

# Wearable Computers As Intelligent Agents

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# Background

- Assistant Professor of Computing, Georgia Tech
- Founder, Charmed Technologies
- Founder, MIT Wearable Computing Project
- IEEE ISWC and Wearable Information Systems TC
- Everyday use since 1993 (earliest and longest non-medical, everyday use)



# Outline

- Wearable computing visions and definitions
- Questions about hardware
- Comparison to PDAs and laptops
- Necessity of wearable agents
- Example agents and interfaces

# 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)

# Wearable Computing Vision

- Pocket or clothing based computing
- Peripherals distributed around the sensors and actuators of the body, connected wirelessly
- Runs entire day
- Replace all portable consumer/computing electronics – MP3, DVD, PDA, laptop, medical devices, ...
- Video - Interact Atlanta

# Miniature Head-up Displays

MicroOptical prescription  
display eyeglasses





# Teleprompter

Thad Starner  
Problem Set 2  
Sept 23, 1994

1) acoustics: The tapping of a foot falls under acoustics (sound), but does not count as articulation or speech production (in terms of vocal tract, tongue, etc.)

articulation: A cough is formed by a configuration of the vocal tract, but is not phonetic.

phonetics: The nonsense word "spak" is perfectly pronounceable, and has a phonetic translation, but has no lexical meaning.

lexical: An ASL translation that reads "black

Emacs: ps2<2>

9:22am 0.01

(Funda

# Keyboards

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





# CharmIT Wearable Computer

266MHz Intel Pentium or 800MHz Transmeta Crusoe



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

# Everyday Applications

- Used for similar applications as a modern PC, but not used like a PC:
  - Consumer devices: CD player, movies, cell phone, pager, medical, e-mail, etc.
  - Instant messenger (zephyr)
  - Instant referencer (webster, google, thesaurus, etc.)
  - Remote monitoring (telnet)
- Real benefit is in creating interfaces not previously possible with PCs and PDAs

# Just-in-time Information

- Dictionary, thesaurus, books, experimental data...
- Web searches – google
- Instant messaging – connect with hundreds of minds when needed
- Wearable Agents
- 60 Minutes, Scientific American

# 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?
- ...

# Wearable Computing as Interaction (Life)Style, Not Hardware

- Rhodes [Rhodes97]
  - Portable while operational
  - Enable hands-free or hands-limited use
  - Capable of getting the user's attention even when not in active use
  - Always “on”
  - Sense the user's context in order to serve him better
- Starner [Starner PhD 1999]
  - Persists and provides constant access
  - Senses and models context
  - Augments and Mediates
  - Interacts seamlessly



# 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?
- If I was to schedule an appointment with you right now, how would it happen?

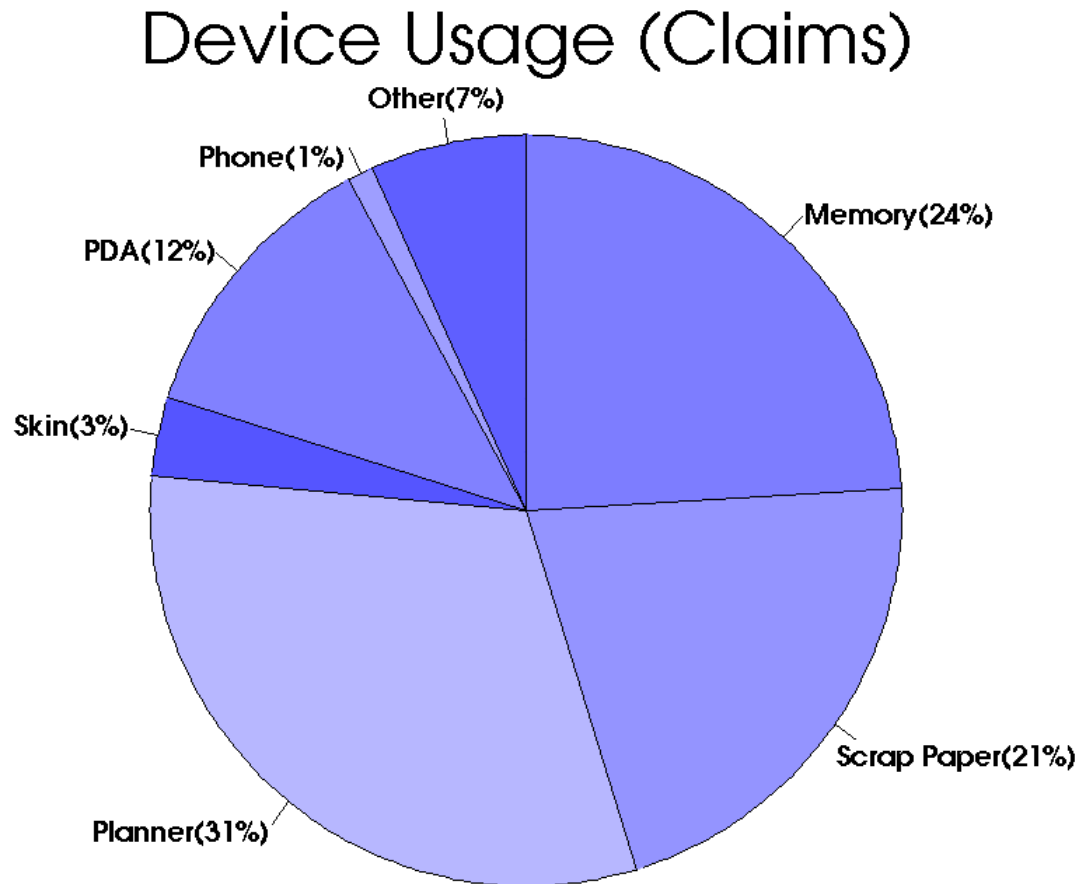
# Scheduling Device Survey

- 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

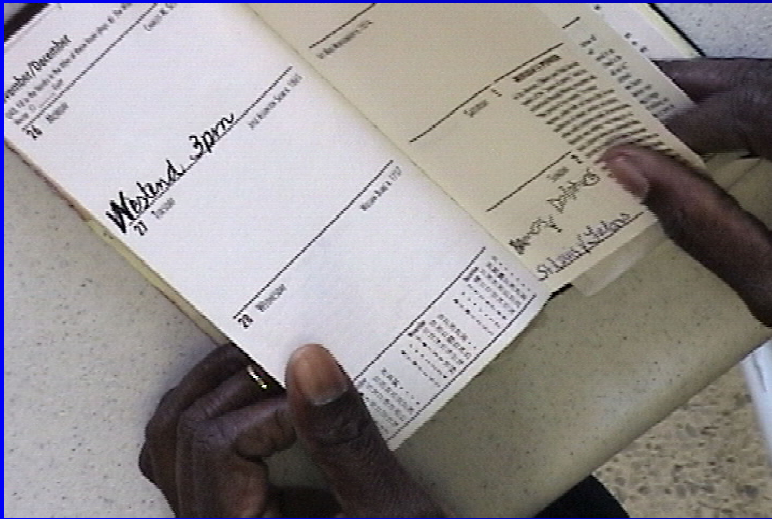
# Satisfaction (2)

