Hybrid Collaborative Environments for Distributed Decision Making

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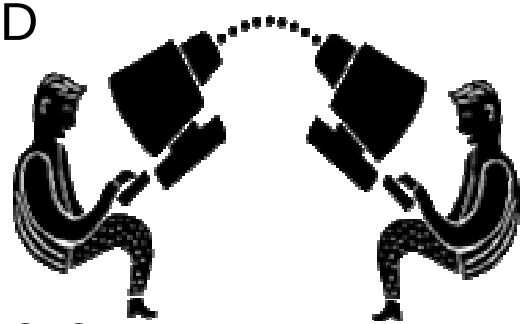

Review of Human Factors
Discovery and Invention Projects

Code 342
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Timberland
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Research Team

<u>2004- 2005</u>

- David Kirsh – PI
- Greg Elliott – software
- Bryan Clemons – run experiments
- Nicole Peterson – ethnographer
- Jerome le Merrer – software
- Benjamin Fouillot – software
- UG volunteers – about 3 per quarter

Project Summary Overview

I. **Project Summary Overview**
   Objectives
   Potential impact, applications

Project Overview

- Objectives

Objectives

- Provide **methodology and tools** for scientific study of distributed collaborative activity
  - Technology
  - Theory
  - Formalisms

Objectives

- Technology
  - support tools for digital ethnography
    - media review tool
    - video in sync tool
    - Virtual wall - testbed
    - capture environment – testbed

Completion

……. alpha release

……. alpha release

……. alpha release

……. documentation

Objectives

- Theory & Concepts
  - Collaborative use of representations
  - Stabilization
  - Personal Metadata
  - Activity Space

Objectives

- Theory
  - Reconceptualize **theory of collaborative error**
    - Time course of error
    - Marginal cost of error
    - Safe fail design

Objectives

- Design Guidelines
  - Principles for understanding and designing environments

Highlighted Annual Research issues

- Role of representation in structuring activity
  - Taxonomy and analysis of representation in distributed cognition
- Define and explain the concept of an operational space
  - Cost benefit of each operational space
  - How do rules of use evolve
  - How are different operational spaces coordinated
- Define and explain the concept of cost structure of error
- Define and explain the concept of activity space and cost structure of activity space

Technical Plan

Contribution to Collaboration Technologies

Collaboration Technology: Software 1

1. Digital ethnography software
   - Large software system based on QuickTime for reviewing and annotating multiple videos
   - Methodology for studying collaboration

Collaboration Technology: Software 2

2. Digital Ethnography Software
   - Light Weight Ethnography tool
   - Helps transcription

Why we needed a more powerful tool

- Help synchronize
- MS Media player has bad synchronized playing
- Helpful for transcription but impossible to move back and forth easily
- We want a product that can support filtering
- We want greater control of tracks

Collaboration Technology: Software 3

3. Digital Window to support continuous collaboration
   - Large scale high resolution AV
   - Support tools for synchronous distributed collaboration

backup

Collaboration Technology: Guidelines

- Design methods for building complex collaborative environments
  - Guidelines for setting up effective collaborative environments
  - Guidelines for setting up good research environments

Collaboration Technology: Guidelines

Environments are organized Operational spaces

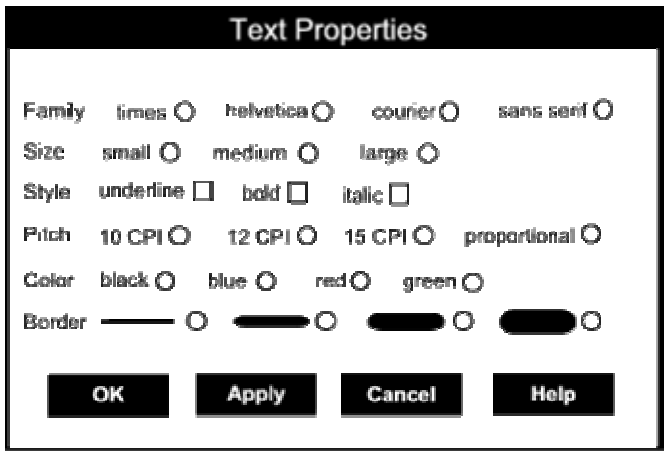
1. Choose appropriate operational spaces to provide effective
   - Coordination – support coordinating representations
   - Interruption recovery – stabilization
   - Error recovery

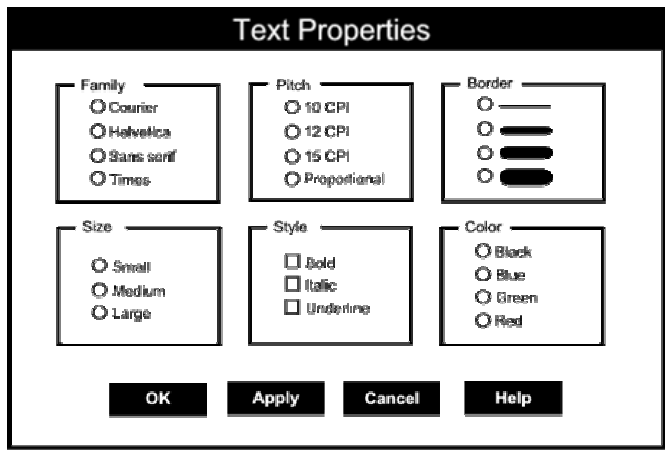
Environments should minimize cost of vigilance

2. Organize operational spaces to maximize vigilance without intrusion
   - Designing according to safe-fail principle
   - Lower cost of vigilance by:
     - Providing vigilance supports
   - Lower cost of asking for help

Environments should be visually simple

3. Principles visual design
   - What goes together semantically goes together visually
   - Principles of cue structure for attention management
     - Add concept of cue structure to concept of affordance





Collaboration Technology: Metrics

- Formalisms
  - Triangle diagrams
  - Cost structure of Error
  - Support for vigilance

Research Hypotheses

Research Hypotheses

1. The effectiveness of distributed collaboration depends on:
   - The appropriateness of mechanisms for coordinating individual and group activity:
     1. Representations – lists, tables, outlines – these serve as focal points in coordinating group activity
     2. Organizational structures
     3. Good visual design and screen layout

Research Hypotheses

1. The effectiveness of distributed collaboration depends on:
   - Having the appropriate ‘operational spaces’ for the organizational structure in use
   - Having effective ‘rules of use’ regulating behavior in operational spaces
     - These rules evolve and force changes in the operational space behavior and organizational (power) structure, often in response to breakdowns

Research Hypotheses

2. Errors arise from imperfect use of
   - Operational spaces
   - Coordination mechanisms
   - Representations
     - This encompasses all procedural errors
3. Vigilance prevents errors from becoming too costly
   - Errors have a cost structure

Research Hypotheses

4. Shared understanding is not just in the head but distributed between people and the resources in their environment
   - Some is implicit some explicit
   - Examples: spatial layout of resources, physically and on computer desktops
     - Beside whom, when, keep window revealed so others can see

5. Environments can be construed as superposition of activity layers
   - Errors in interpretation, coordination and external representation, can arise from failure to separate layers correctly

Results – Selected Theories

1. Operational Spaces
   - Breakdowns and repairs
2. Formalisms
3. Mechanisms for coordinating work
   - Role of Representation as focusing agents
   - Attention management
4. Stabilization
5. Environment as superposition of activity layers
6. Initial Design Recommendations

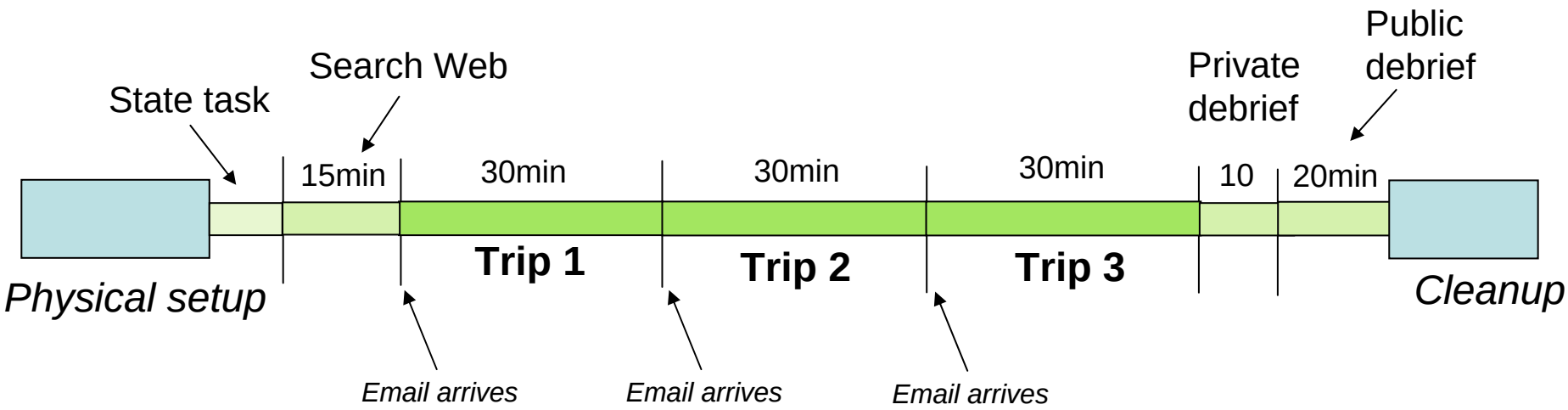
Experimental Design

Experimental Design

1. Trip Experiment
2. Setup Experiment
3. Furnishing Experiment
4. Netmeeting Experiment

Trip Experiment

Trip Task



Objective of team:

- team of three – work as travel agents,
- must plan three daily itineraries for a client
- initial 15-minute period to search 8-9 websites – gaining background knowledge,
- they receive email stating client's requirements,
- must write a reply with itinerary and budget.
- Final product is three email replies, one for each day.

