

# Introduction to Wearable Computers

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Georgia Tech

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Ricoh Innovations

# Science Is Beginning to Look Like Science Fiction

- o Science fiction writers are paying attention and provide good scenarios/motivation based on current research
  - o Fast Times at Fairmont High (recent Vinge)
  - o Historical Crisis (Kingsbury) in Far Futures anthology (Benford)
  - o The Diamond Age, Snowcrash (Stephenson)
  - o Islands in the Net (Stirling)



# Georgia Tech/MIT Cyborgs: a living experiment



# Outline

- What are you wearing?
- Comparisons to past and current technology
- A bit of history...
- Current state of industry
- Wearable computing visions and definitions
- Just-in-time information systems and fun demos
- Four major challenges
- Some lessons
- Resources

# The Toys

# Miniature Head-up Displays

MicroOptical prescription  
display eyeglasses





# Teleprompter



# Keyboards

- Twiddler
  - Chording
  - In 5 min. alphabet
  - In 1 hr touch typing
  - Speed of 60 wpm
- Half QWERTY
- Embroider in a jacket





# CharmIT Wearable Computer

- 266MHz Intel Pentium or 800MHz Transmeta Crusoe



([www.charmed.com](http://www.charmed.com))

# Questions About Hardware...?

- How can I see with that thing in front of my eye?
- Eye strain?
- Isn't it socially interruptive?
- Why do they cost so much?
- Isn't that bad on your hands?
- Why do you tuck the display into your shirt pocket?
- ...



# Comparison With Old Technology

# Human-computer evolution

- Mainframe -> mini -> PC -> wearable
- Initially lose on features
  - Less CPU capacity
  - Lower bus speed
  - Less disk storage
- Gain on interface
  - Personalization
  - Interactivity

(Starner PhD 1999)

# Why not a PDA?

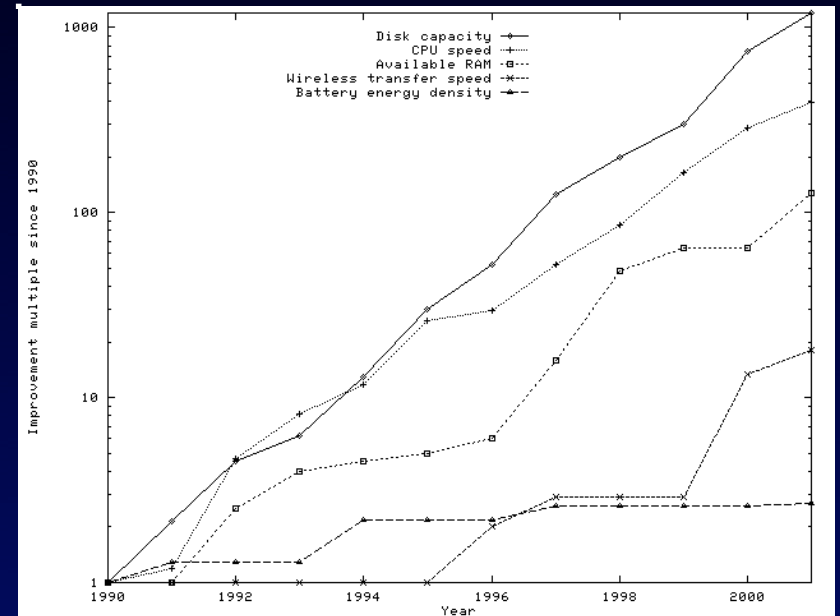
- Too much cognitive load
  - Augment, not replace task
  - Two hands, both eyes
- Socially awkward
- Low functionality
  - Input speed
  - Data storage
  - “Hot sync” effect
  - Applications

# Quick Survey

- How many people
  - Own one?
  - Have it with them?
  - Why is that?
- If we were to schedule an appointment with you right now, what would be the procedure?

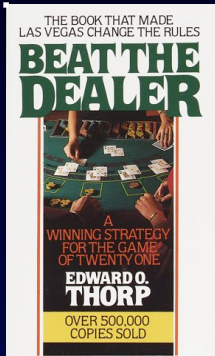
# Why Not a Thin-Client?

- 100X RAM
- 400X CPU
- 1200X disk (>Moore's Law)
- 20X wireless speed
- 3X battery



Exponential improvement in mobile tech since 1990

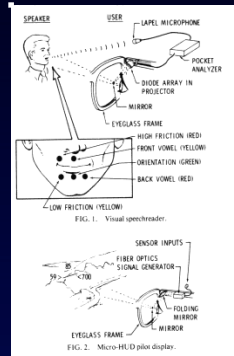
# Brief History



1961



1966



1968



1977

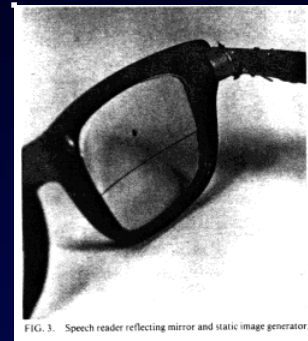
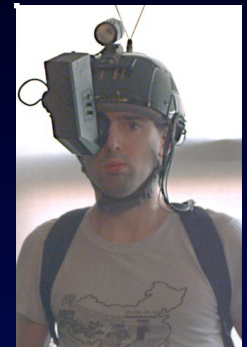


FIG. 3. Speech reader reflecting mirror and static image generator.

1980



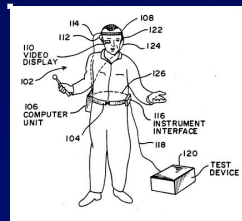
1981



1991



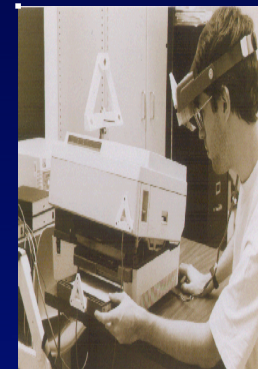
1991



1992



1993



1993



1996

# Current “General Purpose” Commercial Systems

- CharmIT & CharmIT Pro (R&D)
- Hitachi WIA/POMA
- Via series
- Xybernaut MA series
- 
- Mentis?
- Past systems: Reddy Systems, Park Engineering,  
...

# Applications





# Application Areas

- Warehouse picking
- Inspection
- Maintenance
- Repair
- “Line-busting”
- Security
- Military (Land Warrior/Pacific Consultants)

# Controlled Studies

- CMU VuMan3 (Siewiorek/Smailagic)
  - Military inspection task
  - 2:1 savings in personnel
  - 40% faster
  - Custom design (many design generations)
- Georgia Tech Task Guidance (Ockerman)
  - Small airplane inspection by pilots
  - Basic manual emulation— no feedback
  - Wearable interface hindered expert!
    - Similar to checklist?
    - Providing context helped

# Vocollect Series





# Symbol Technologies WS series



# Symbol's Success

- \$5 million development costs
  - People sweat
  - Body armor
  - Plastic wears
  - Wearer buy-in through demonstration
- > 100,000 units; \$3500-\$5000 list
- Unique differentiator
- New markets

# CharmBadge

- One of the simplest wearable computers
- Exchange business card information between attendees at conferences
- Allows attendees to sort conference contacts by length of conversation
- Similarly, product information can be remembered and sorted based on interaction time

# Portable Entertainment Systems

- MP3 players
  - Rio: 10,000/week
  - Wearables or not?
  - \$3 billion/year
- Video
- Portable phones/games/...

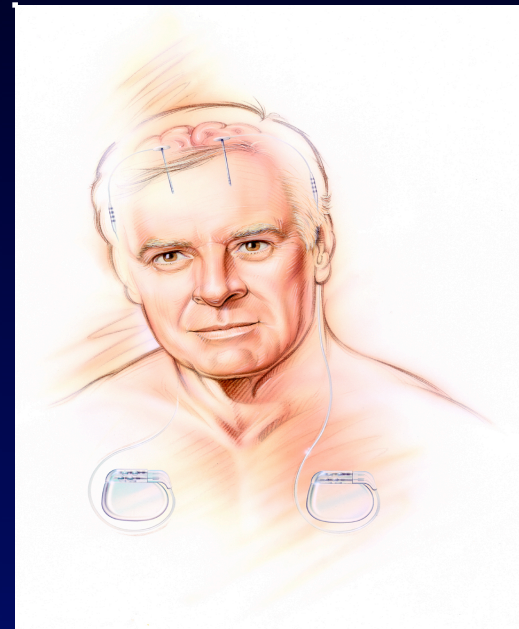




# Medical and Fitness Systems



FitSense



Medtronic



# Fashion



Music Jacket  
(MIT)



Galvactivator  
(MIT)

# The Vision

# Wearable Computing Vision

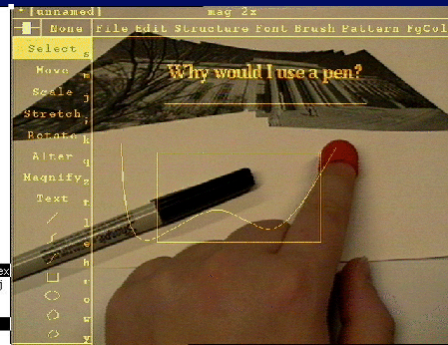
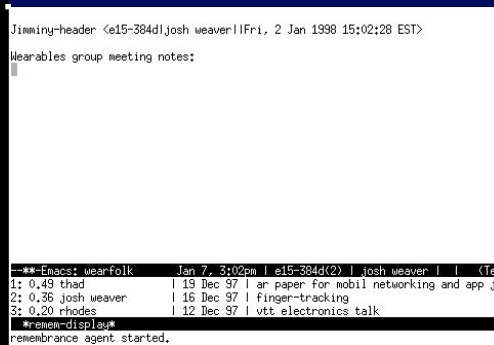
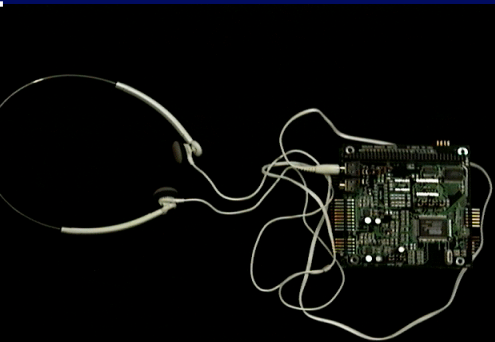
- Pocket or clothing based computing
- Peripherals distributed around the sensors and actuators of the body, connected wirelessly
- Runs entire day

# Interaction (Life)Style, Not Hardware

- Rhodes [Rhodes97]
  - Portable while operational
  - Enable hands-free or hands-limited use
  - Capable of getting user's attention
  - Always “on”
  - Sense the user's context in order to serve him better
- Starner [Starner99]
  - Persists and provides constant access
  - Senses and models context
  - Augments and mediates
  - Interacts seamlessly

# Everyday Applications

- Consumer devices (CD, movies, cell)
- Instant messenger (zephyr)
- Instant reference (webster, google)
- Remote monitoring (telnet)



# Man-Machine Symbiosis

# Intelligence Enhancement



- “Strengthen” the mind
- Train how to use the mind more effectively

Smart foods, brainstorming techniques, memory tricks, etc.

# Intelligence Augmentation



- Support mental task
- Constrain thinking
- Maintain flexibility



# Not a New Concept

- Douglas Engelbart (1962)
  - Intelligence augmentation
- JCR Licklider (1960)
  - Man-computer symbiosis

# Intelligence Augmentation

- Human Intelligence (normal thinking)
- Artifacts (autonomous systems)
- Combination (intelligence augmentation)

# Man-Computer Symbiosis

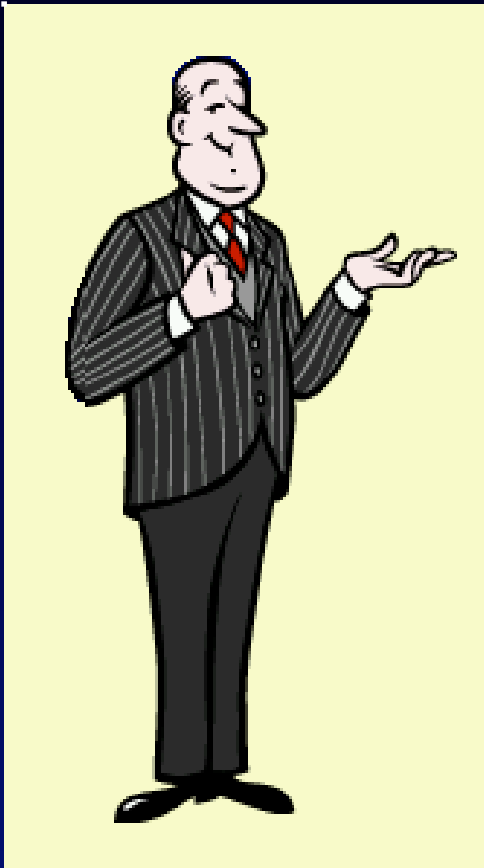
JCR Licklider, 1960

“Man-computer symbiosis... will involve very close coupling between the human and the electronic members of the partnership.”

