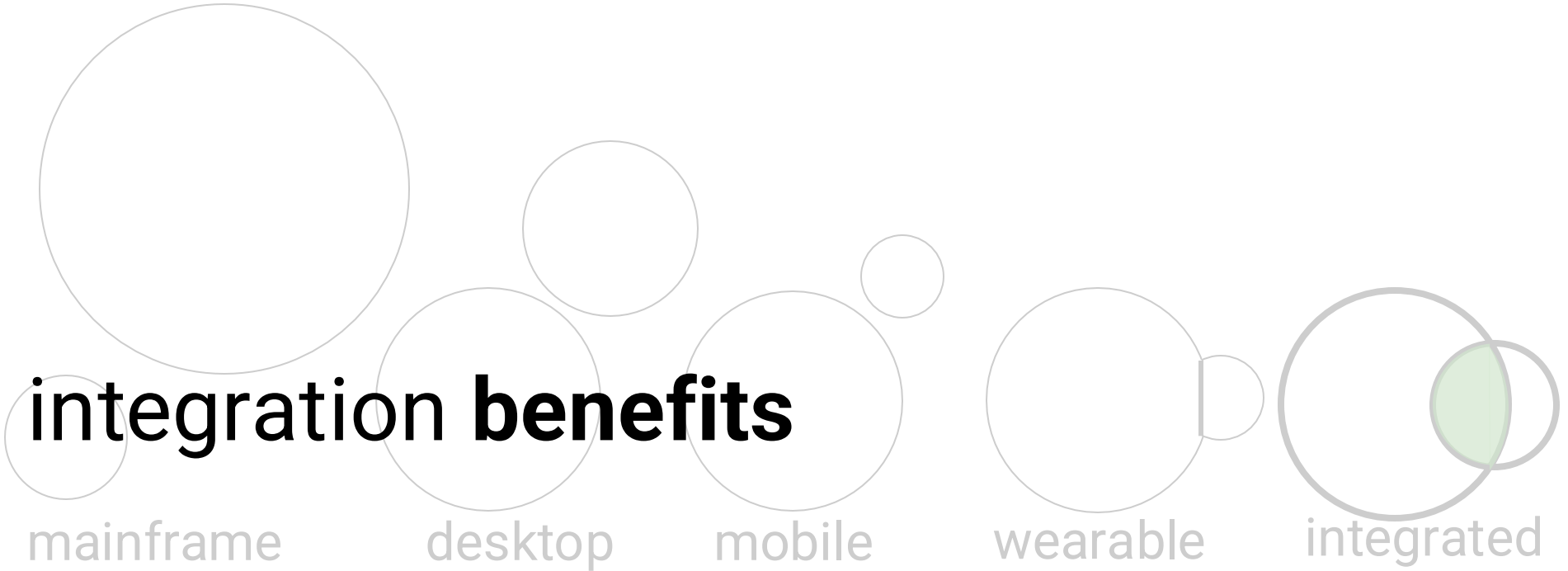
mainframe

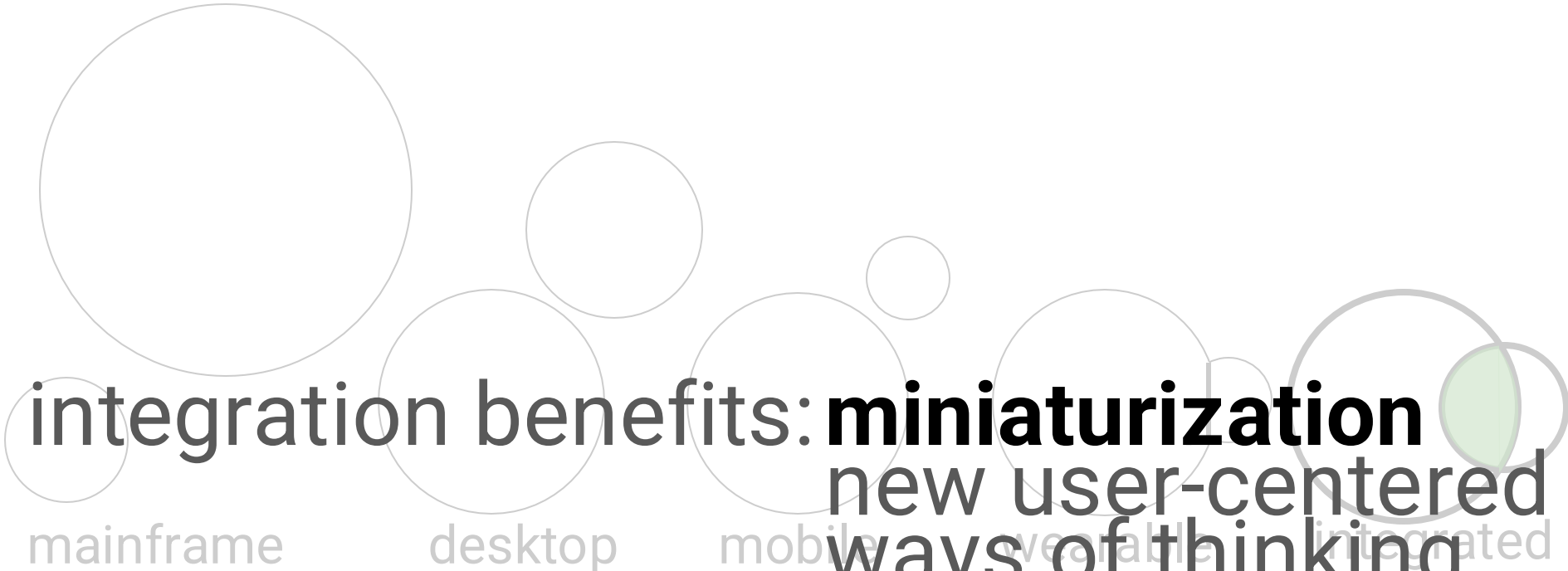
Clode/Makin et. al,
science robotics

MATE-XB exoskeleton

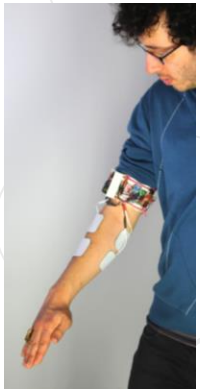
Furuya et. al, 2025
science robotics




integration **benefits**
mainframe
desktop
mobile
wearable
integrated

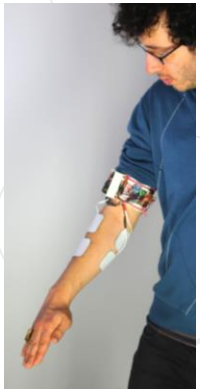

integration benefits: **miniaturization**
new user-centered
ways of thinking
new abilities
mainframe
desktop
mobile
wearable
integrated

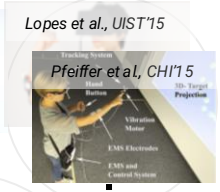
Pose-IO
Lopes, CHI'15

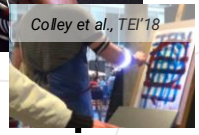


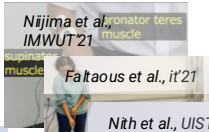
ame desktop mobile wearable integrated

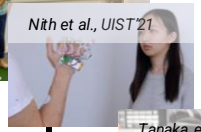
Pose-IO
Lopes, CHI'15

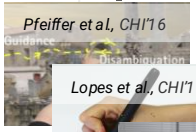


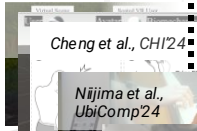


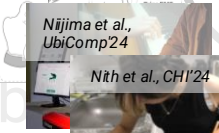






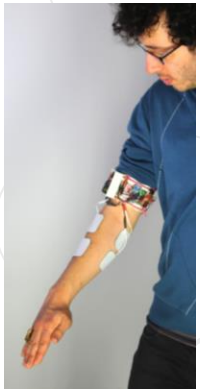


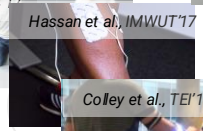


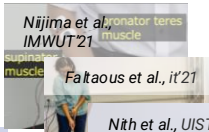


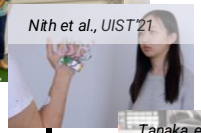
[timeline by Yun Ho & Romain Nith, apropos CHI'25 talk]

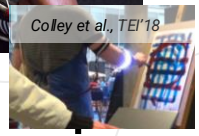
Pose-IO
Lopes, CHI'15

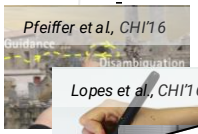






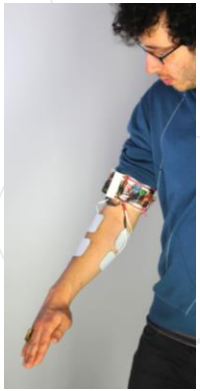


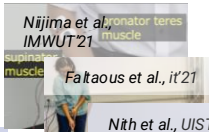


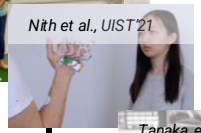


151 papers (as of 2022)
Faltaous et al., MUM'22

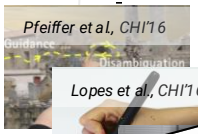
Pose-IO
Lopes, CHI'15

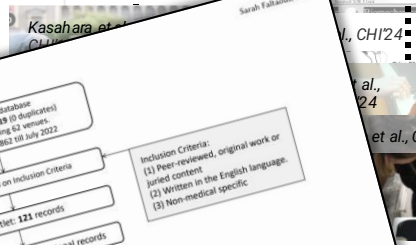






why the excitement?





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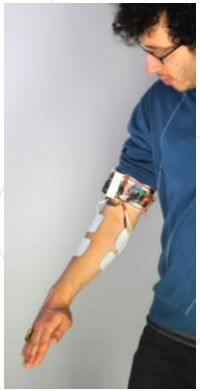
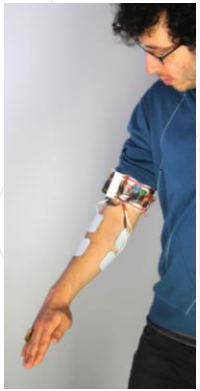
Pose-IO
Lopes, CHI'15



why the excitement?

ame desktop mobile wearable integrated

Pose-IO
Lopes, CHI'15



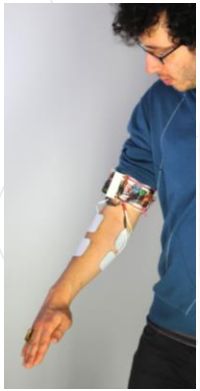
EXO-UL7, Perry at al., 2009
Applied Bionics & Biomech

why the excitement?

integrating with body **circumvents limitations** of traditional interfaces

desktop mobile wearable integrated

Pose-IO
Lopes, CHI'15

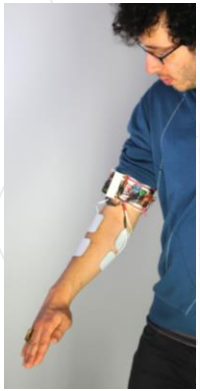


EXO-UL7, Perry at al., 2009
Applied Bionics & Biomech

why the excitement?
integrating with body **circumvents limitations** of traditional interfaces
since **directly stimulating neurons** results in much **smaller interfaces**

desktop mobile wearable integrated

Pose-IO
Lopes, CHI'15



EXO-UL7, Perry at al., 2009
Applied Bionics & Biomech

force-feedback

why the excitement?
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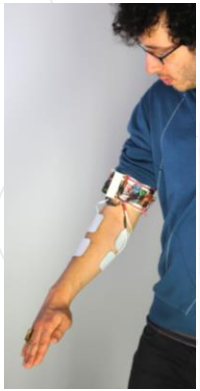
desktop mobile wearable integrated

Pose-IO
Lopes, CHI'15



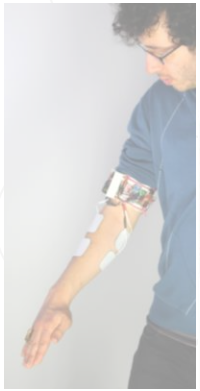
EXO-UL7, Perry at al., 2009
Applied Bionics & Biomech

force-feedback

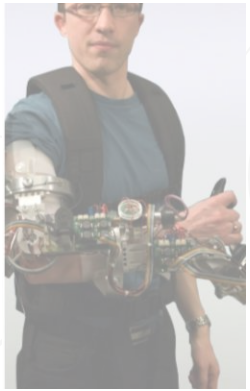
why the excitement?
integrating with body **circumvents limitations** of traditional interfaces
since **directly stimulating neurons** results in much **smaller interfaces**

desktop mobile wearable integrated

Pose-IO
Lopes, CHI'15



EXO-UL7, Perry at al., 2009
Applied Bionics & Biomech



force-feedback

thermal lamps
Buckey et al.