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

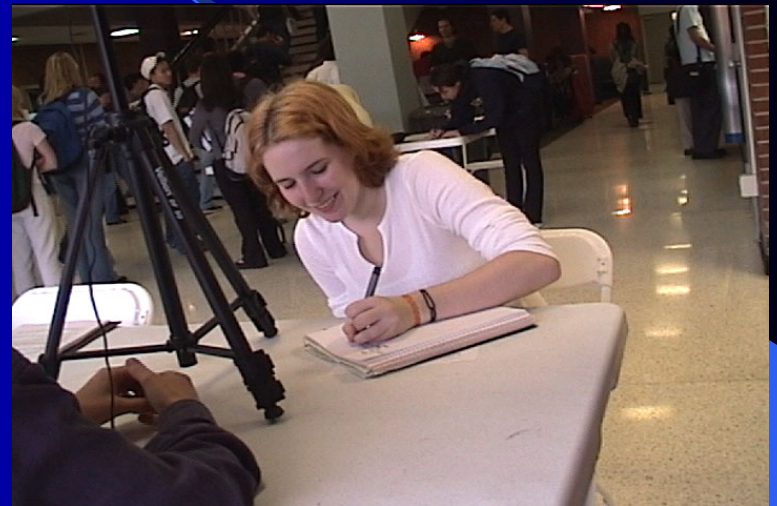
# What Really Happens

- 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

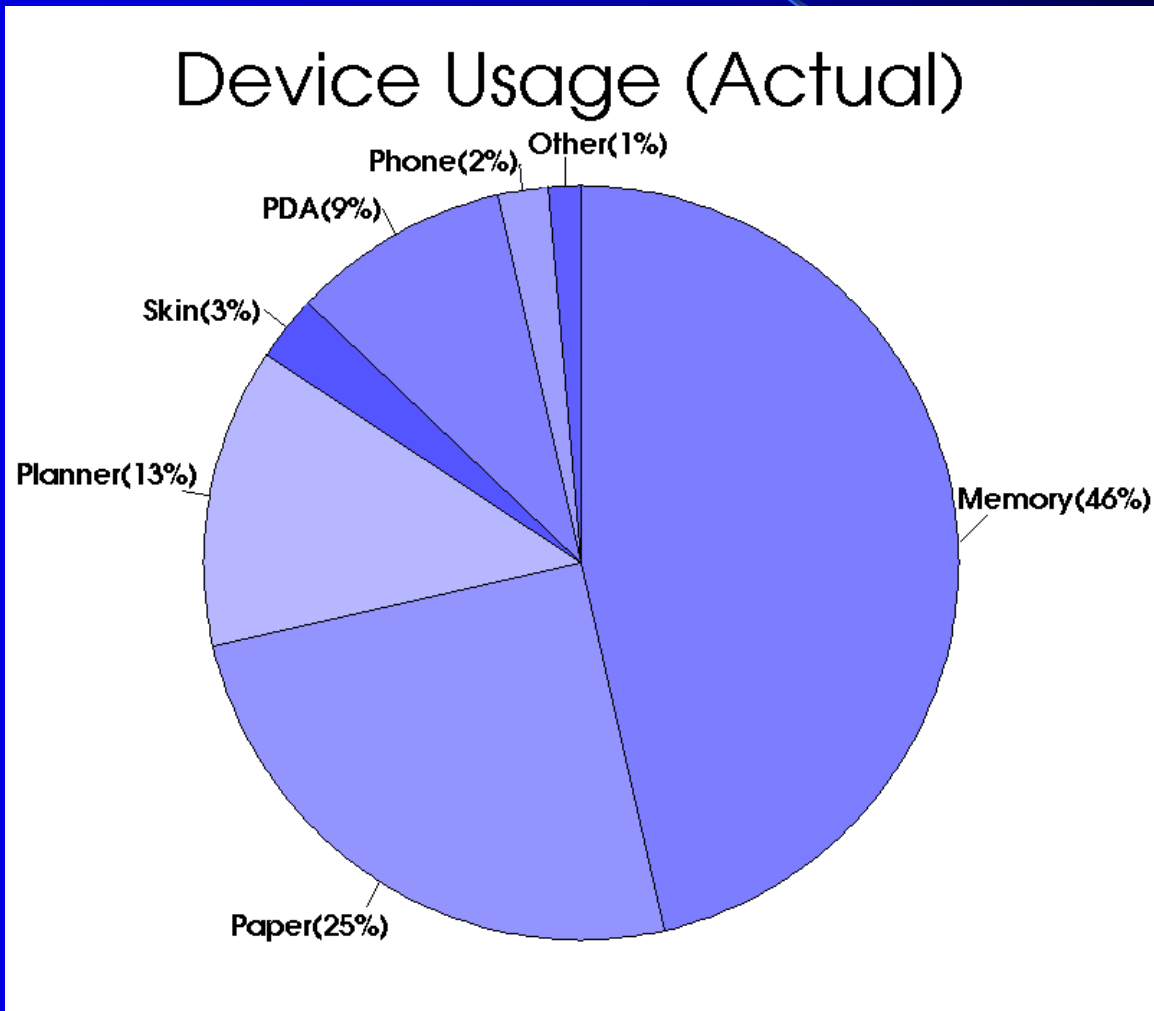