“[A person could] in general interact with [a computer] very much as he would with another engineer, except that the ‘other engineer’ would be a precise draftsman, a lightning calculator, a mnemonic wizard, and many other valuable partners all in one.”

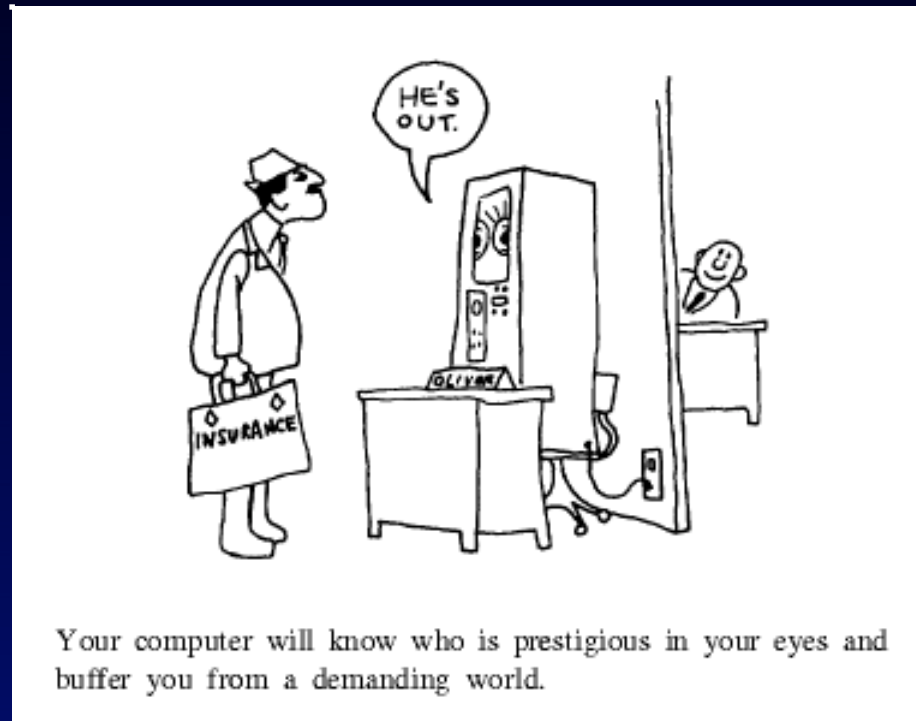
“[In his self-study] Much more time went into finding or obtaining information rather than digesting it”

# Software Agents



- Personalized
- Autonomous
- Sense the environment
- Act on your behalf

# Communications Filtering Agent



[JCR Licklider, “The computer as a Communications Device,”  
Science and Technology, April 1968]

# Nomadic Radio



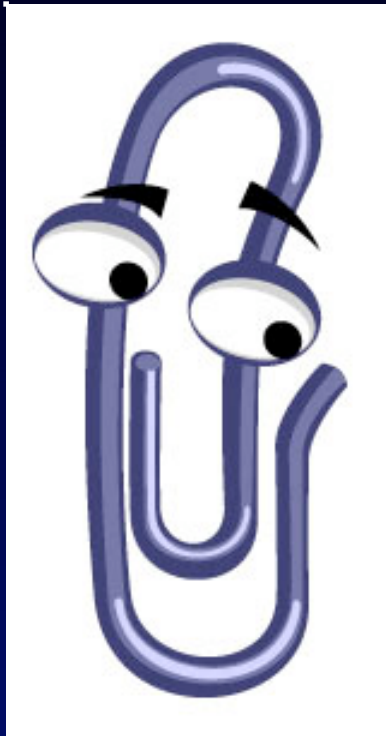
(Sawhney, MIT Media Lab)

- Audio interface
  - Voicemail, news, email
- Dynamic interruption
  - Importance of info
  - Personal profile
  - Conversation detection

# Software Agents

- Effective
  - Well defined task
  - Necessary information available to agent
- Break down
  - Open-ended task
  - Require “mind reading”

# The Annoying Intern



- Help task too open-ended
- Need to know user's intent

Communication between user  
and agent is too distracting!



# Prosthesis For The Brain



- *Less* autonomy
- Constant, low-load communication
- Tight integration with environment and task

# Information Retrieval

# Just-in-time Information Retrieval

- Automatically provide information
- Based on local environment
- Do it without driving people nuts

# Remembrance Agent

```
\subsubsection*{Criteria for Evaluation (Relevance vs Usefulness)}
```

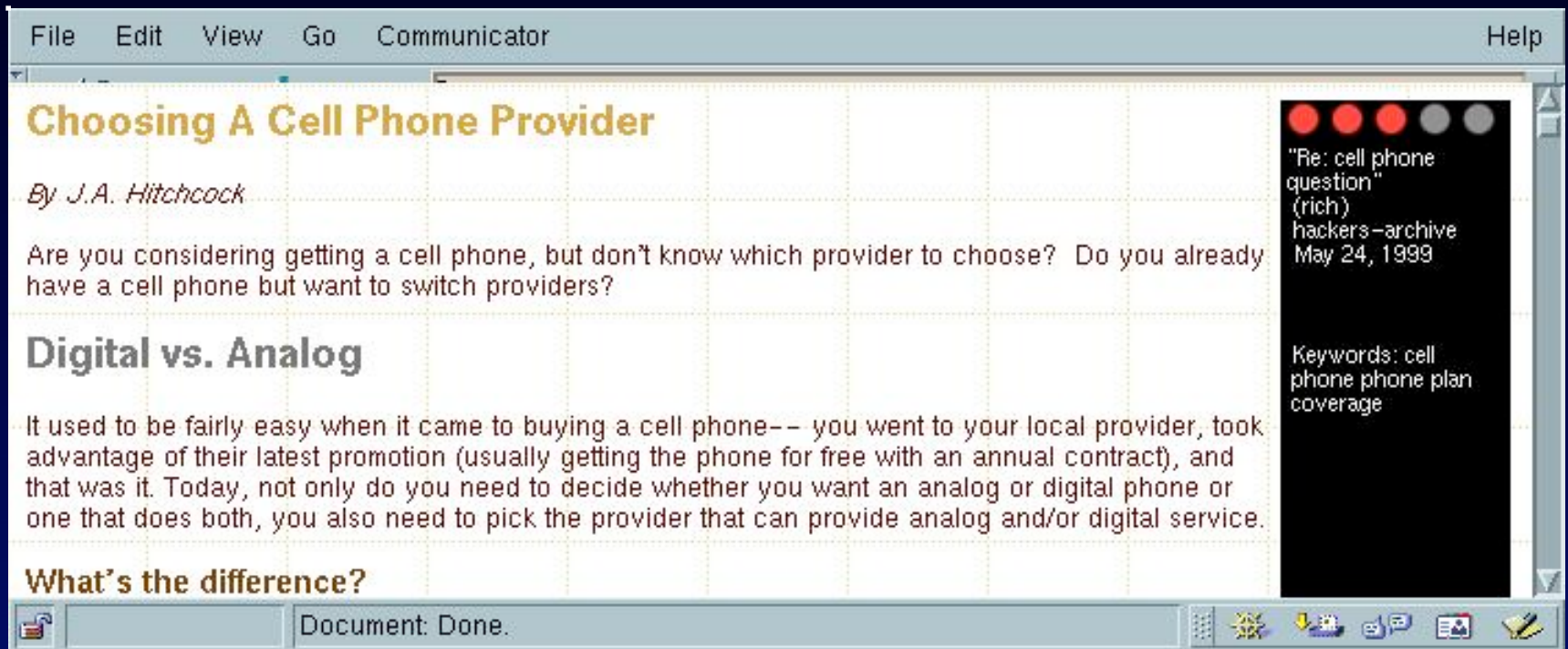
For the IR field, algorithms are typically evaluated based on whether the documents returned are relevant to the given query. It is assumed that the query is a good indication of the user's interests, though queries are often still represented in natural language. Remembrance agent queries are automatically created, so relevance isn't good enough. To evaluate the information retrieval algorithm of an RA, one needs to show that the hits returned are useful to a person given his current task. While relevance may correlate with usefulness, the two are not the same. For example, a citation from the INSPEC database could be relevant to a paper a researcher is writing but still be useless if the suggested document is already well known by the researcher.

```
\subsection{Interface Design}
```

The most important design constraint for remembrance agents is that reading suggestions be a secondary task for a user. Unlike users of a search

```
:-:-- ibm-systems-ra.tex 12:16AM 0.02 (LaTeX Fill)--L209--24%-----
1 + Rhodes Star March 1996 Remembrance Agent: a continuously running autom$
2 + Rhodes Star April 1996 Remembrance Agent: a continuously running autom$
3 + Wildemuth Dec. 1995 Oc Defining search success: evaluation of searcher$
4 Spink Greis May 1997 Partial relevance judgments and changes in user$
-:;% *remem-display* 12:16AM 0.02 (Remembrance Agent)--L1--All-----
```

# Margin Notes



The screenshot shows a web browser window with a menu bar (File, Edit, View, Go, Communicator, Help) and a status bar (Document: Done.). The main content area displays an article titled "Choosing A Cell Phone Provider" by J.A. Hitchcock. The article text discusses the difficulty of choosing a cell phone provider. On the right side, there is a "Margin Notes" panel with a black background and white text. It contains a subject line "Re: cell phone question" (rich) hackers-archive, a date "May 24, 1999", and keywords "cell phone phone plan coverage". The panel also features a set of five colored circles (three red, two grey) at the top.

File Edit View Go Communicator Help

## Choosing A Cell Phone Provider

By J.A. Hitchcock

Are you considering getting a cell phone, but don't know which provider to choose? Do you already have a cell phone but want to switch providers?

### Digital vs. Analog

It used to be fairly easy when it came to buying a cell phone-- you went to your local provider, took advantage of their latest promotion (usually getting the phone for free with an annual contract), and that was it. Today, not only do you need to decide whether you want an analog or digital phone or one that does both, you also need to pick the provider that can provide analog and/or digital service.

### What's the difference?

Re: cell phone question  
(rich)  
hackers-archive  
May 24, 1999

Keywords: cell  
phone phone plan  
coverage

Document: Done.

# JITIR Interfaces

- Progressive disclosure (Ramping interface)
  - Low-cost false positives
  - Lots of opportunities to bail out
  - Allow control over when information is viewed
- Follow *proximity compatibility* principle
  - Use local environment as part of interface
- Two-second rule (Miller, 1968)

# Controlled Evaluation Results

- Essay-writing experiment with news articles
- Subjects read three times as many articles using the RA as with a search engine
- RA use was in addition to search engine use, not a replacement

*Ease-of-access changed behavior*

# Value of JITIRs

- Provide new material
  - Answering questions as they're asked
- Provide supporting material
  - “I write opinions, the RA gives me the facts”
- Contextualize
  - “...nice to see how other people talked about this.”
- Help with another (related) task



# Jimminy (Wearable RA)



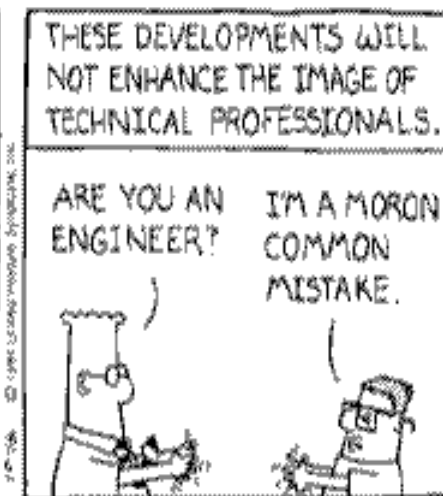
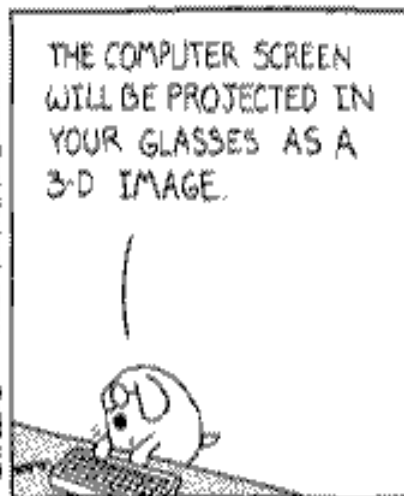
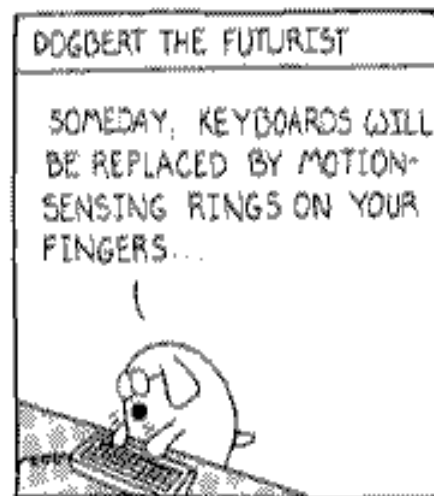
```
Notes on conductive cloth technology...

-:** *scratch* 9:49PM (Lisp Interaction)--L1--All-----
1 + pamme embroidery machine class 06/29/99 e15-335, conductive, c$
2 + david mizell contact 03/29/99 mizell $
3 + dave mizell ar 03/15/98 mizell $
4 + testarne Re: wearable fashion show 08/18/97 cloth $
-4.1.4.1- e15-335 ||mizell
```

