

HCI Foundations and Frontiers

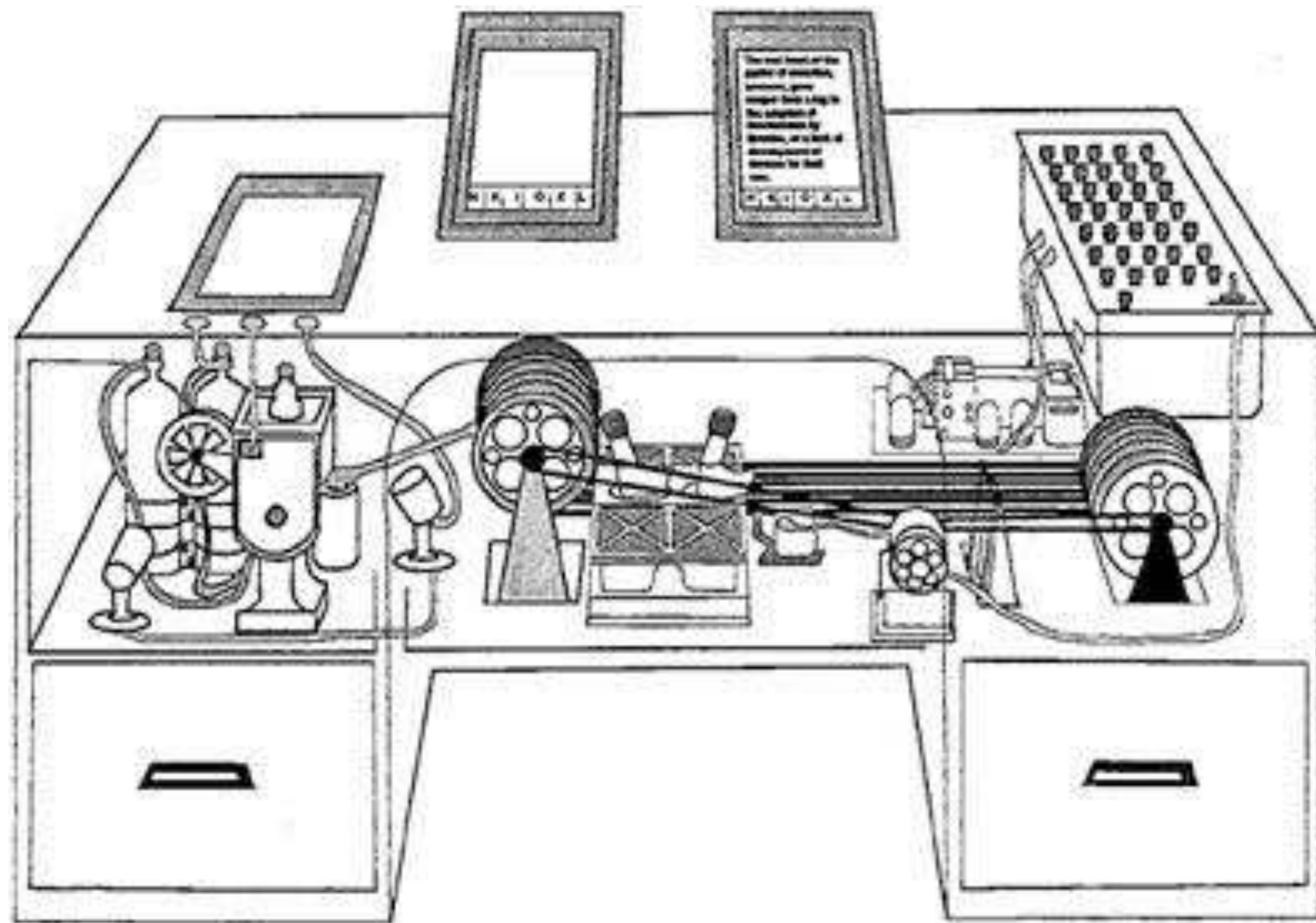
CS 347

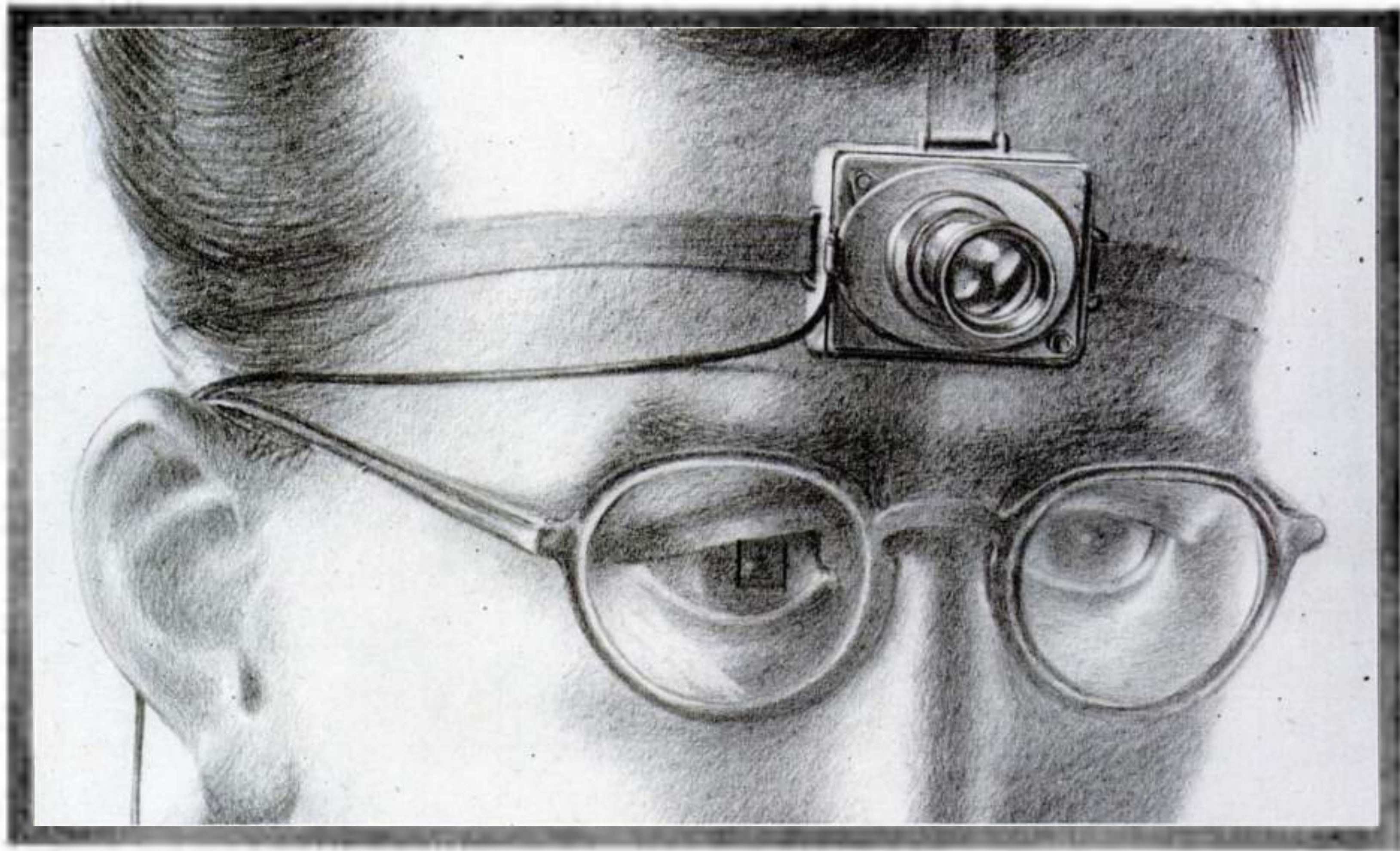
Michael Bernstein

Stanford University



“As we may think”, written by Vannevar Bush in 1945.
Published in The Atlantic—later that year, condensed into Life Magazine





A scientist of the future records experiments with a tiny camera fitted with universal-focus lens. The small square in the eyeglass at the left sights the object (*LIFE* 19(11), p. 112).



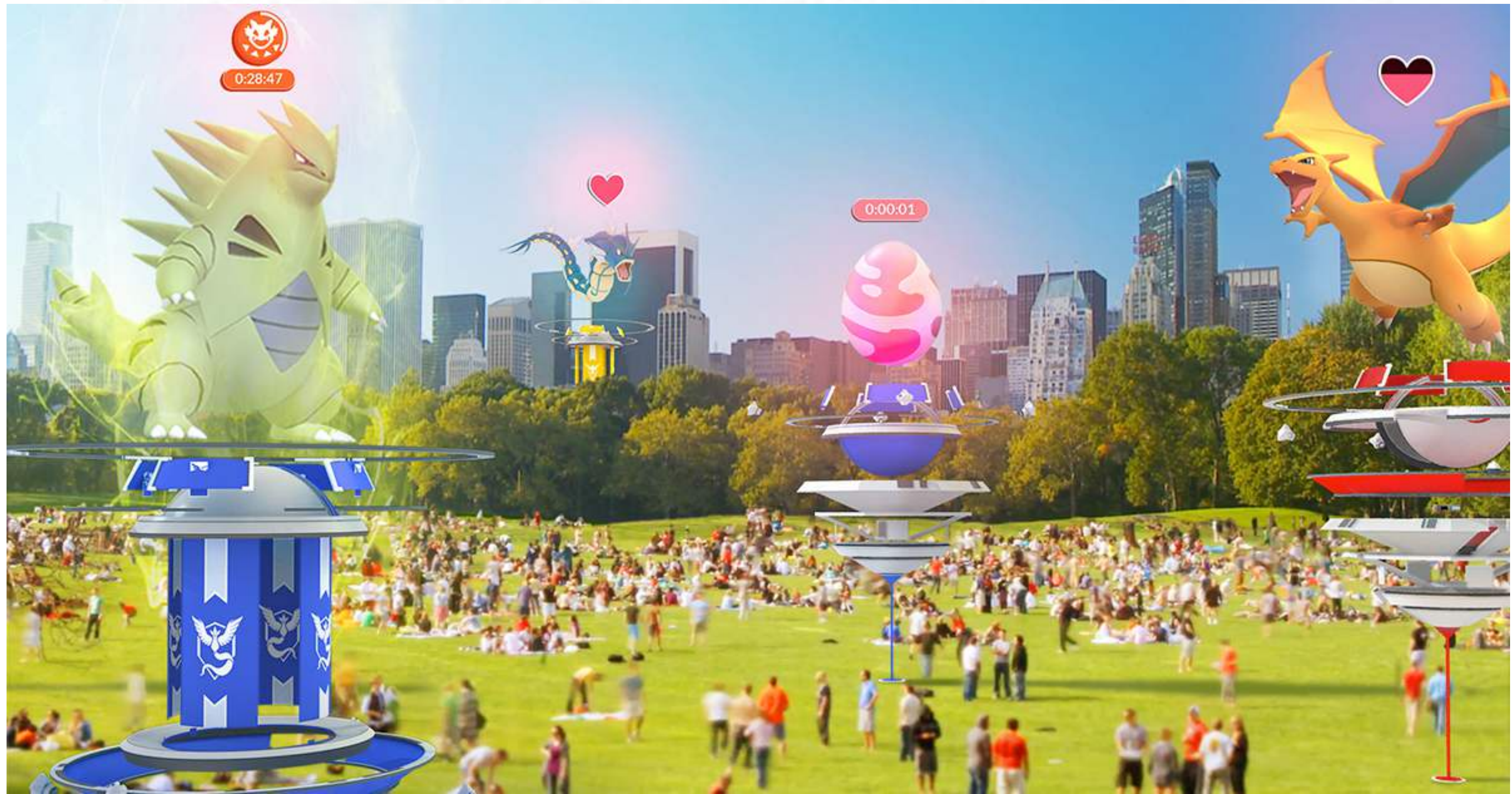
[image from
Wired]

A scientist of the future records experiments with a tiny camera fitted with universal-focus lens. The small square in the eyeglass at the left sights the object (*LIFE* 19(11), p. 112).