Scheduling device



Subject view

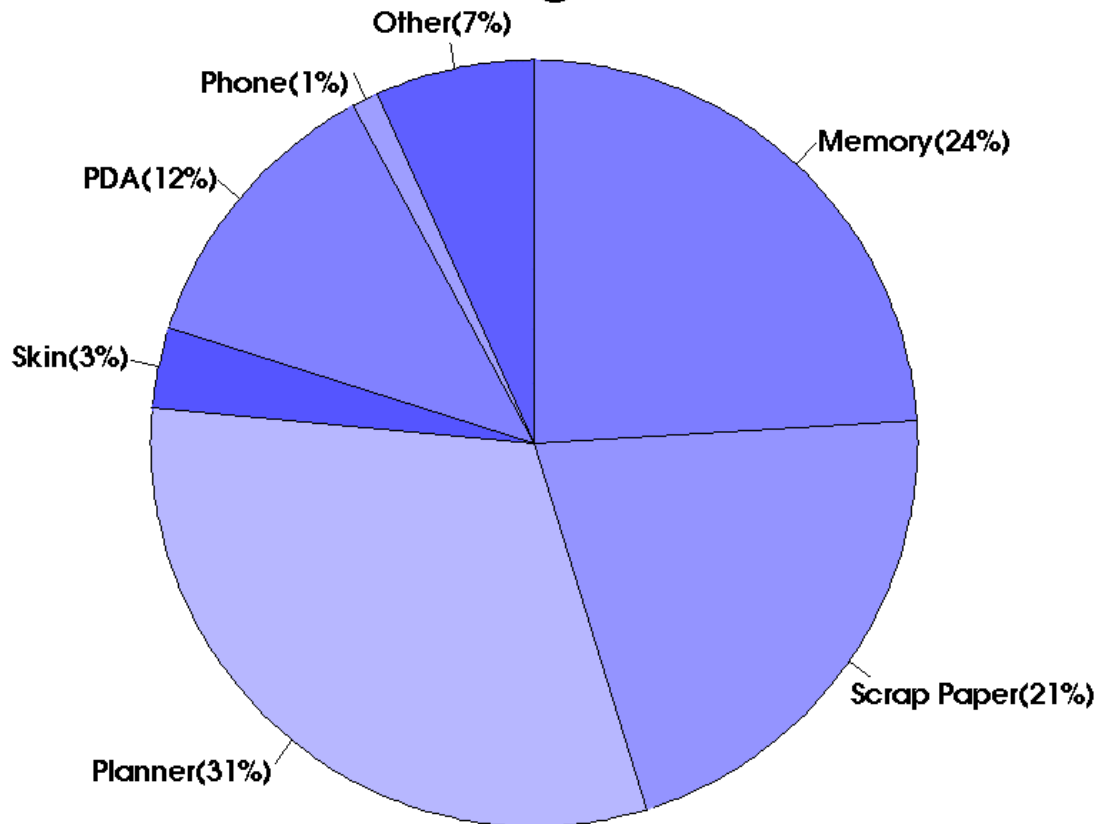
# Actual Device Usage



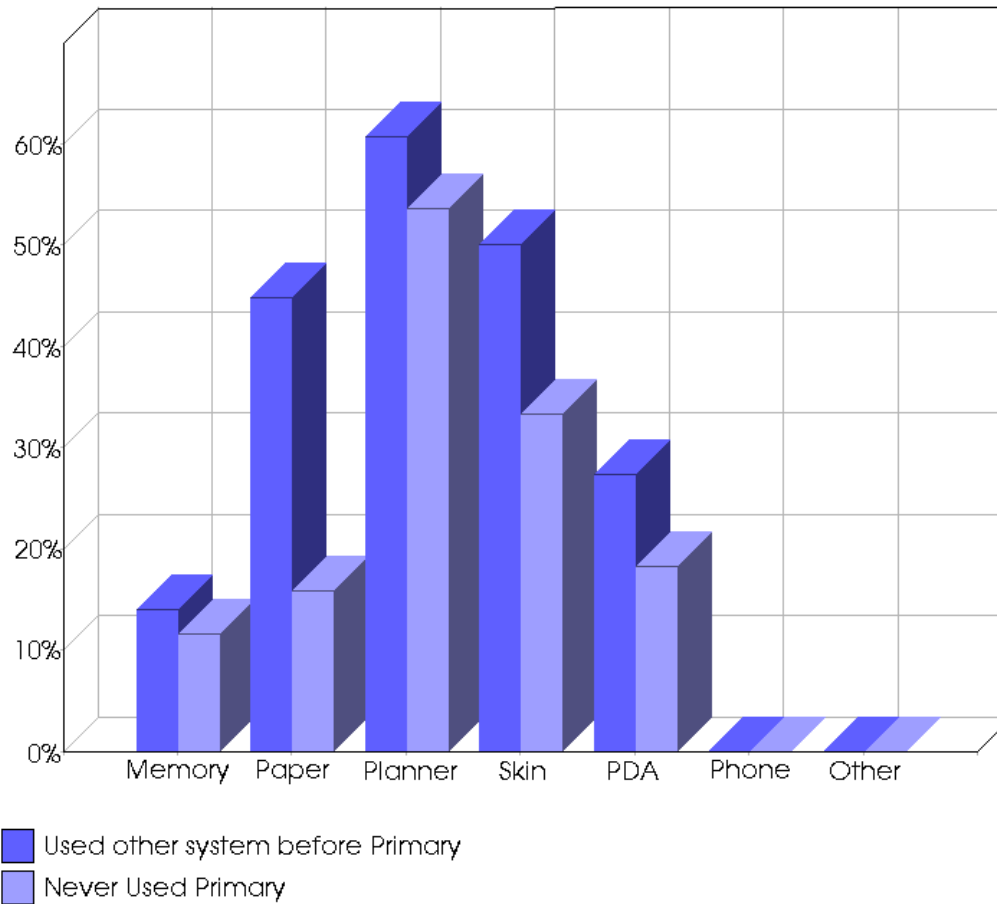


# What Subjects Say They Use

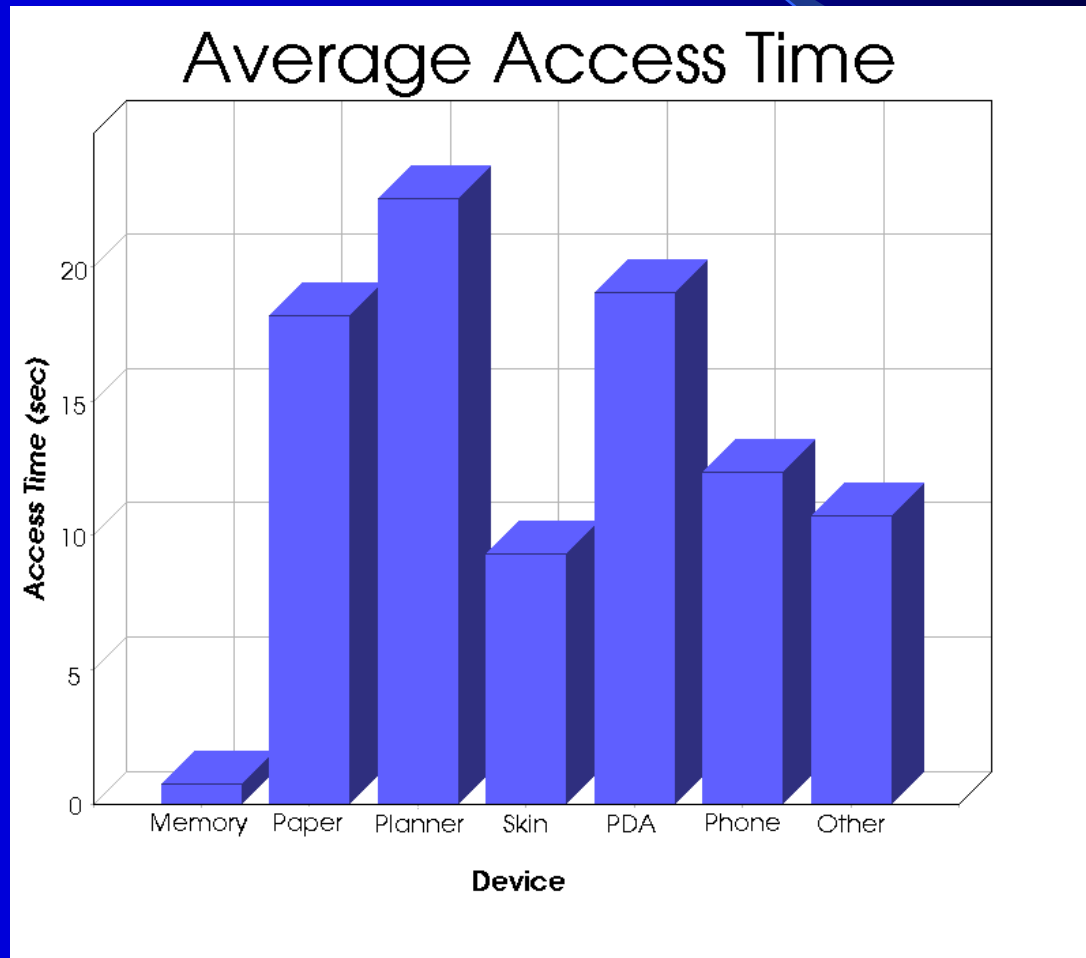
Device Usage (Claims)