# Jimminy

- Environment automatically sensed
  - Location
  - People in area
  - Time
  - Topic
- Physical context not good marker for “useful information”
- Output too dense for conversational speeds

# Augmented Reality



E-Mail: SCOTTADAMS@AOL.COM

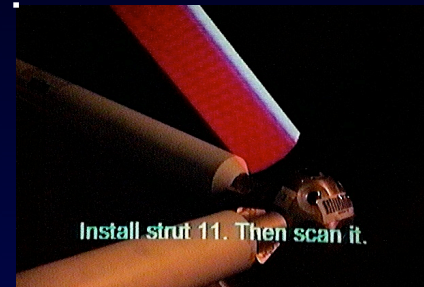
©1994 United Feature Syndicate

# What Is Augmented Reality?

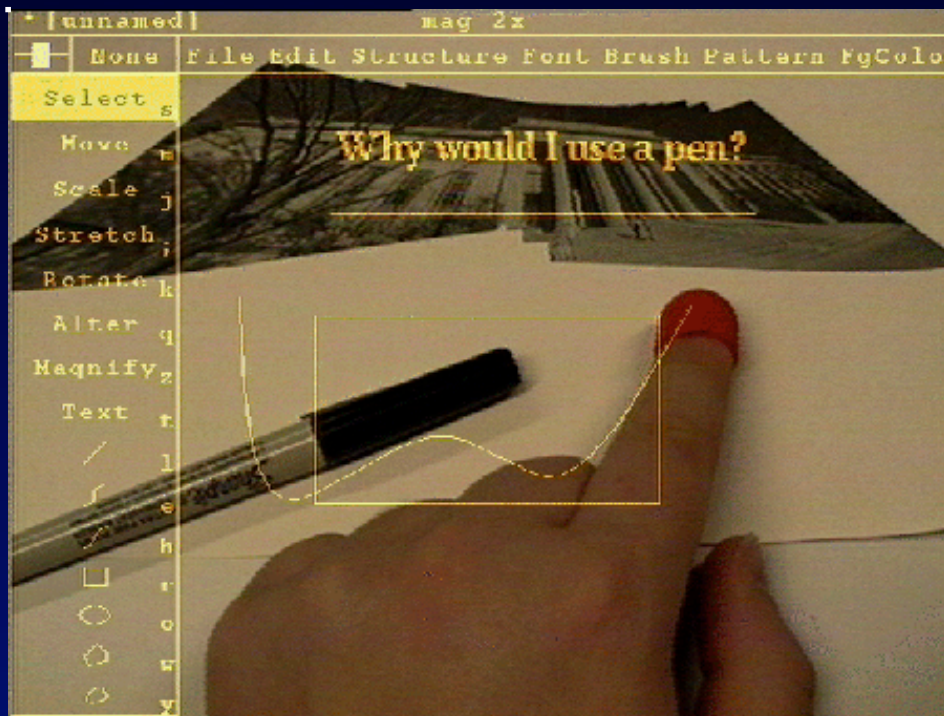
- Uses real world (context) as part of message
- Information where needed most

# Columbia University Augmented Reality (1993)

- Applications
  - Instruction
  - Mobile information
- Focus on graphics, speed
- Good evaluation
- Wired ultrasonic sensors

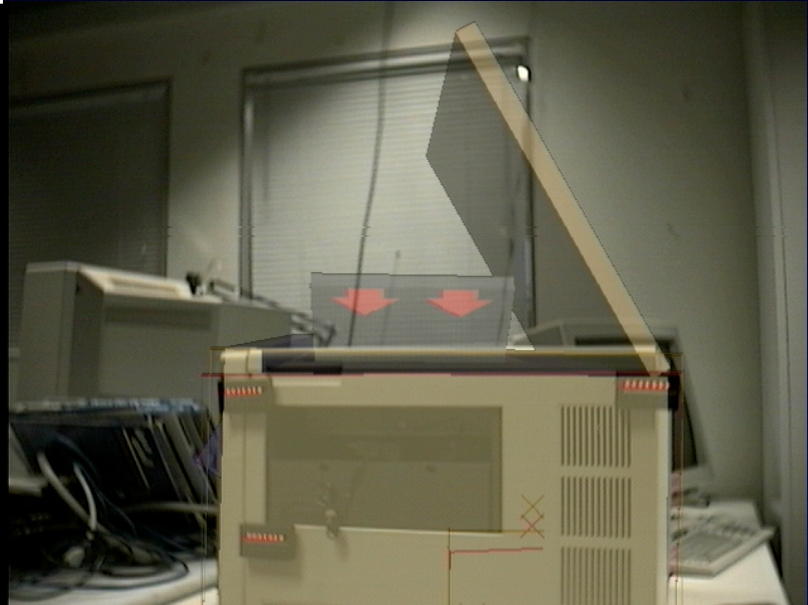


# Vision-based AR: finger as mouse (1995)

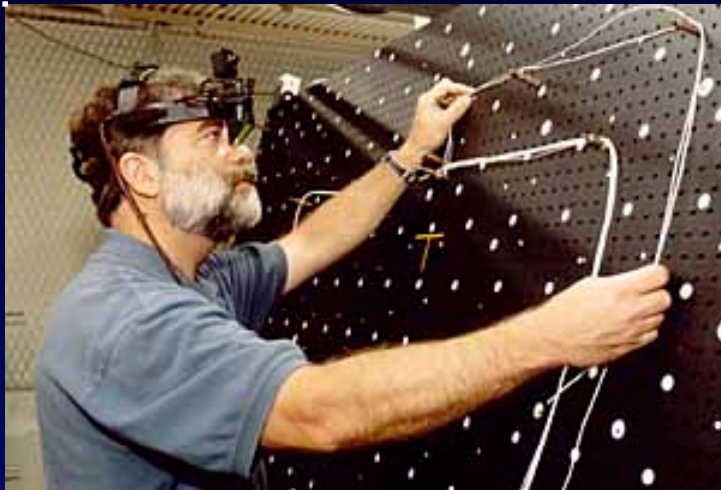




# Repair/Inspection/Maintenance

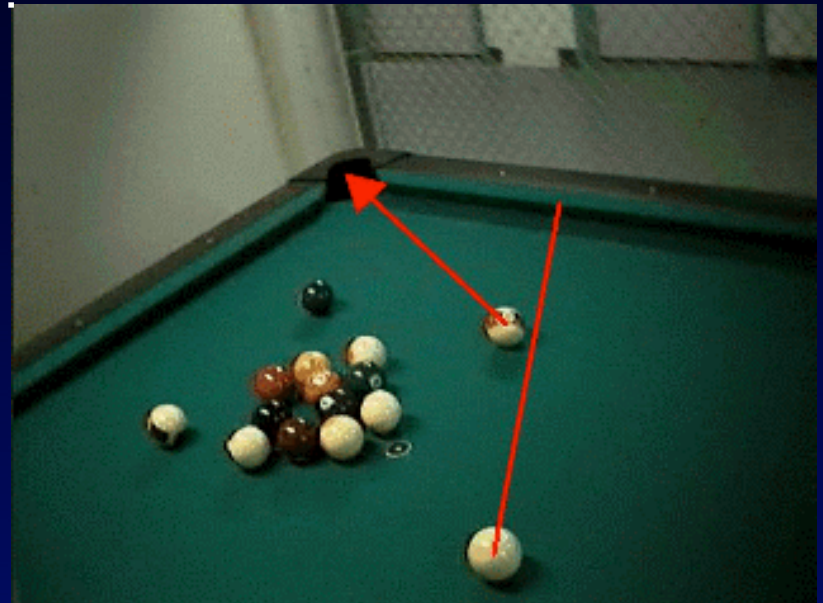


# Other Examples



Wiring AR System

(Mizell, Boeing)



Billiards Assistant

(Jebara, MIT Media Lab)

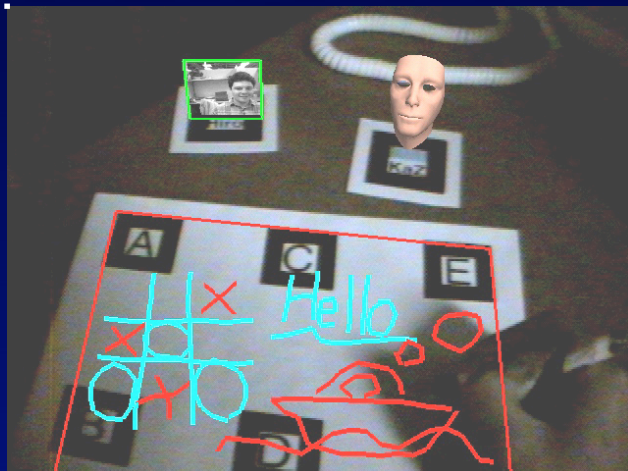
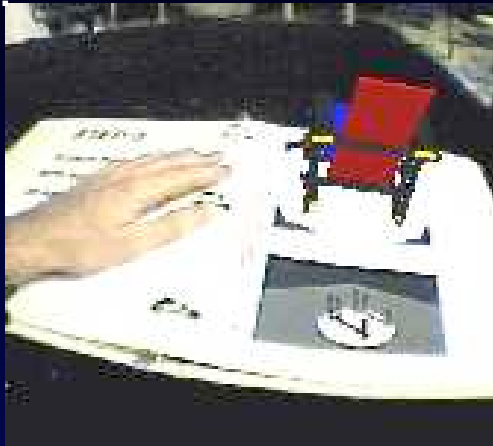


# Physical World Wide Web



video

# ARToolkit (Billinghurst)



video

# Perception

# Sensors



ASL translator  
(MIT)



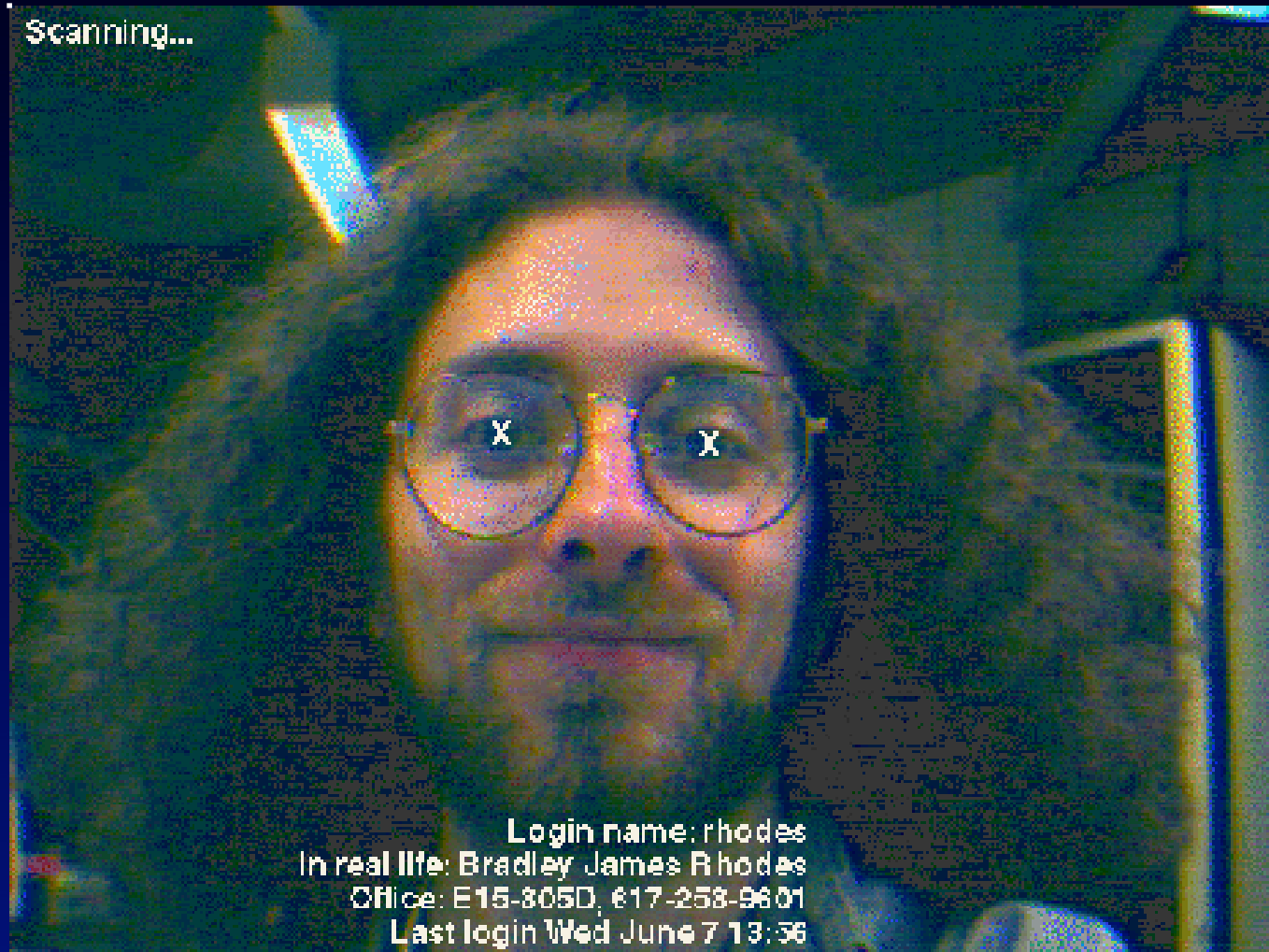
Sensate Liner  
(Georgia Tech)