[image from
apple]

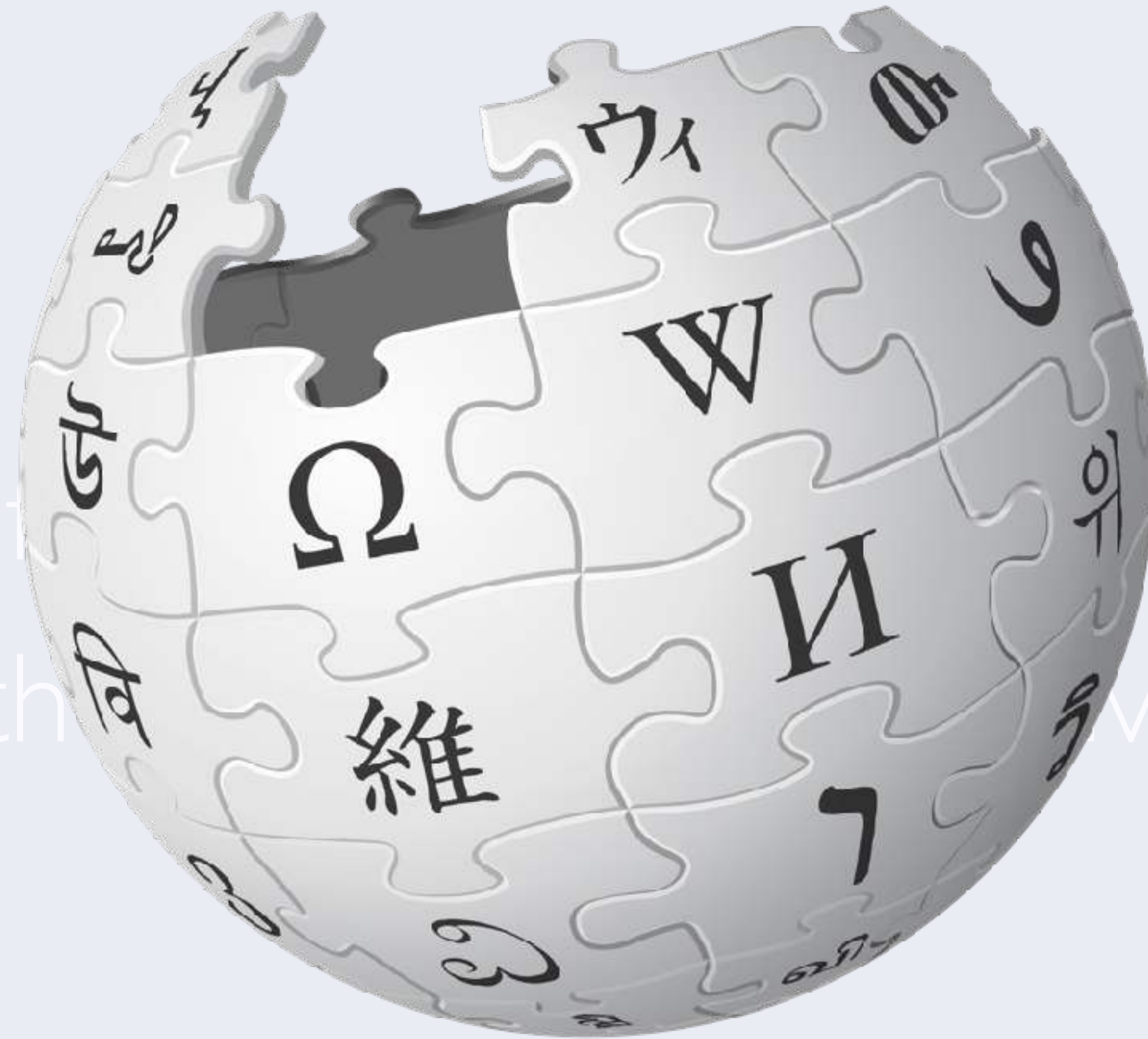
A scientist of the future records experiments with a tiny camera fitted with universal-focus lens. The small square in the eyeglass at the left sights the object (*LIFE* 19(11), p. 112).



A scientist of the future records experiments with a tiny camera fitted with universal-focus lens. The small square in the eyeglass at the left sights the object (*LIFE* 19(11), p. 112).

“Wholly new forms of encyclopedias will appear, ready-made with a mesh of associative trails running through them.”

“Wholly new information has
ready-made with trails running
through them.”



WIKIPEDIA
The Free Encyclopedia

Xerox PARC. 1973.
The Xerox Alto.

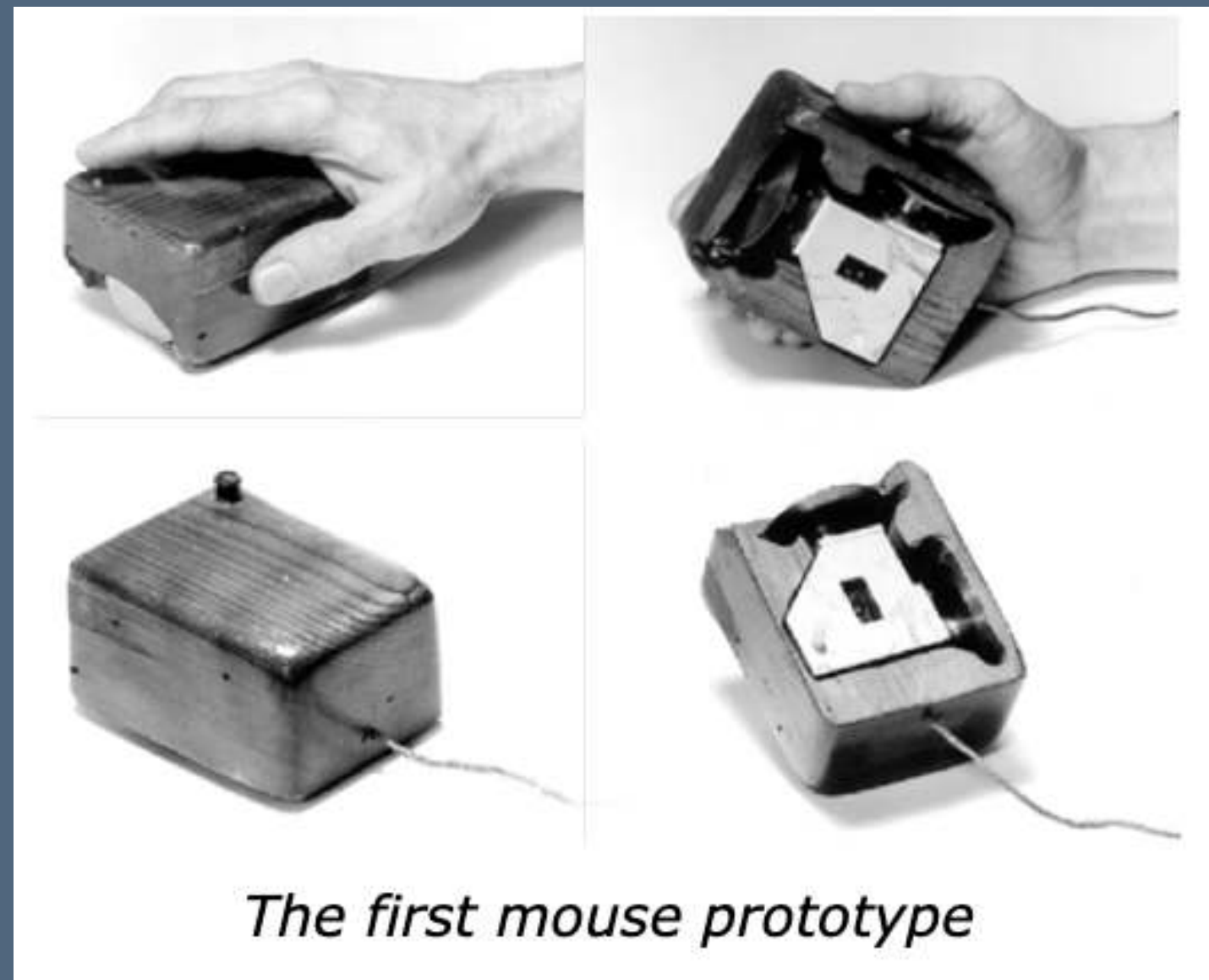


[Image from Ken Shirriff]

Modern MacOS desktop



Engelbart 1963-64
First mouse prototype



Card, English and Burr. 1978.
Evaluation of mouse, rate-controlled
isometric joystick, step keys, and text
keys for text selection on a CRT.



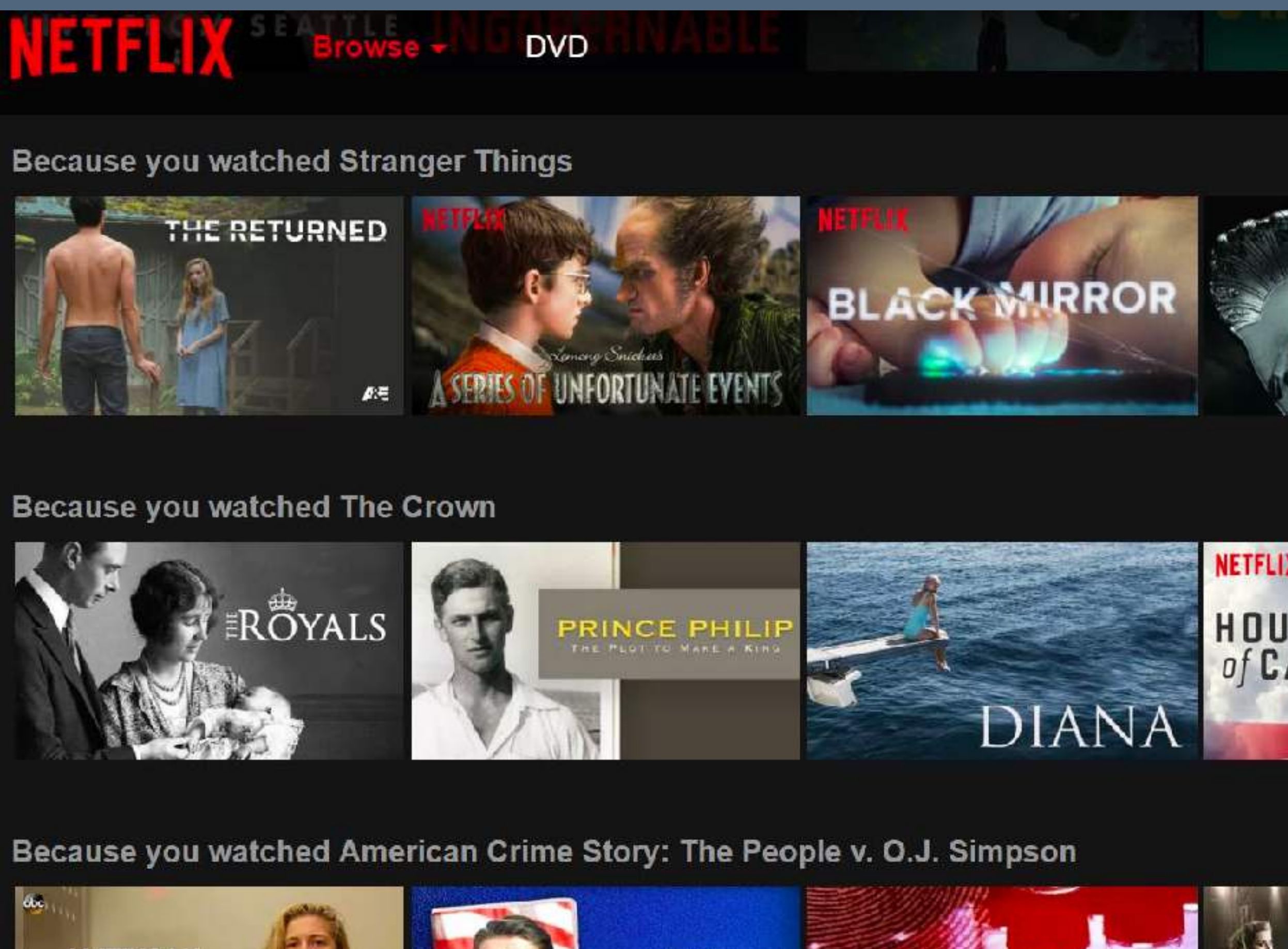
Modern mouse



Resnick et al. 1994. GroupLens:
an open architecture for
collaborative filtering of netnews.