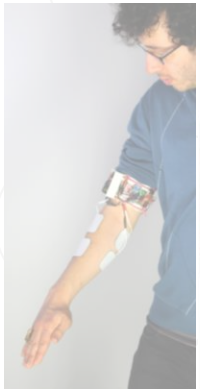
chemical thermal illusion
Brooks et al. CHI'20

temperature

wearable

integrated

Pose-IO
Lopes, CHI'15



EXO-UL7, Perry at al., 2009
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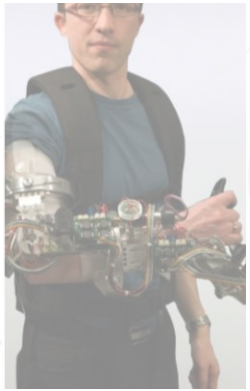

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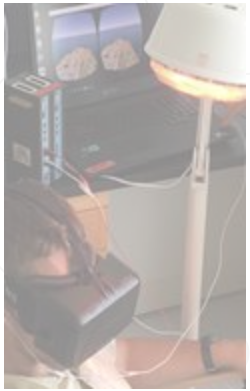
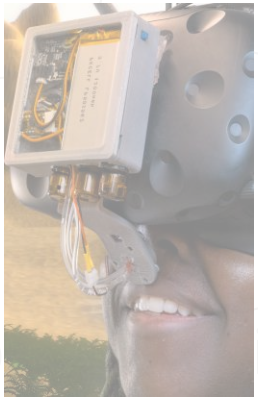
Buckey et al.

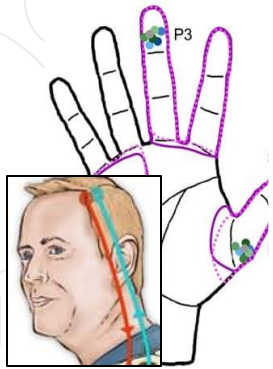


chemical thermal illusion
Brooks et al. CHI'20

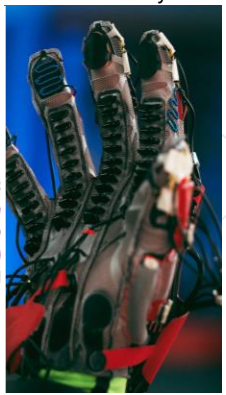


temperature

Ortiz-Catalan, Greenspon,
Bensmaia et al., Cell Reports'20



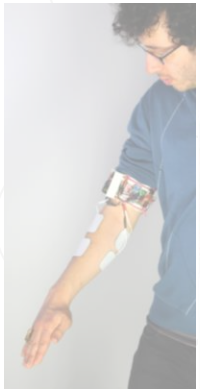
Glove, Meta
Reality Labs



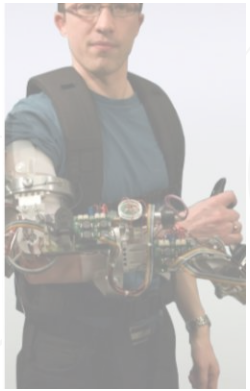
touch

integrated

Pose-IO
Lopes, CHI'15



EXO-UL7, Perry at al., 2009
Applied Bionics & Biomech



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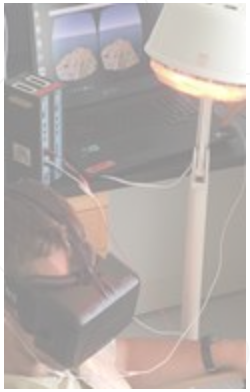
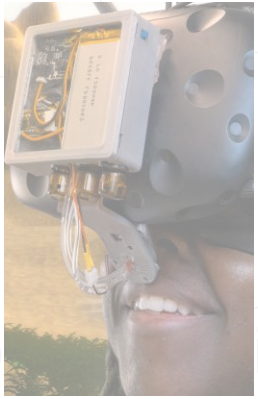
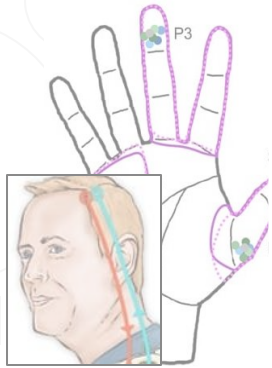


chemical thermal illusion
Brooks et al. CHI'20

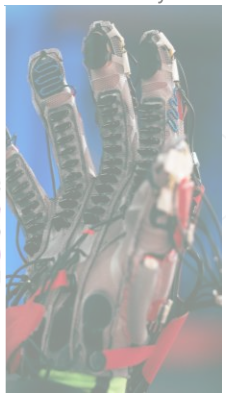


temperature

Ortiz-Catalan, Greenspon,
Bensmaia et al., Cell Reports'20



Glove, Meta
Reality Labs



touch

Imparted User Interfaces
Holz et. al., CHI'12

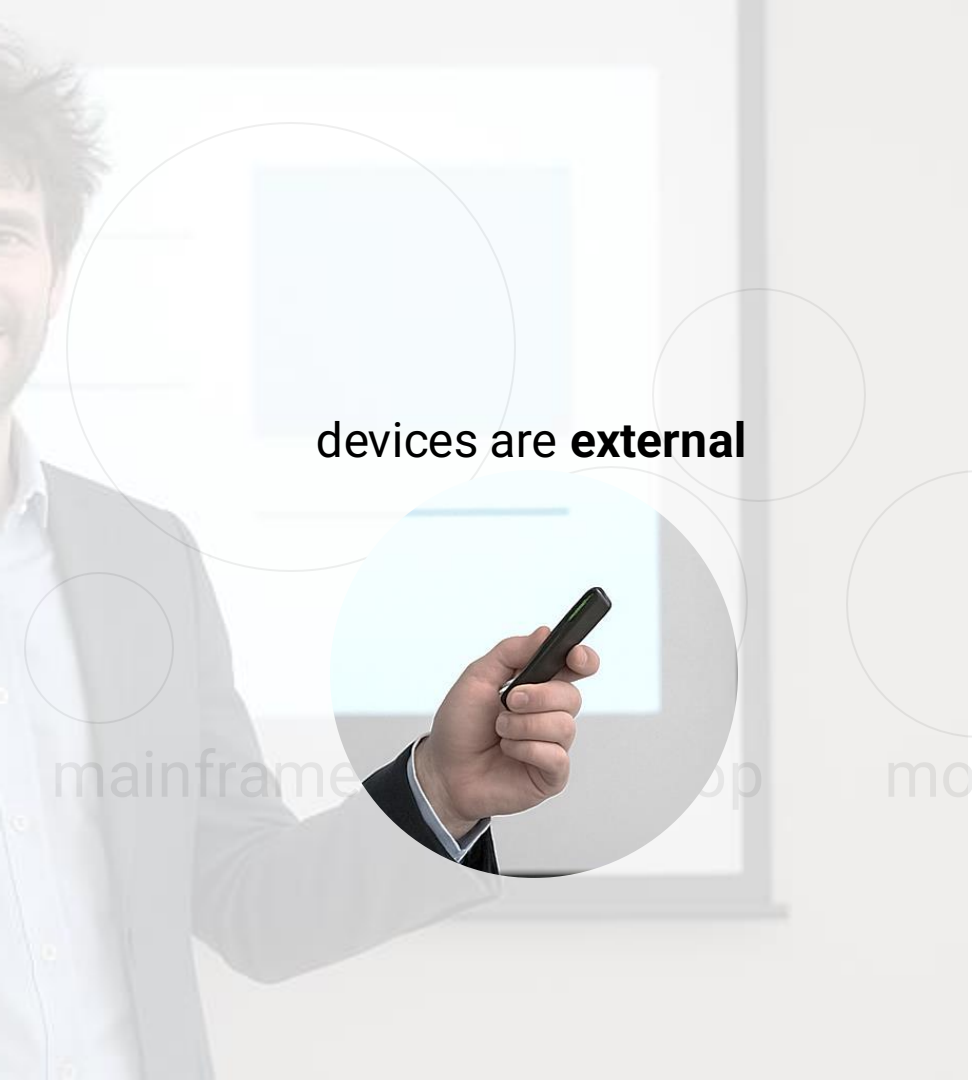
I/O


integration benefits: miniaturization
new user-centered
ways of thinking
new abilities
mainframe
desktop
mobile
wearable
integrated

obile

wearable

integrated



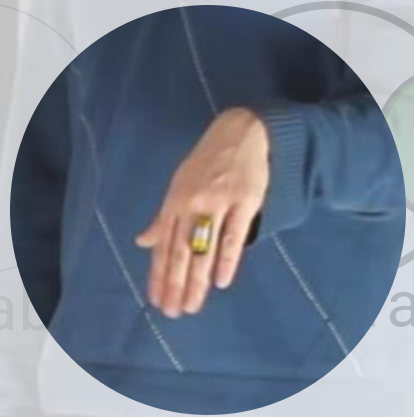
devices are **external**

mainframe mobile wearable integrated

devices are **external**

devices are **external**

body **becomes** the device



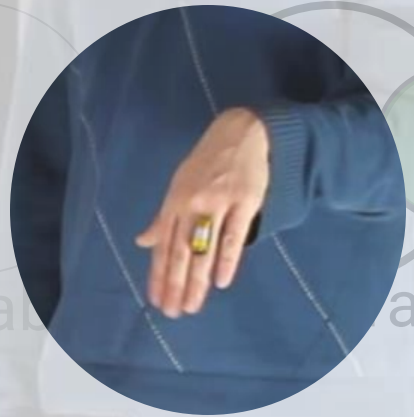
mainframe desktop mobile wearable integrated


SHARP

devices are **external**

new meaning to user-centered

body **becomes** the device



mainframe desktop mobile wearable integrated

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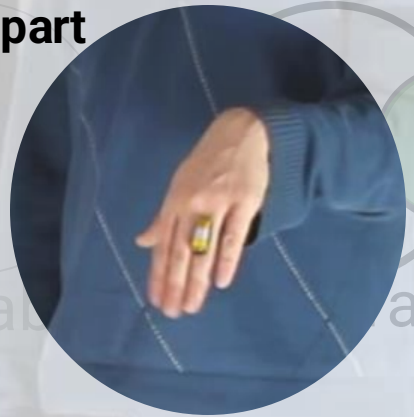
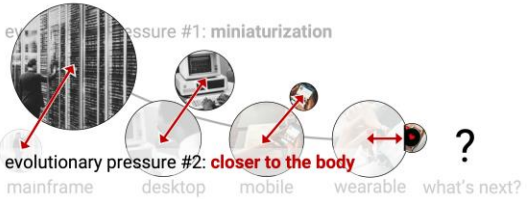
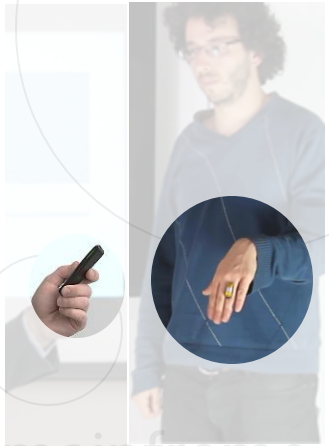


replace **device-part** with **biological-part**

replace **device-part** with **biological-part**



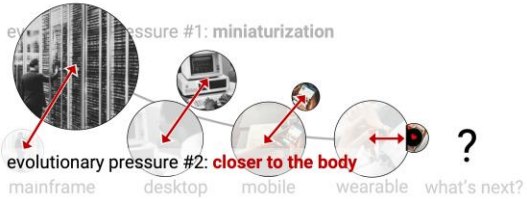
body as I/O device
Lopes et. al. CHI'15



mainframe desktop mobile wearable integrated

replace handheld

replace **device-part** with **biological-part**



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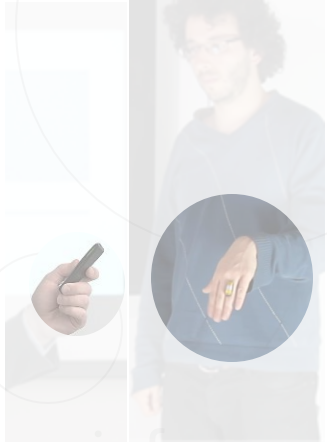
Lopes et. al. CHI'15

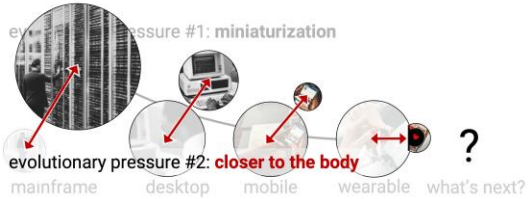


imaginary phone
Gustafson et. al. UIST'11

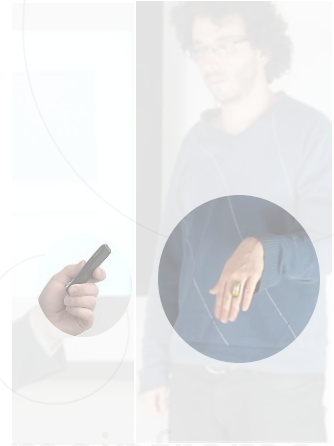
mainframe desktop mobile wearable integrated

replace handheld

replace **device-part** with **biological-part**



body as I/O device
Lopes et. al. CHI'15



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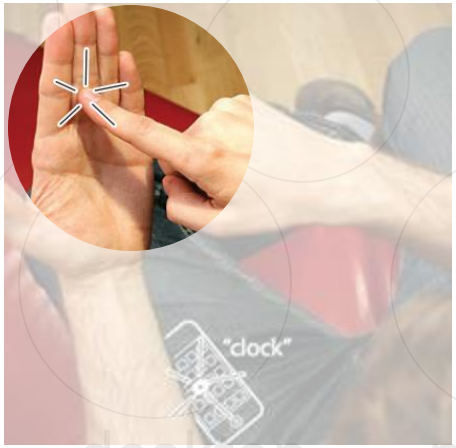
Gustafson et. al. UIST'11