Blood pressure  
sensor earring  
(MIT)

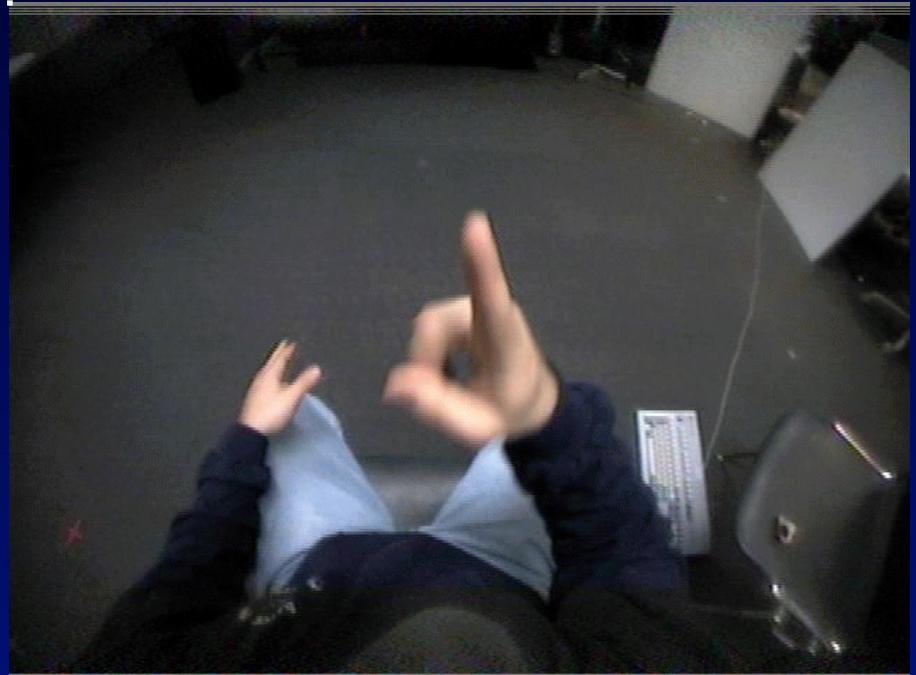


# Face Recognition



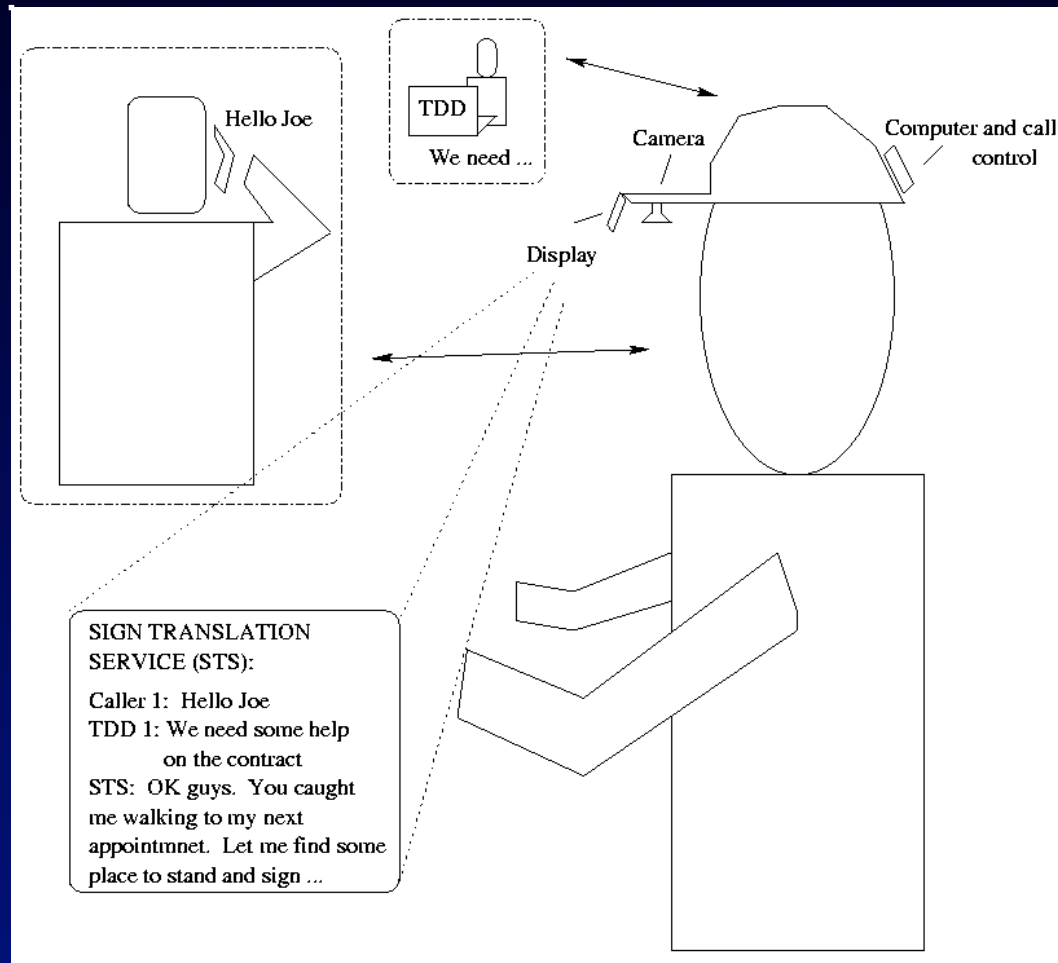
# Recognizing Gesture

- Wearable American Sign Language recognition: 97% accuracy



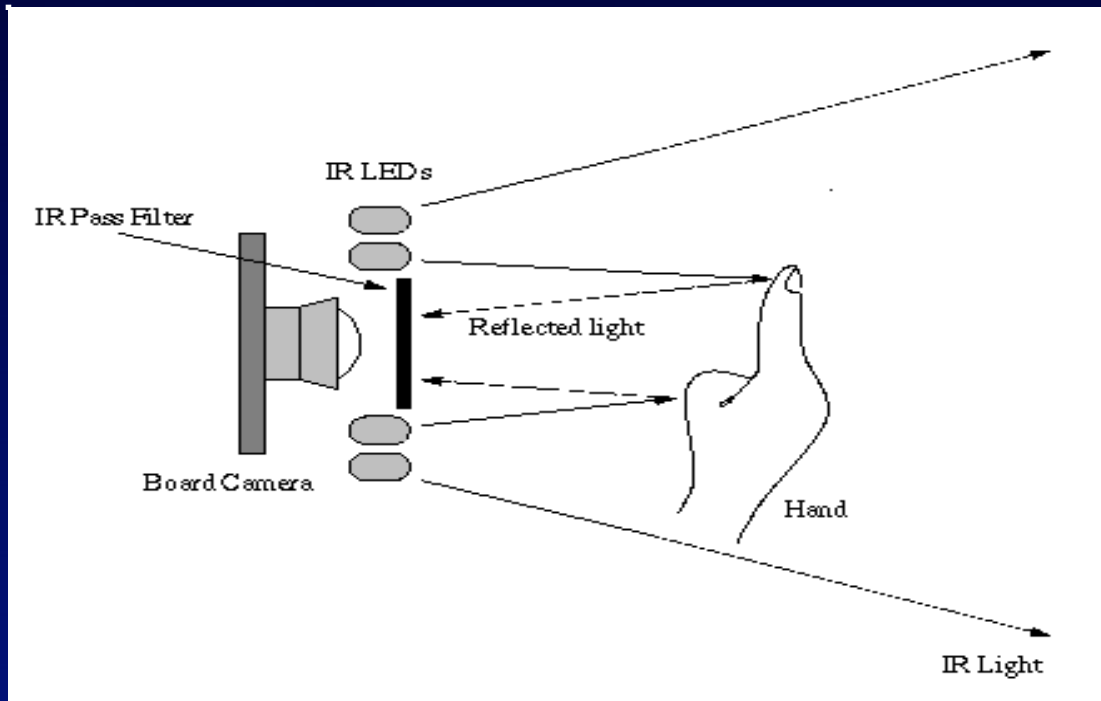
video

# Current effort: Cellular Phones for the Deaf



# Gesture Pendant

- Home appliance control
- Medical monitoring



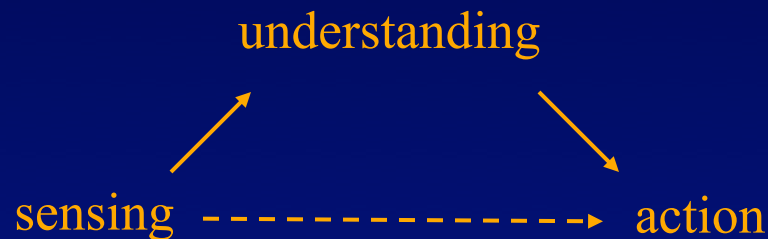
# Challenges

# Human/Machine Interface Bottleneck (HCI)

- Progressive disclosure
  - Easy to use
  - Easy to ignore
- Use context
  - Disambiguate instruction for the computer
  - Explain output for user

# Machine Understanding of Context (AI)

- Sensors are easy, mind-reading is hard
- Proxies for context
  - “in my office” implies I’m working
  - “talking” implies not to be disturbed
- Proxies can only go so far





# Integration With The Task (Activity Theory)

- The details matter
- Need to combine
  - Cognitive
  - Ergonomic
  - Social
  - Practical
  - Environmental
- Can we be integrated and still general?

# Wearable Trade-offs

- Power and heat (mips/watt)
- On and off-body networking (bits/joule)
- Privacy
- Interface (additional capability vs. load)
  - User Interface (cognitive load)
  - Machine understanding of context
  - Ergonomics/human factors (weight, heat, etc.)