# Disuse



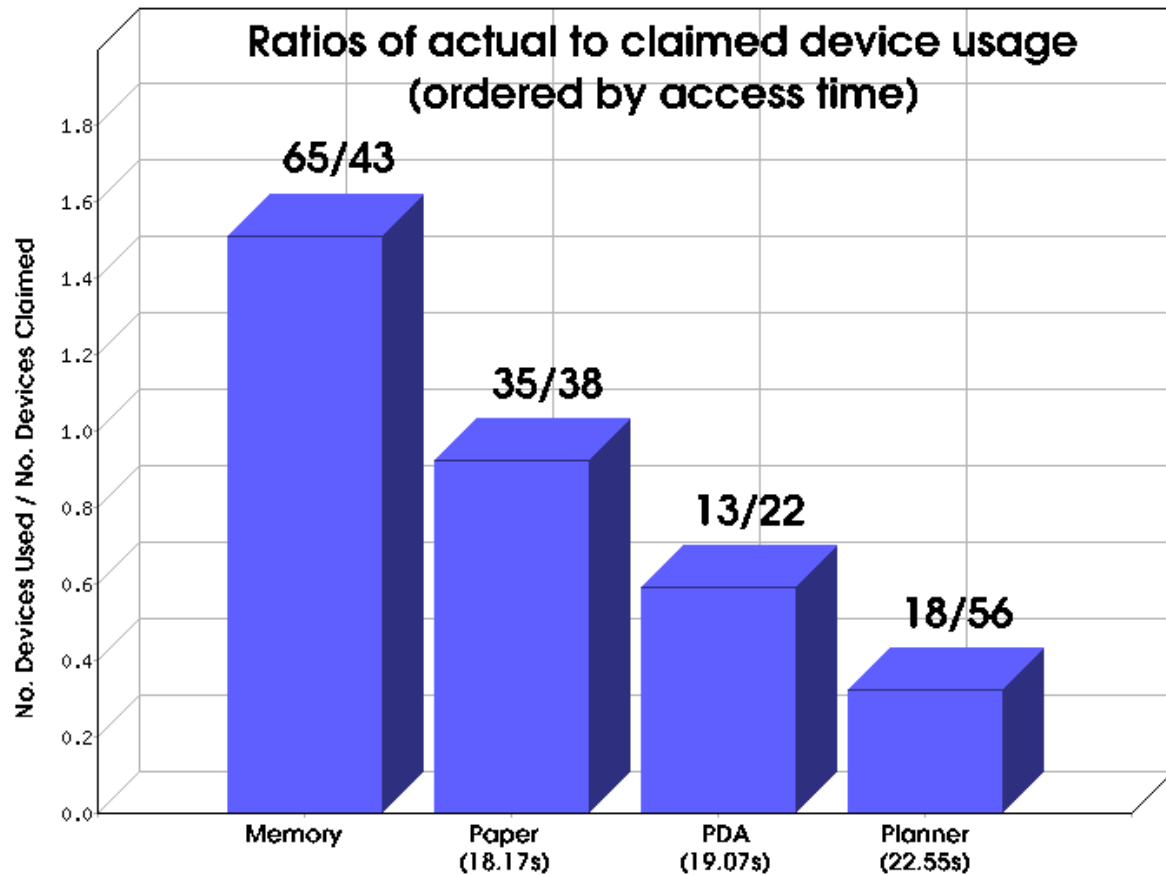
# Access Time for Scheduling Systems



# 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?

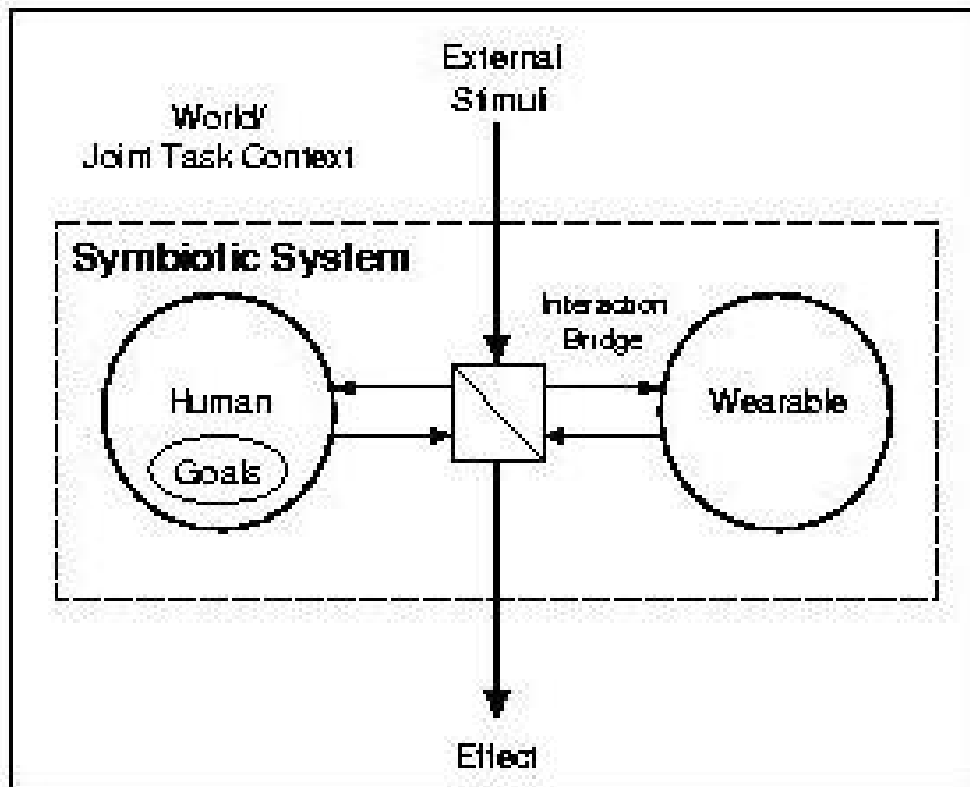
- Scheduling appointments very interruptive; people tend not to multitask
- Subjects in study showed evidence of delaying cognitive load of navigating interfaces until later (using memory or scratch paper as a stop-gap method)
- Brain imaging surveys
  - Show conflict between memory encoding and multitasking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

# Wearable Agents and Man-machine Symbiosis



# 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 conditions

# Session 2: Last Time

- Wearable computing as an interaction lifestyle
- Access time predicts disuse
  - 2 second hypothesis
- Evidence of high cognitive load when multiplexing some tasks
  - Anecdotal evidence with scheduling experiment
  - Brain imaging studies – phonological loop
  - Memory studies: distraction during encoding of memories more harmful than during recall
- Users naturally employ delaying tactics

## Last time (2)

- HCI question: How do we make interfaces for situations where the computer is not the primary focus of attention?
- Must be careful of modality
  - Jane experiment suggests audio-only information agent is not sufficient
  - Not enough context for pro-activity
  - Can be socially interruptive