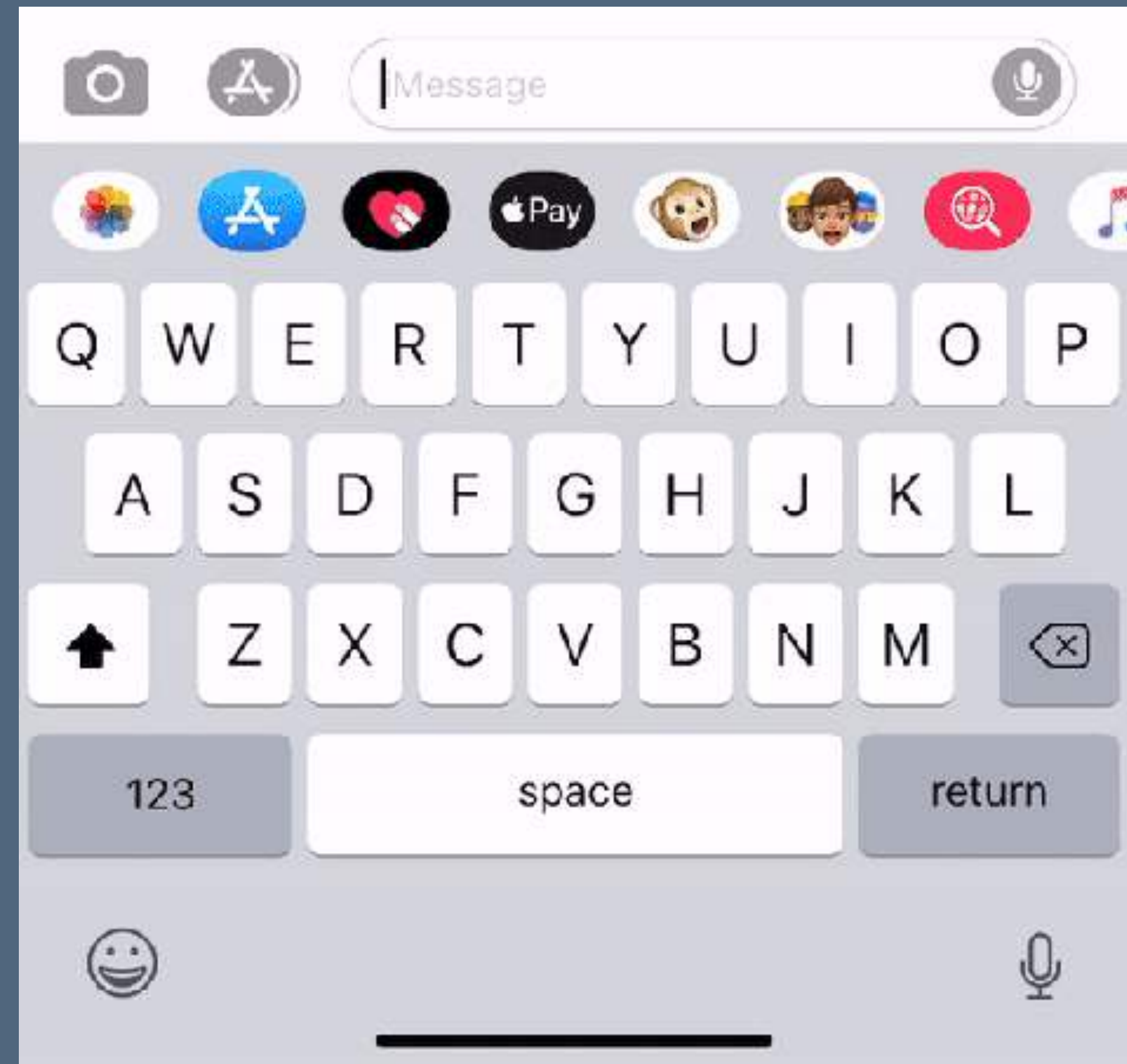
Modern recommender systems
[image from HBS]



Zhai and Kristensson. 2003.
Shorthand writing on a stylus
keyboard.

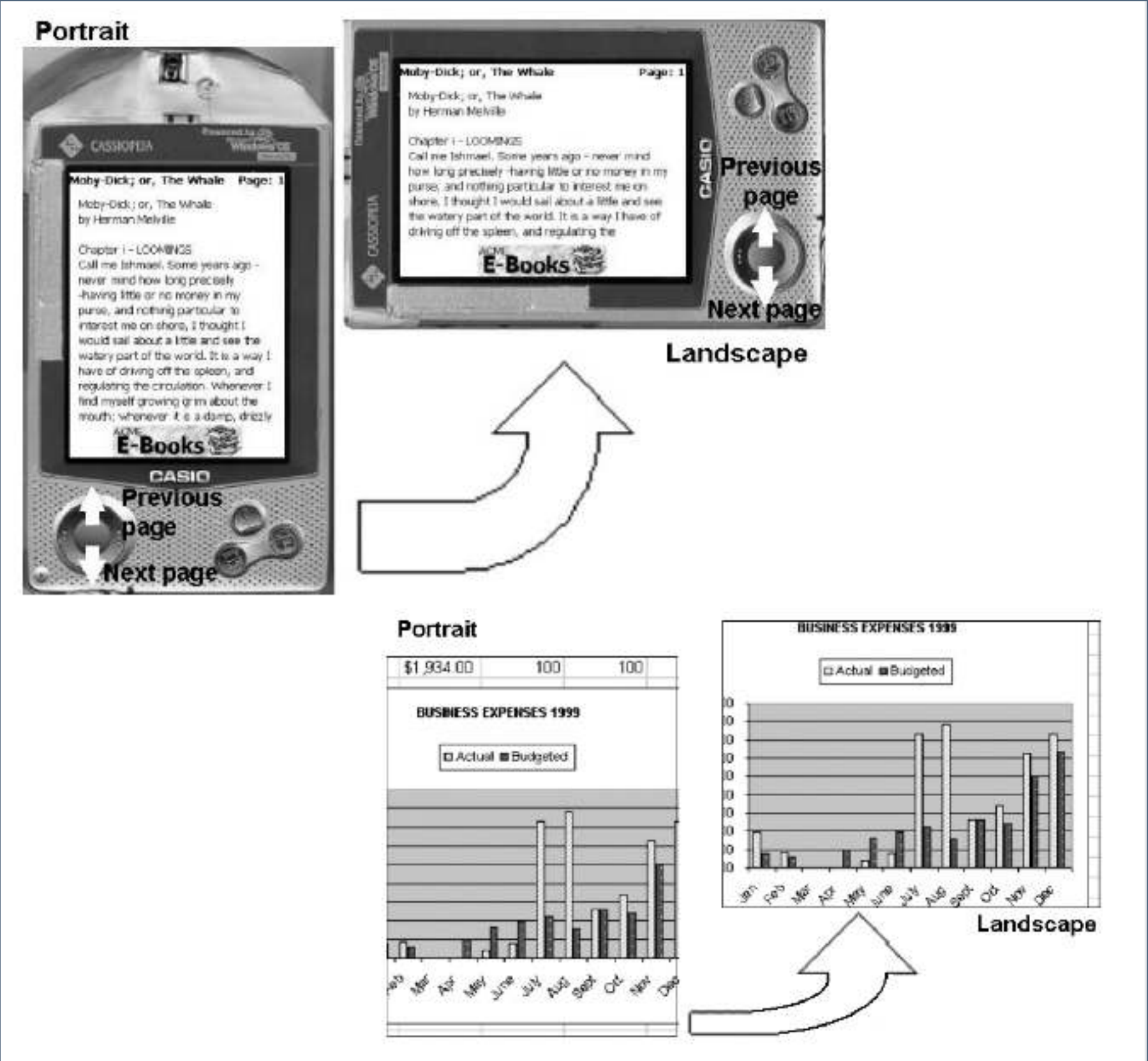


Swipe keyboards (iOS, Android)
[image from 9to5mac]



Hinckley et al. 2000. Sensing techniques for mobile interaction.

Auto-rotating phone media
[@arstories on Instagram]



Consolvo et al. 2008. Activity sensing in the wild: a field trial of UbiFit Garden.



Modern fitness trackers
[image from Apple]



Kelley et al. 2010. Privacy Nutrition Labels.

Apple + Google Privacy Labels
[image from Apple]

The Acme Policy

types of information	how we use your information					who we share your information with	
	provide service & maintain site	research & development	marketing	telemarketing	profiling	other companies	public forums
contact information	!	!	OUT	OUT	—	IN	—
cookies	!	!	OUT	OUT	—	IN	—
demographic information	—	—	—	—	—	—	—
financial information	—	—	—	—	—	—	—
health information	—	—	—	—	—	—	—
preferences	!	!	OUT	OUT	—	IN	!
purchasing information	!	!	OUT	OUT	—	IN	—
social security number & govt ID	!	—	—	—	—	—	—
your activity on this site	!	!	OUT	OUT	—	IN	!

 **Data Linked to You**

The following data may be collected and linked to your identity:

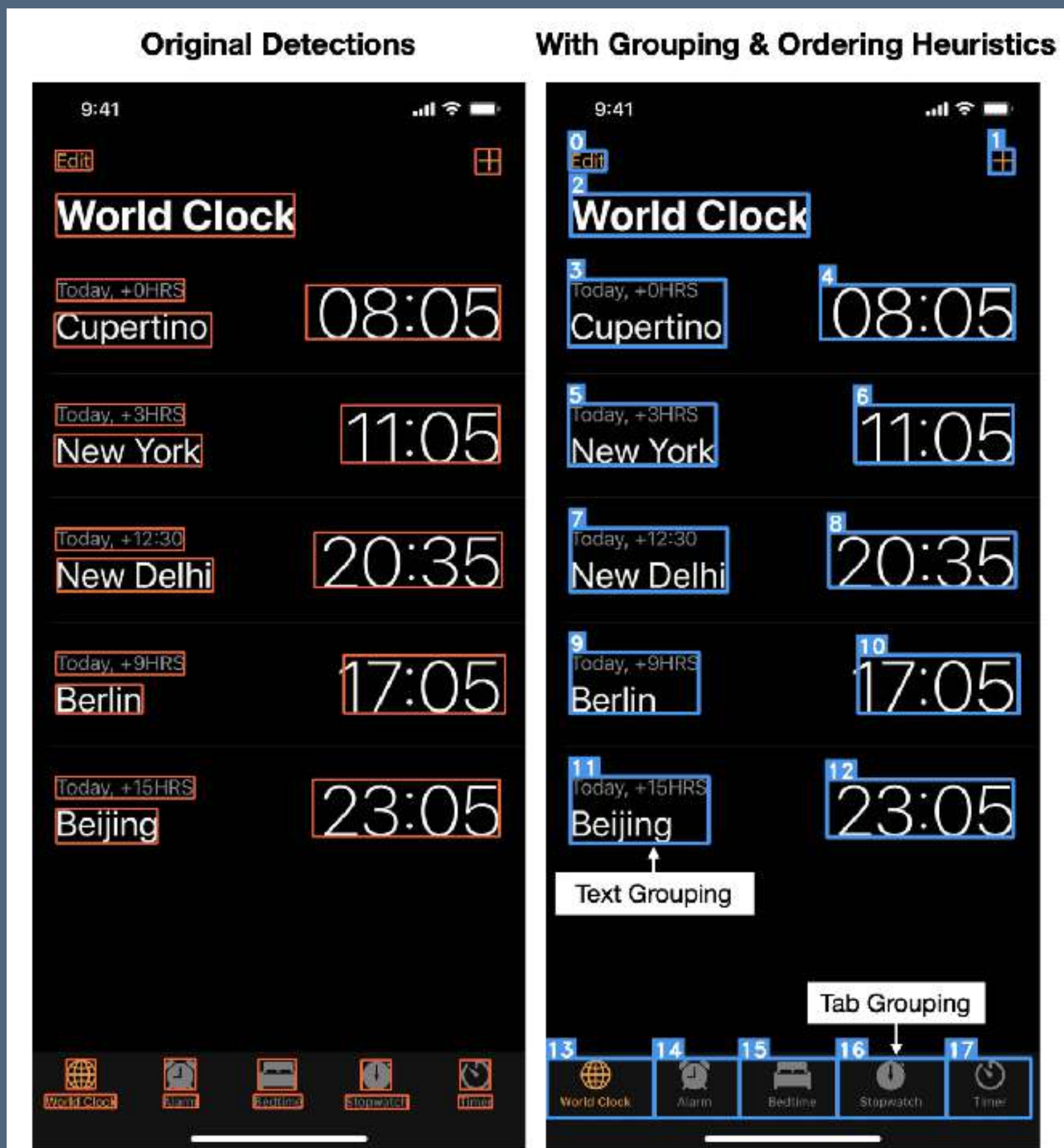
-  User Content
-  Identifiers

 **Data Not Linked to You**

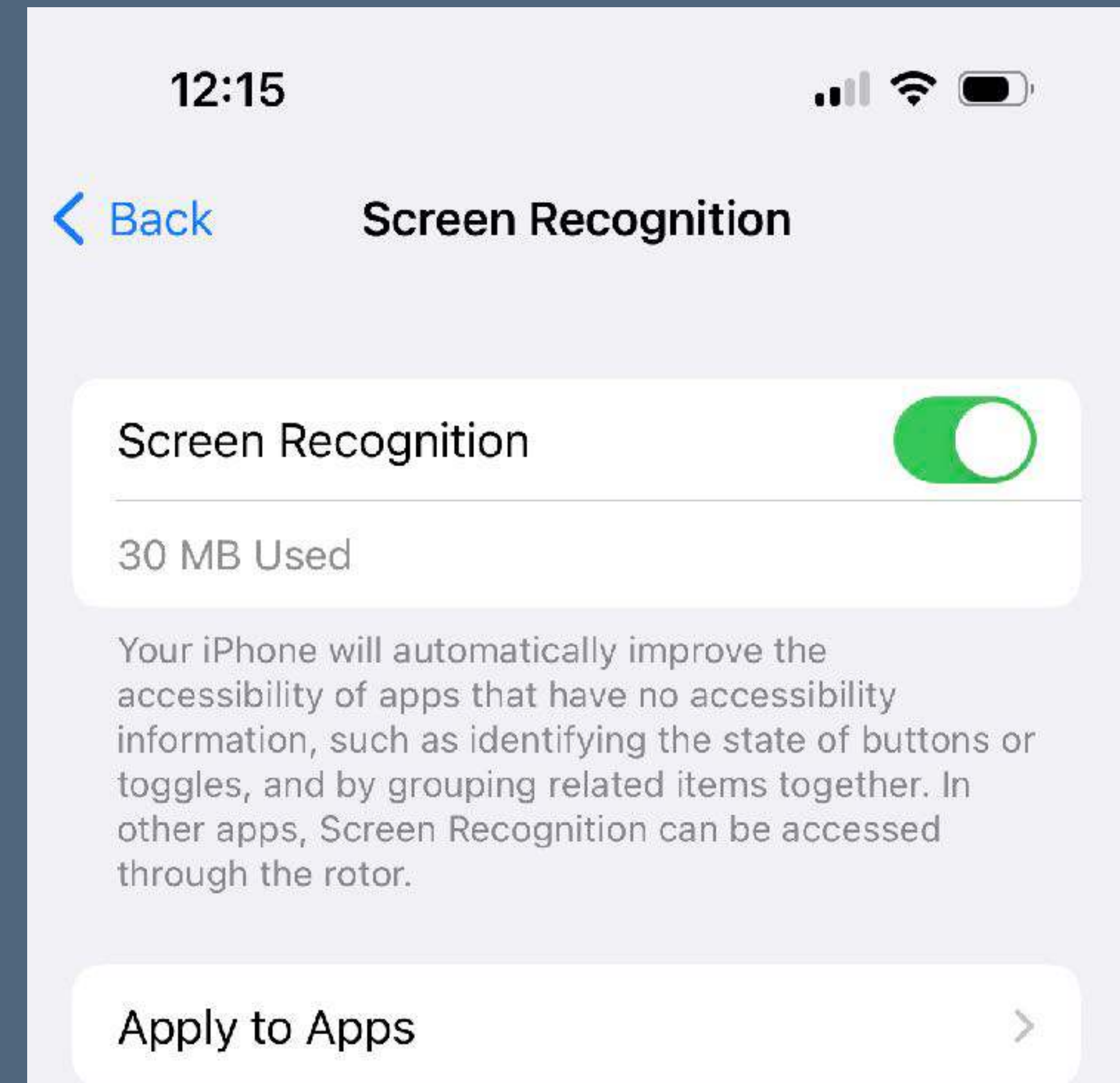
The following data may be collected but it is not linked to your identity:

-  Location
-  Usage Data
-  Search History
-  Diagnosing

Zhang et al. 2021. AI-powered screen reader accessibility.

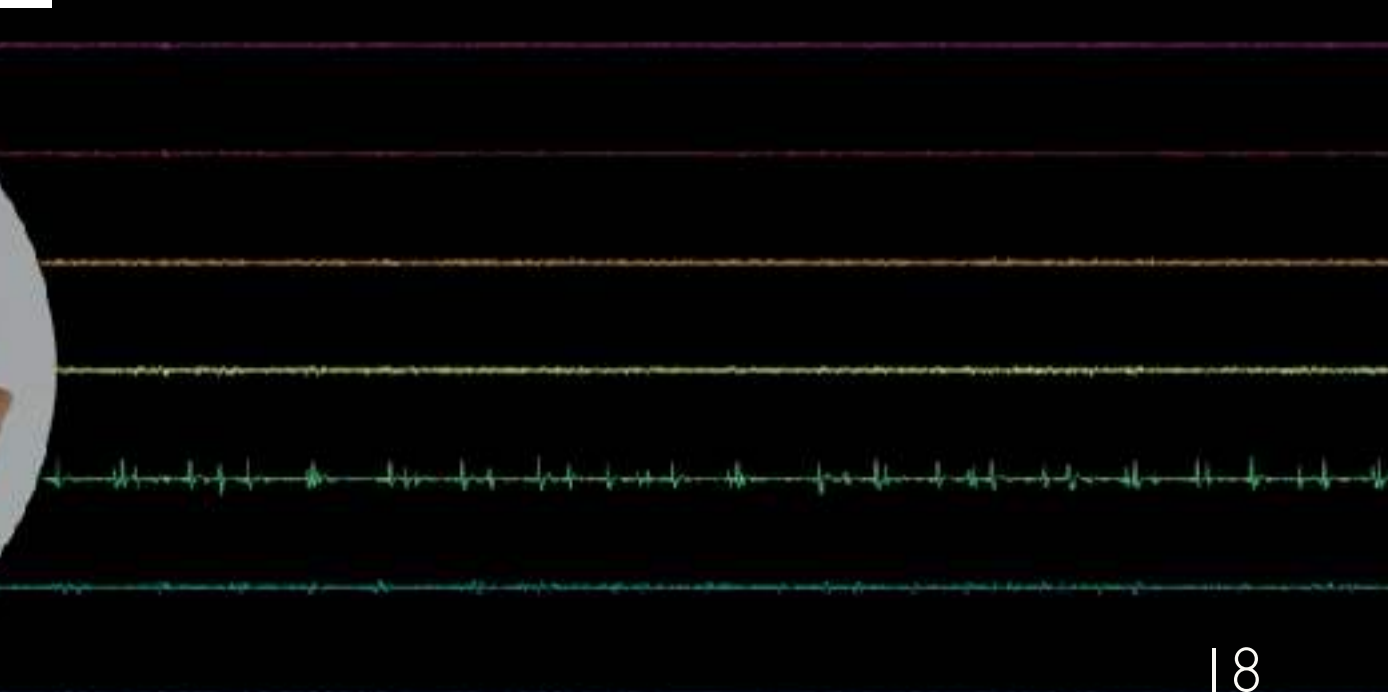
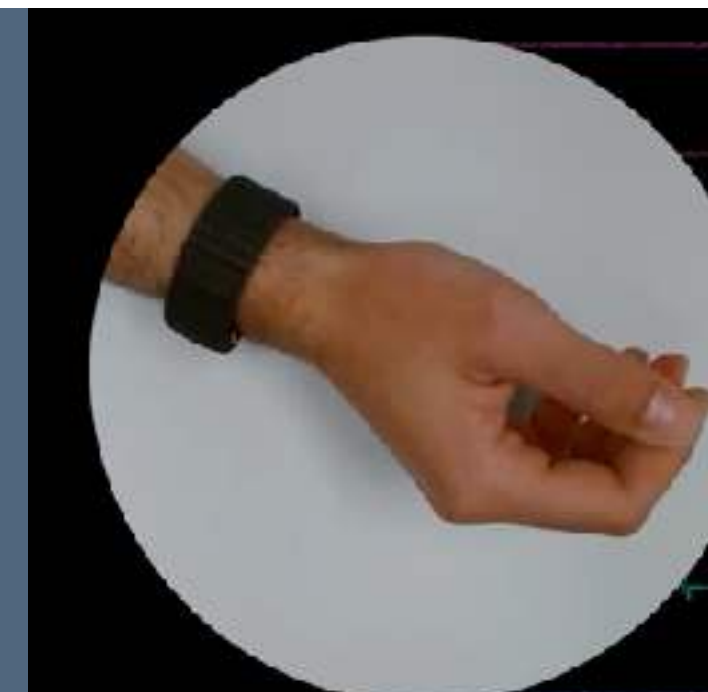
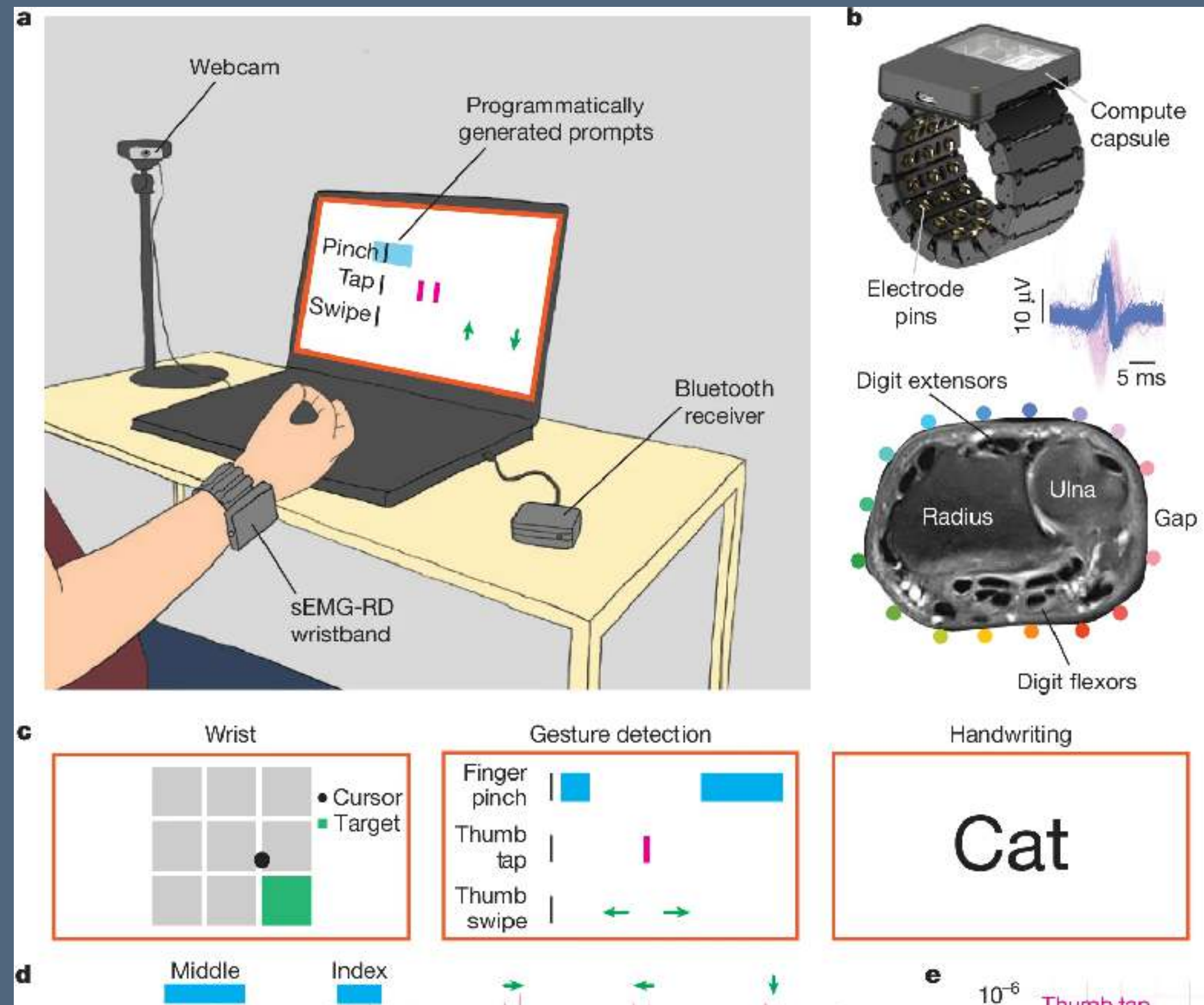