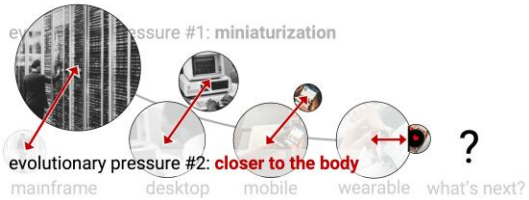


mainframe desktop mobile wearable integrated

replace handheld

replace phone

replace **device-part** with **biological-part**



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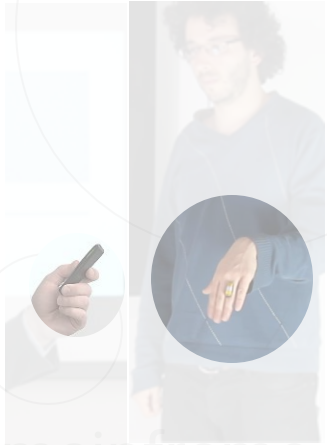
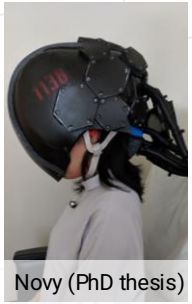


replace handheld

imaginary phone
Gustafson et. al. UIST'11

replace phone

TMS phosphenes, e.g.,
Dugué et al., Cur.Bio.'16,



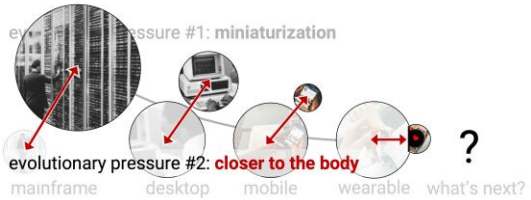
Novy (PhD thesis)

phosphenes guidance
Higuchi et al., AH'17

replace screens

integrated

replace **device-part** with **biological-part**



body as I/O device
Lopes et. al. CHI'15

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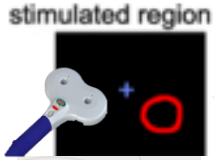

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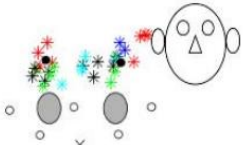
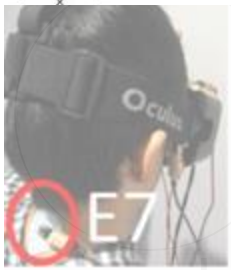




replace screens

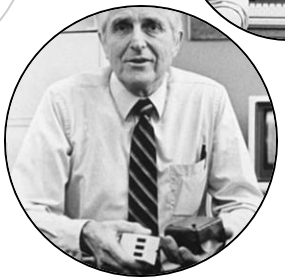
integrated

integration benefits: miniaturization
new user-centered
ways of thinking
new abilities

the mainstream mode of thinking with **computers is symbolic (textual, iconic)**

mainframe desktop

the mainstream mode of thinking with **computers is symbolic (textual, iconic)**



mainframe

desktop

the mainstream mode of thinking with **computers is symbolic (textual, iconic)**

mainframe desktop

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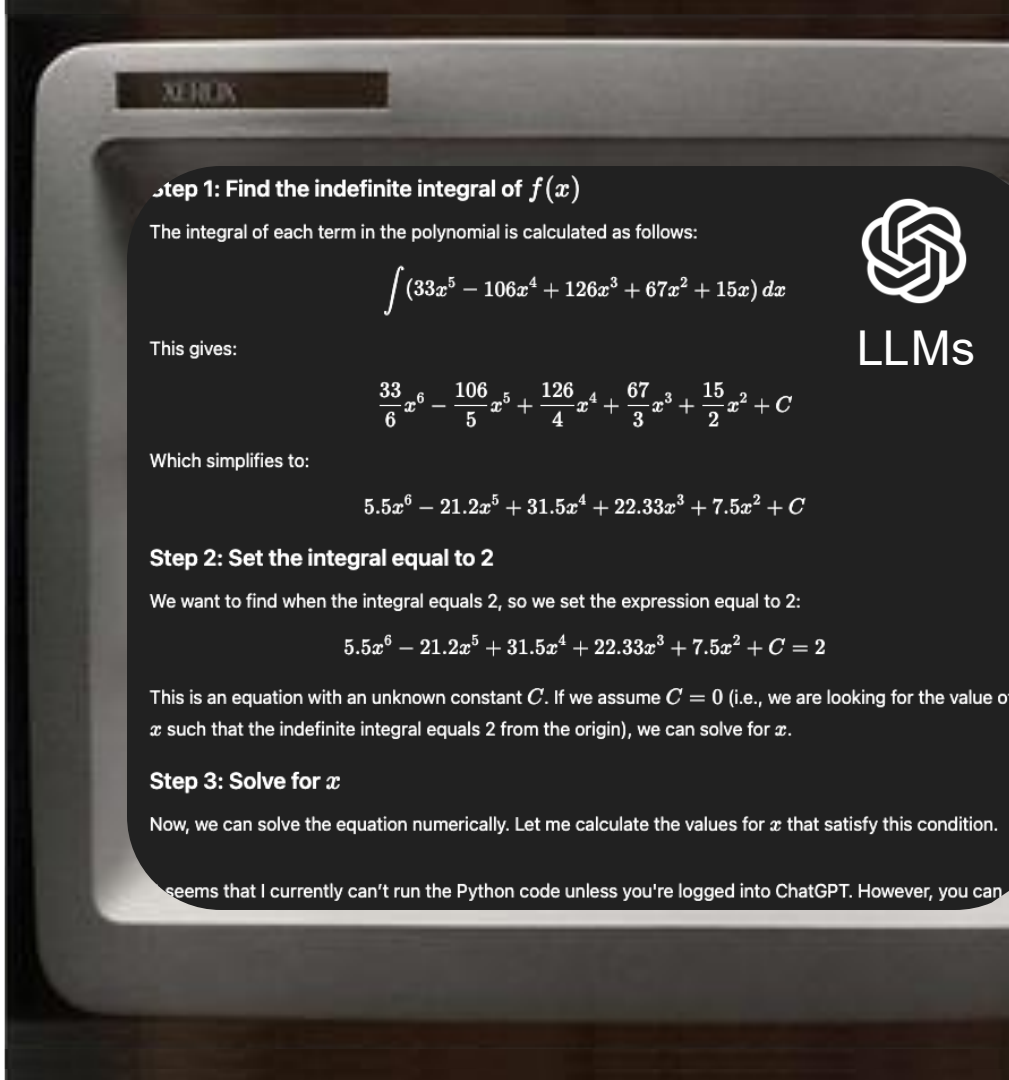


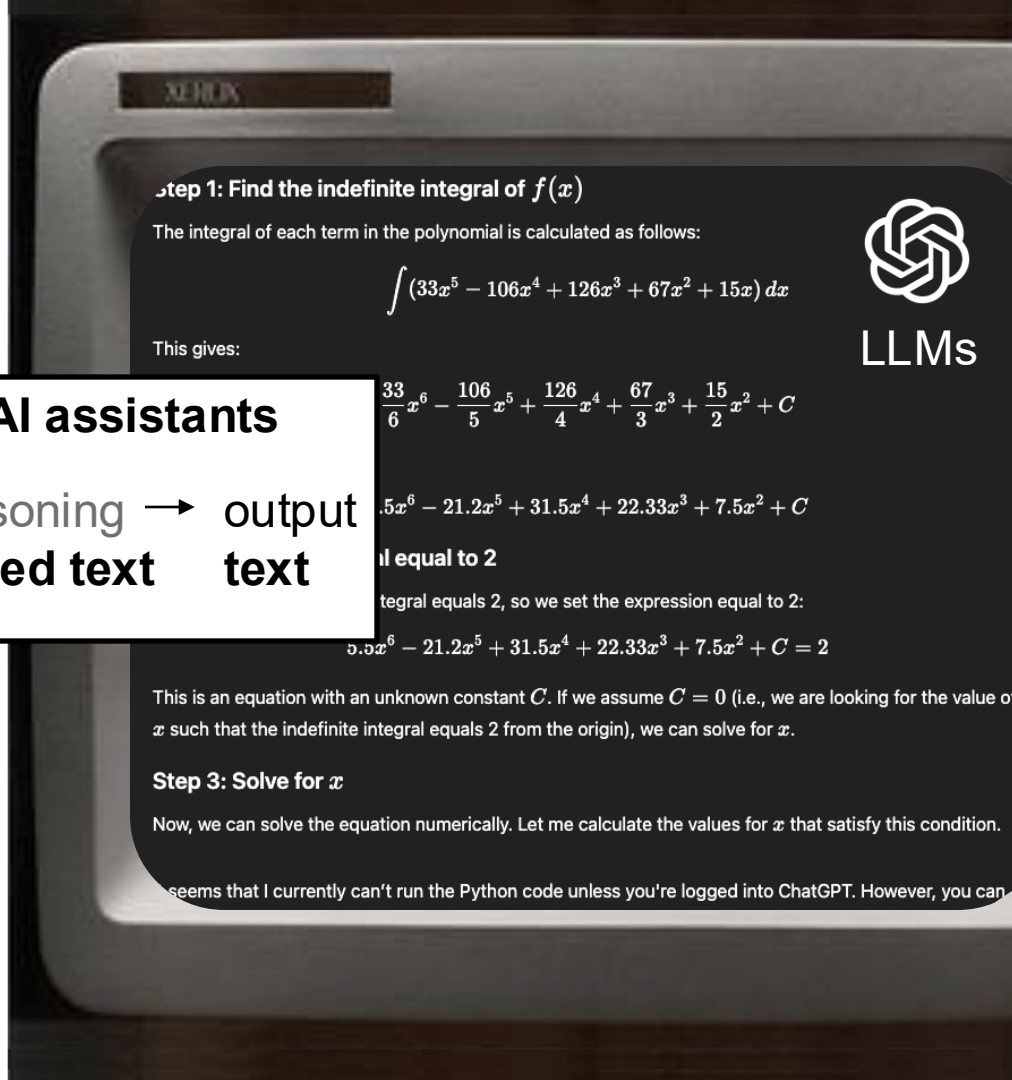
the mainstream mode of thinking with **computers is symbolic (textual, iconic)**

modern AI assistants

input → reasoning → output

text **learned text** **text**

mainframe desktop



the mainstream mode of thinking with **computers is symbolic (textual, iconic)**

modern AI assistants

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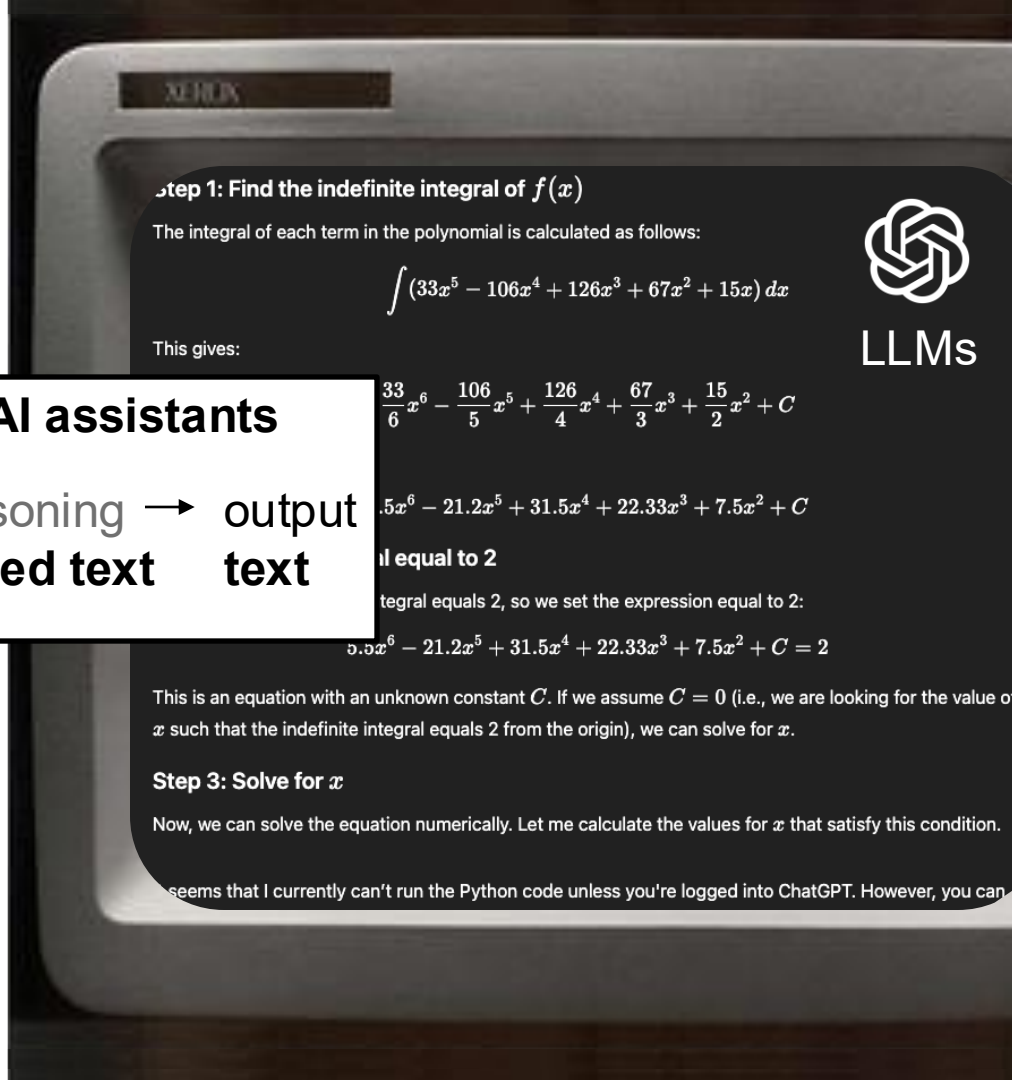
text **learned text** **text**