Trip Task Experimental Design

YAHOO! Mail

Justin Thyme Travel Agency

Greetings from Bali!

Our flight got in late last night and we checked in to our hotel. Unfortunately the hotel we booked is a cockroach motel! That's why we're emailing you at 6AM our time! Please book us in a nicer hotel so we can move in by 10AM or at least get our bags over there. Well…at least the weather is sunny here. Here's our guidelines for the day:

• A new hotel!
• We need a rental car
• We'll need transportation to the rental car depot
• We want to do some sort of outdoor activity in the sun
o Are there any good beaches near our new hotel?
• Perhaps sometime in the afternoon…we'd love to attend some sort of local event. What is going on today?
• We don't have any lunch or dinner plans…help!
o We are in the mood for local food today…
• Our day budget today is $100

We look forward to having our plans!

Thanks!

Jack and Jill

Instructions – Canada
Instructions – Central America
Instructions – Indonesia

Lesson learned

- Studying errors and error recovery is less important than studying vigilance and coordination management

Lesson learned

- Design advice:
  - Provide scaffolds for vigilance
    - Passive monitoring
      - Public representation – checklist, to do’s,
      - Effective visual design
      - Effective choice of Operational spaces supporting vigilance
    - Active checking
      - Voice
  - Provide scaffolds for signaling need for help

Concept

Error: Cost structure & Vigilance

New View of Error

- Old view:
  - Errors occur at specific moment. They are anomalies.
  - Prevention must happen before error occurs.
  - If not prevented error must be detected and repaired
- New View:
  - Near error is the normal state. Regular activity is an error waiting to happen (waiting to get worse)
    - Walking is balancing between instabilities
    - Control consists in compensating for imminence of error
    - Error requires additional events to become consequential

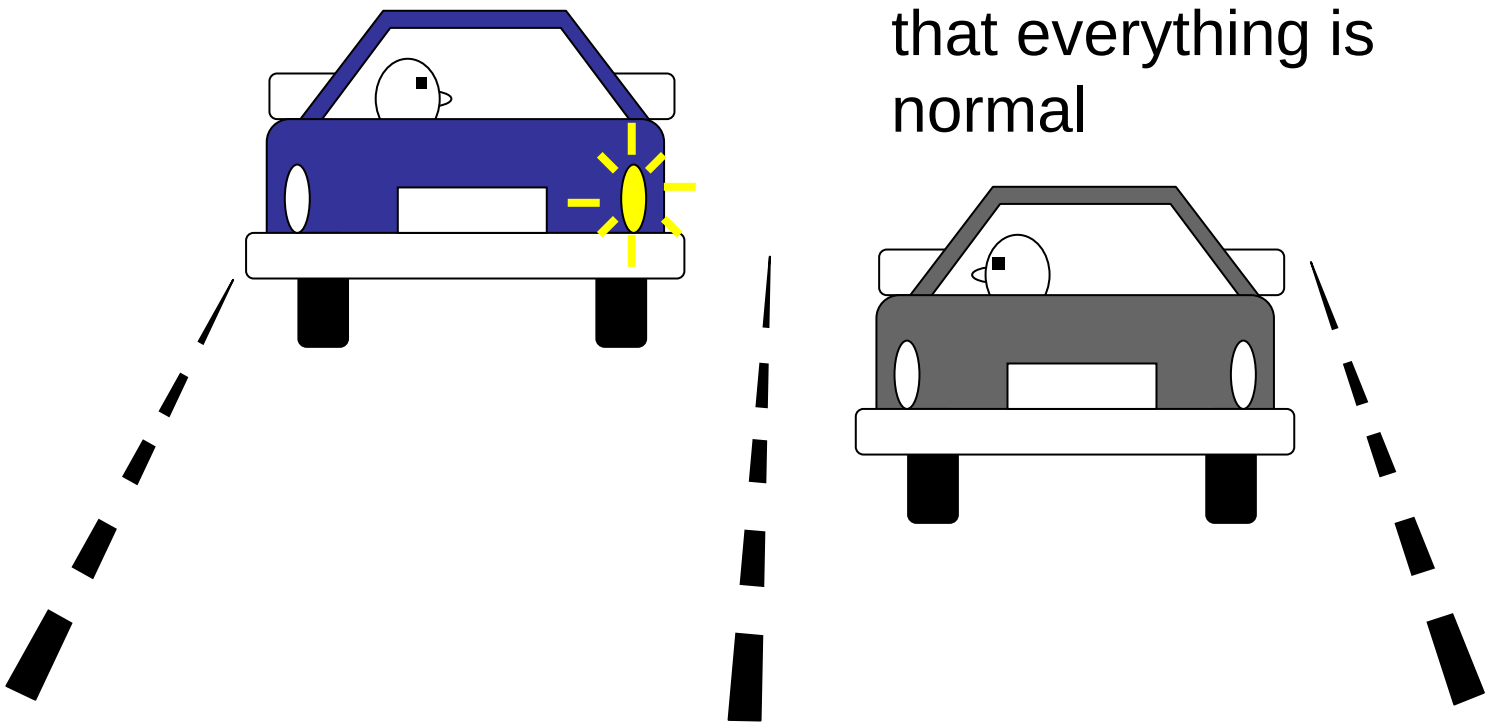
Driving model of action

Signaling

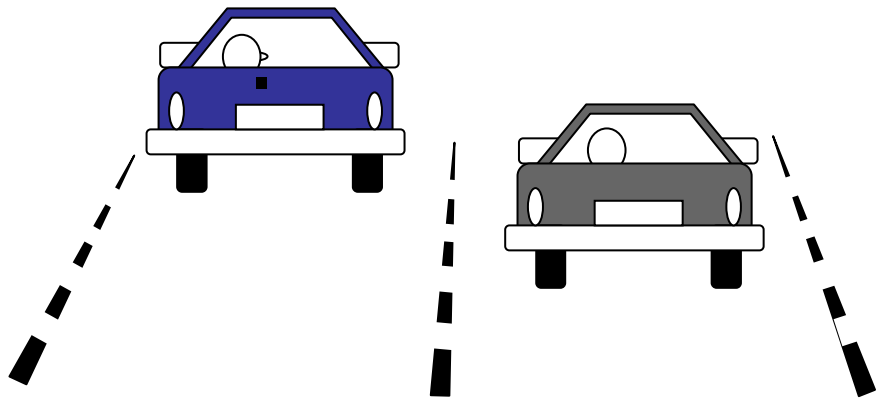
A checks and then signals

Vigilance

B constantly checks that everything is normal



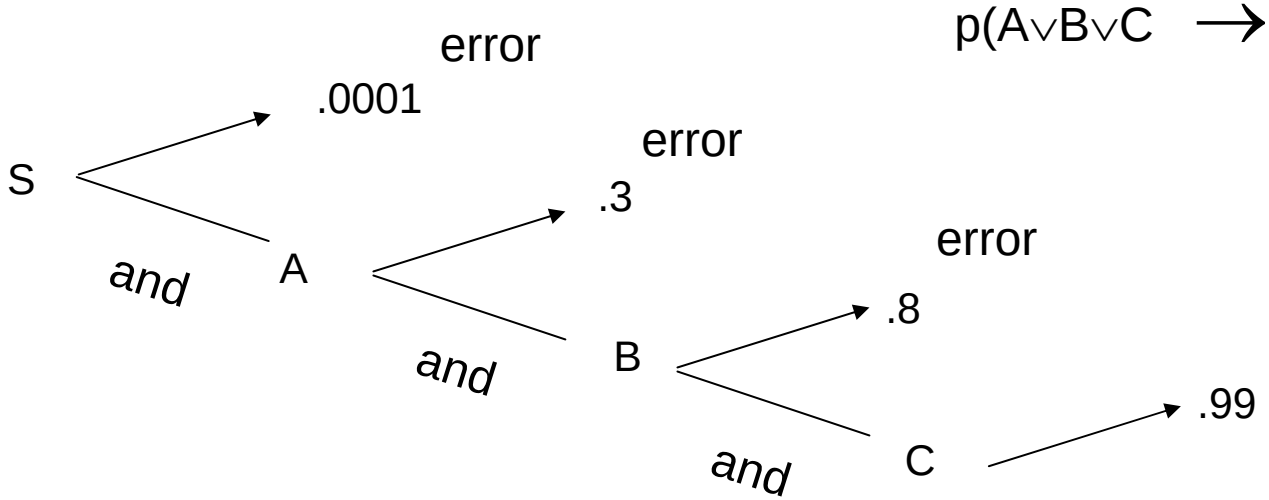
Error requires many other events or states occurring also