iOS Screen Recognition



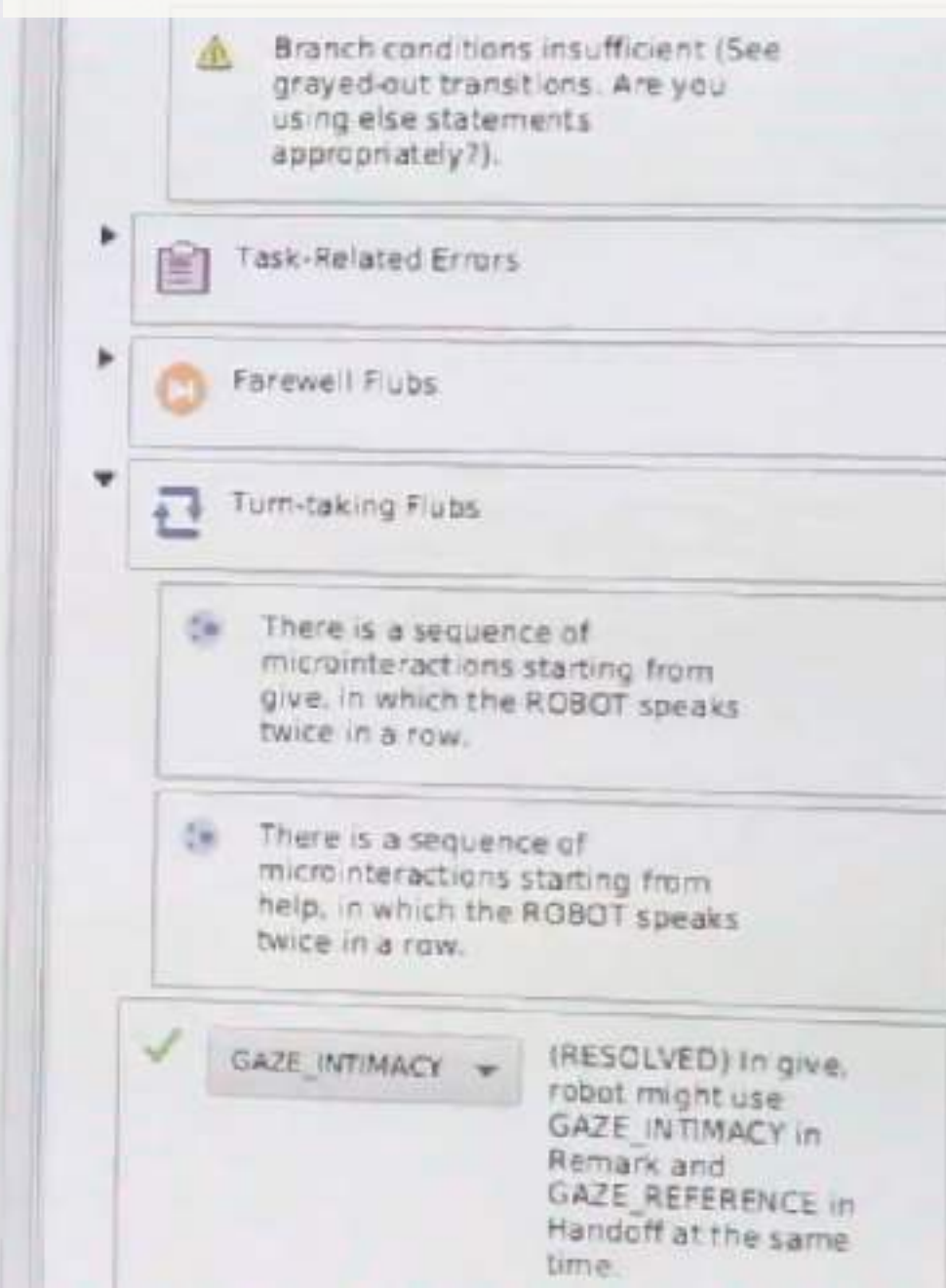
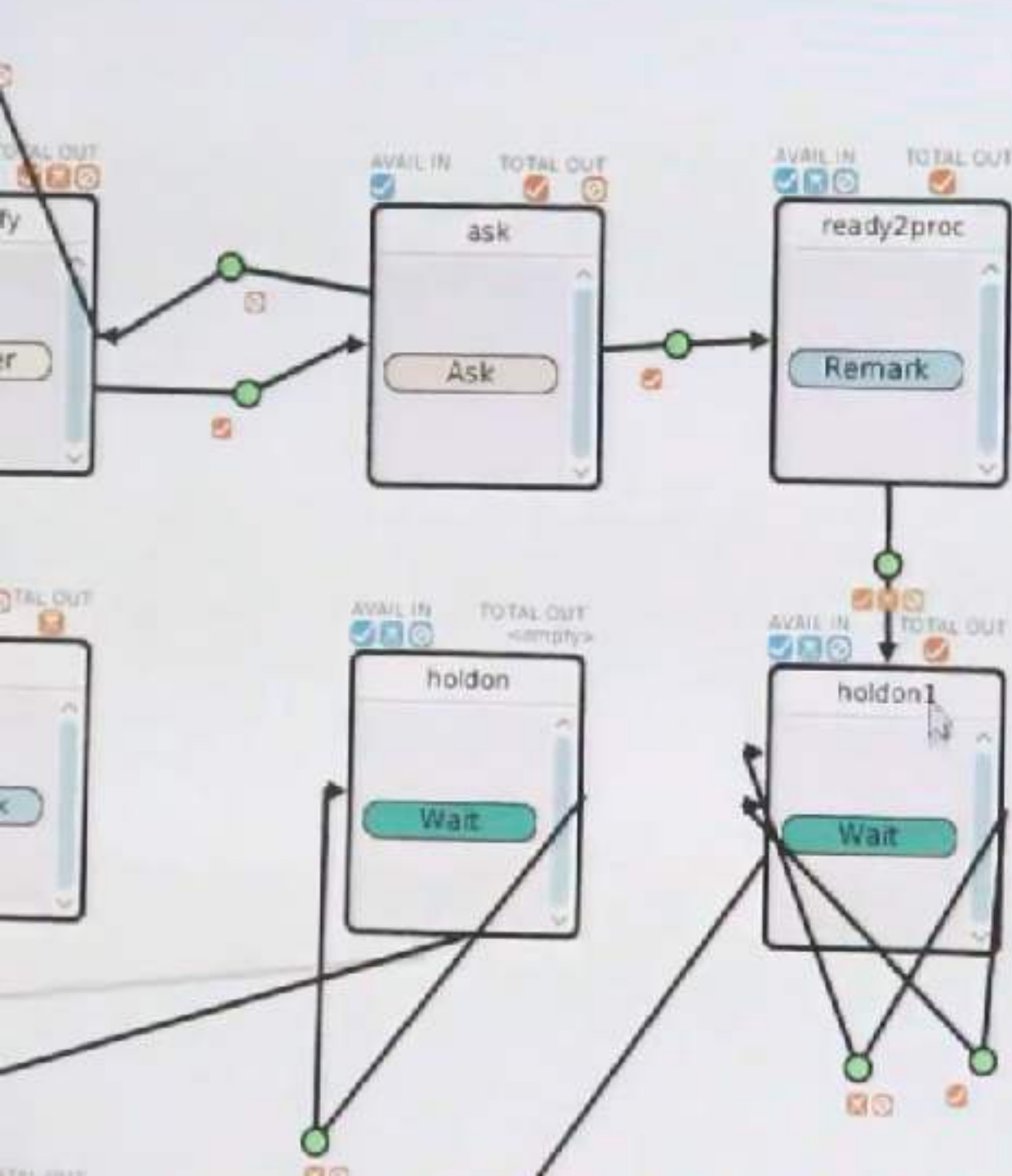
Kaifosh et al. 2025. A generic non-invasive neuromotor interface for human-computer interaction.

Meta Neural Band.
(Same team productized)





What's next? And why?



Splines

“NeuroVerse is an AI-native VR collaboration platform that uses multimodal foundation models to generate persistent, photorealistic virtual workspaces, while a blockchain-based identity and provenance layer tokenizes user-generated assets into interoperable smart-contract primitives. Its decentralized “cognitive mesh” continuously fine-tunes autonomous AI agents on encrypted interaction embeddings, enabling zero-knowledge personalization, on-chain reputation, and dynamically evolving metaverse experiences synchronized across devices via edge-rendered spatial computing.”

Why is this a bad idea?

(ChatGPT prompt: “Generate a tech product idea that is full of technobabble about VR, blockchain, and AI. One short paragraph.”)

This class

Envisioning and understanding
the future of interaction
between people, society, and technology

This class

Teaches foundational theories
and modern frontiers

Learning goals

This is not like other HCI classes.

Your goal is **not** just to **design** an alignment between people and technology.

Your goal is to articulate, critique, and generate entirely new ideas about that relationship.

Foundations and frontiers

You will learn the major theories and concepts that underpin HCI

You will engage in critical analyses of these theories and concepts, apply them, and extend them



Ubiquitous computing

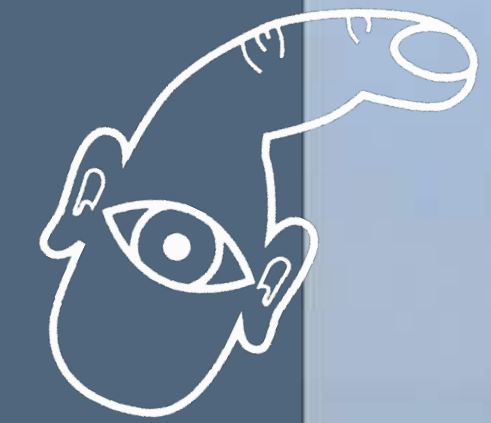
Unit I

ubiquitous and tangible computing
input and output
activity, health, and behavior



Mobile phone's
model of a person
[O'Sullivan and Igoe 2004]

The future of interaction?



“...this vision, from an interaction perspective, is *not visionary*. It's a timid increment from the status quo, and the status quo, from an interaction perspective, is actually rather terrible.” — Bret Victor

<http://worrydream.com/ABriefRantOnTheFutureOfInteractionDesign/>



vs. “Pictures Under Glass”
[Victor 2011]



Why is this so terrible?

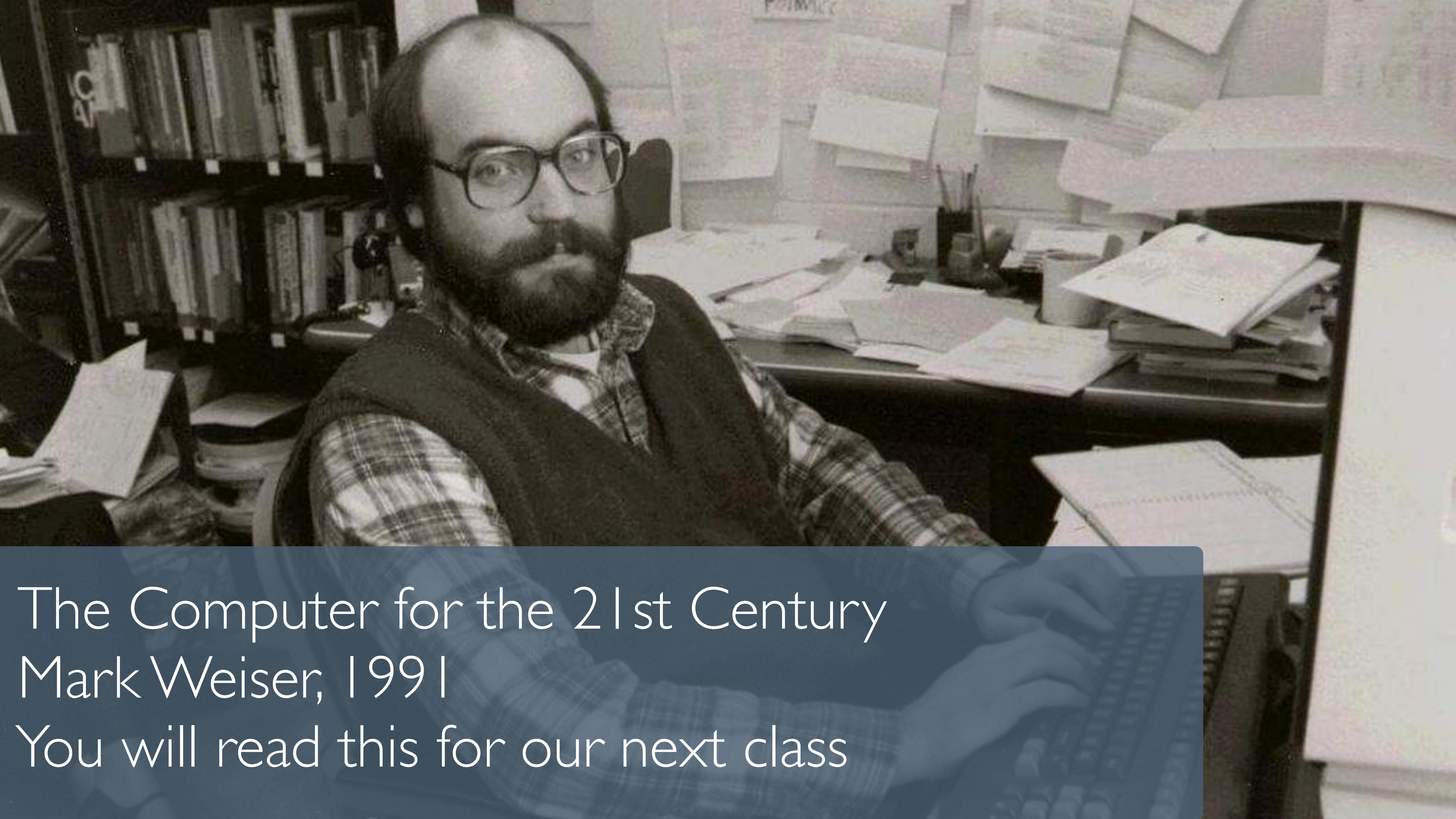
[Hutchins 1995, Dourish 2004; Klemmer, Hartmann, Takayama 2006]