# Resources

- Charmed Technologies ([www.charmed.com](http://www.charmed.com))
  - Inexpensive wearables for prototyping
- IEEE Wearable Information Systems Technical Committee ([computer.org](http://computer.org))
- [www.cc.gatech.edu/~thad](http://www.cc.gatech.edu/~thad)
- [www.bradleyrhodes.com](http://www.bradleyrhodes.com)
- Research mailing list: [wearables@cc.gatech.edu](mailto:wearables@cc.gatech.edu)

# Bonus Material

# Calendar Study

# Attention and Access: Scheduling Device Survey

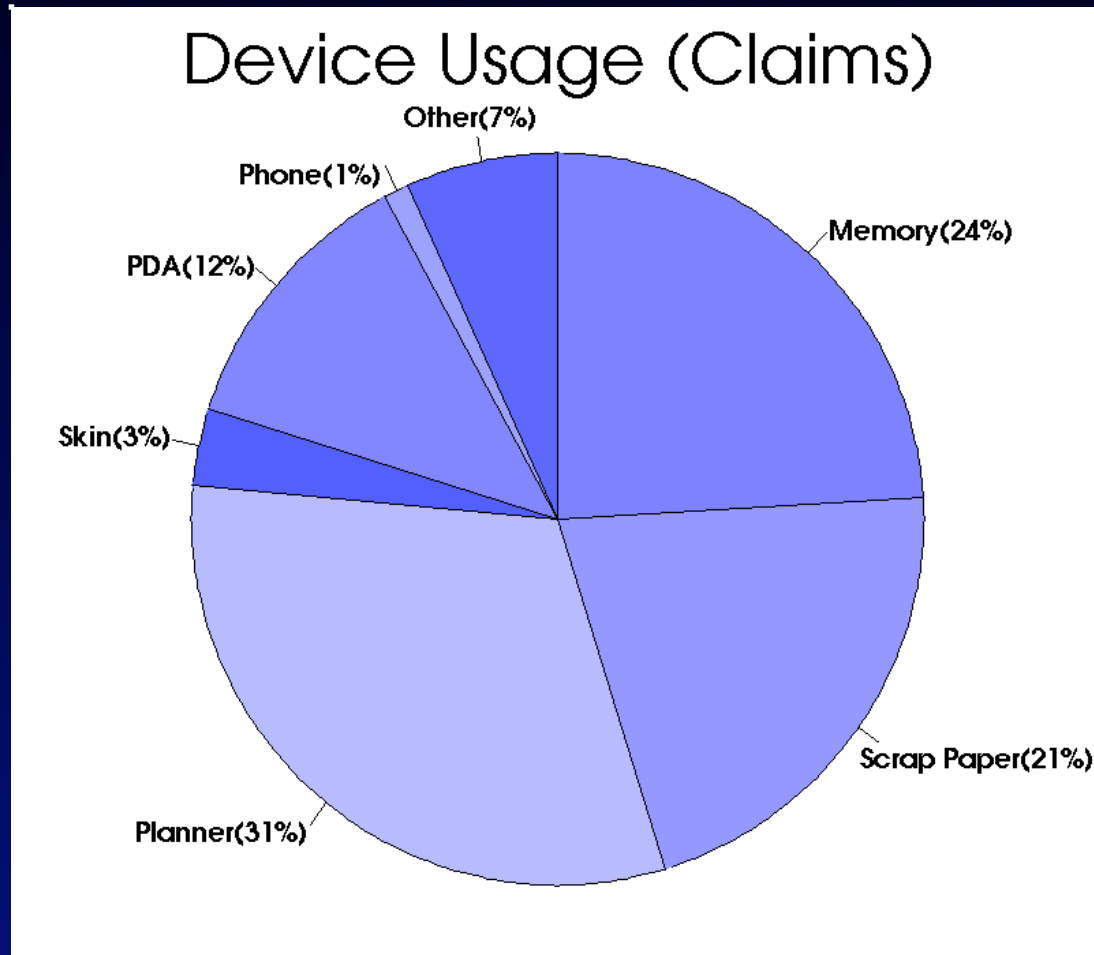
- What sort of devices are used for scheduling/remembering appointments while mobile?
- What are the user's perceptions of that device?
- Why do not more people use these devices/have them with them?
- 
- (Georgia Tech GVU TR #02-17 with Ben Wong and Robert Maguire co-authors; submitted to Trans. Computer Human Interface)

# Scheduling Device Survey (2)

- 158 subjects
  - Georgia Tech student center
  - 90% students; 88% age 18-25; 70% male
- What is your primary scheduling system while mobile?
- 8 Likert scale questions on effectiveness, ease of use, speed, and reliability
- Open response questions



# What People Say They Use



# Satisfaction

- For every device, with moderately positive results, subjects thought that their device was
  - Appropriate
  - Sufficient
  - Somewhat necessary

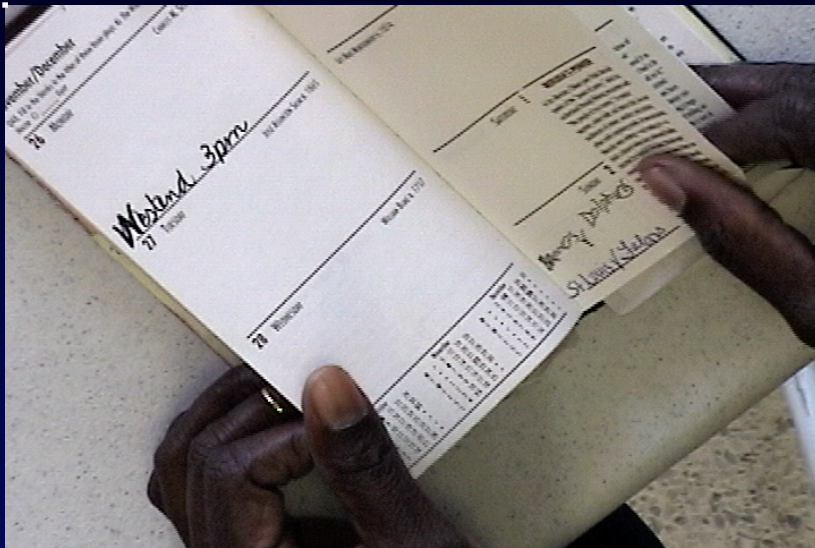
## Satisfaction (2)

- For every system, subjects thought their system was
  - Easy to use
  - Fast to access
- Curiously, many subjects admit to delaying entering appointments

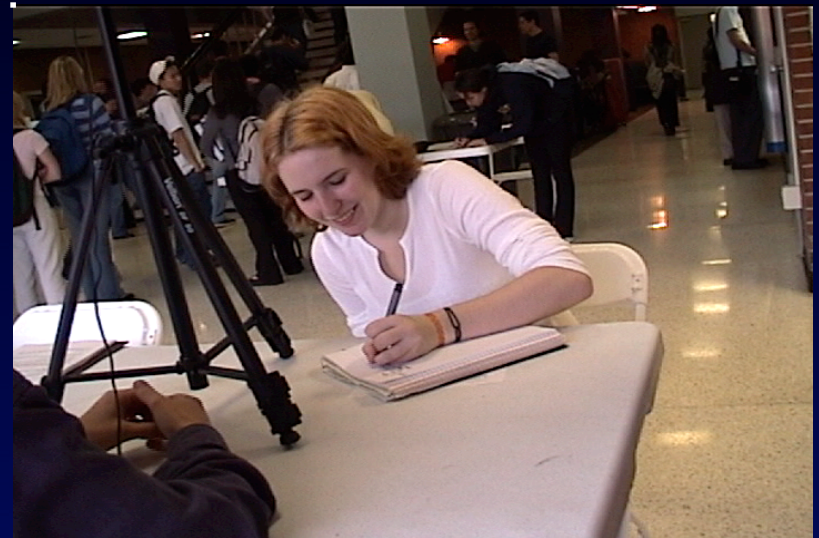
# What Really Happens

- After taking survey, subjects scheduled appointments with the experimenter
  - Could we meet sometime next Monday?
  - Could we schedule a time to meet in the second week of February (three months in the future)?
  - Could we schedule a time to meet tomorrow?
  - Could we reschedule our appointment in February from the 10<sup>th</sup> to the 11<sup>th</sup>?