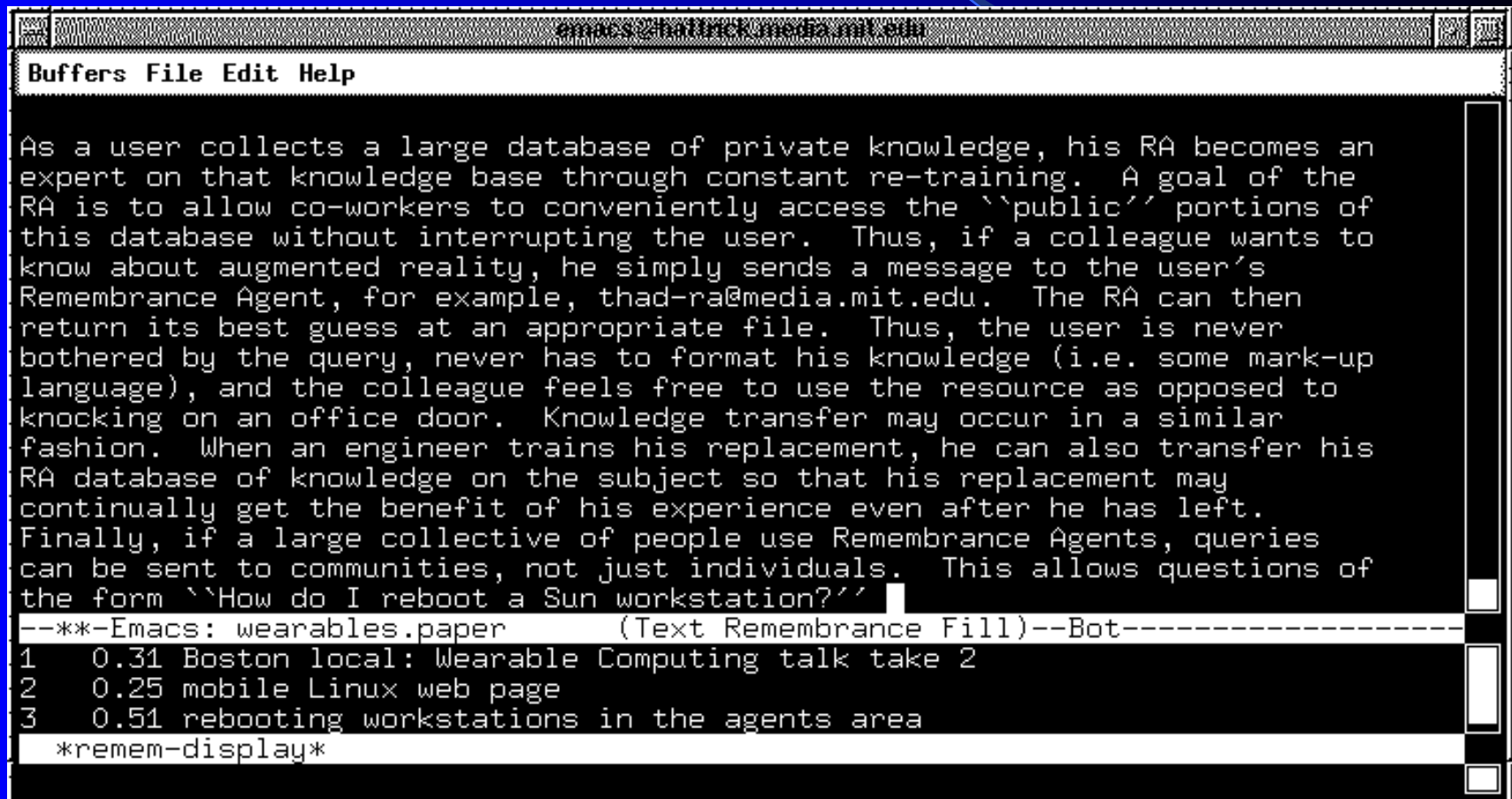
# Necessity of Wearable Agents

- User attention is the scarcest resource
- Current interface devices and desktop metaphor is not appropriate
  - Hand-eye coordination of mouse/menu system distracts from physical world
  - Can use physical world for “icons” instead of virtual representations (e.g. ARToolkit)
  - Original “intellectual augmentation” work that led to the SRI/Xerox/Apple WIMP system had to assume desktop due to physical limitation of the machines (Licklider, Engelbart, Kay, etc.)

# 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

# The Remembrance Agent



```
emacs - halfrick.media.mit.edu
Buffers File Edit Help

As a user collects a large database of private knowledge, his RA becomes an
expert on that knowledge base through constant re-training. A goal of the
RA is to allow co-workers to conveniently access the ``public`` portions of
this database without interrupting the user. Thus, if a colleague wants to
know about augmented reality, he simply sends a message to the user's
Remembrance Agent, for example, thad-ra@media.mit.edu. The RA can then
return its best guess at an appropriate file. Thus, the user is never
bothered by the query, never has to format his knowledge (i.e. some mark-up
language), and the colleague feels free to use the resource as opposed to