mainframe desktop

however, this does not represent the **entirety of being human,** nor **all of us**



integrated AI assistants

input → reasoning → output

body **non-verbal** **body**

watch video: https://www.youtube.com/watch?v=0n738nXm5AM

Lopes et al., UIST'16

tep 1: Find the indefinite integral of $f(x)$

The integral of each term in the polynomial is calculated as follows:

$$\int (33x^5 - 106x^4 + 126x^3 + 67x^2 + 15x)\,dx$$

This gives:

$$\frac{33}{6}x^6 - \frac{106}{5}x^5 + \frac{126}{4}x^4 + \frac{67}{3}x^3 + \frac{15}{2}x^2 + C$$

$$.5x^6 - 21.2x^5 + 31.5x^4 + 22.33x^3 + 7.5x^2 + C$$

l equal to 2

tegral equals 2, so we set the expression equal to 2:

$$5.5x^6 - 21.2x^5 + 31.5x^4 + 22.33x^3 + 7.5x^2 + C = 2$$

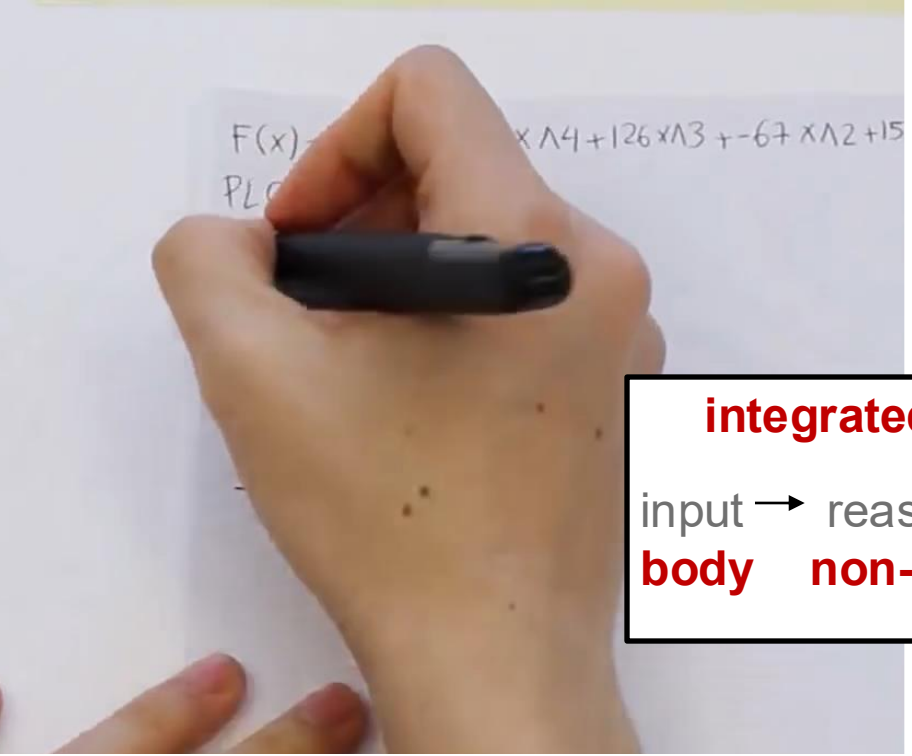
This is an equation with an unknown constant C. If we assume $C = 0$ (i.e., we are looking for the value o x such that the indefinite integral equals 2 from the origin), we can solve for x.

Step 3: Solve for x

Now, we can solve the equation numerically. Let me calculate the values for x that satisfy this condition.

seems that I currently can't run the Python code unless you're logged into ChatGPT. However, you can

LLMs



Explaining Math: Gesturing Lightens the Load

December 2001 · Psychological Science · 12(6):516-22

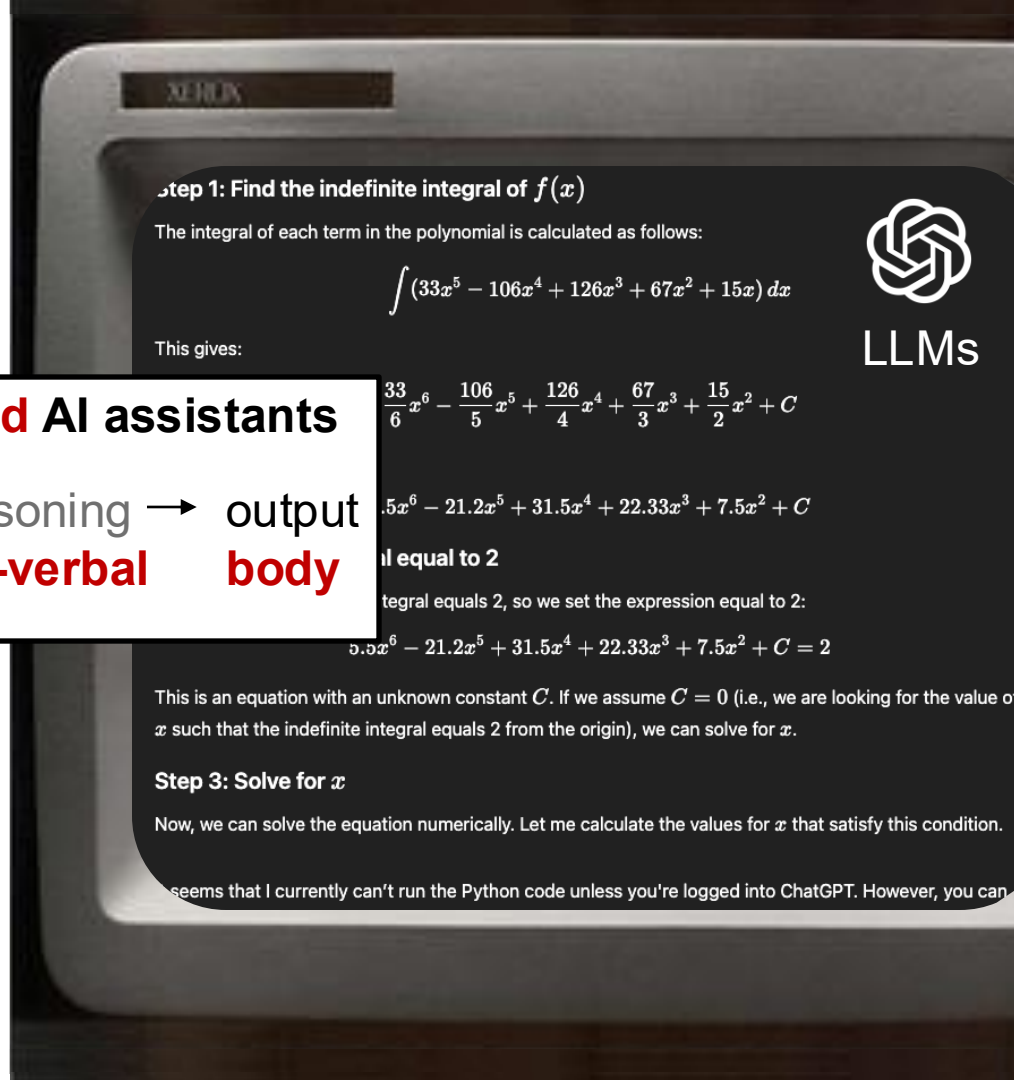
DOI: 10.1111/1467-9280.00395

Susan Goldin-Meadow · Howard Nusbaum · Spencer Kelly · Susan Wagner Cook

integrated AI assistants

input → reasoning → output

body **non-verbal** **body**

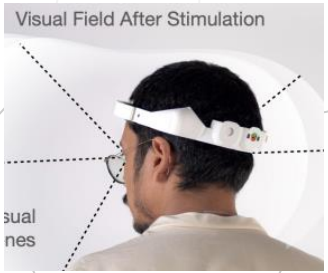


integrated interfaces allow us to explore **non-symbolic modes of reasoning** *

Lopes et al., UIST'16

physical reasoning

Danry et al., AH'24



spatial reasoning

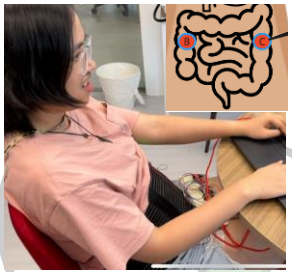
Bhandarkar / Seim / Starner at al., ISWC'22

subconscious reasoning

Horowitz et al., Sci. Reps.'23

unconscious reasoning

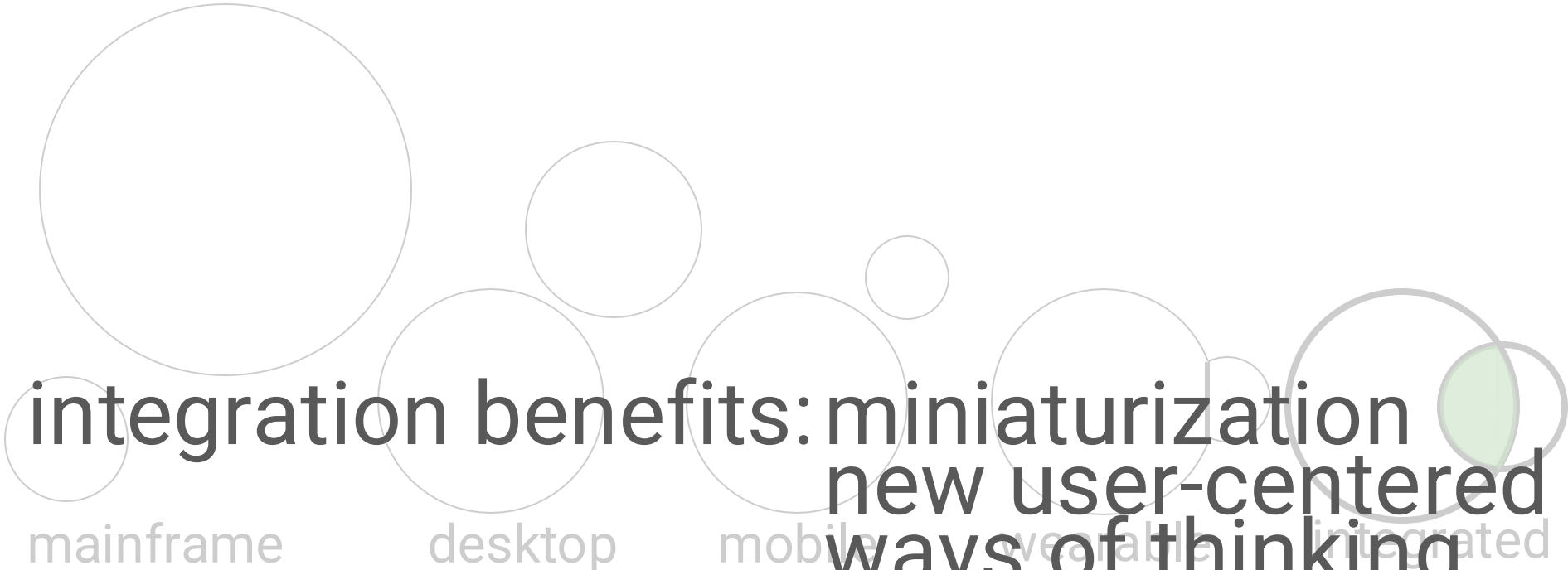
Nguyen et. al., UIST EA'24



interoceptive reasoning

mainframe desktop mobile wearable integrated

* see significant shifts in last decades of HCI towards non-verbal thinking (e.g., Ishi's Tangible Bits, Höök's Soma design, and more)


integration benefits: miniaturization
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integration allows **endowing** users with **new abilities**

integration allows **endowing** users with **new abilities**

Tanaka et al, UIST'25

accelerated reactions

mainframe desktop mobile wearable integrated

integration allows **endowing** users with **new abilities**

Tanaka et al, UIST'25

accelerated reactions

super human speed up with **electrical muscle stimulation**

guinnessworldrecords.com/world-records/693523-fastest-artificially-assisted-reaction-times

Who	What
PEDRO LOPES, JUN NISHIDA, SHUNICHI KASAHARA	**0.05 SECOND(S)**
Where	**When**
UNITED STATES (CHICAGO)	**MAY 2019**

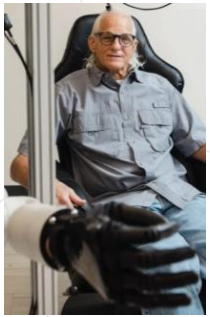
The fastest artificially-assisted reaction time is 50 miliseconds from stimulus to action, which was achieved using electro-muscular stimulation (EMS) by researchers from the University of Chicago (USA) and Sony CSL (JPN). A typical human reaction

integration allows **endowing** users with **new abilities**

Tanaka et al, UIST'25

accelerated reactions

Bensmaia/Greenspon et al., Nature Comm.