Our cognition leverages **embodiment**—our bodies:

- We learn through interaction with the world

- We leverage the environments around us to make us smarter

- We communicate our intent through much broader mechanisms than just our fingertips: consider musicians, dancers, construction workers, professors on stage trying to get your attention



The Computer for the 21st Century
Mark Weiser, 1991
You will read this for our next class

“The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it.”
— Mark Weiser

[Weiser 1991]

Ubiquitous Computing [Weiser 1991]

Ubiquitous computing: a vision in which computers “**vanish into the background**” rather than focus our attention on a single box

This vision requires interactive systems to become reactive, context-aware, ambient, and embedded in everyday activities

Activity recognition [Laput et al. 2015]



Detecting ambient EM signals transmitted through body using commodity smart watch

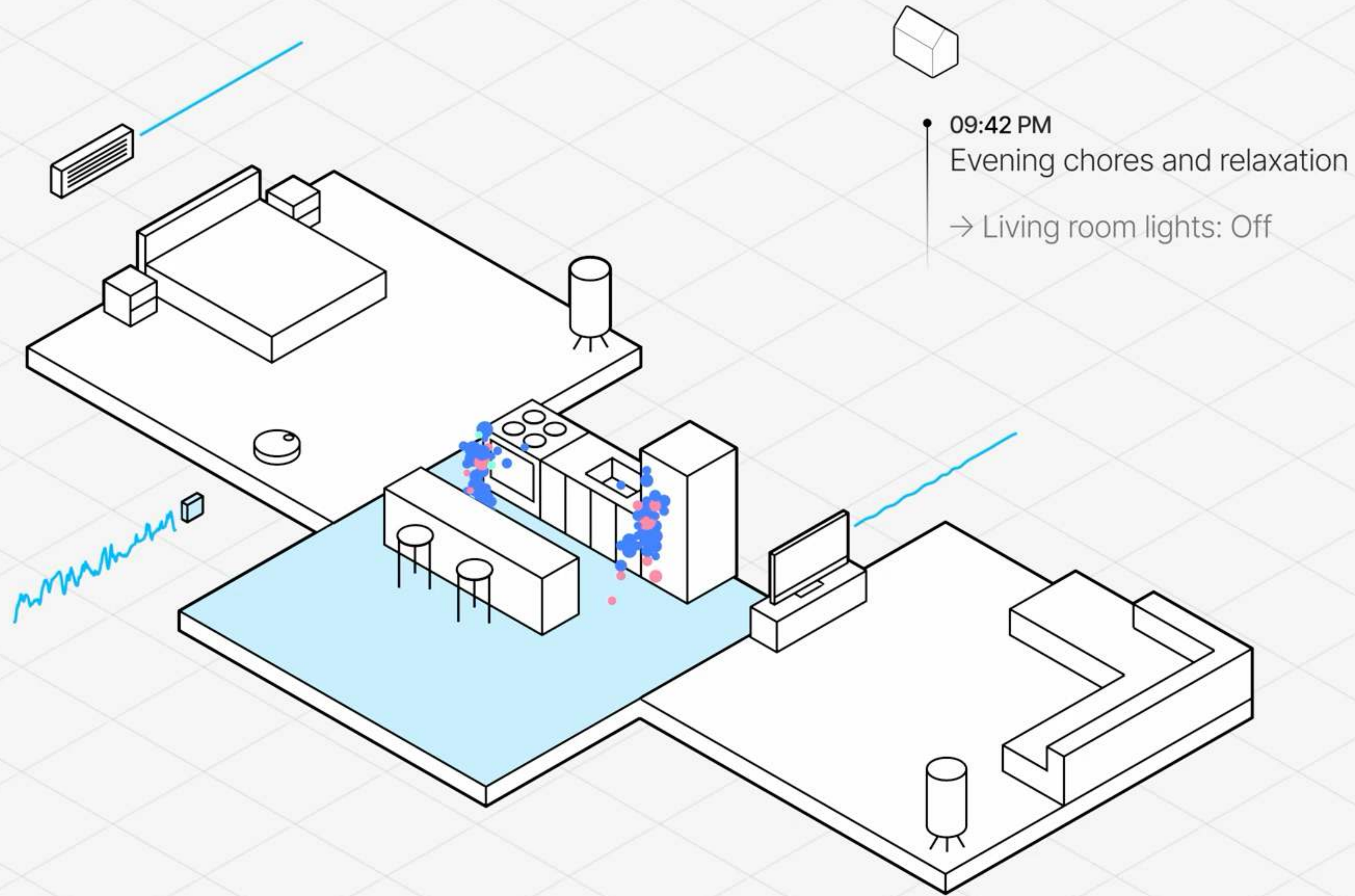
Context-aware computing

Collect information about the user's environment, and use it to customize their computing experience

Some types of context: location, social surroundings, activity, ...

Towards a Better Understanding of Context and Context-Awareness

Anind K. Dey and Gregory D. Abowd



Ivan Poupyrev's Archetype AI: <https://www.youtube.com/watch?v=LTb0HomVI8Y>

Programmable objects [Jin et al. 2019]



Photochromic inks change color when exposed to lights of a specific wavelength

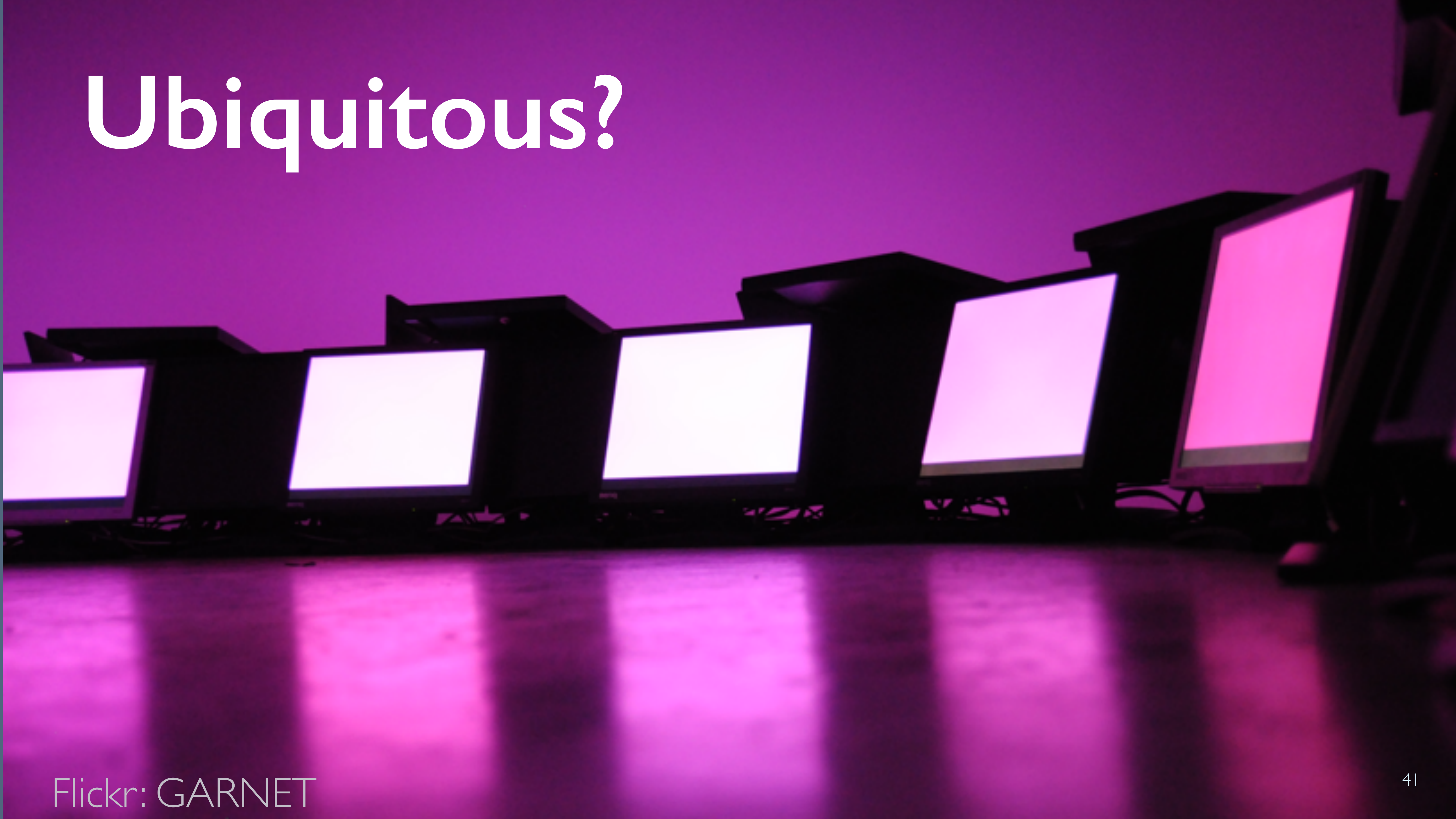
Privacy [Chen et al. 2020]



Wearable
microphone
jamming:
ultrasonic
speakers are
read as white
noise by mics

Wearing the
bracelet means
the speakers
move, so we
get better
coverage

Ubiquitous?

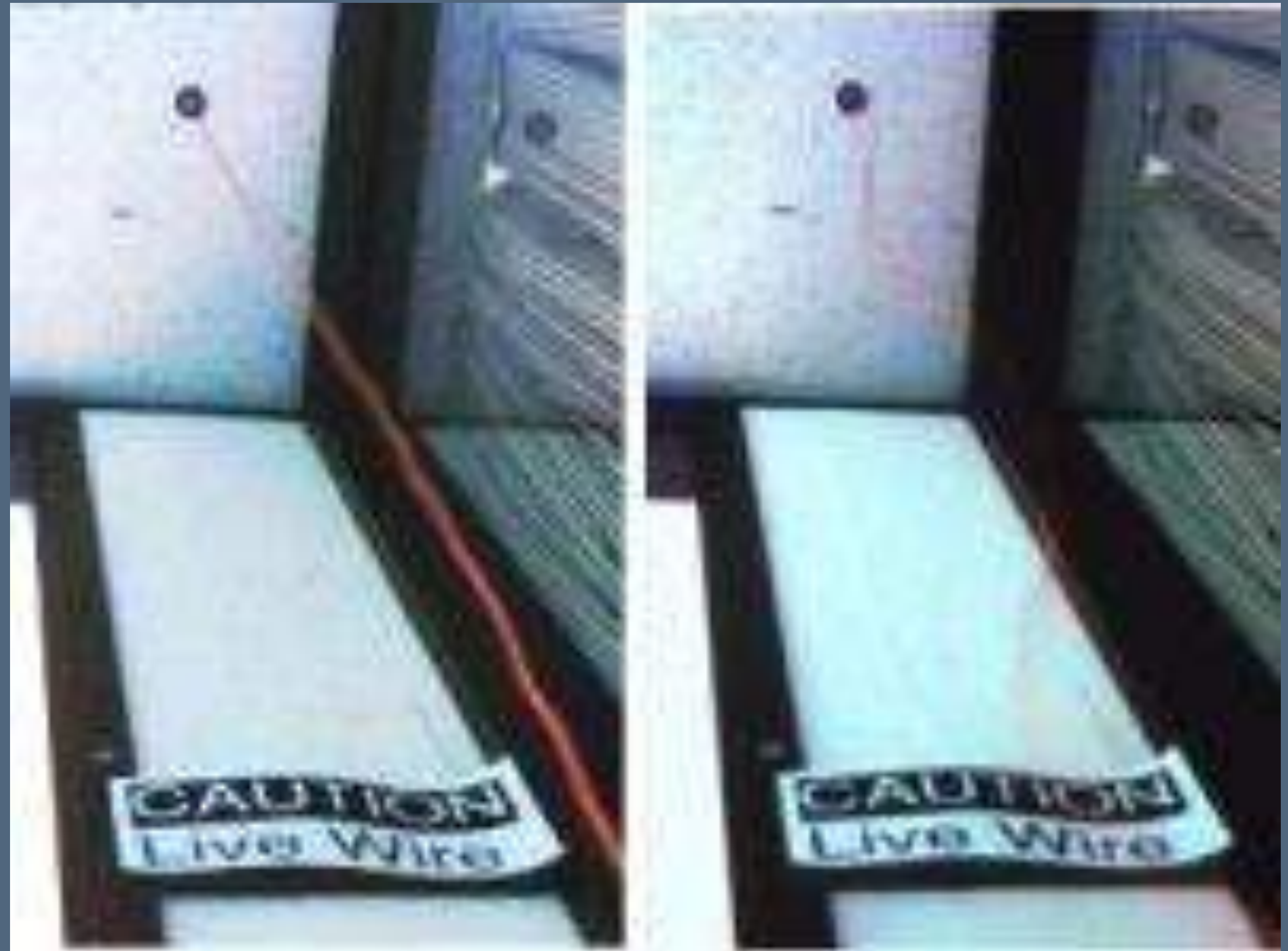


Ubiquitous?