knocking on an office door. Knowledge transfer may occur in a similar
fashion. When an engineer trains his replacement, he can also transfer his
RA database of knowledge on the subject so that his replacement may
continually get the benefit of his experience even after he has left.
Finally, if a large collective of people use Remembrance Agents, queries
can be sent to communities, not just individuals. This allows questions of
the form ``How do I reboot a Sun workstation?``

--**--Emacs: wearables.paper (Text Remembrance Fill)--Bot-----
1 0.31 Boston local: Wearable Computing talk take 2
2 0.25 mobile Linux web page
3 0.51 rebooting workstations in the agents area
*remem-display*
```

# 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																																																							
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◀ 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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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

3:00AM  
 3:30AM  
 9:00AM video shoot  
 9:30AM ALL DAY  
 10:00AM  
 10:30AM  
 11:00AM  
 11:30AM  
 12:00PM  
 12:30PM  
 1:00PM  
 1:30PM  
 2:00PM  
 2:30PM  
 3:00PM  
 3:30PM  
 4:00PM

◀ 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

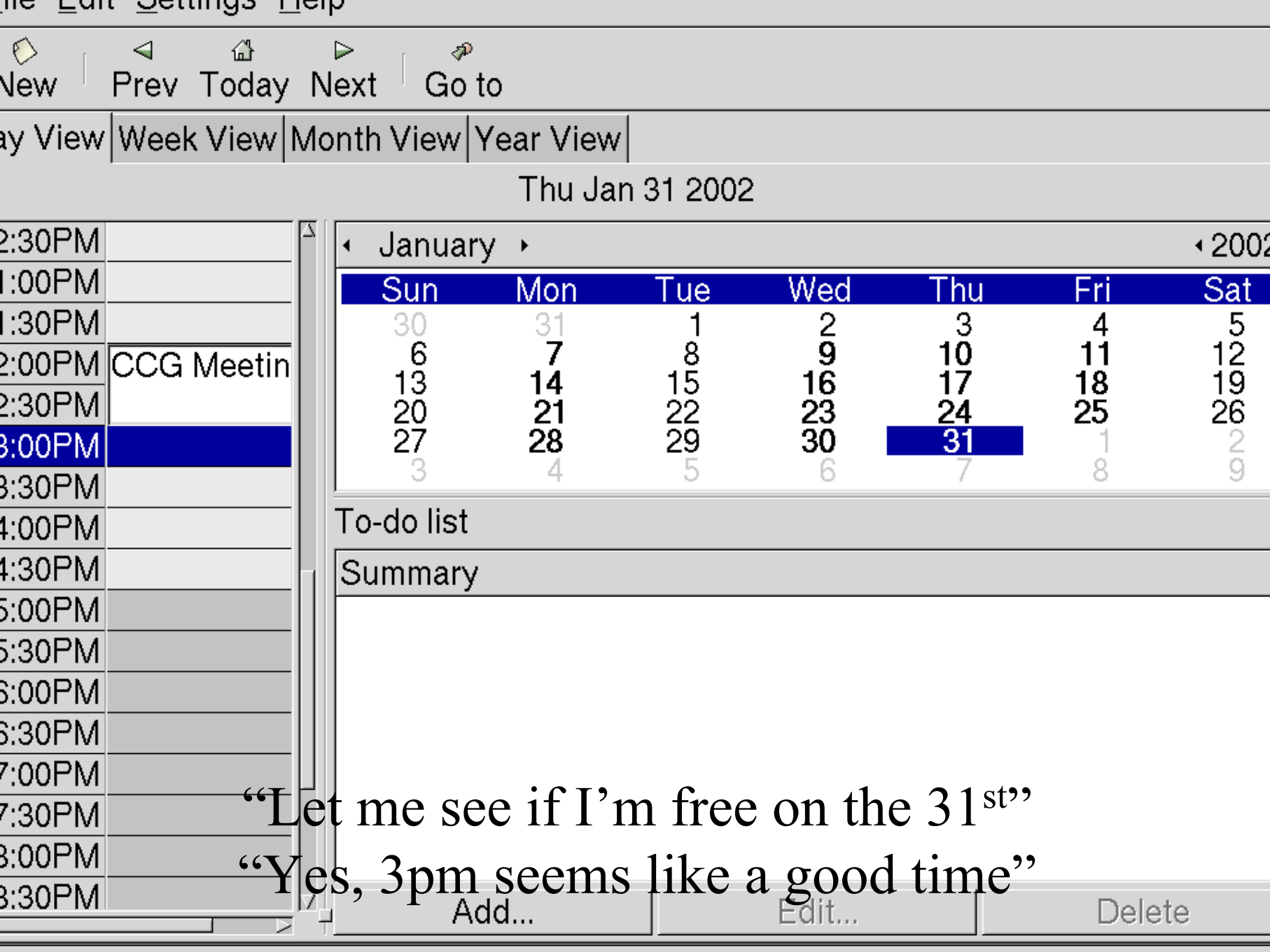
“Let me see if I’m free on the 24<sup>th</sup>”

Add...