	Events		Prob
A	Car 1 changes lane without looking	P(A)	.3
B	Car 1 does not signal	P(A| B)	.5
C	Car 2 is not looking	P(A| B∧C)	.8
D	Car 2 has slow reaction time	P(A| B∧C∧D)	.99
S	Structural condition: cars side by side		

Causal model of error

$p(A \vee B \vee C \rightarrow \text{error}) = .3$



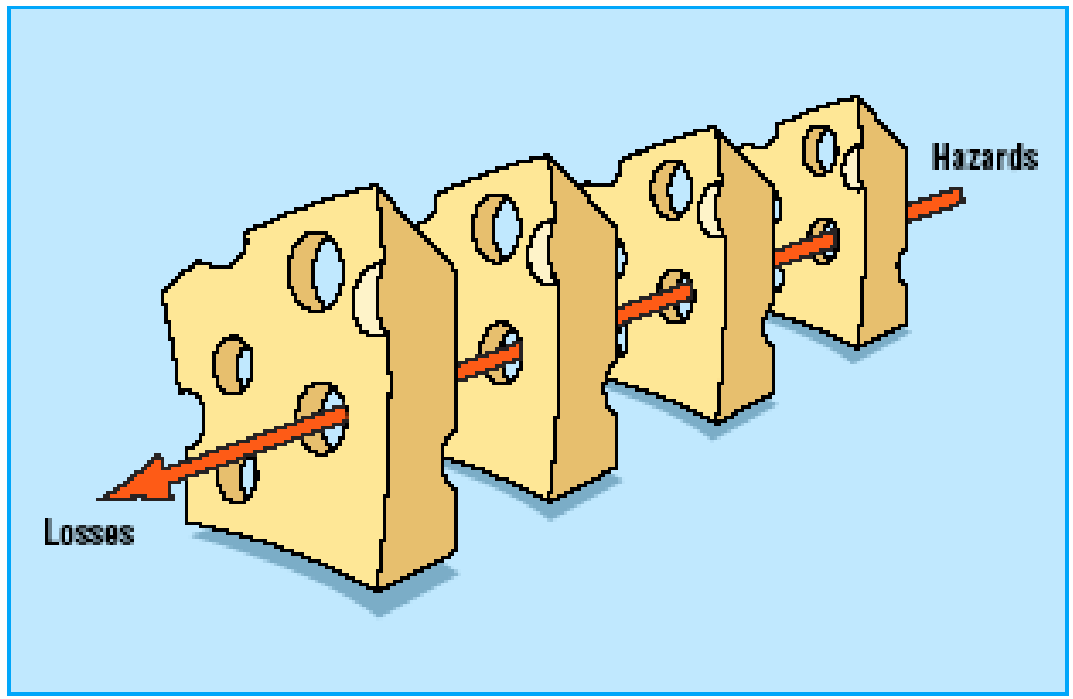
Causation is more complicated:

- requires a variety of features to be aligned
  - swiss cheese model (alignment or contribution of causes).
- Can now be extended to models of collective causation
  - broken telephone

Swiss Cheese model
(Reason 2000)

Similar to Reason's Swiss Cheese model of error

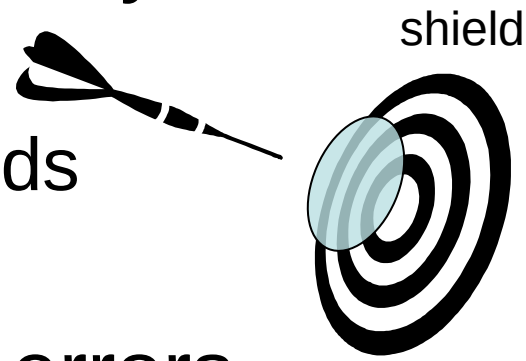
- errors occur when opportunities are aligned so that they allow an "accident trajectory," as through holes in Swiss cheese.



The Swiss cheese model of how defences, barriers, and safeguards may be penetrated by an accident trajectory

Implications: design *safe-fail* Env's

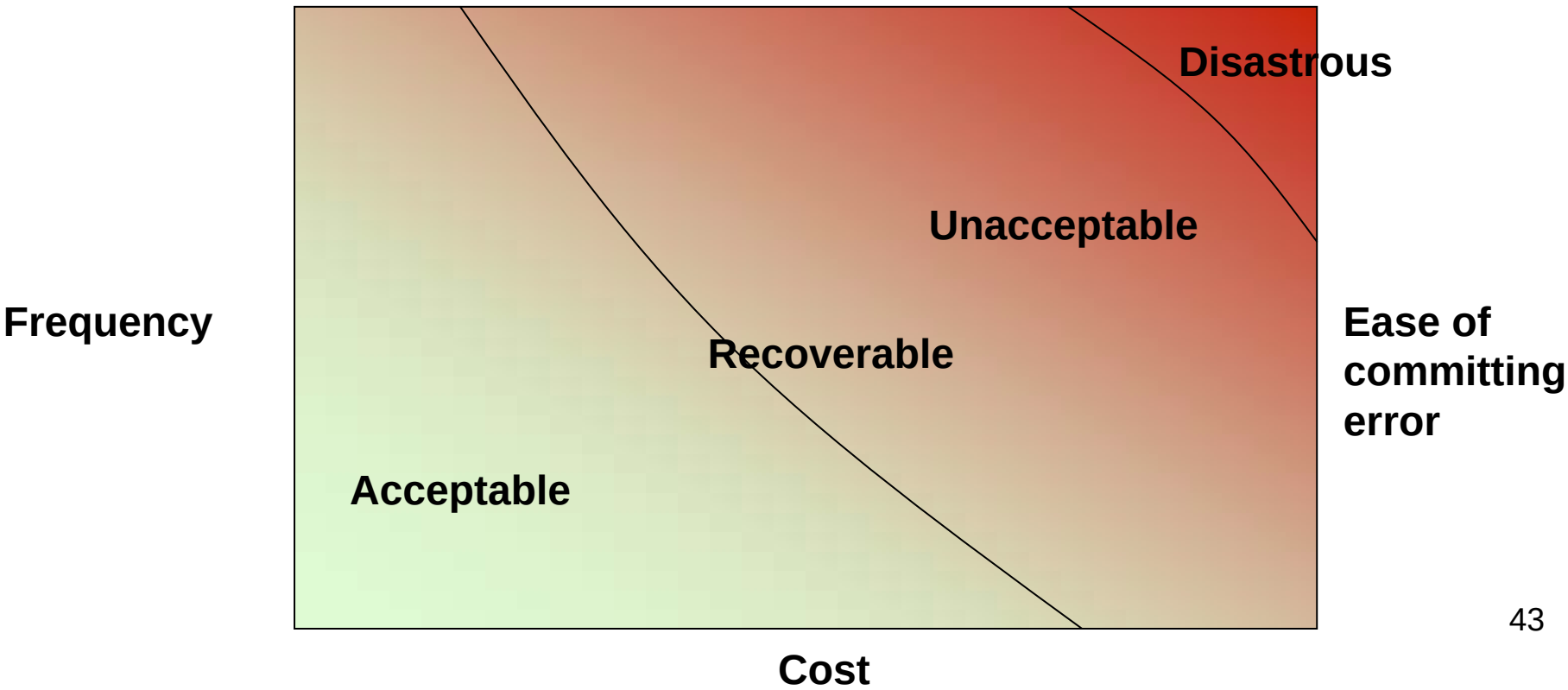
- **Fail safe**: minimize the probability of error
  - Make it hard for errors to arise
  - Double check, extra steps, shields



- **Safe fail**: minimize the cost of errors
  - Make it hard for errors to be consequential
    - Defensive driving, vigilance, safeguards to catch in time