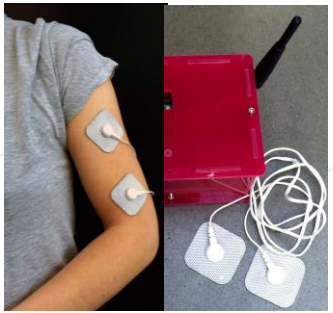


remote touch

Strohmeier et al., AHs'20

feeling EM

Grönvall et al., DIS'16

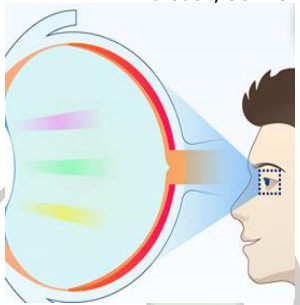


feeling wifi

Brooks et al., CHI'21

smelling in stereo

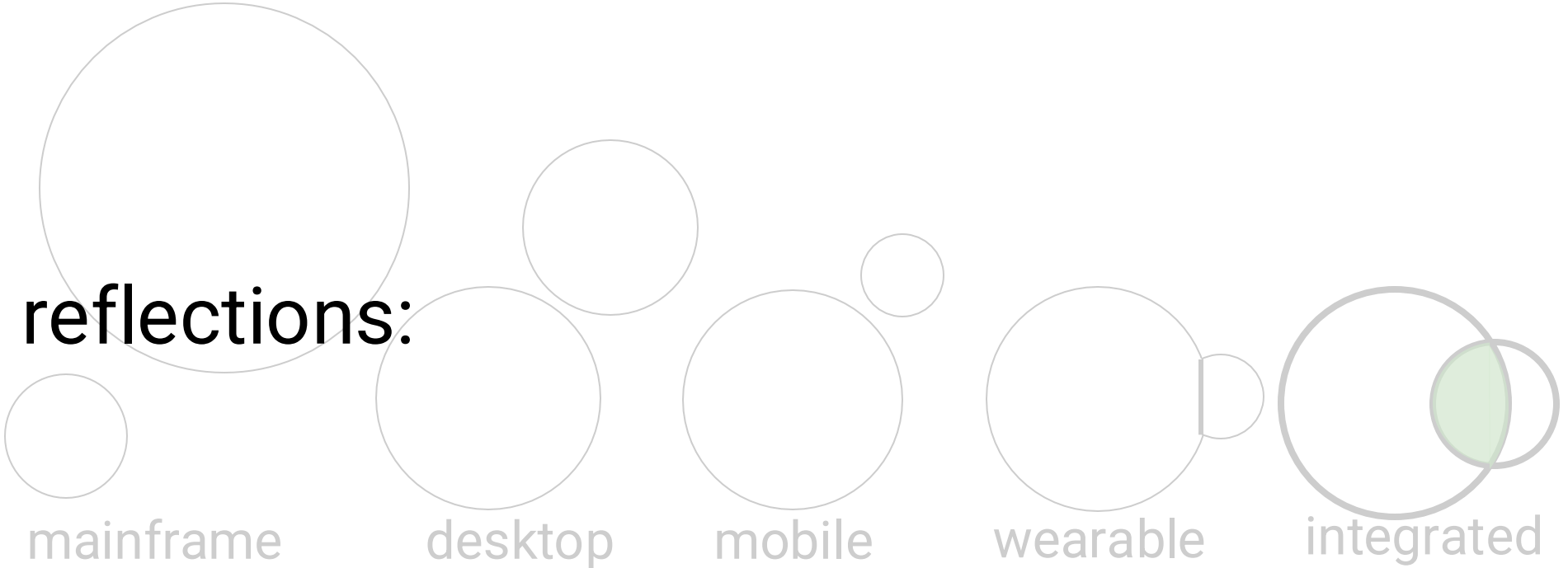
Ma et al., Cell'25

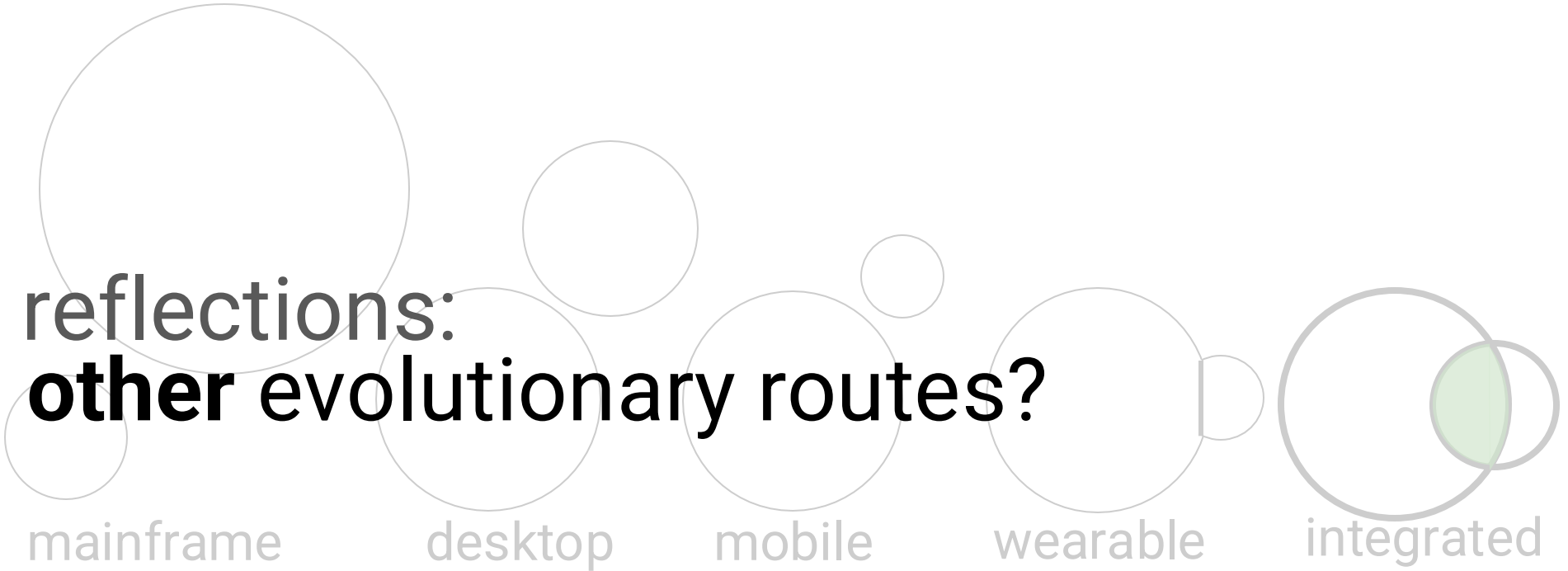


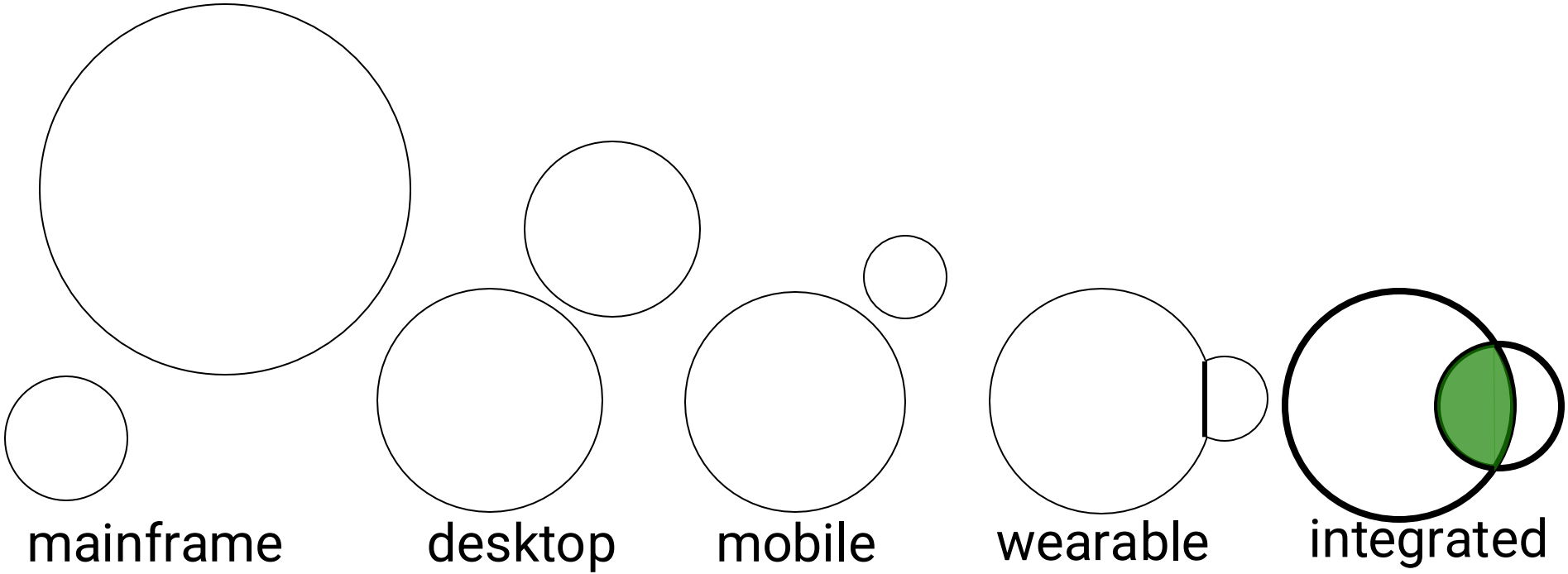
seeing near-IR

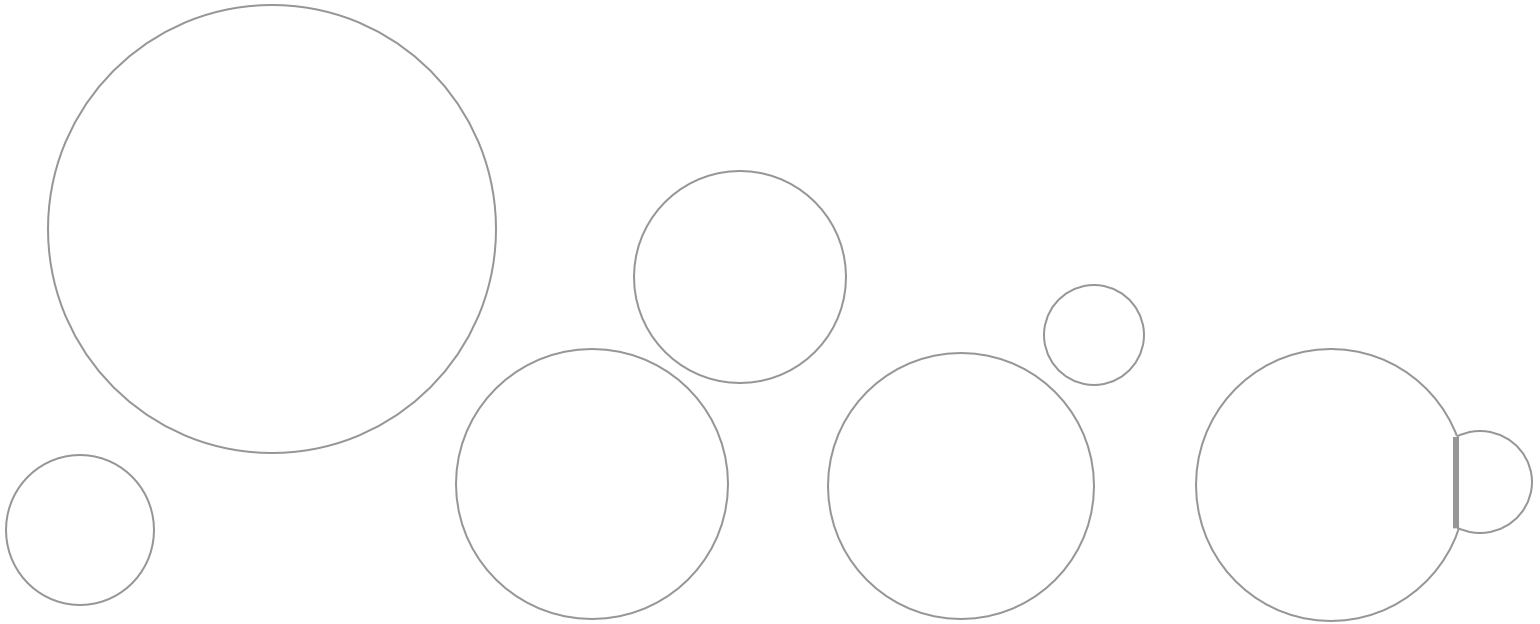
mainframe desktop mobile wearable integrated

reflections:




reflections:
other evolutionary routes?
mainframe
desktop
mobile
wearable
integrated