Ubicomp is backgrounded

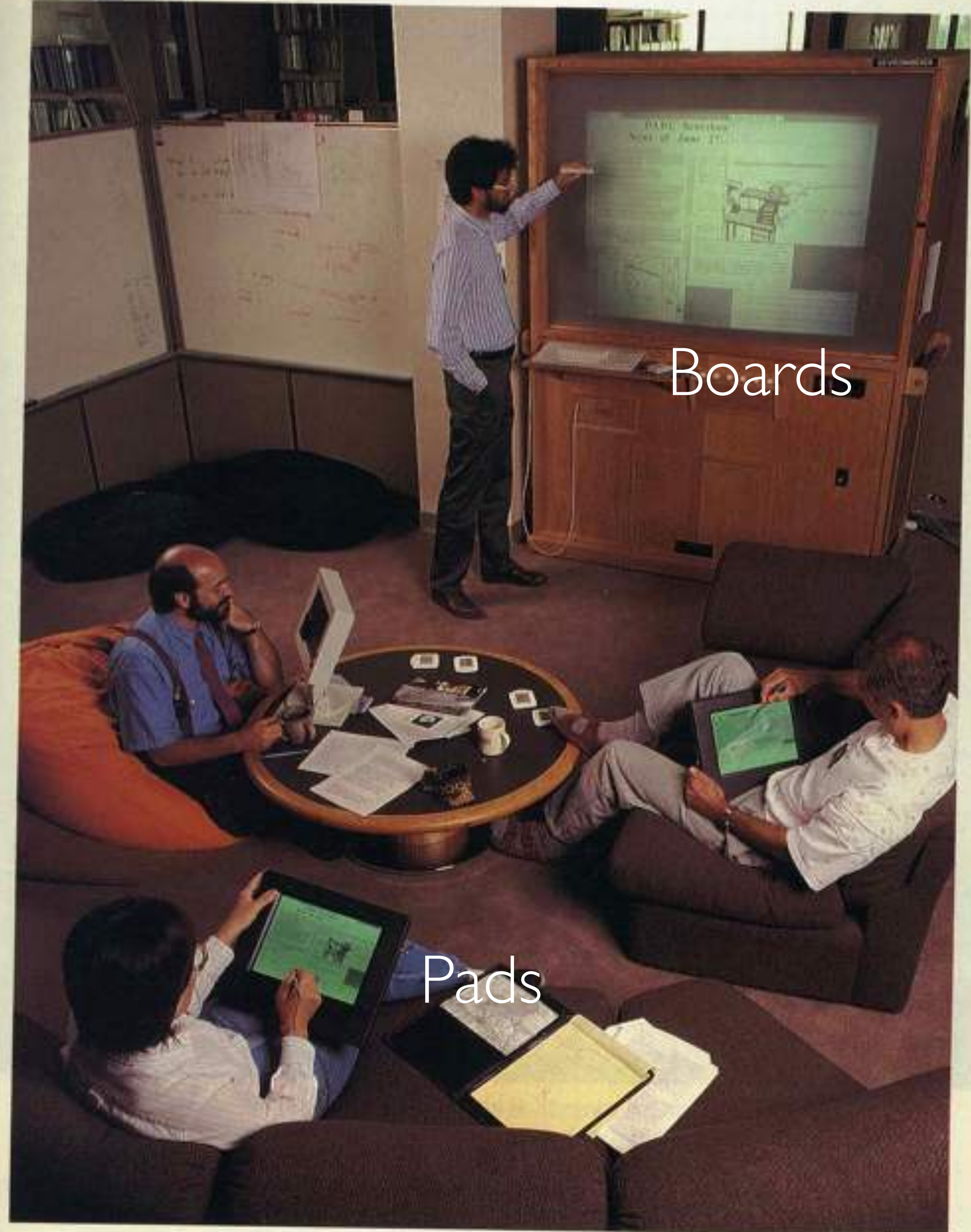
What Weiser calls one of the first “calm” technologies: Live Wire, a wire on a stepper motor, monitoring net traffic [Jeremijenko 1995]





Tabs

Weiser envisioned ubiquitous computing devices at three scales: tabs, pads, and boards.



Boards

Pads

Tabs

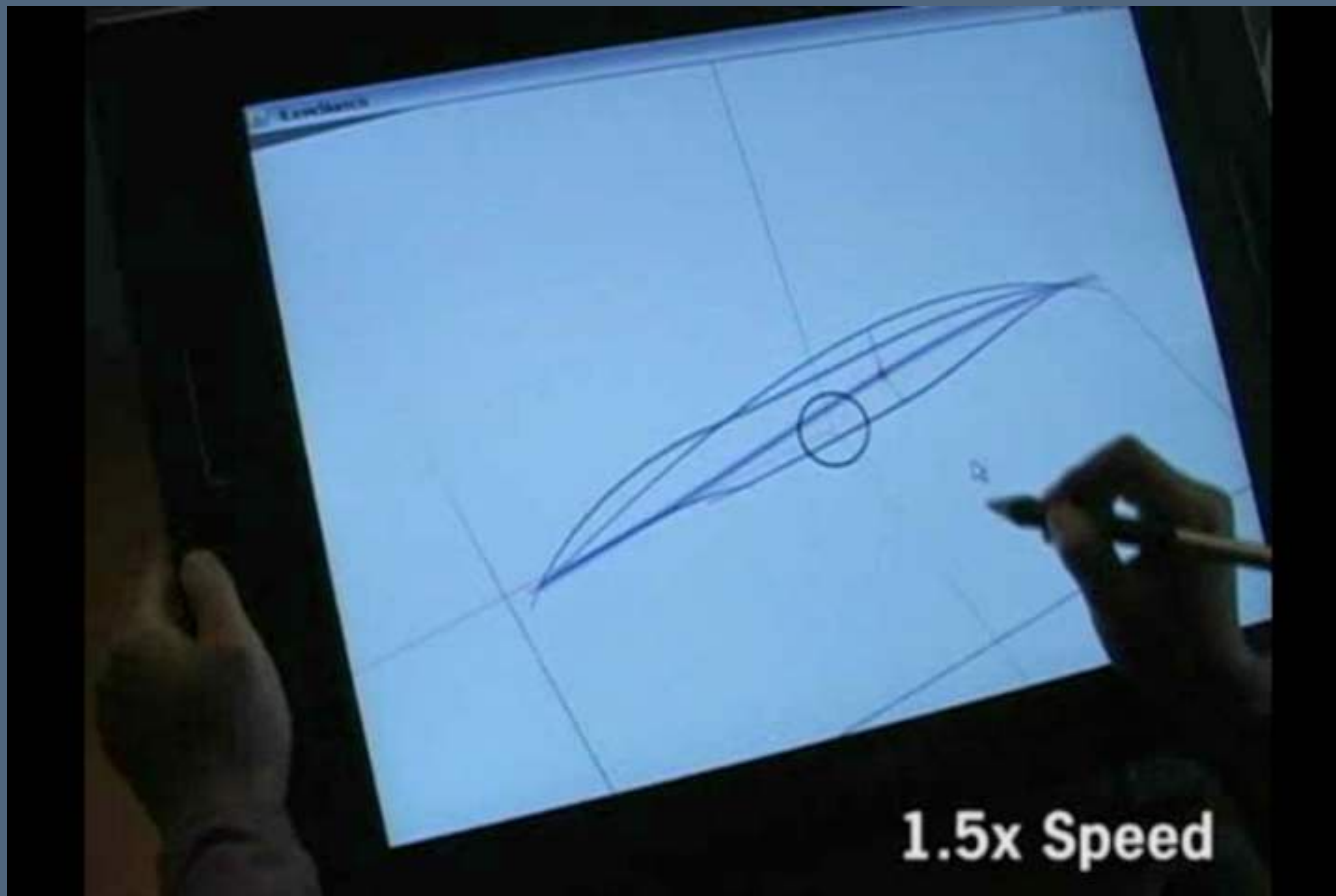


Most similar to today's smart watches

Significant
Otter: sharing biosignals with romantic partners [Liu et al. 2021]

Pads

Most similar to today's tablets



[Bae, Balakrishnan, and Singh 2008]



[Hinckley et al. 2010]

Boards



Create a grid of conductive diamonds similar to a phone screen

Sense the columns and scan the rows to ID the touch location

[Zhang et al. 2018]

Tangible computing

Tangible Computing

Directly-manipulable physical interfaces to data and computation

‘Pure’ form of ubicomp in that there is no computer to be seen

You will read this for our next class

Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms

Hiroshi Ishii and Brygg Ullmer

MIT Media Laboratory

Tangible Media Group

20 Ames Street, Cambridge, MA 02139-4307 USA

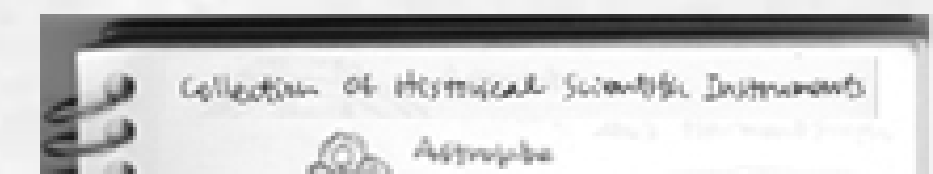
{ishii, ullmer}@media.mit.edu

ABSTRACT

This paper presents our vision of Human Computer

BITS & ATOMS

We live between two realms:

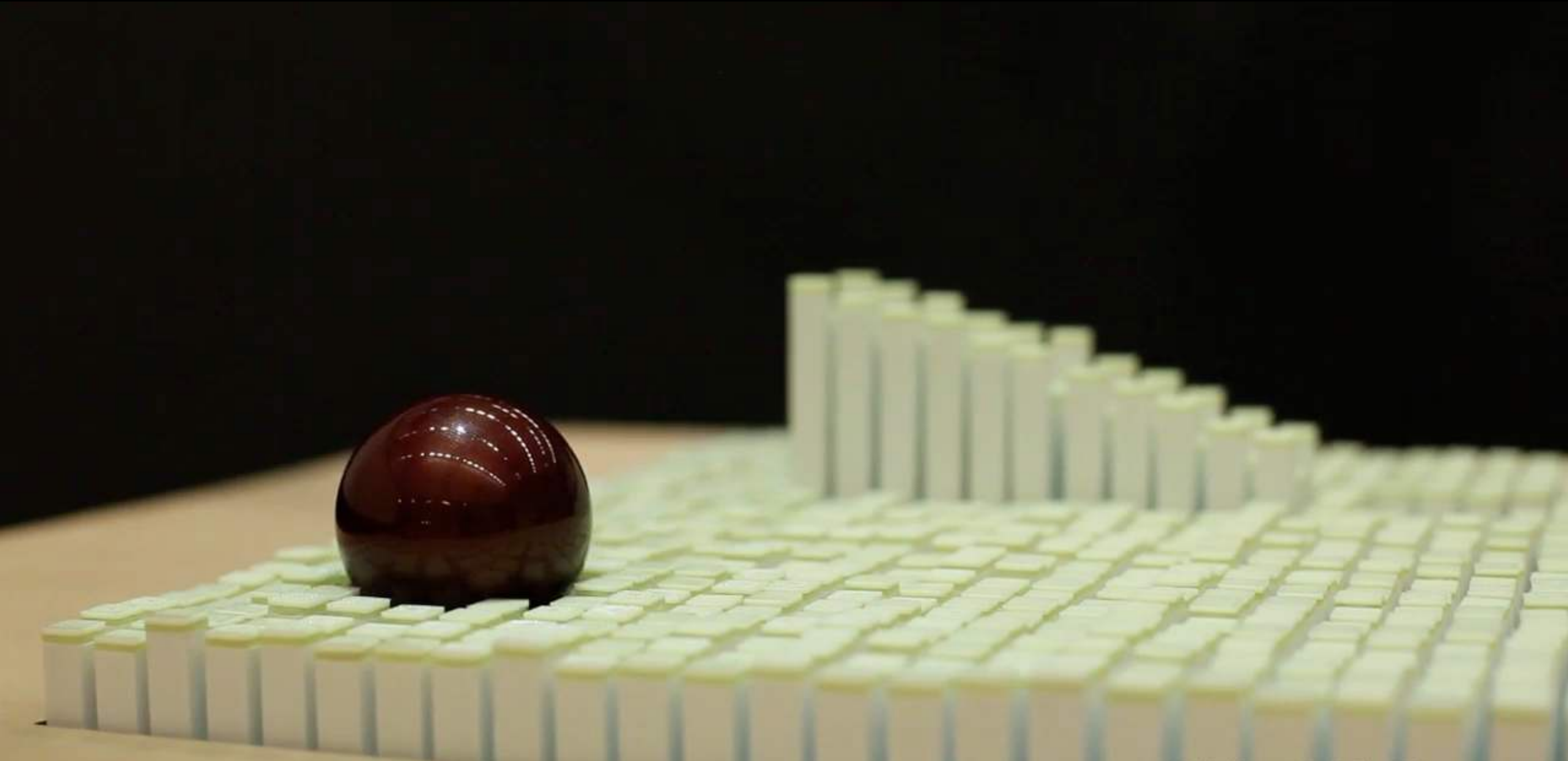




Urp: a luminous-tangible workbench for urban planning and design.
Underkoffler, Ishii. CHI '99.