Cost and prevalence of errors

- An acceptable design for an environment allows low cost errors



Error propagates unevenly

- Subject receives bad input or mistypes input
- Benefits of catching error depends on both where the subject is in calculation process and where the error is

Total = col 1 + col 2 + col 3

Col 1	Col 2	Col 3
134	12	35
102	110	11
7	32	112
+20	+34	+ 4
263	188	162

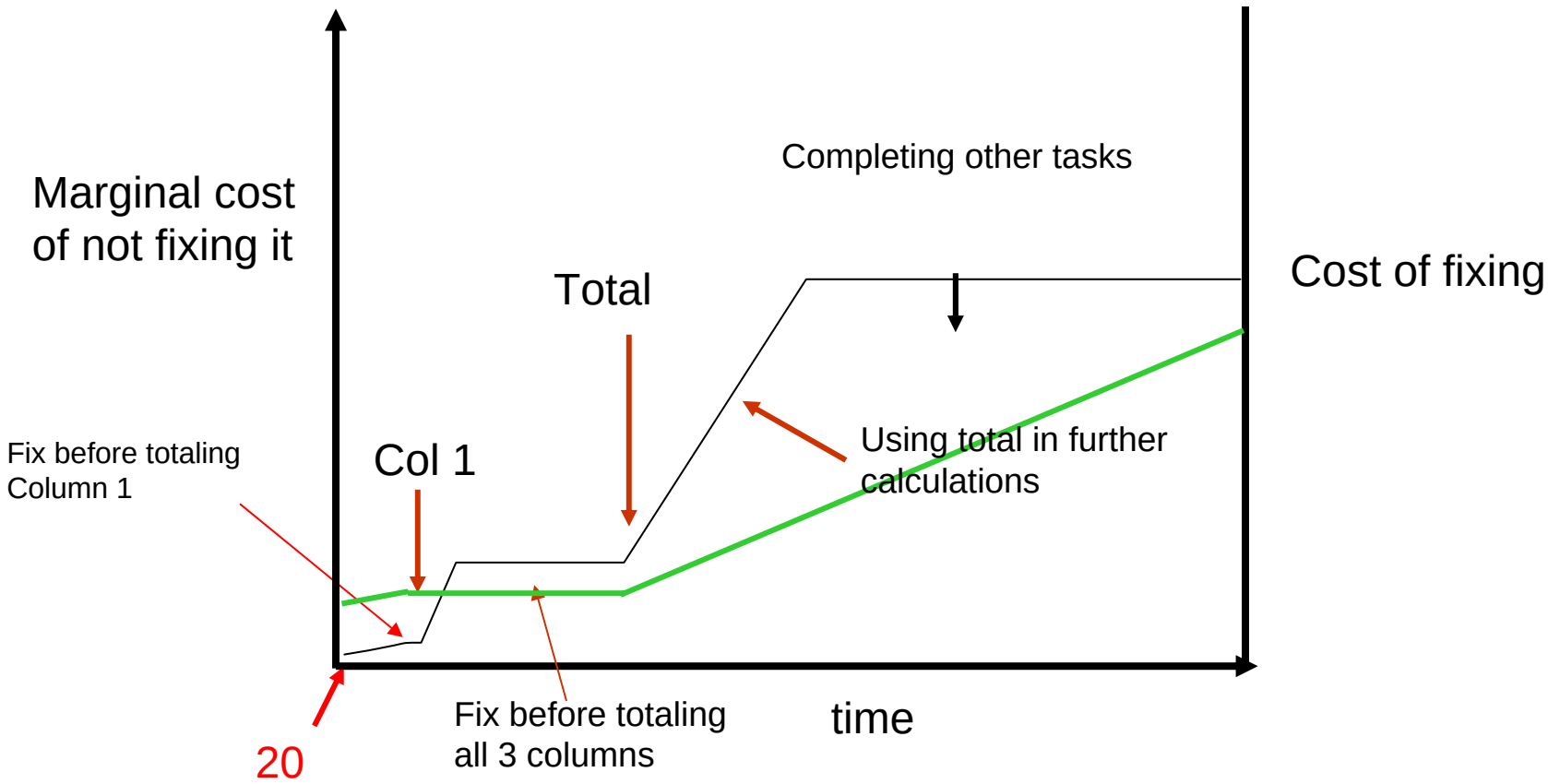
Col 1	Col 2	Col 3
20	12	35
134	110	11
102	32	112
+ 7	+34	+ 4
263	188	162

Col 1	Col 2	Col 3
35	12	134
11	110	102
112	32	20
+ 4	+34	+ 7
162	188	263

20 should really be 29

Catch it early then redo before summing the whole column

Error has a cost structure



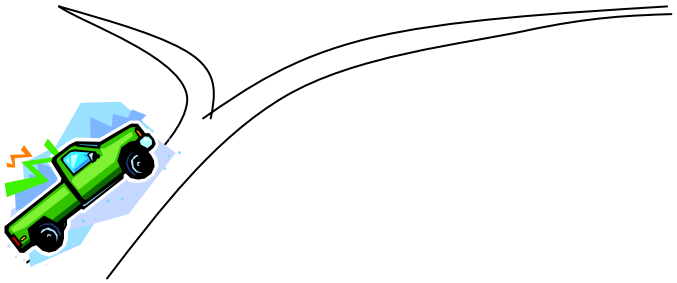
Designing for error

- Create resources that lower the costs of either
  - signaling or
  - vigilance
  - Which one to lower depends on marginal cost of lowering
- To determine costs
  1. compare the amounts of signaling and vigilance in two different environments
  2. determine which leads to better error outcomes.
- Our hypothesis: increased signaling and vigilance are beneficial
  - they reduce the costs of errors by suggesting places they can be cheaply corrected or compensated for

Current research

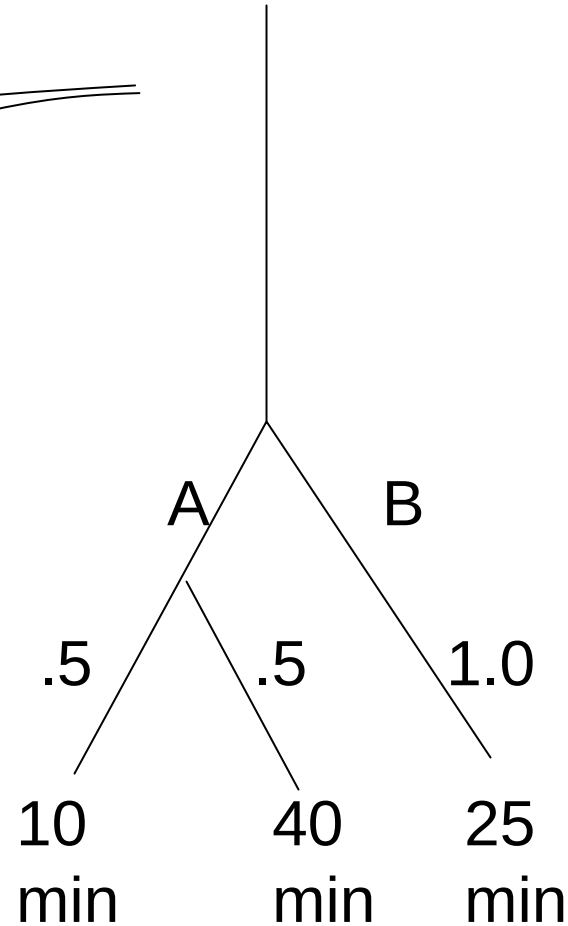
- New typology of error
  - Contrasting individual errors with collaborative errors or errors of miscoordination
- Varieties of vigilance
  - Vigilance is interesting because it has its fingers in so many phases in the cost structure of error
  - Using value of information theory, we can produce a cost-benefit analysis of vigilance

Driving choices - Value of info theory



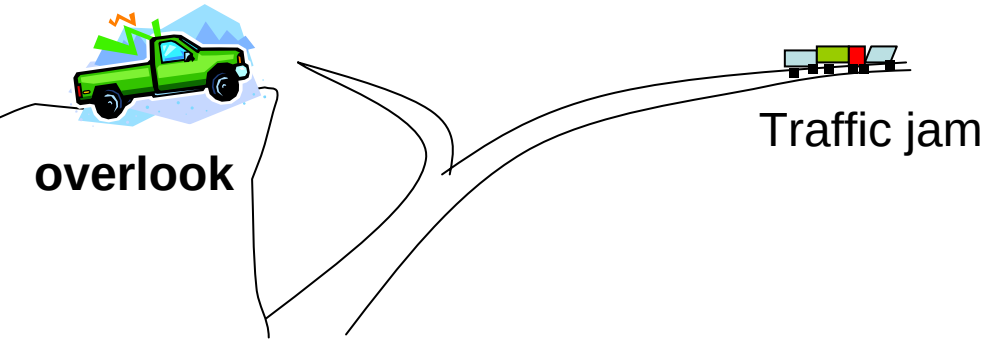
At a highway split, the driver is unsure which route will be faster