Edit...

Delete





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

“Yes, 3pm seems like a good time”

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

meet maribe

3:30PM

4:00PM

4:30PM

5:00PM

5:30PM

6:00PM

6:30PM

7:00PM

7:30PM

8:00PM

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

OK, I'll put "meet Maribeth" at 3pm in my calendar

Add...

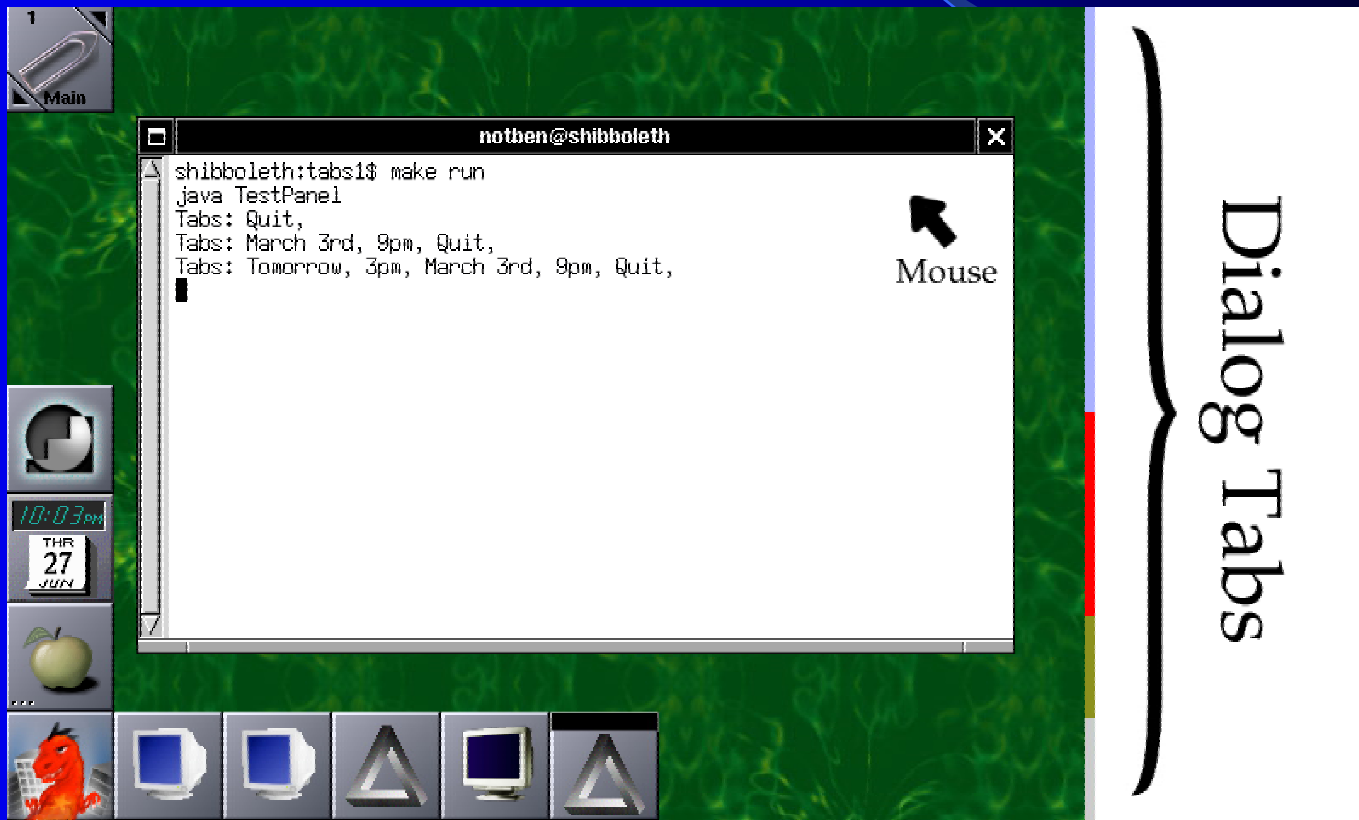
Edit...

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

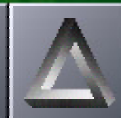
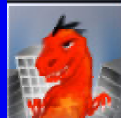
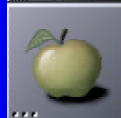
# Dialog Tabs: Augmenting Conversational Memory