Urp: a luminous-tangible workbench for urban planning and design.
Underkoffler, Ishii. CHI '99.



Follmer, Leithinger, Olwal, Hogge, Ishii. inFORM: Dynamic Physical Affordances and Constraints through Shape and Object Actuation. UIST '13.

Questions you ought to be asking

Why do, and don't, we have elements of the ubiquitous and tangible computing visions in our lives today, thirty five years later?

What are resilient challenges or mistaken assumptions, and what challenges might we actually be able to tackle?

Yesterday's tomorrows

[Bell and Dourish 2007]

Ubiquitous computing is driven not by a technological goal, but by a shared vision of the future.

However, this vision is a future as imagined in 1991, when Weiser's article was released.

What should the future of ubicomp be, from today's perspective?

Where we go from here

week 1	Ubicomp
week 2	Ubicomp
week 3	Design
week 4	Design / Social Computing
week 5	Social Computing
week 6	Software and Tools
week 7	[UIST]
week 8	Cognition
week 9	Cognition
week 10	Global Citizenship

How this class works

Class activity I of 3: Readings

Yes, you are reading in a Computer Science class.

There will be two papers to read for each class day.

This will take substantial time. It will get faster as the course proceeds and you get more used to reading papers.

If you are reading off-campus, use the Stanford library proxy linked at the top of the syllabus webpage.

Commentaries

After reading the papers for each class, you will reflect on the main ideas in each paper and submit a written commentary.

These commentaries serve as a mechanism to drive deeper reflection on the concepts in each paper.

Commentaries are **due at noon the day of lecture.**

Completion is to prepare you for the tutorial discussion; the commentaries are only graded for completion

Do's: writing a strong commentary

Do: engage with the core contributions —

Step 1 (Reflection): State the main point but then **reflect on why the ideas in the reading made sense from the authors' perspectives.**

Step 2 (Synthesis): How effectively does it convince you of that argument? **How could the argument be even more persuasive, on its own terms?**

Step 3 (Future work): What are the implications of the argument? **Given the ideas presented in the paper, what would you want to work on, or how would you modify those ideas?**

Don'ts: writing a strong commentary

Do not: stop after just disagreeing with what the authors wrote

Step 1 (Reflection): We get lots of commentaries that are mostly summary. Don't stop here. We've all read the paper. 1–2 sentences max.

Step 2 (Synthesis): It's easy to just lob criticisms and negativity. Too many commentaries are just lists of complaints. Instead, focus on: what's at the core of this idea, and why is it holding sway? What might be a better version of this idea, if you're unconvinced?

Step 3 (Future work): Too few commentaries cover this! Instead, ask yourself: what are applications of these ideas, and what follow-up ideas might be worth exploring?

~~“This paper has so many problems:”~~

“This paper inspired me to develop an idea:”

Example Length

I enjoyed learning about how the researchers used different approaches and compared-and-contrasted them in order to see how various tools categorized the importance of different graphical sections. I was most interested by the difference between Ground Truth BubbleView clicks and Predicted Importance projections. Specifically, I thought it was interesting that many of these graphics were magazine-esque layouts, with background images that projected the theme, but often didn't have super specific information, and large amounts of text in various sizes, colors, and placements. With BubbleView, it seemed that lots of people would click on the text, as well as these background images, but Predicted Importance often thought that the background image wasn't too important. I thought this finding reiterated how important it is to choose background images that are intentional, and not just filler images to make the page important. If people's attention goes there more than we'd expect, it's crucial to spend time choosing images that accentuate your points rather than distract the reader.

One experience this reminded me of is other AI tools and algorithms that I have seen on social media sites, specifically those that try to decide the important areas of an image that should be showcased when cropped. Specifically, I remember similar cropping / importance algorithms being used on Twitter / X. However, these tools turned out to be extremely problematic, often cropping the images to focus on those who are white, thin, and female. Many articles dived into understanding this, and users themselves tested by adding photos with underrepresented populations vs. more privileged groups and saw the ethical issues themselves. Many tech people wrote articles (ex. [Twitter's Photo-Cropping Algorithm Favors Young, Thin Females](#) Links to an external site.), as well as Twitter themselves ([Sharing learnings about our image cropping algorithm](#) Links to an external site.). The biases present in this algorithm were deeply connected to general biases in AI, and I would have loved to see the article dive into that possibility more. They do not touch on any biases in their training data, or any edge cases they see that might need further exploration.

Overall, I felt that future work for this article relies on more than just making the tool open source for people to explore themselves. Certain fonts, text patterns, and images grabbed the attention of the user greatly, and a guide to those recommendations would make these learnings even more applicable to the average designer. Although these guides of design tips may exist now, I am sure that at the time of the release of this article, these suggestions would have really changed how people presented media online.

Our first readings

The Computer for the 21st Century

Specialized elements of hardware and software, connected by wires, radio waves and infrared, will be so ubiquitous that no one will notice their presence

by Mark Weiser

The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it.

Consider writing, perhaps the first information technology. The ability to represent spoken language freed information for long-term storage freed memory from the limits of individual memory. The technology is ubiquitous in many countries. Not

is approachable only through complex jargon that has nothing to do with the tasks for which people use computers. The state of the art is perhaps analogous to the period when scribes had to know as much about making ink or baking clay as they did about writing.

The arcane aura that surrounds personal computers is not just a "user interface" problem. My colleagues and I at the Xerox Palo Alto Research Center think that the idea of a "personal computer" is misplaced and that the vision of laptop machines, dynabooks and knowledge navigators is only a step toward achieving the

The idea of integrating computers seamlessly into the world at large runs counter to a number of present-day trends. "Ubiquitous computing" in this context does not mean just computers that can be carried to the beach, jungle or airport. Even the most powerful notebook computer, with access to a worldwide information network, still focuses attention on a single box. By analogy with writing, carrying a super-laptop is like owning just one very important book. Customizing this book, even writing millions of other books, does not begin to capture the real power of literacy.

Furthermore, although ubiquitous computers may use sound and video in addition to text and graphics, they must make them "multimedia" in a way that makes them ir-

PAPERS

Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms

CHI 97 * 22-27 March 1997

Hiroshi Ishii and Brygg Ullmer
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Tangible Media Group

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ABSTRACT

This paper presents our vision of Human Computer Interaction (HCI): "Tangible Bits." Tangible Bits allows users to "grasp & manipulate" bits in the center of users' attention by coupling the bits with everyday physical objects and architectural surfaces. Tangible Bits also enables users to be aware of background bits at the periphery of human perception using ambient display media such as light, sound, airflow, and water movement in an augmented space. The goal of Tangible Bits is to bridge the gaps between both cyberspace and the physical environment, as well as the foreground and background of human activities.

This paper describes three key concepts of Tangible Bits: interactive surfaces; the coupling of bits with graspable physical objects; and ambient media for background awareness. We illustrate these concepts with three prototype systems - the metaDESK, transBOARD and ambientROOM - to identify underlying research issues.

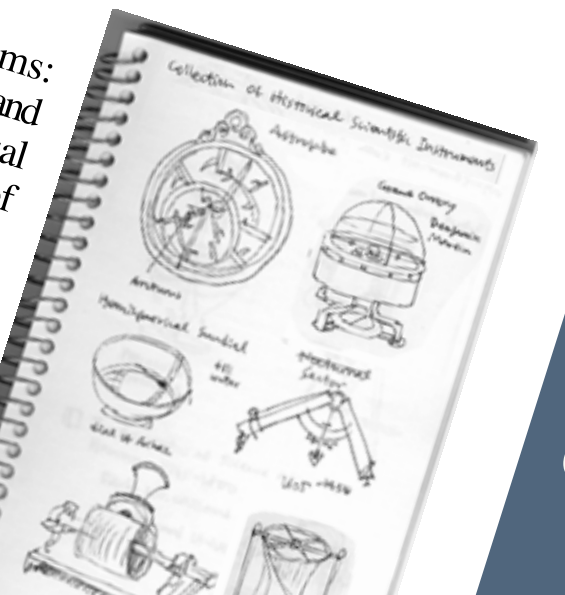
Keywords

tangible user interface, ambient user interface, augmented reality, and periphery

BITS & ATOMS

We live between two realms: our physical environment and cyberspace. Despite our dual citizenship, the absence of these parallel existences leaves a great divide between the worlds of bits and atoms. At the present, we are torn between these parallel but disjoint spaces.

We are now almost constantly "wired" so that we can be here (physical space) and there (cyberspace).



Metacommentary discussion

Each day after lecture, we will engage in a class-wide critique and meta-commentary session

I'll run an analysis to summarize the themes in your critiques, and kick off with some of my reactions to your feedback

This may lead to additional feedback guidelines in the commentary submission system!

Class activity 2 of 3:

Tutorials

Yes, there is human-human interaction in a CS class.

Tutorials will be small-group discussions about the papers, led by a TA

You will dig into themes that arose in commentaries and in class

Tutorials are closed-laptop, closed-notes

Other than printouts of the paper, if you want to bring them

Tutorial signups are getting emailed out to the class soon—keep an eye out, this will be a fast turnaround

Being a discussant

Each week, in tutorial, you may be asked to serve as discussant for one of the papers.

When you are a discussant:

1. Open discussion on the paper for the group: 2–3 minutes laying out your take on the paper.
2. The TA will follow up with some Q&A to deepen your discussion
3. Then, help the TA drive discussion on the paper with the wider group

Class activity 3 of 3:

Quizzes

Four quizzes + a final

Quizzes cover the lecture content, every two weeks

Each quiz will cover content spanning from the lecture day of the previous quiz up until, but not including, the current quiz's day

e.g., Quiz 1, at the start of Week 3, will cover today through the last lecture of Week 2

e.g., Quiz 2, at the end of Week 5, will cover the lectures from the same day as Quiz 1, through the last lecture of Week 4

Comprehensive final quiz during our last lecture of the quarter

All quizzes are closed-book, will ask you to recognize and apply the concepts from lecture

Quiz Timeline

week 1

week 2

week 3 Quiz

week 4

week 5 Quiz

week 6

week 7 Quiz

week 8

week 9 Quiz

—Thanksgiving—

week 10 Final

Prereqs and background

Most important: are you prepared to dive deep into foundational HCI theories and critique/discuss them?

Helpful:

Depth in at least one of (computer science, social science methods, design, STS)

Experience in human-computer interaction (e.g., CS 147, CS 247)

Grading

40% Tutorials (includes commentary completion)

40% Four quizzes

20% Final

Enrolling

Click “None” for discussion section when enrolling: we will manage discussion section times ourselves

All other times will look like they are at capacity; ignore it.

Introductions

Michael Bernstein

Professor of Computer Science

Office hours: Wednesdays 4:15pm-5:30pm
CoDa E350



TAs



Jordan Troutman
PhD student in
Computer Science



Beleicia Bullock
PhD student in
Computer Science

Contact us

Email: cs347@cs.stanford.edu

Readings, policies, light entertainment: cs347.stanford.edu

Commentary submission is on the course website

Questions?

References

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