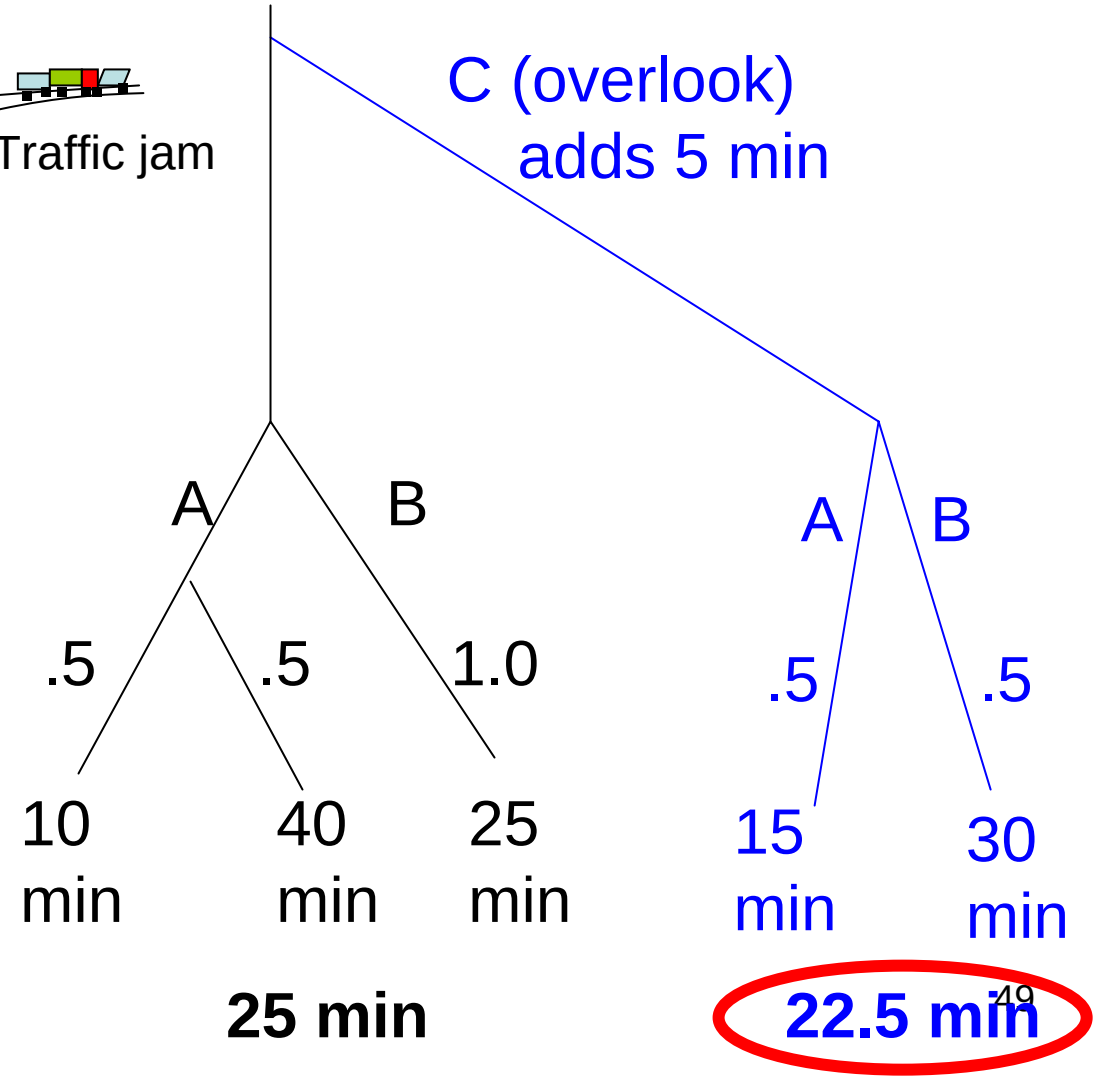
- Route B is always 25 min,
- A can be 10 or 40 minutes.



Expected time at choke point: **25 min**

Driving choices: Value of info theory





However, a quick trip to an overlook can determine traffic conditions.

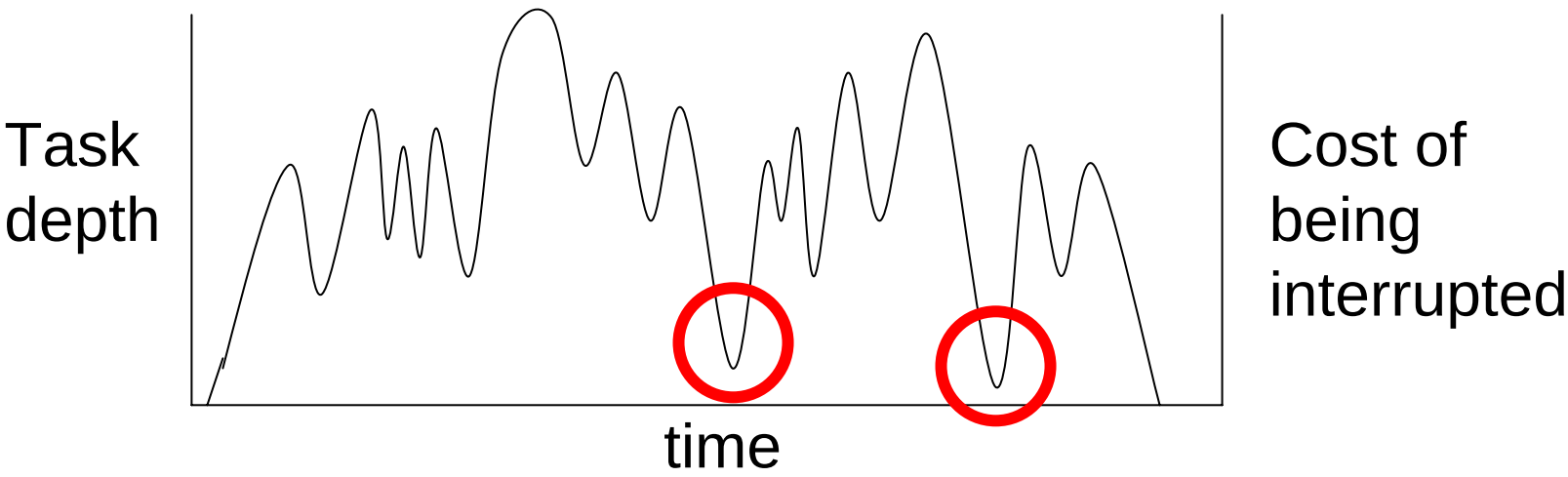
Is it worth it?

Expected time at choke point:

Vigilance which involves asking

- Knowing when to interrupt

Other person's task depth over time



Bottom Line

- Vigilance is a factor that should be:
  - Analyzed
  - Estimated
  - Designed for
- Errors are imminent and only sometimes need to be prevented