mainframe
desktop
mobile
wearable
integrated



mainframe desktop mobile wearable

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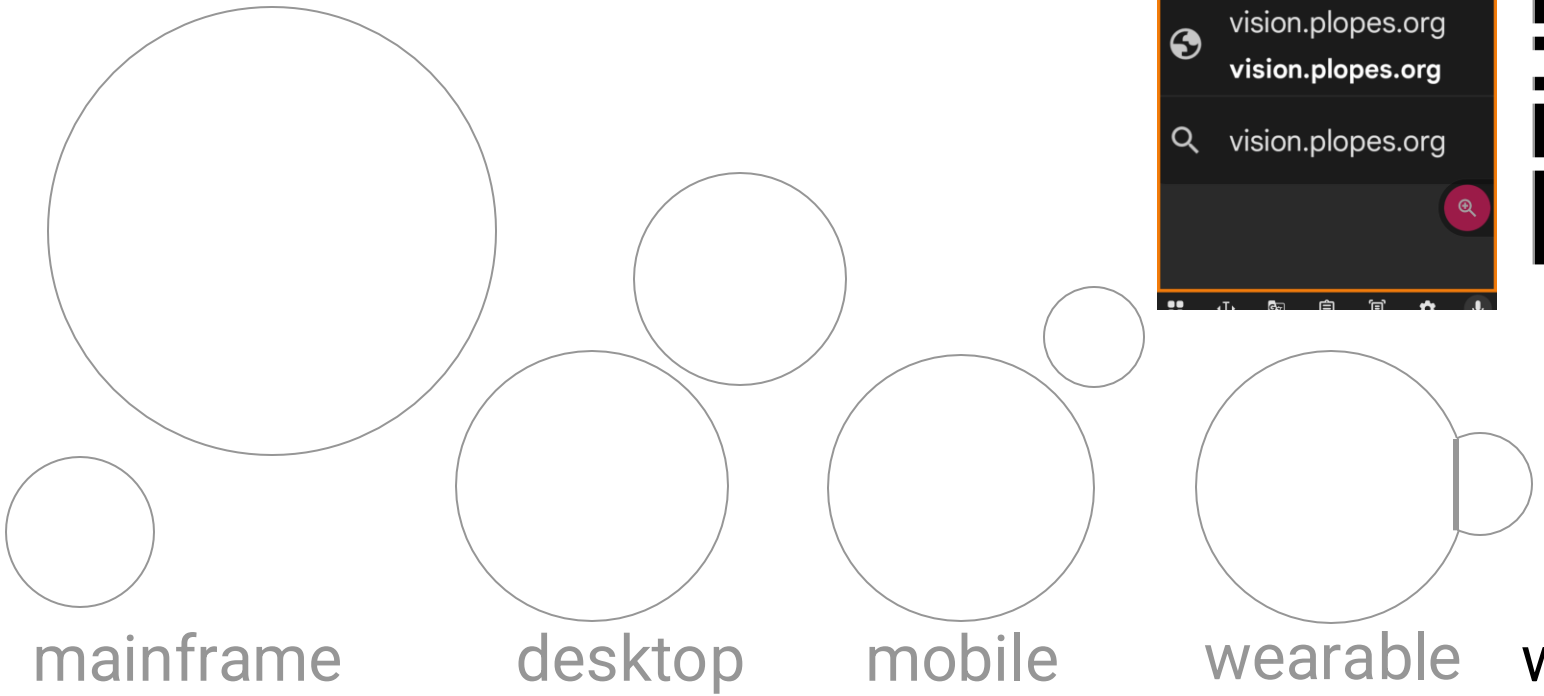
what’s next?



mainframe desktop mobile wearable

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?

what’s next?

reflections:
integration for a **different AI**

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mainframe desktop mobile wearable integrated

reflections:
integration for a **different AI**

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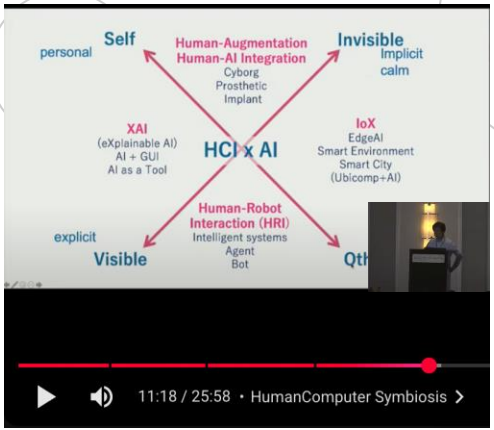
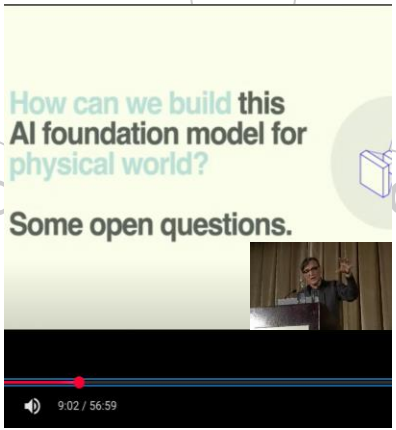
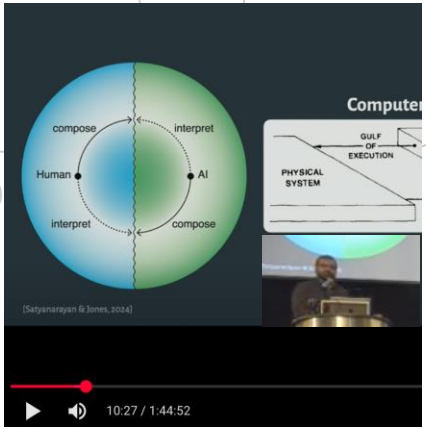
Rekimoto (2019): The Era of Human-AI Integration



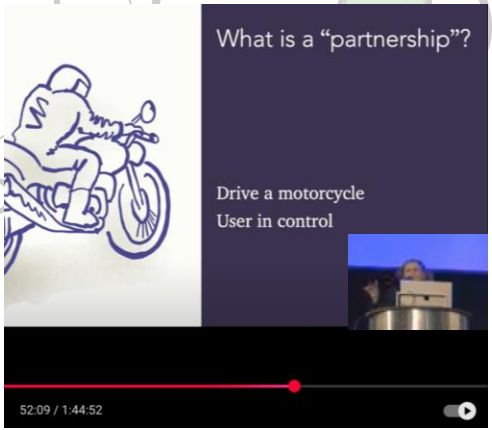
Poupyrev (2023): The Ultimate Interface



Satyanarayan (2024) Intelligence as Agency



Mackay (2024) Parasitic or Symbiotic?



reflections:
integration for a **different AI**

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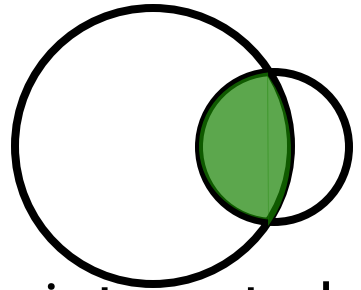

integrated

mainframe desktop mobile wearable

reflections:
integration for a **different AI**

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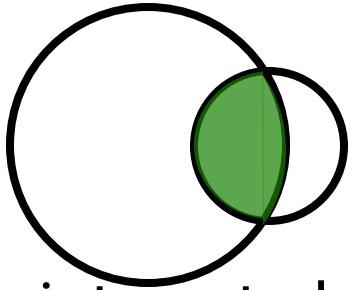
Google deepmind, Gemini Robotics

robotic automation
for everything

ktop mobile wearable



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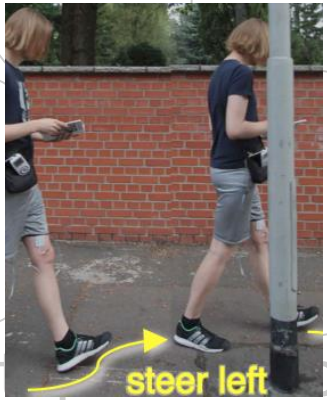
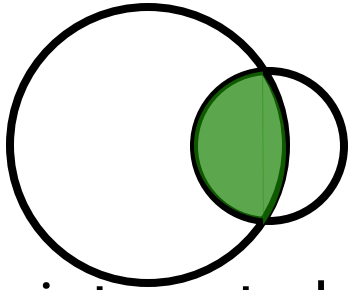
Pfeiffer et al., CHI'15



body automation
for safety



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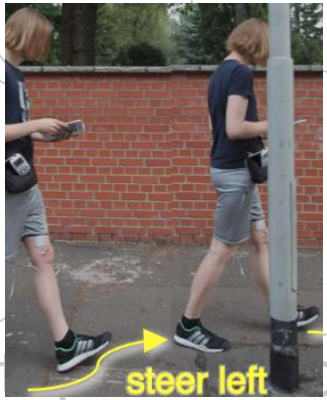
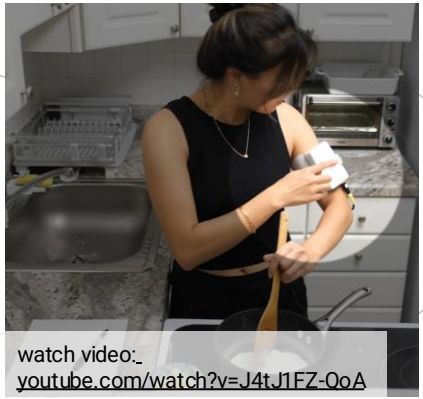
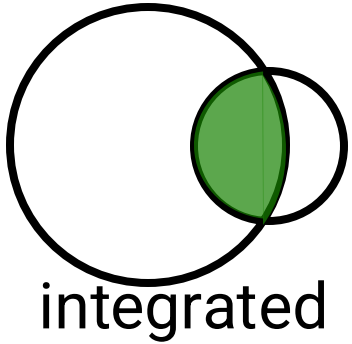


body automation
for safety

NIth et al., CHI'24



body automation
for repetitiveness



reflections:
integration for a **different AI**

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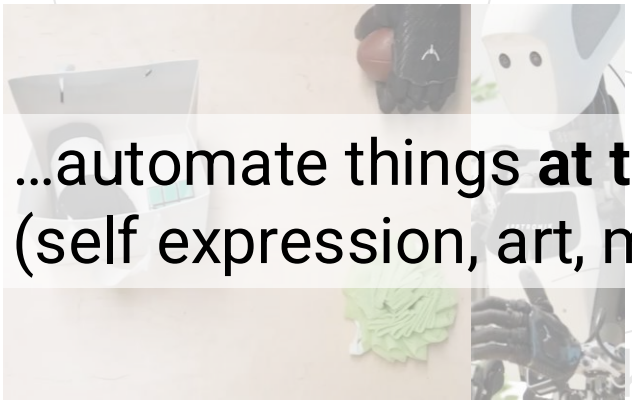
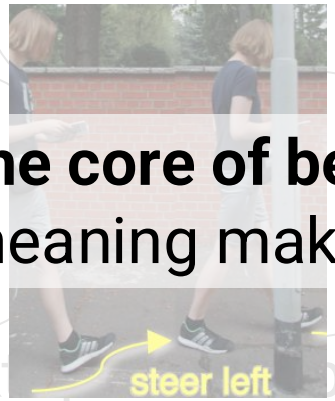
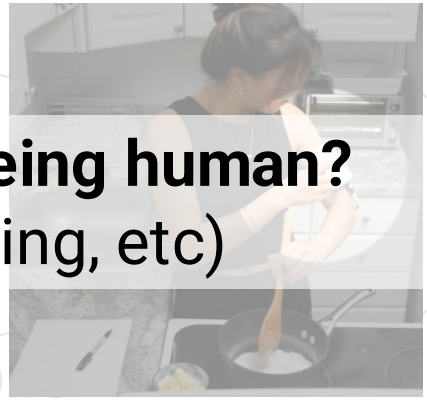
Google deepmind, Gemini Robotics



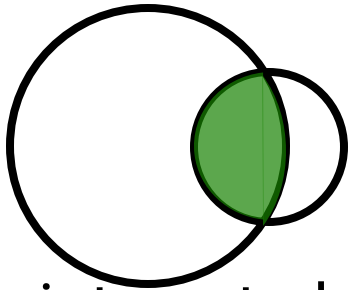
Pfeiffer et al., CHI'15



NIth et al., CHI'24



…automate things **at the core of being human?**
(self expression, art, meaning making, etc)



robotic automation
for everything

body automation
for safety

body automation
for repetitiveness

reflections:
integration for a **different AI**

vision.plopes.org

Hughes et al., Science Robotics'18

robotic automation
for everything

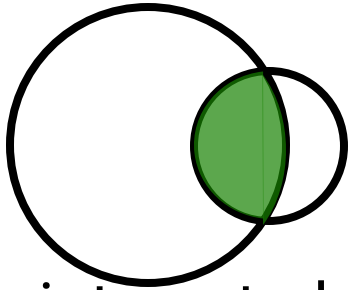
Choudhary et al., CHI'25

watch video:
youtube.com/watch?v=VqqpRu269QE

automation **of what makes us human?**

mobile

wearable



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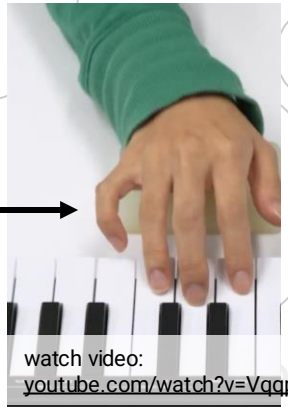
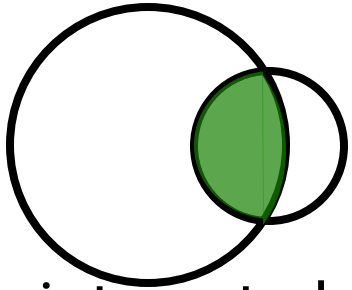


watch video:
youtube.com/watch?v=VqqpRu269QE

body automation
for **learning**

wearable



integrated

reflections:
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Hughes et al., Science Robotics'18

robotic automation
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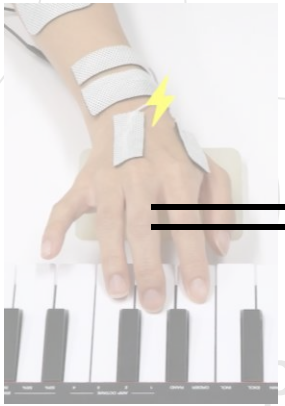
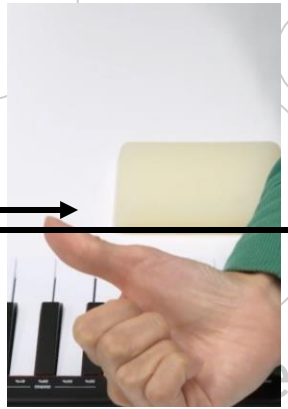
Choudhary et al., CHI'25