# Videotaped Interactions

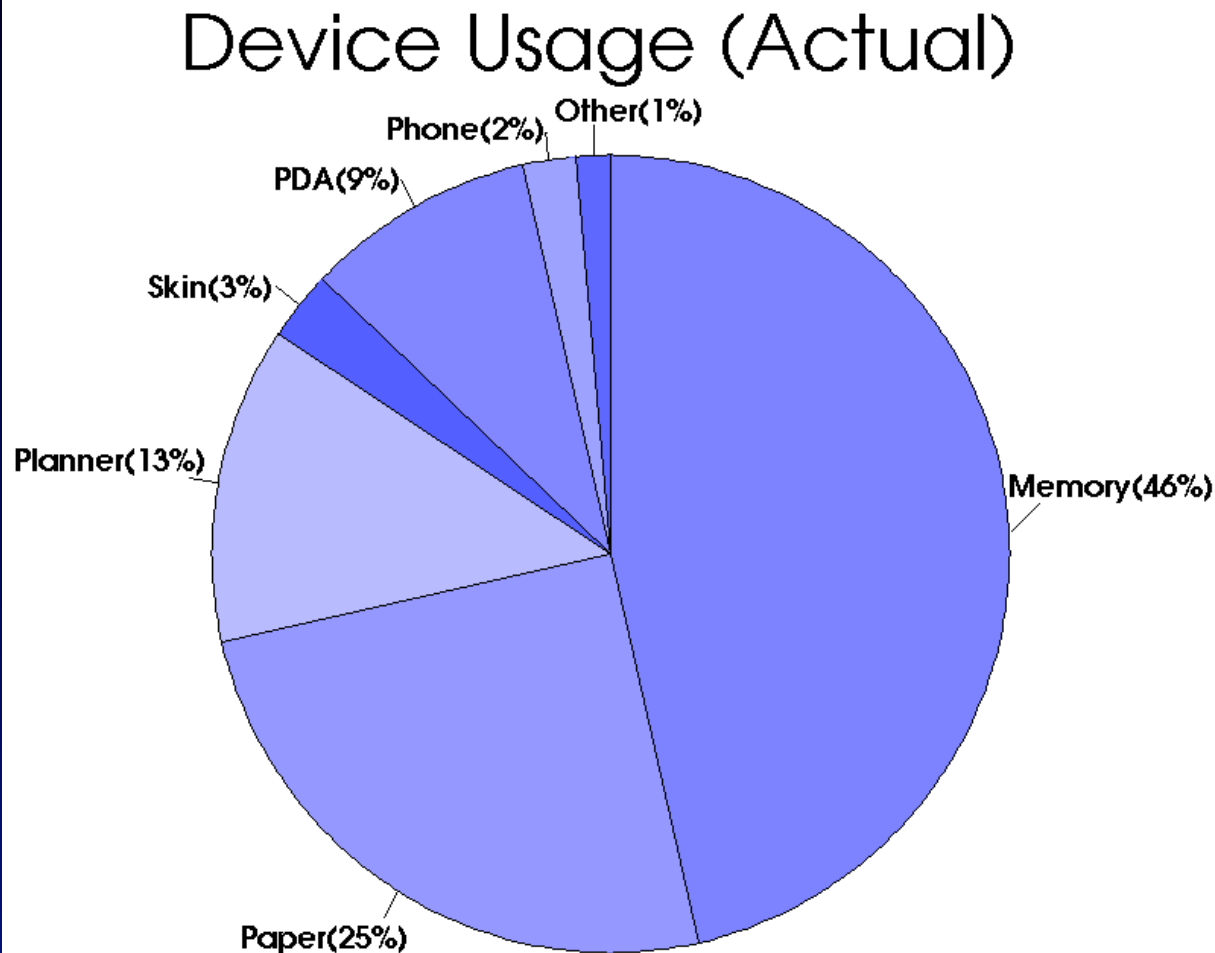


Scheduling device

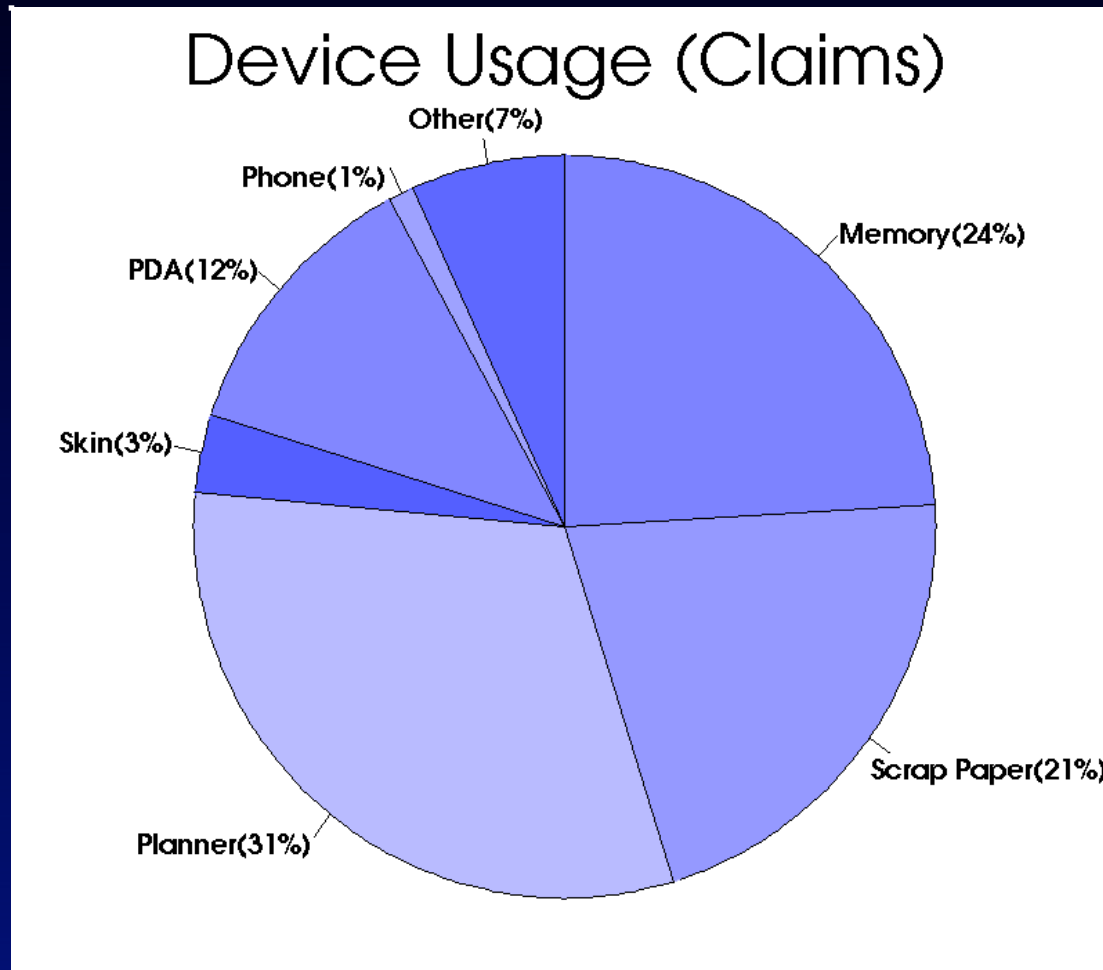


• Subject view

# Actual Device Usage

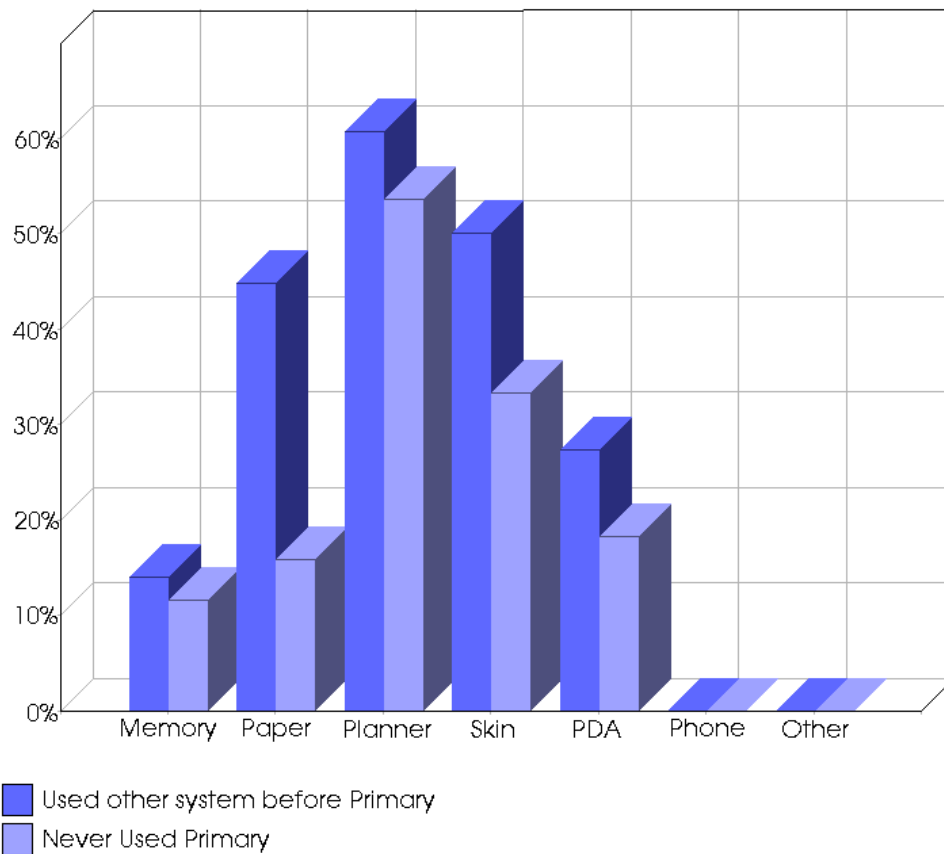


# What Subjects Say They Use

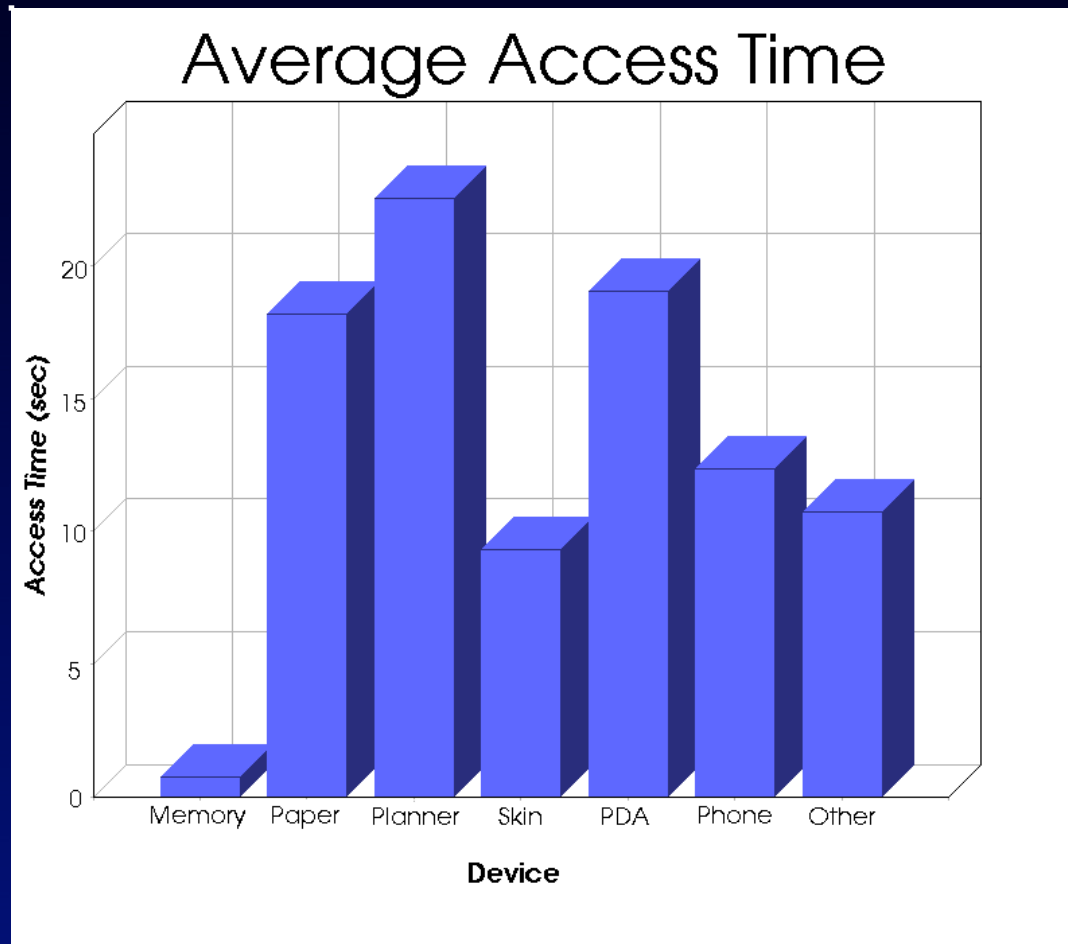




# Disuse



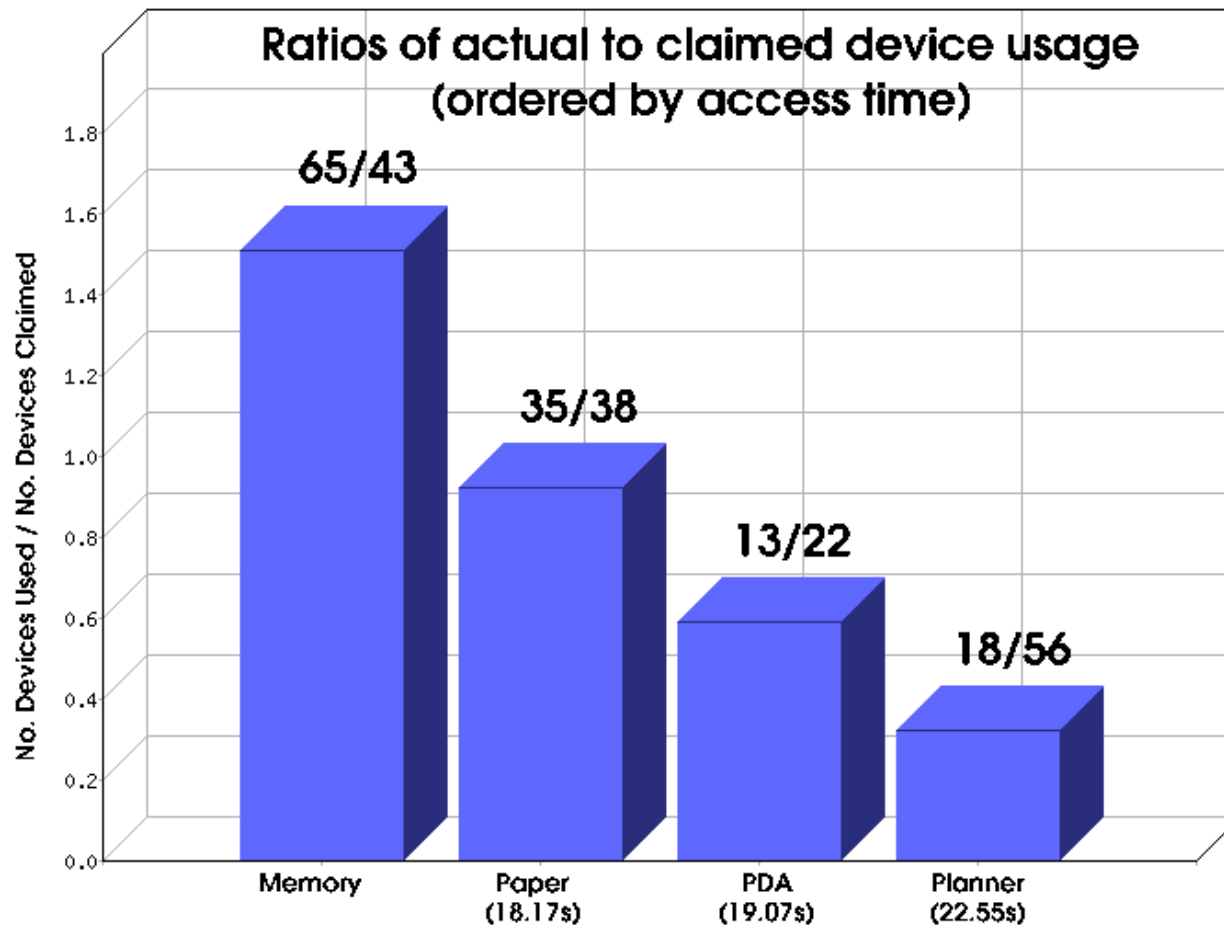
# Access Time for Scheduling Systems



# What Did We Learn?

- People are bad at introspection:
  - Access time is actually significant
  - Often don't use what they say they use
- Once subjects learn a system, they make themselves (somewhat) satisfied with it
  - Hard to introduce new devices
  - Subjects suffer from shortcoming blindness

# Access Time vs. Disuse



# Access Time Predicts Use!

- Related to the 2-second rule
- If something takes longer than 2 seconds to do, its use will go down exponentially or linearly depending on the type of task
- Informal verification in the literature
  - Multitasking (Miller)
  - Web links (Shneiderman)
  - Agents (Rhodes)
- Implications for wireless service providers

# Cognitive Load an Issue?

- Scheduling appointments very interruptive; people tend not to multitask
- Subjects in study showed evidence of delaying cognitive load of navigating interfaces until later (using memory or scratch paper as a stop-gap method)
- Brain imaging surveys
  - Show conflict between memory encoding and multitasking with the phonological loop

(Schacter01)



# New HCI Question?

- How do we create interfaces where the computer task is NOT the primary one?
  - Conversations
  - Maintenance/Repair
  - Inspection
  - Touring physical reality
- Similar domains
  - Automobile interfaces
  - Head-up displays/interfaces for aircraft

# Perceptive Agents

# Perceptive Wearable Agents

- See what the user sees; hear what the user hears
- Use new generation of sensors to recover context
- Monitor interaction with traditional user interface
- Exploit user's “natural” behaviors
- Pro-actively perform tasks for the user