Setup Task at SuperComputer Center

Step One

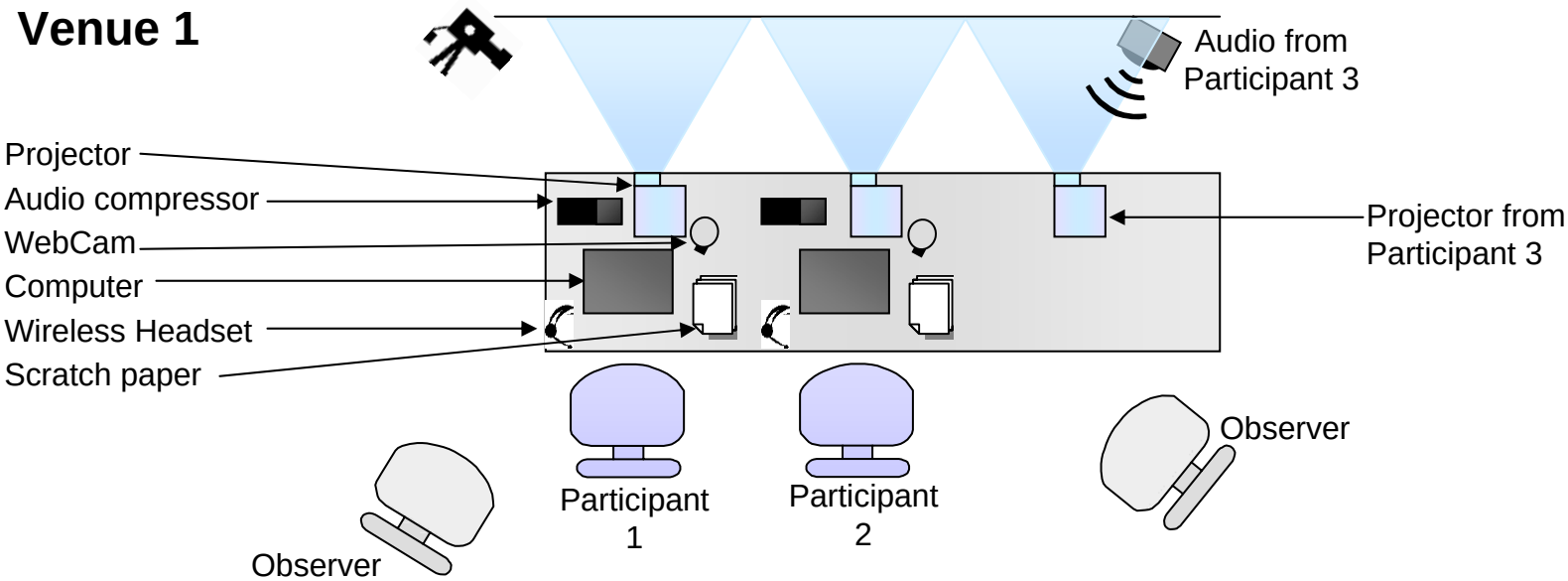
Step Two

Objective of team:

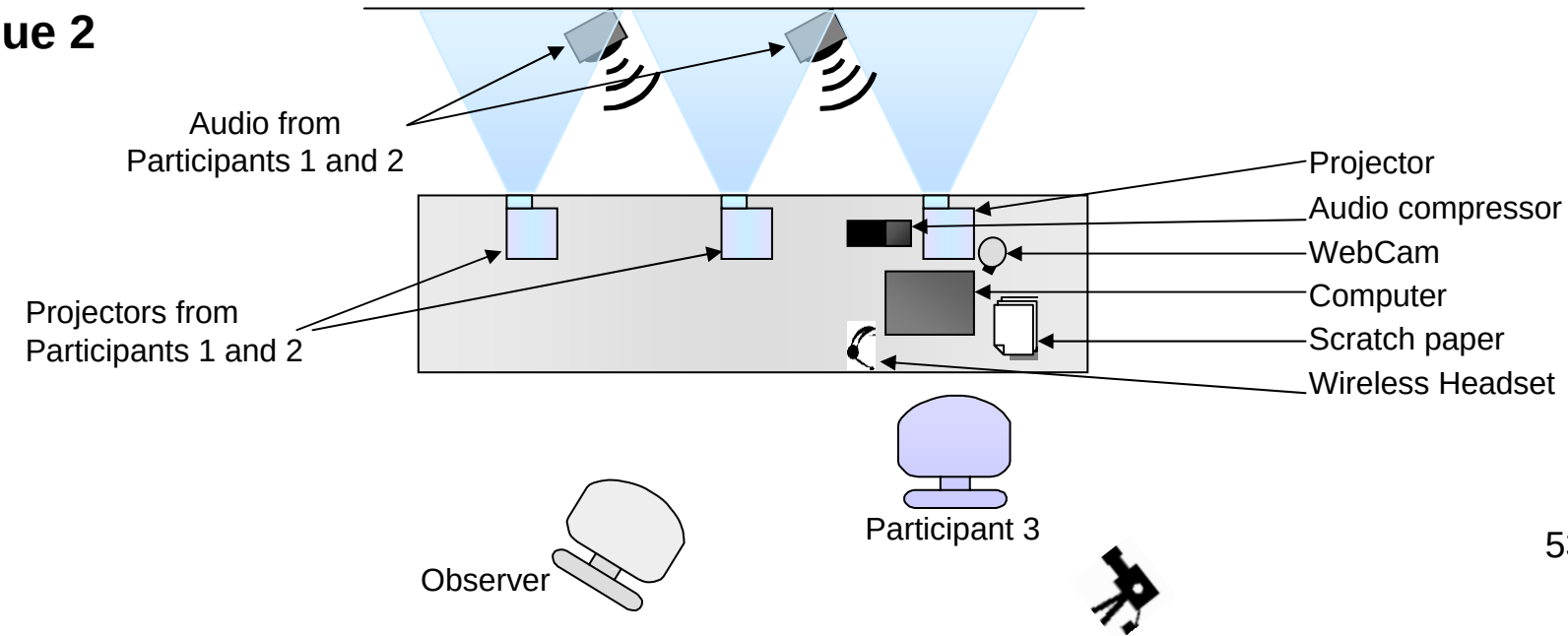
- team of 2-4 people prepares the venues for the Trip or Furnishing Experiment.
- includes
    - physical setup (computers, projectors, etc.), wireless audio system, internet configuration, distributed meeting software settings, and recording hardware and software.

Experimental Setup for Experiments at San Diego Supercomputer Center

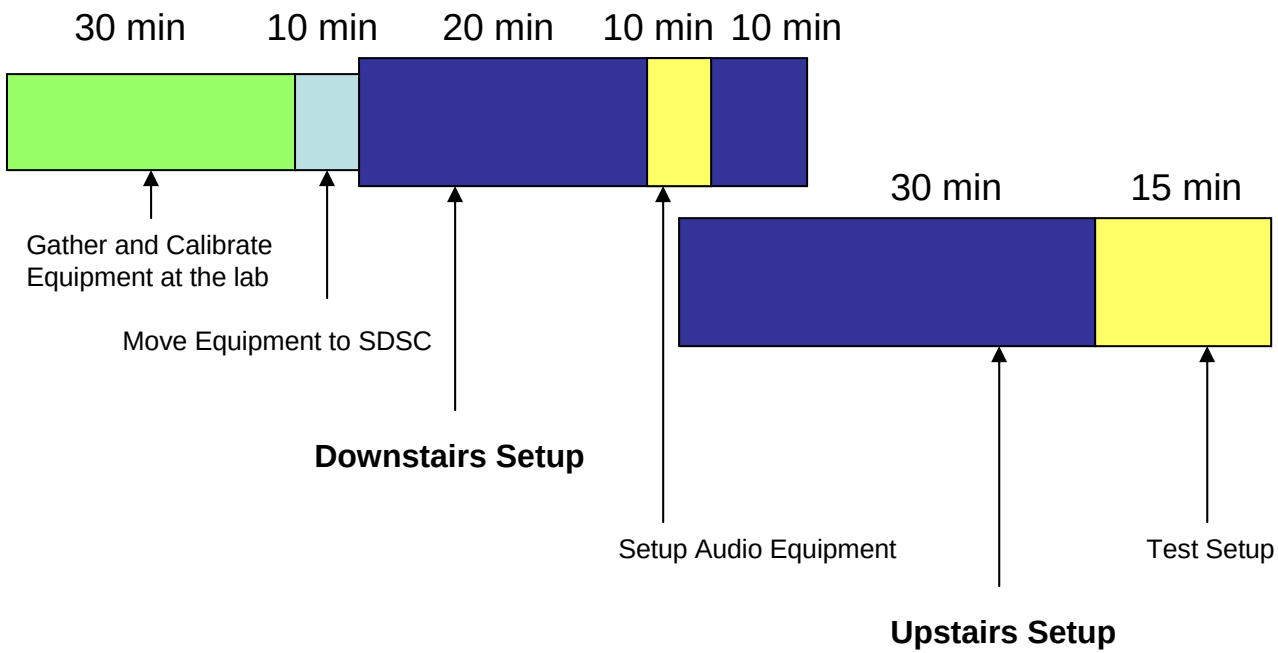
Venue 1



Venue 2



Setup Timeline



About the task:

- *Use of representations to coordinate behavior:* checklists, desktop displays, readouts from equipment to synchronize task completion and standardize process.
- *Collaborative preparation:* Gathering the equipment and doing some preparation before the setup.
- *Responding to new information:* Troubleshooting equipment problems.
- *Large amount of information:* Multiple tasks with many options
- *Time constraint*

Lessons Learned - Setup Task

- Power of a *checklist* as coordinating mechanism – centrality of representation
- People have to learn how to use checklist
  - Tick it off
  - Coordinate with others
  - Vigilance in maintaining it
- Well designed environments will always have well designed coordinating reps

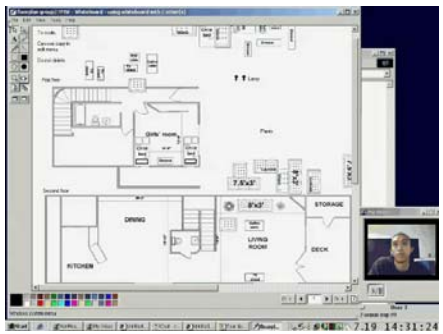
Follow up

- IBM is currently working on using a checklist metaphor as the primary organizing function in future versions of IBM Lotus Notes