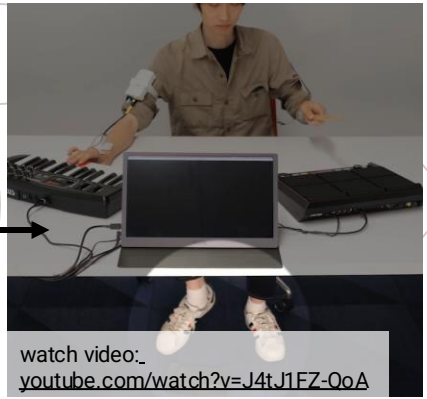
automation **of what makes us human?**

Choudhary et al., CHI'25

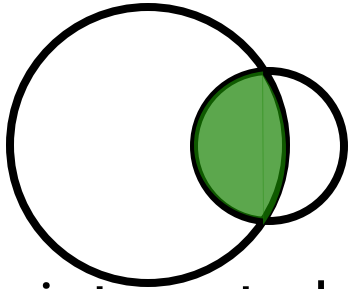


body automation
for **learning**

Nith et al., CHI'24



body automation
for **new forms of art**



integrated

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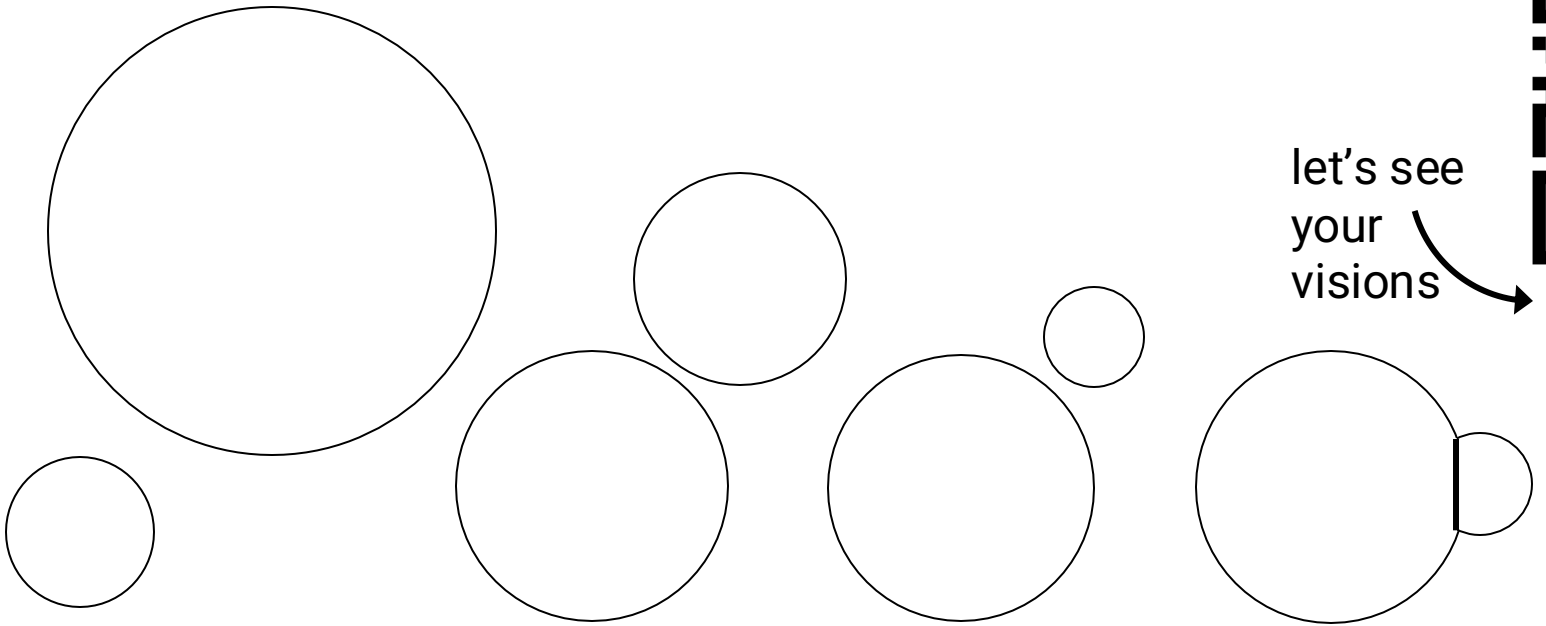
reflections:
other evolutionary routes?

?

mainframe desktop mobile wearable what’s next?



let’s see your visions

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mainframe

desktop

mobile

wearable

?

what’s next?

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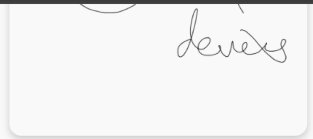

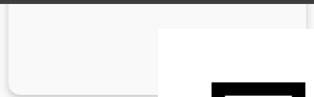

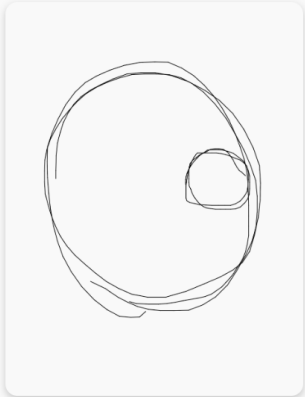

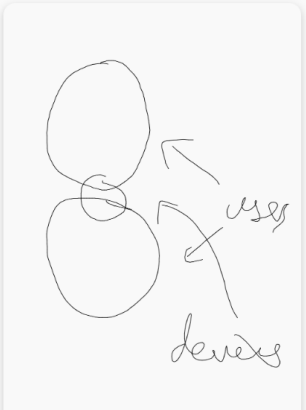

after the talk, I closed the website's ability to submit sketches **here are some of the 100+ submissions during the talk**

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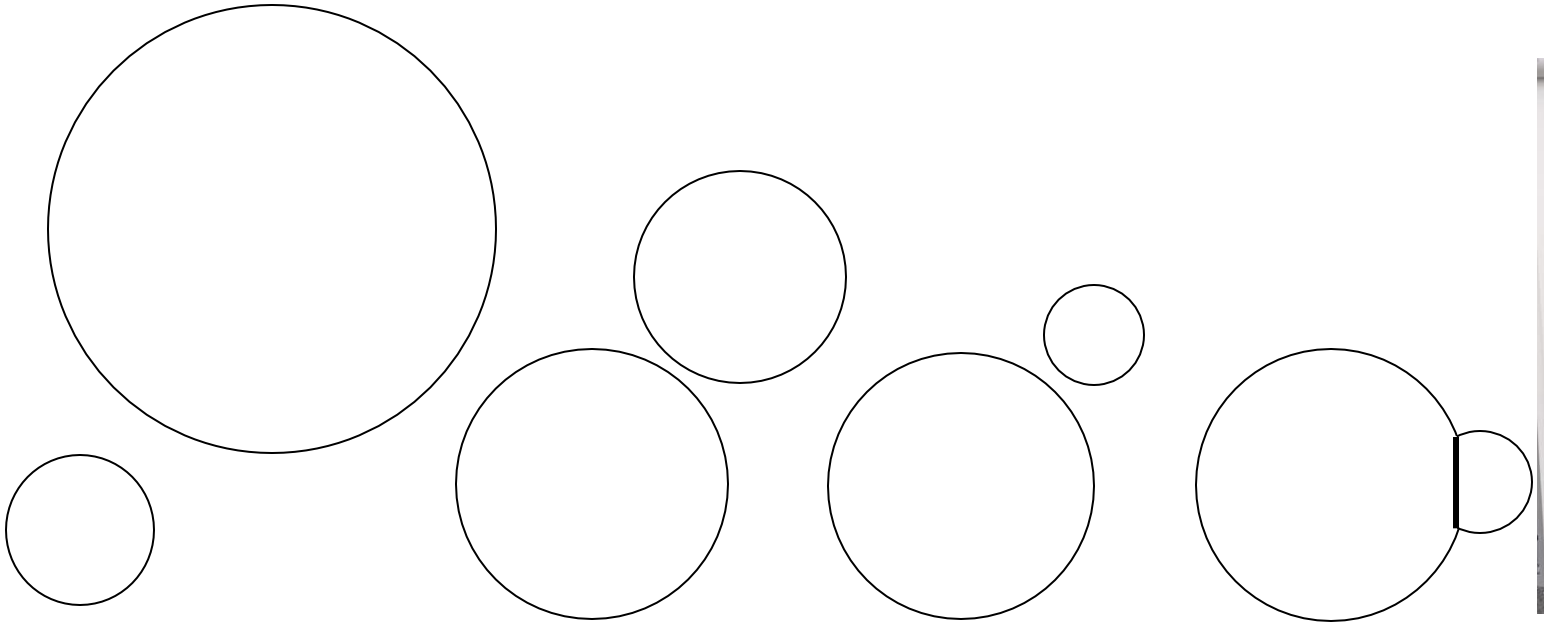
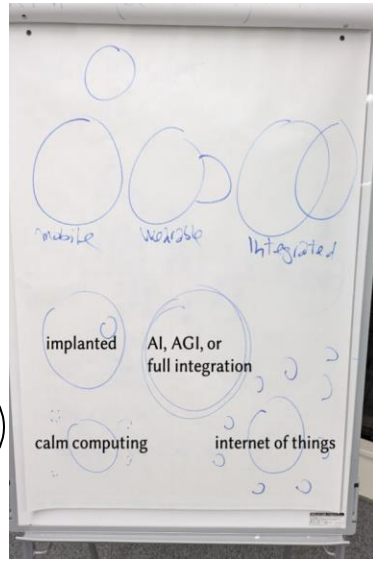
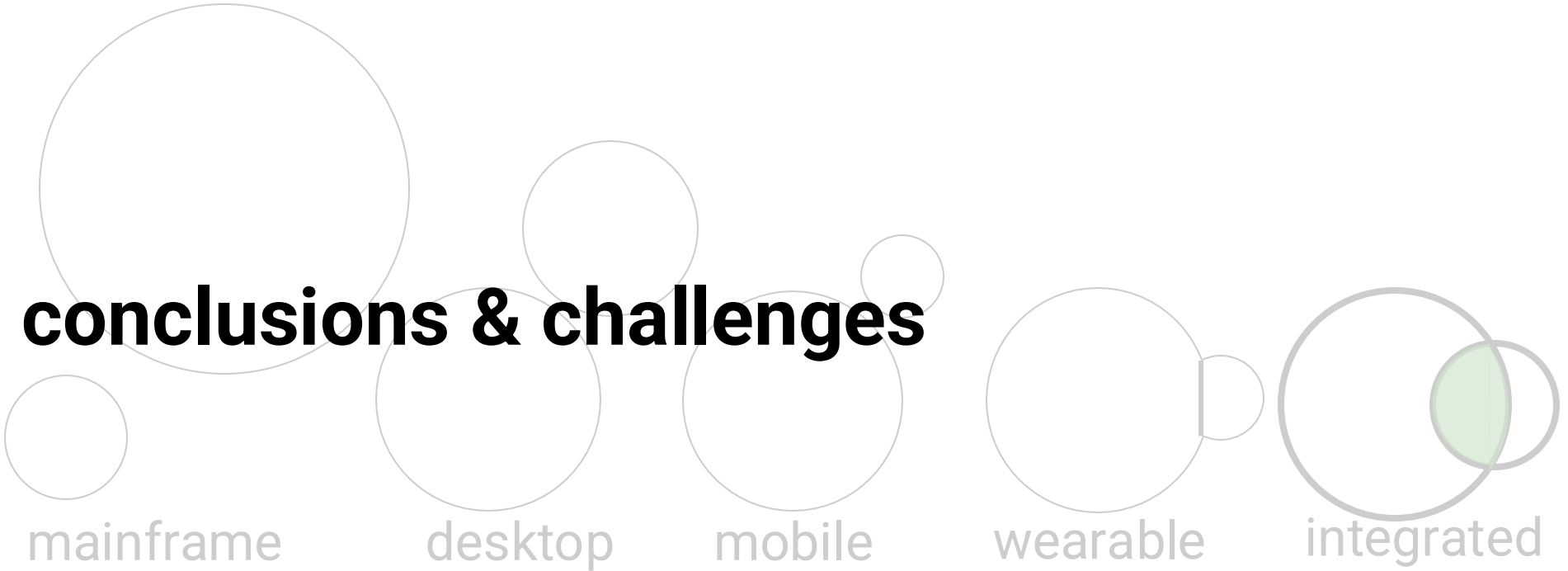