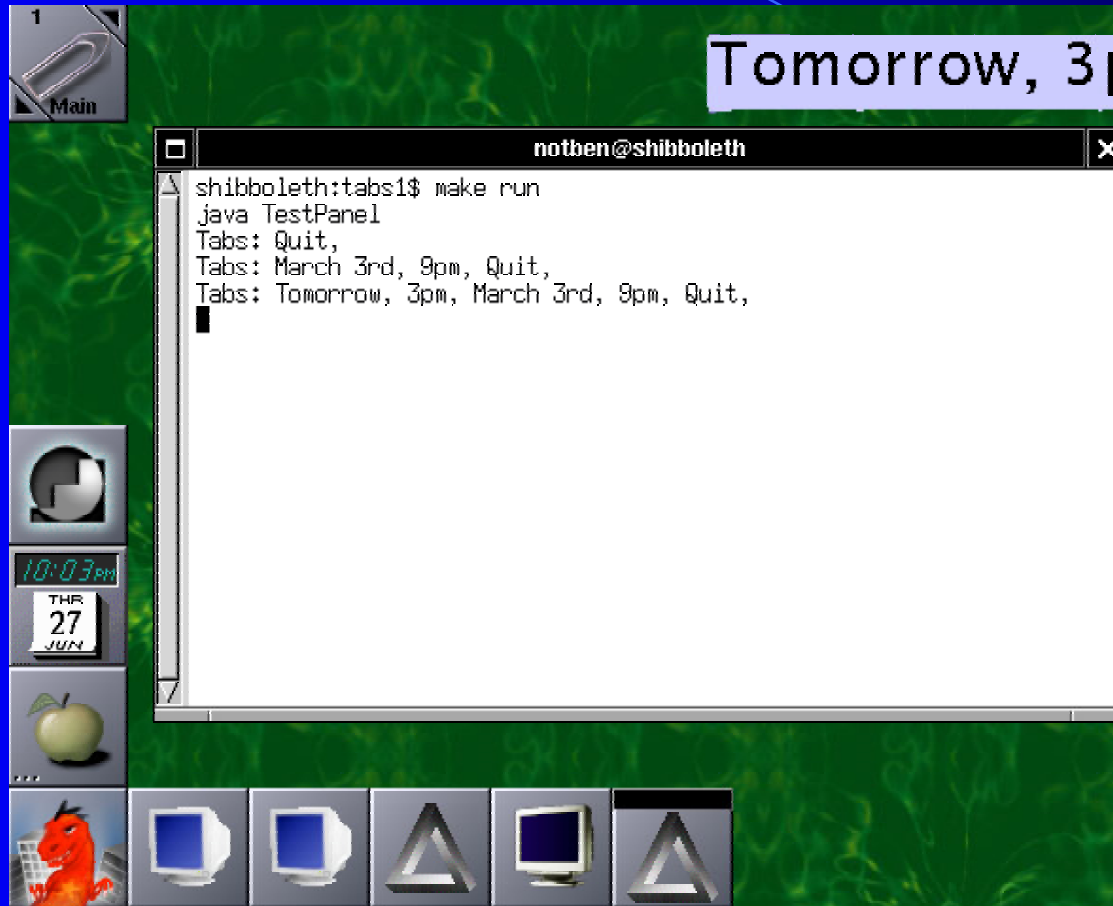


```
notben@shibboleth
shibboleth:tabs1$ make run
java TestPanel
Tabs: Quit,
Tabs: March 3rd, 9pm, Quit,
Tabs: Tomorrow, 3pm, March 3rd, 9pm, Quit,
```

March 3rd, 9pm



Tomorrow, 3pm



# 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

Demonstration

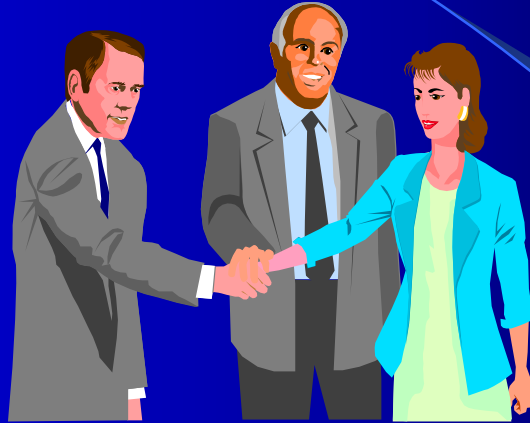
([www.charmed.com](http://www.charmed.com))



# Recognizing Social Engagement

- What if?: You never forgot a face/name
- You could recall details of prior interactions
- Your cell phone never interrupted important conversations
- We start by learning to recognize the beginning of important social situation (social engagement)

# Social Engagement Definition



- a location
- a 1 ft to 7 ft social proximity
- verbal display of intent to communicate (greeting, assertion, etc...)
- nonverbal display of intent to communicate (gaze, handshake, eye fixation, locus of attention, etc...)

# For Example



# Can We Detect It?

Academic conference with 300+ participants

Recorded and annotated engagements of  
wearer at conf.

Extracted n 2-sec subsets containing  
engagement and other gestures

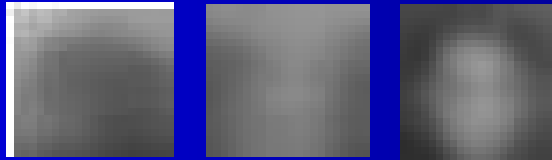
Learned 2 class HMM for enagement and  
other gesture classes

(Singletary01 RATFG-RTS)

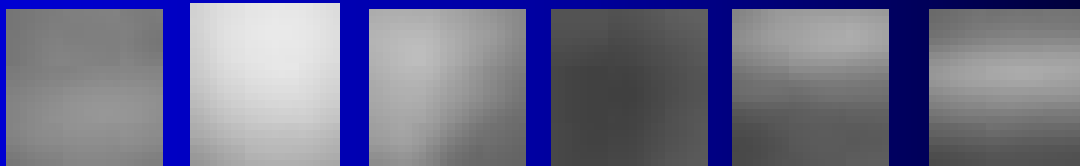
# Results

- Train: Engagement 82.1%; Other 91.3%
- Test: Engagement 83.3%; Other 91.3%

**Engagement  
States**



**Other  
States**



# DUCK!

- Towards a wearable perceptive interface without direct manipulation
- “Paintball” style game in a building with one-shot rubber dart guns
- Goal: Create an agent that communicates team members’ positions and activities (gun at ready, aiming, and firing) using only on-body sensing

(Starner98 ISWC)

# DUCK! Apparatus

- Forward-looking and downward-looking (at hands) cameras
- Not used: 360 degree camera, ambient and user microphones, dead reckoning system



# DUCK! Camera Views



video



# Results

- Room-level location accuracy: 82%
- Action recognition (isolation): 86%
- Extremely favorable reaction by expert players of simulated interface

# Representing Work From

- Ricoh
  - Bradley Rhodes
- MIT
  - Alex Pentland, Josh Weaver, Jeff Levine, Steve Mann
- ETH
  - Bernt Schiele, Bastian Leibe
- Georgia Tech
  - Grads: Ben Wong, Brad Singletary, Kent Lyons, Rob Melby, Tracy Westeyn, Fleming Seay, and Helene Brashear
  - Undergrads: Dan Ashbrook, Robert Maguire, Amy Hurst, and many, many “Janes.”

# Sponsors

- Availability at Dagstuhl: ETH and DARPA
- Mitsubishi, Accenture, Motorola, Intel, Visteon
- National Science Foundation Career Grant
- NIDRR
- Georgia Tech Broadband Institute

# Resources

- Charmed Technologies ([www.charmed.com](http://www.charmed.com))
  - Inexpensive wearables for prototyping
- IEEE International Symposium on Wearable Computers (ISWC)
  - <http://iswc.gatech.edu>
  - 2002 Seattle, USA
- IEEE Wearable Information Systems Technical Committee ([computer.org](http://computer.org))
- Home page: [www.cc.gatech.edu/~thad](http://www.cc.gatech.edu/~thad)
- Research mailing list: [wearables@cc.gatech.edu](mailto:wearables@cc.gatech.edu)