Furnishing Experiment

Furniture Task Experimental Design

Sharing a graphic increases amount of communication



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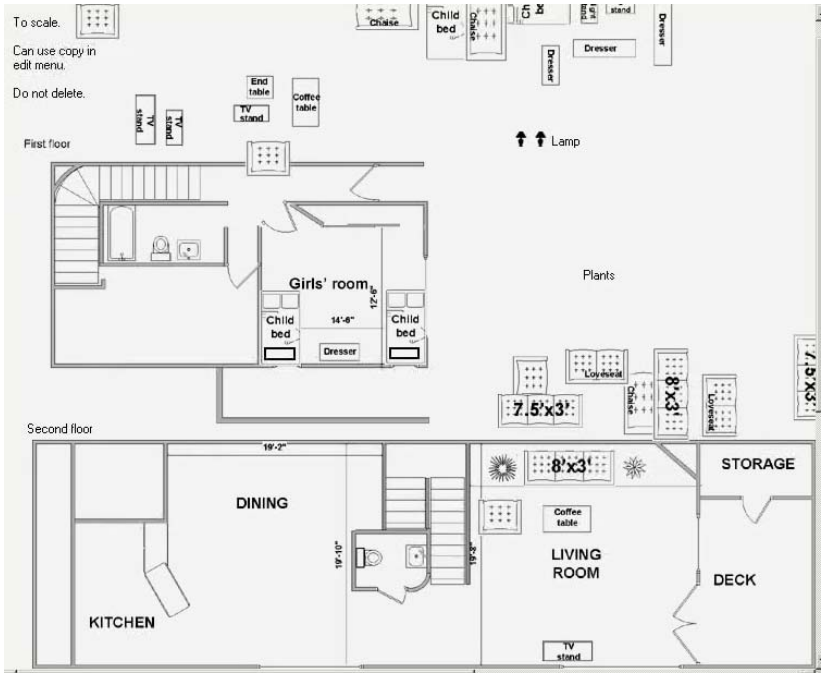
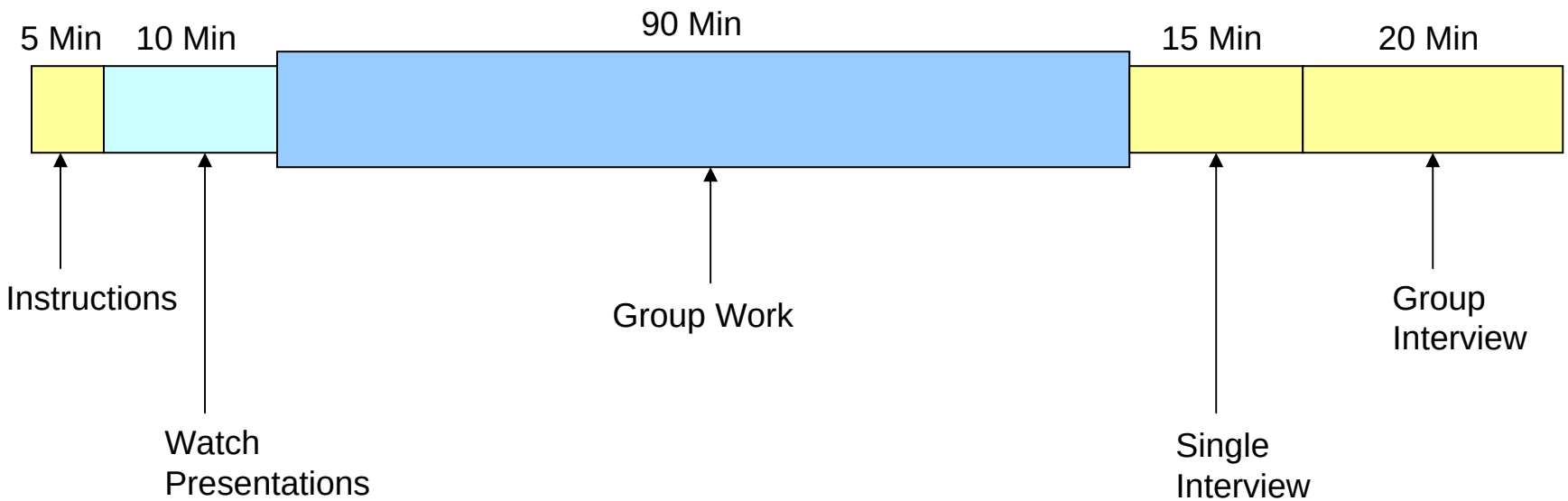


Objective of team:

- team of three – working as interior designers,
- Select and lay out the furniture for a family redecorating their home
  - living room, kitchen with dining area, master bedroom, child's room
- Final product is PowerPoint presentation for the client, detailing the furniture layout and costs

Furniture Task Timeline



About the task:

Heterogeneous knowledge - Roles: team members know different things about the “client” and their preferences, depending on the presentation they watch at the beginning of the experiment.

Power Structure: boss and two assistants with different tasks and responsibilities .

Lessons learned – Furniture Task

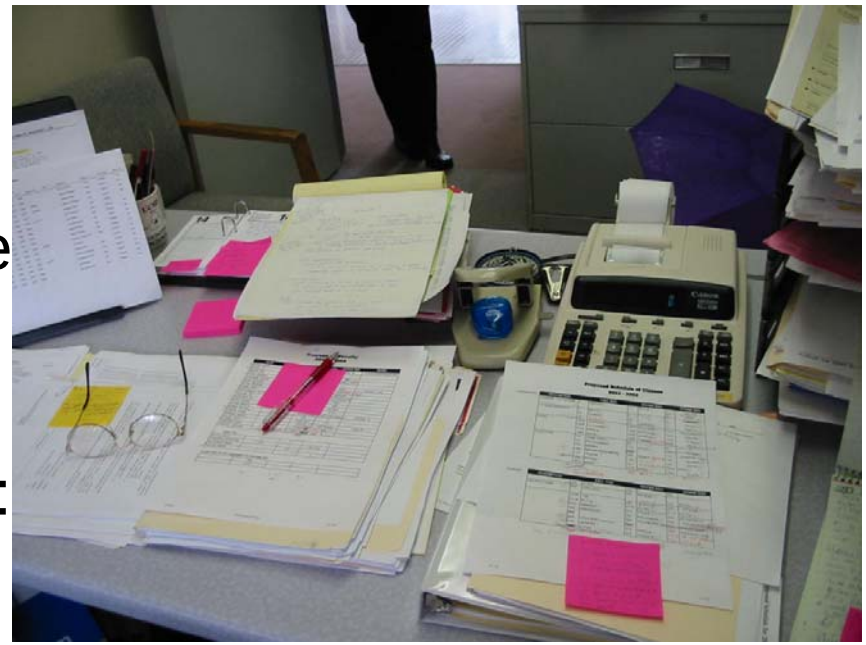
- 3rd man out is eliminated if boss is in the other venue
- Design advice: balance team by analyzing communication payoffs and exploiting power structure

Concept

Stabilization

Stabilization

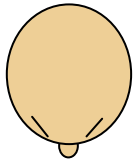
- ways of adapting the environments to make it easier to pick up activity later
- Make transient or changeable state sufficiently persistent to be reliably present later
- Immunize from bad effects of:
  - Interruption
  - Multi-tasking
  - Distraction



What are they?