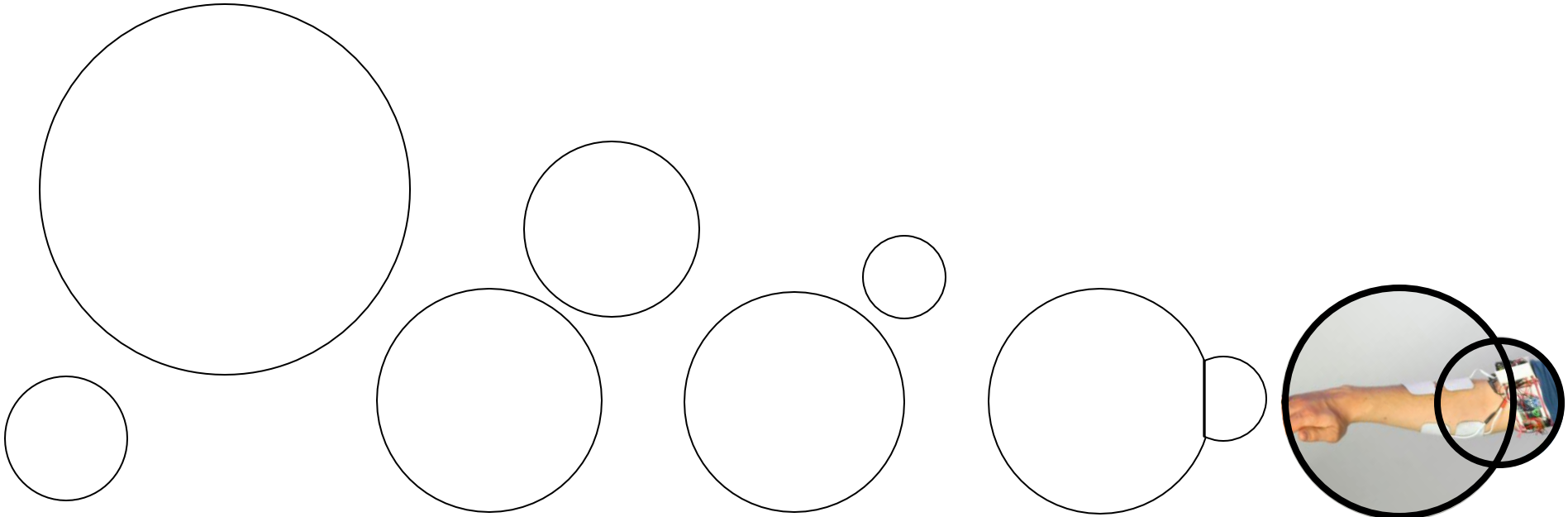
mainframe desktop mobile wearable



what’s next?

conclusions & challenges




mainframe
desktop
mobile
wearable
integrated

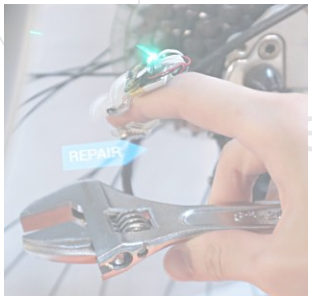
“what if **I** in HC**I** stands for Integration?”
… as a strategy for problem solving

mainframe desktop mobile wearable integrated

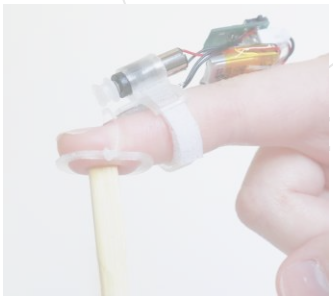
integrating distractions
UIST'22

integrating organisms
UIST'22

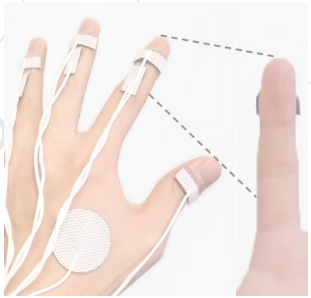
"what if **I** in HC**I** stands for Integration?"
... as a strategy for problem solving



Touch & Fold CHI' 21



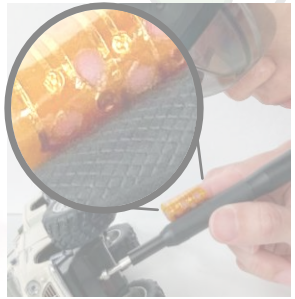
Alter Softness UIST'21



Back-of-Hand CHI'23

FeetThrough UIST'23

Stick&Slip CHI'24



Permeability CHI' 24

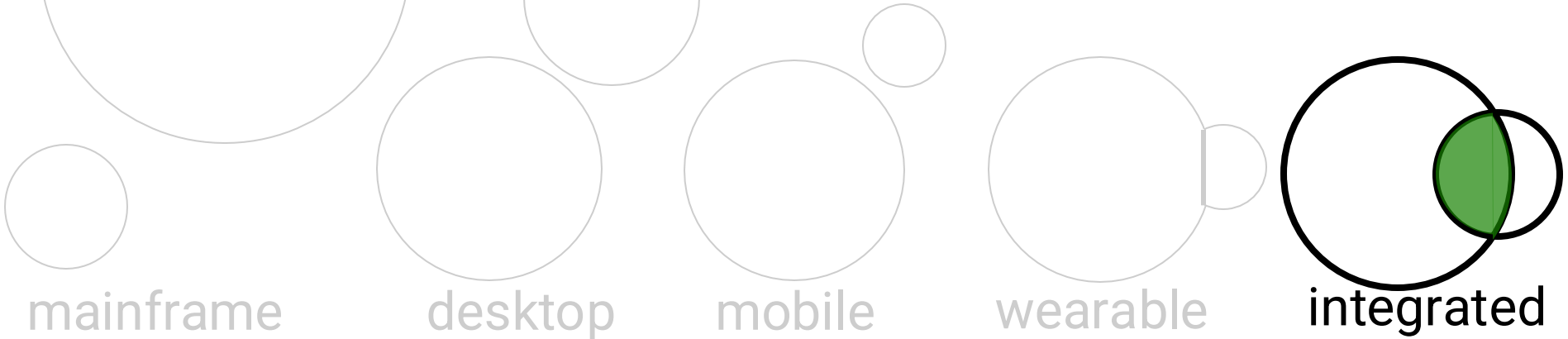
integrating haptics with the real world

“what if **I** in HC**I** stands for Integration?”
… as a strategy for problem solving

mainframe desktop mobile wearable integrated

conclusions & challenges

do we **lose ourselves** if devices integrate?



conclusions & challenges

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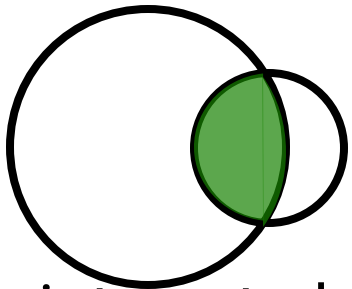
ethics

mainframe

desktop

mobile

wearable



integrated

conclusions & challenges

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ethics

call for collaborative action


Ethics of the electrified mind: Defining
principled use of brain stimulation in r

Laura Y Cabrera [1], Emily L Evans [2], Roy H Hamilton [2,3]

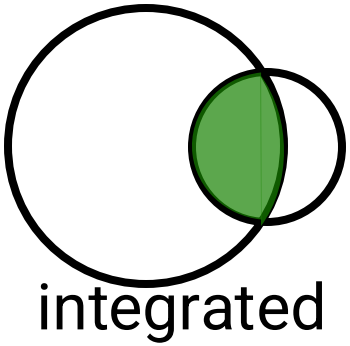
Author information · Article notes · Copyright and Lice

PMCID: PMC3806889 NIHMSID: NIHMS488405 PMID: 23733

Abstract

In recent years, non-pharmacologic approaches
gained increasing attention. One of these approa
either the direct application of electrical current
indirect application of current by means of electr
manipulate the brain have generally been regarc
ain-related conditions and the cap
gh brain stimulatio

desktop mobile wearable



conclusions & challenges

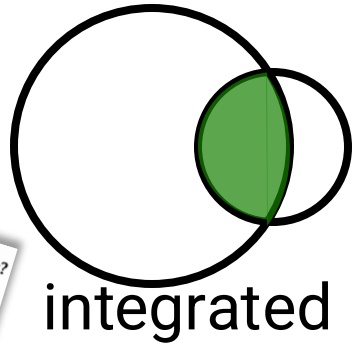
do we **lose ourselves** if devices integrate?

ethics

call for collaborative action

sense of agency

understanding sense of agency



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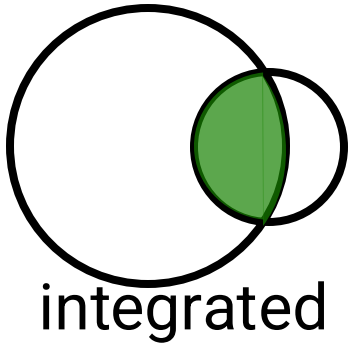
sense of agency

designing for agency in integration

agency tradeoffs — CHI'19, TOCHI'21

agency neural mechanisms — Cortex'19, JNeuro'23, Jneuro'25



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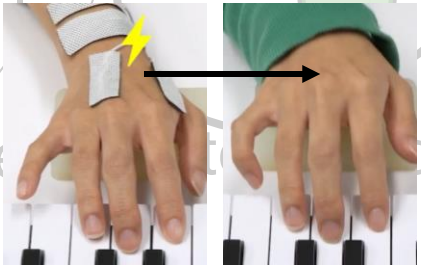
dependency
design for absence



aim for **learning** not replacing us — CHI'21 CHI'25

acknowledgements

human computer integration lab

THE UNIVERSITY OF CHICAGO

our team

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Yun Ho
PhD student

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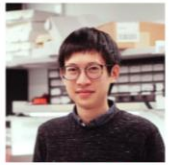

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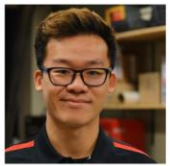
PhD -> Prof. NTU

Jasmine Lu
PhD student



Romain Nith
PhD Student

Yudai Tanaka
PhD Student

Lonnie Chien
PreDoc

you!
come work with us
all positions

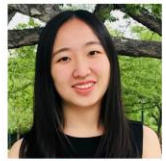
Mithil Guru
Collaborator

Haley Breslin
Ugrad

Andre De La Cruz
Ugrad

some of our alumni

Jun Nishida
Postdoc 2019-22
Now: Prof. UMaryland



Yujie Tao
Master 2021-22
Now: Stanford PhD

Alex Mazursky
PhD student
Now: Apple Engineer

Joyce Passananti
Ugrad Spring 2022
Now: UCSB PhD

Arata Jingu
Intern Winter 2022
Now: Saarland PhD

Siya Choudhary
Highschooler
Now; UIUC

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human computer integration lab

thanks for your attention, questions?

what if the “I” in HCI stands for Integration?

pedro lopes
associate prof. in computer science

slides:
vision.plopes.org/slides

see the sketches from the UIST audience
vision.plopes.org

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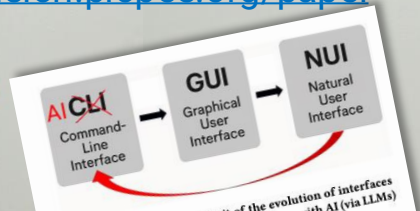
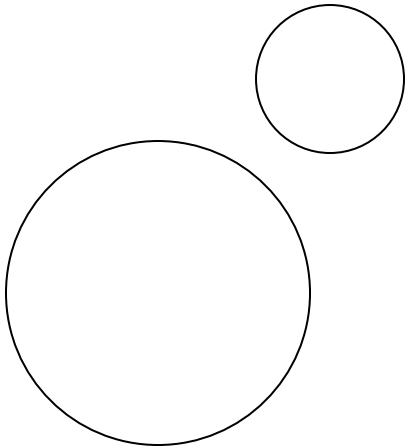
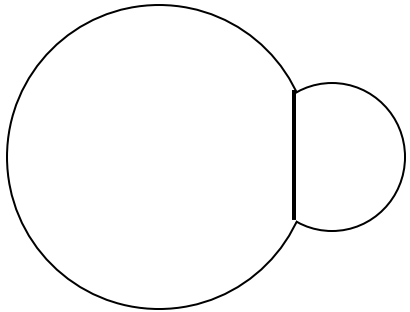


agency ✓

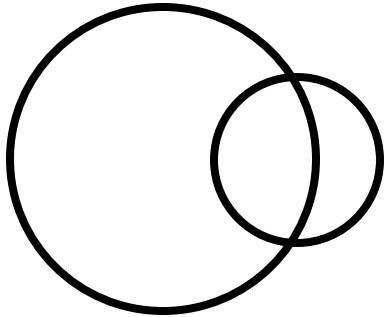
agency ✗



mobile



wearable



integrated with body

https://www.youtube.com/watch?v=UsL48gkh3GI

ethical implications of EMS

patrick baudisch
HPI


Ars Electronica 2017

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