# How Not to Do It: The Jane Experiment






- Continuous audio-based agent
  - Inspired by Card's "Ender's Game"
  - Access to user's e-mail
  - Internet search engines
- Wizard of Oz experiment failed:
  - "Agent" could not respond quickly enough
  - Audio output was interruptive
  - Not enough context to be pro-active
  - Context could not accumulate due to experimental

# Calendar Navigator Agent

- Interface used in parallel during conversation when scheduling an appointment
- User's speech performs dual roles: social communication and direction of interface
- Might someday be faster than human secretary
  - High resolution screen for feedback
  - Not restricted to linear presentation like speech
- Only works because of
  - Limited vocabulary and grammar
  - Push-to-talk (variation)

(GVU Technical Report #02-17)

# Calendar Navigator Agent

File Edit Settings Help																																																								
    																																																								
New   Prev Today Next   Go to																																																								
Day View   Week View   Month View   Year View																																																								
Tue Jan 22 2002																																																								
◀ January ▶ ▶ 2002 ▶																																																								
<table border="1"><thead><tr><th>Sun</th><th>Mon</th><th>Tue</th><th>Wed</th><th>Thu</th><th>Fri</th><th>Sat</th></tr></thead><tbody><tr><td>30</td><td>31</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr><tr><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td></tr><tr><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td></tr><tr><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td>26</td></tr><tr><td>27</td><td>28</td><td>29</td><td>30</td><td>31</td><td>1</td><td>2</td></tr><tr><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td></tr></tbody></table>								Sun	Mon	Tue	Wed	Thu	Fri	Sat	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9
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To-do list																																																								
Summary																																																								
Add... Edit... Delete																																																								






 New | Prev | Today | Next | Go to

Day View | **Week View** | Month View | Year View

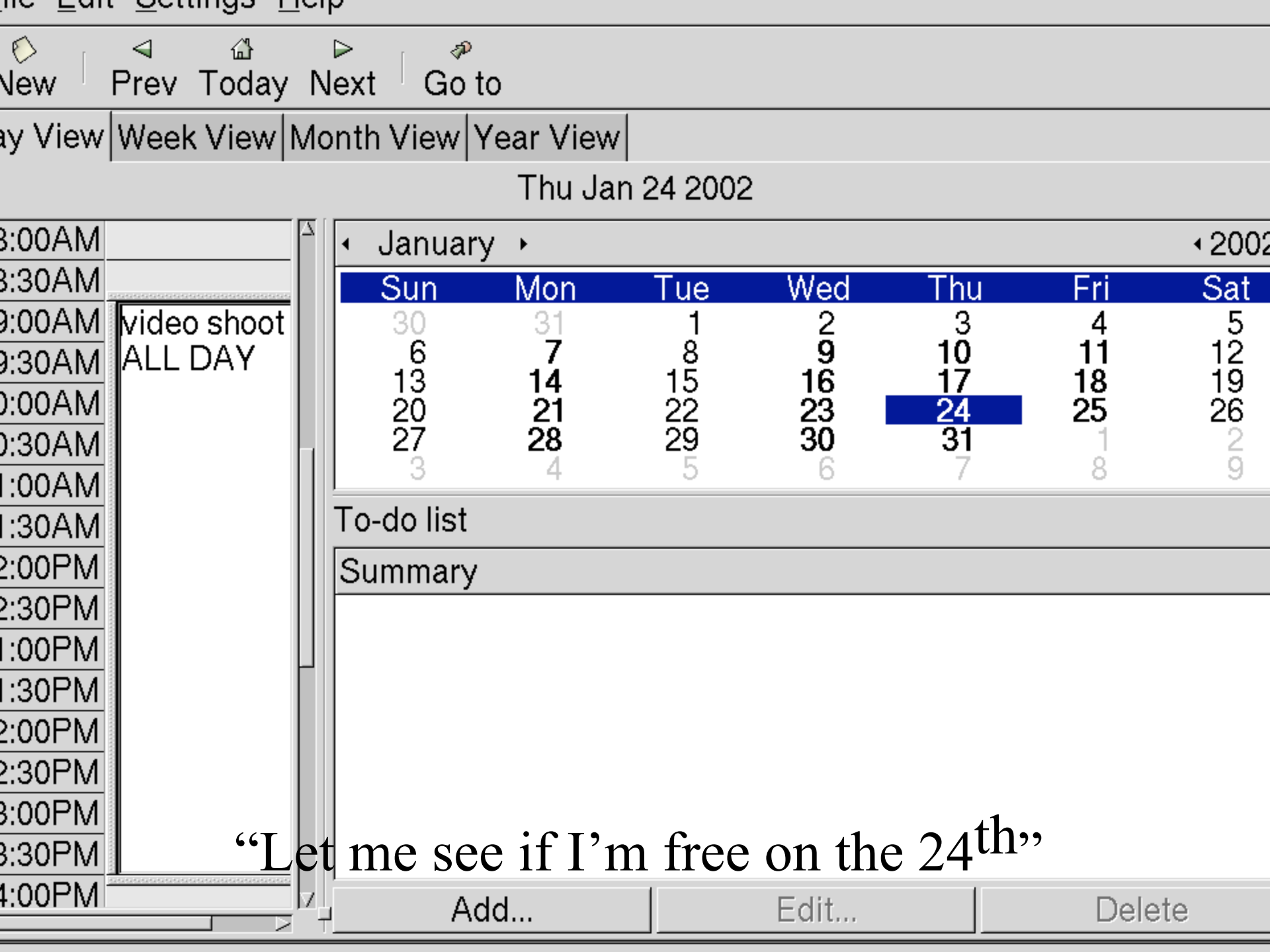
Sun Jan 27 2002 - Sat Feb 02 2002 (Week 05)

Sunday 27	Monday 28	Tuesday 29	Wednesday 30	Thursday 31
	9AM-10AM: fencing 11AM-12:30PM: class 4PM-5PM: class		9:30AM-10:30AM: Kent 12PM-1PM: Tracy 1PM-2PM: Brad 2PM-3PM: Ben 3PM-4PM: Helene 4PM-5PM: class	2PM-3PM: CCG Meeting

January ▸ ◀ 2002 ▸								Friday 01	Saturday 02
	Sun	Mon	Tue	Wed	Thu	Fri	Sat		
1	30	31	1	2	3	4	5	8AM-11:59PM: Tokyo	12AM-11:59PM: Tokyo
2	6	7	8	9	10	11	12	9AM-10AM:	
3	13	14	15	16	17	18	19	fencing	
4	20	21	22	23	24	25	26	11AM-12:30PM:	
5	27	28	29	30	31	1	2	class	
6	3	4	5	6	7	8	9	4PM-5PM: class	

“Can I see you next week sometime?”





New Prev Today Next Go to

Day View Week View Month View Year View

Thu Jan 24 2002

January 2002						
Sun	Mon	Tue	Wed	Thu	Fri	Sat
30	31	1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31	1	2
3	4	5	6	7	8	9

video shoot  
ALL DAY

To-do list

Summary

“Let me see if I’m free on the 24<sup>th</sup>”

Add...

Edit...

Delete

FileEditSettingsHelp

New

Prev

Today

Next

Go to

Day View

Week View

Month View

Year View

Thu Jan 31 2002

2:30PM

1:00PM

1:30PM

2:00PM

CCG Meetin

2:30PM

3:00PM

3:30PM

4:00PM

4:30PM

5:00PM

5:30PM

6:00PM

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8:30PM

◀ January ▶

◀ 2002

Sun	Mon	Tue	Wed	Thu	Fri	Sat
30	31	1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31	1	2
3	4	5	6	7	8	9

To-do list

Summary

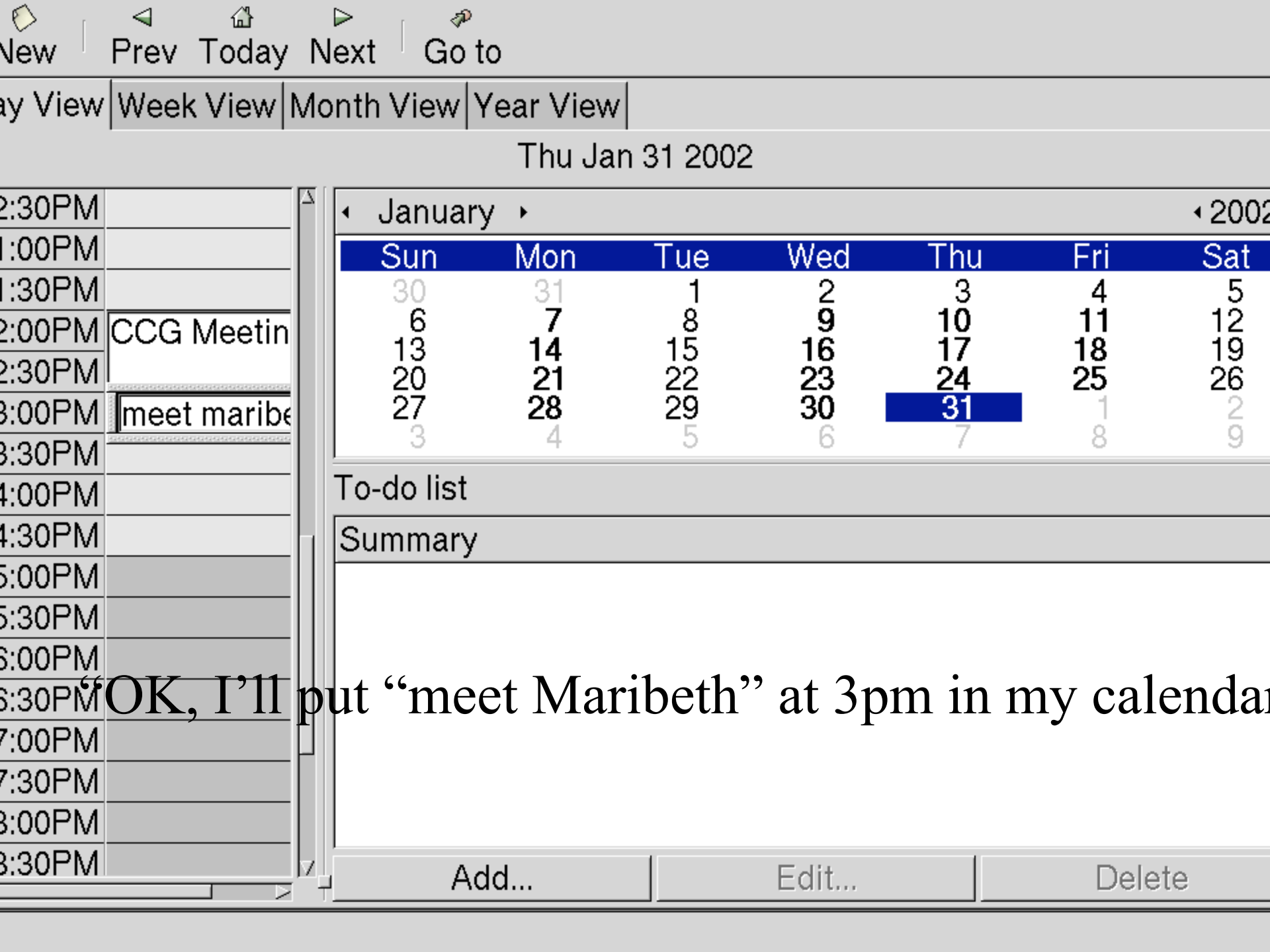
“Let me see if I’m free on the 31<sup>st</sup>”

“Yes, 3pm seems like a good time”

Add...

Edit...

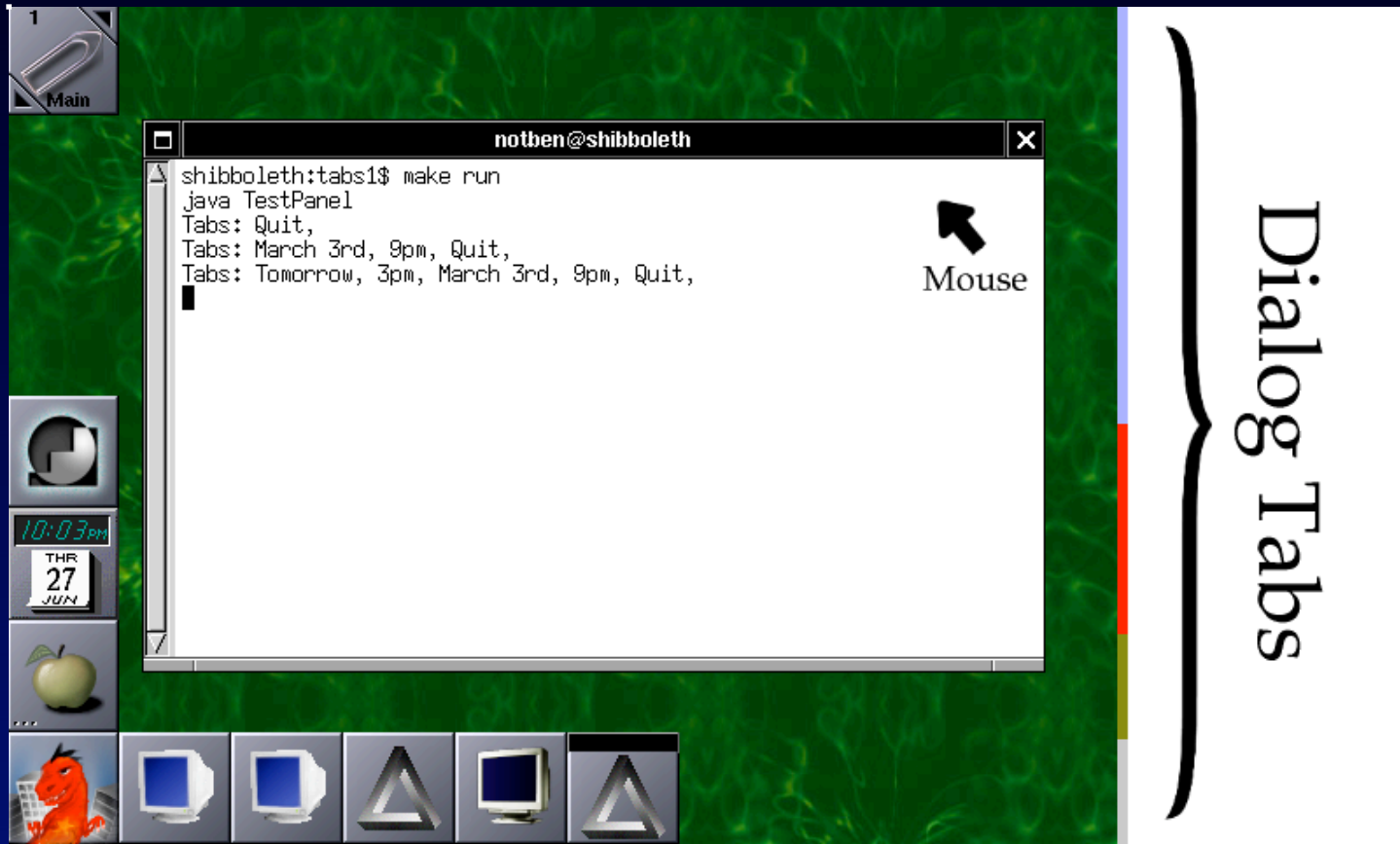
Delete



# Dialog Tabs: Augmenting Conversation Memory

- Record user speech
- Create small bars at corner of the screen whenever an “interesting” conversation heard
- Tabs remind user to process the information later (delaying cognitive load)
- Use (limited) speech recognition to provide cues as to content of tab – similar to Whitaker’s SCANMail

# Dialog Tabs: Augmenting Conversational Memory





```
notben@shibboleth
shibboleth:tabs1$ make run
java TestPanel
Tabs: Quit,
Tabs: March 3rd, 9pm, Quit,
Tabs: Tomorrow, 3pm, March 3rd, 9pm, Quit,
```

March 3rd, 9pm





Tomorrow, 3pm



```
notben@shibboleth
shibboleth:tabs1$ make run
java TestPanel
Tabs: Quit,
Tabs: March 3rd, 9pm, Quit,
Tabs: Tomorrow, 3pm, March 3rd, 9pm, Quit,
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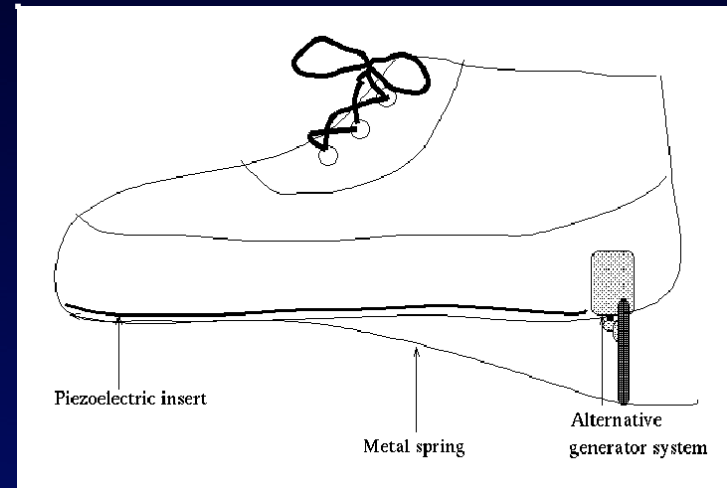
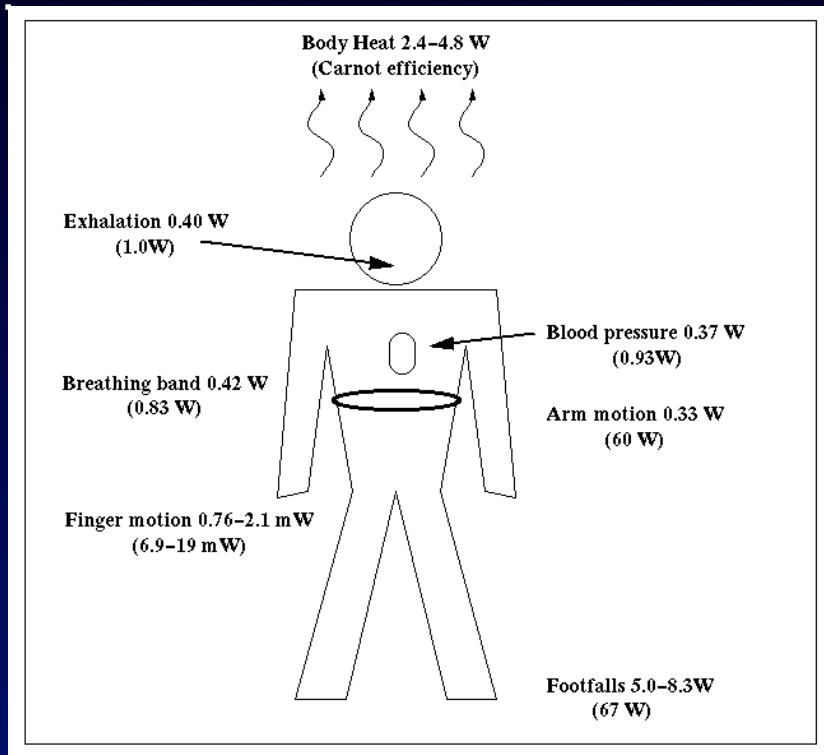


# Power and Heat

# Power

- Where do you put the batteries?
- What is the minimum battery life?
  - Tie recharging with normal life activities
- How distributed can the power be?
  - Replacing batteries
  - Wired/wireless power distribution
  -

# A Different Perspective



# Locust: Environmentally Powered Location/Messaging

- PIC microcontroller
- IR xmit/receive
- >6m range
- Location beacon
- Upload location-based messages
- 300 deployed
- Next version: AM radio powered



(Starner97 ISWC “The Locust Swarm”)

# Alternative “Batteries”

- Compressed air tanks (5.75 Whr/kg)
- Ultracapacitors (3-30 Whr/kg)
- Fuel cells (548Whr/kg)
- Superflywheel (385Whr/kg)
  - Buckytubes give 10x this amount!
  - 
  - (Michael Johnson aries@media.mit.edu unpublished)

# Small Nuclear Sources

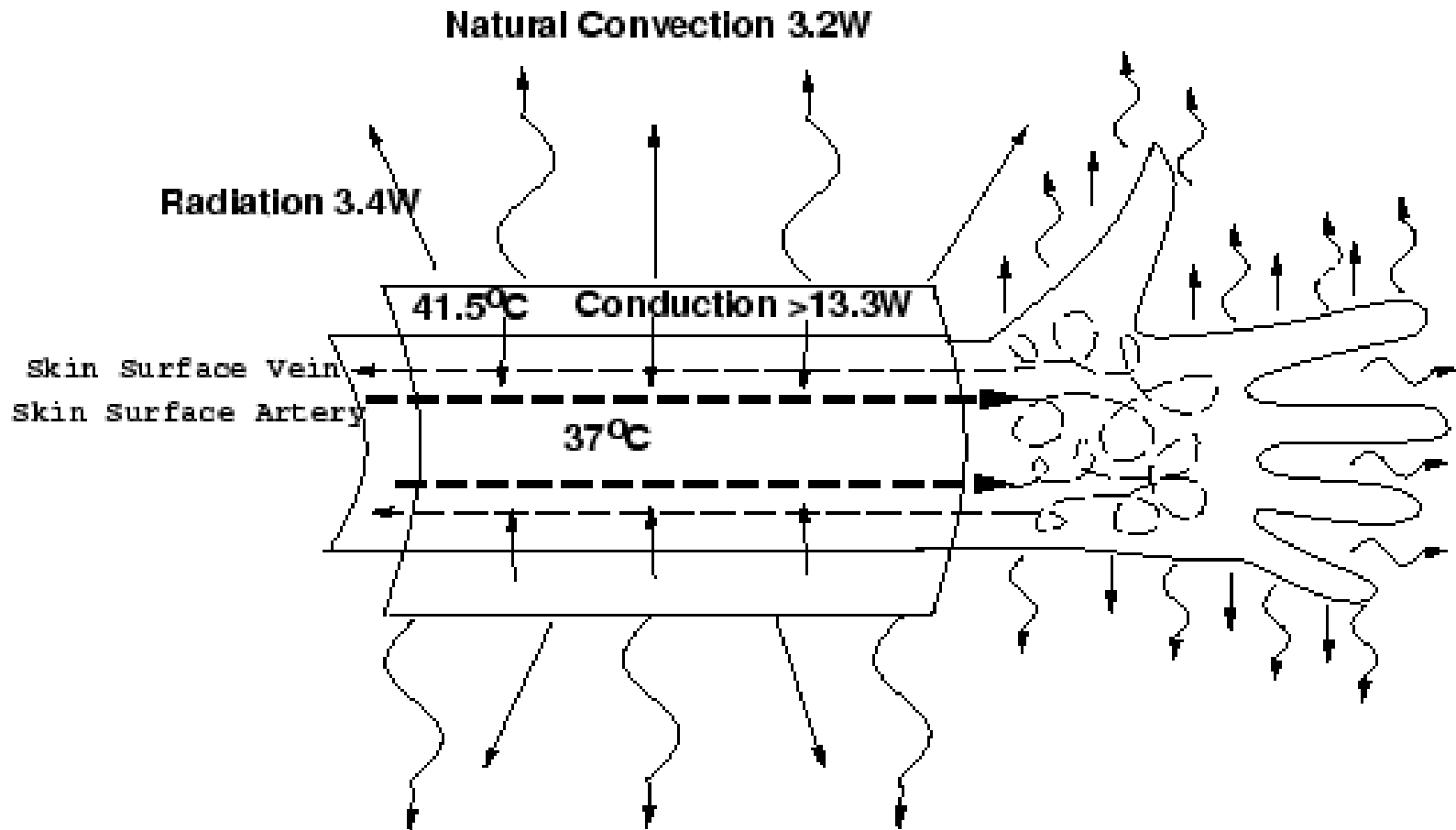
- | • Material | Half Life  | Energy density |
|------------|------------|----------------|
| • Po210    | 0.38 years | 134W/g         |
| • Pu238    | 87 years   | 0.39W/g        |
| •          |            |                |
- 6.6% conversion efficiency
  - \$1500/g Pu238
  - Chinese have used Po210 on space program
  - Plutonium used in pacemakers (1989)

# Heat

- #1 limiter in current laptop computers (23W)
- Methods of removing heat
  - Convection
  - Conduction
  - Evaporation
  - Radiation
  - Storage



# Case Study: Forearm Wearable



- (Starner99 MONET “Heat Dissipation ...”)

# Networking, Privacy and Community

# On and Off-body Networking

- Personal Area Networks (Zimmerman)
- Bluetooth and 802.15
- 802.11, 3G, software radios
- Power issues Mbps/J not Mbps

# Privacy

- Langheinrich's tutorial (Pervasive & Ubicomp Summer School 2002)
- Foner's PhD thesis: Yenta
- Computers, Freedom, and Privacy conference

# University of Oregon

## Wearable Communities

- What to do when Cyborgs meet?”
  - Game theory of task trading (*WALID*)
  - Reputation mechanisms (*DIOGENES*)
  - P2P middleware (*PROEM*)
  -
- - 
  -

<http://www.cs.uoregon.edu/research/wearables/>