- Let’s you pick up where you left off
  - Insulate from decay or writing over, or reusing resource
  - Externalize working memory of partial solutions to save recomputing
  - Record prospective memory
  - Helps to prime recall of personal metadata or ad hoc classifications

Stabilization



Reminders – prospective memory

Ordering

Locate in meaningful regions

Place Holders

Read off rather than infer

Decaying Internal State is now explicit/external

Stabilization – externalizing process state

Task identifier

State in task

		6	6
37	37	37	37
29	x 29	29	x 29
3	3	3	3

More Stable

Most Stable

6

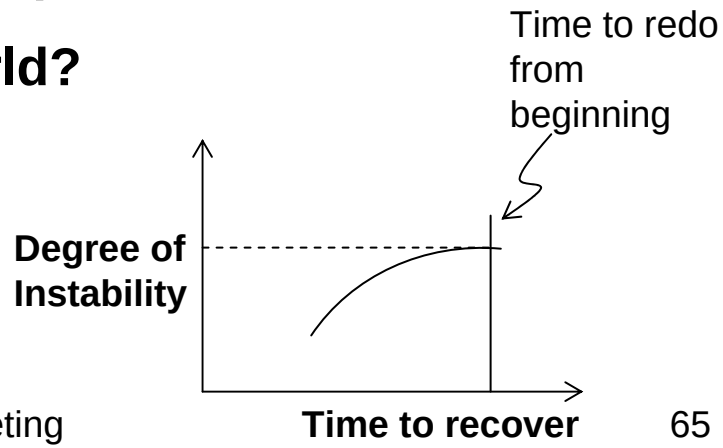
37

x 29

33

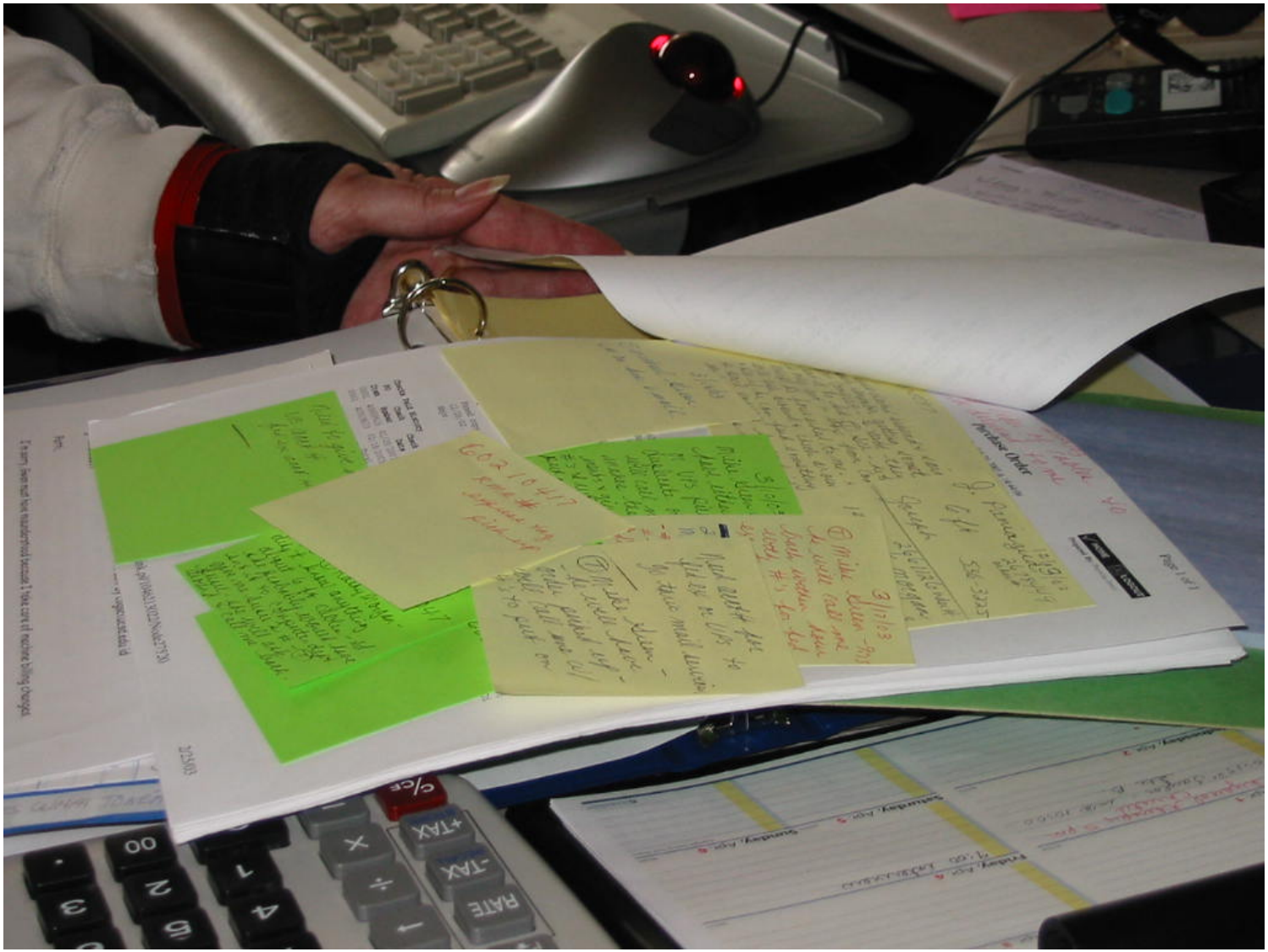
Why is this unstable?

- **How much time is required to pick up the process?**
- **What's in the head and what's in the world?**
- **How ambiguous are these states?**

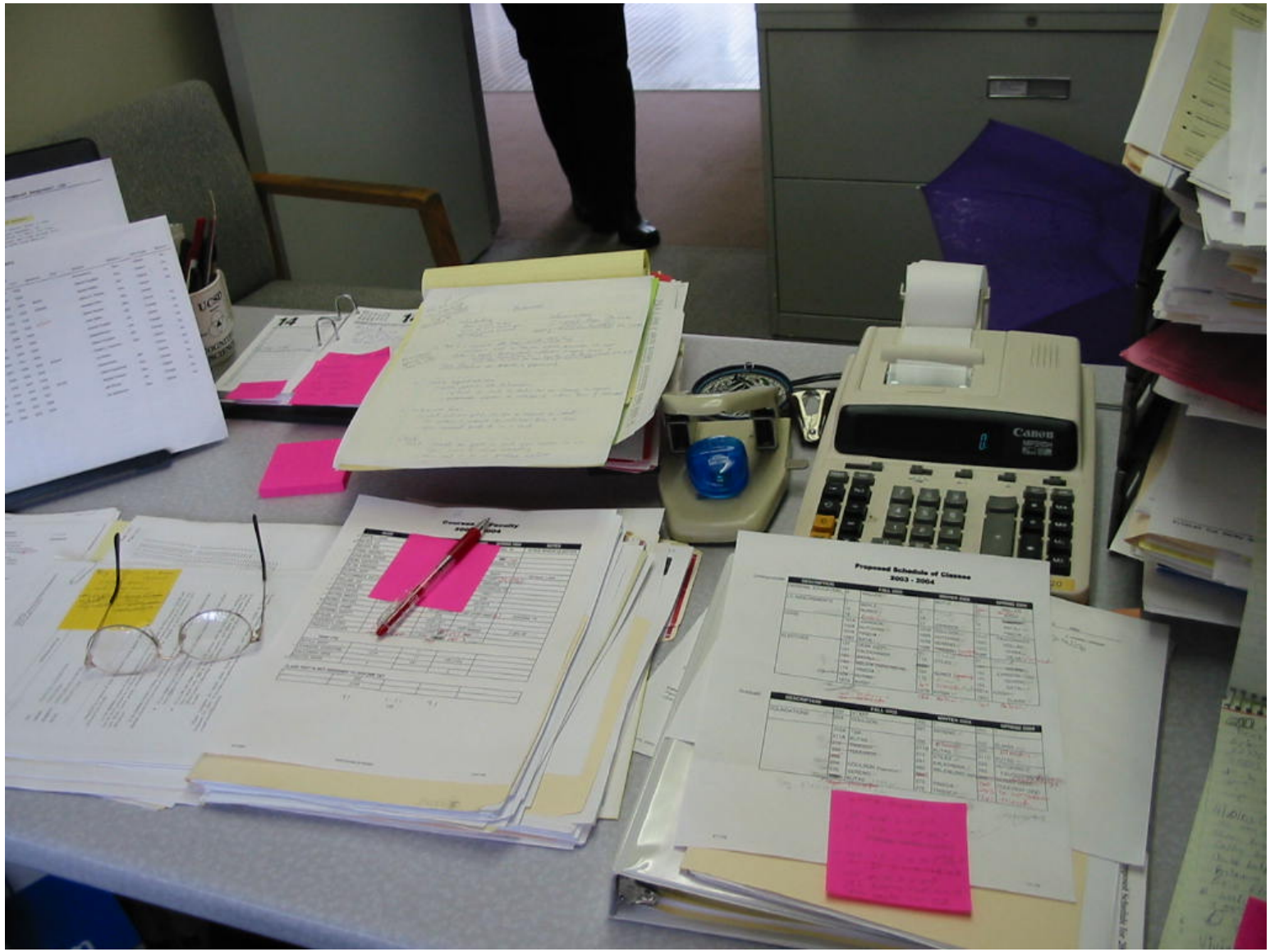


Stabilization

- Advantages:
  - If a state is well stabilized then people should recover better from interruption
  - Reduce errors
  - More efficient to pick up task
  - Possible to have greater control over when to do a task (don’t have to worry about memory decay)



IN BOX


Canon
Proposed Schedule of Classes
2003 - 2004

Stabilizing in response to interruption

backup

Click for 1 min video –interlong.mp4

Stabilizing by leaving reminder and offloading another task

1. Visitor drops off task involving binder

Subject gets up but leaves her binder open on chair as a *reminder*

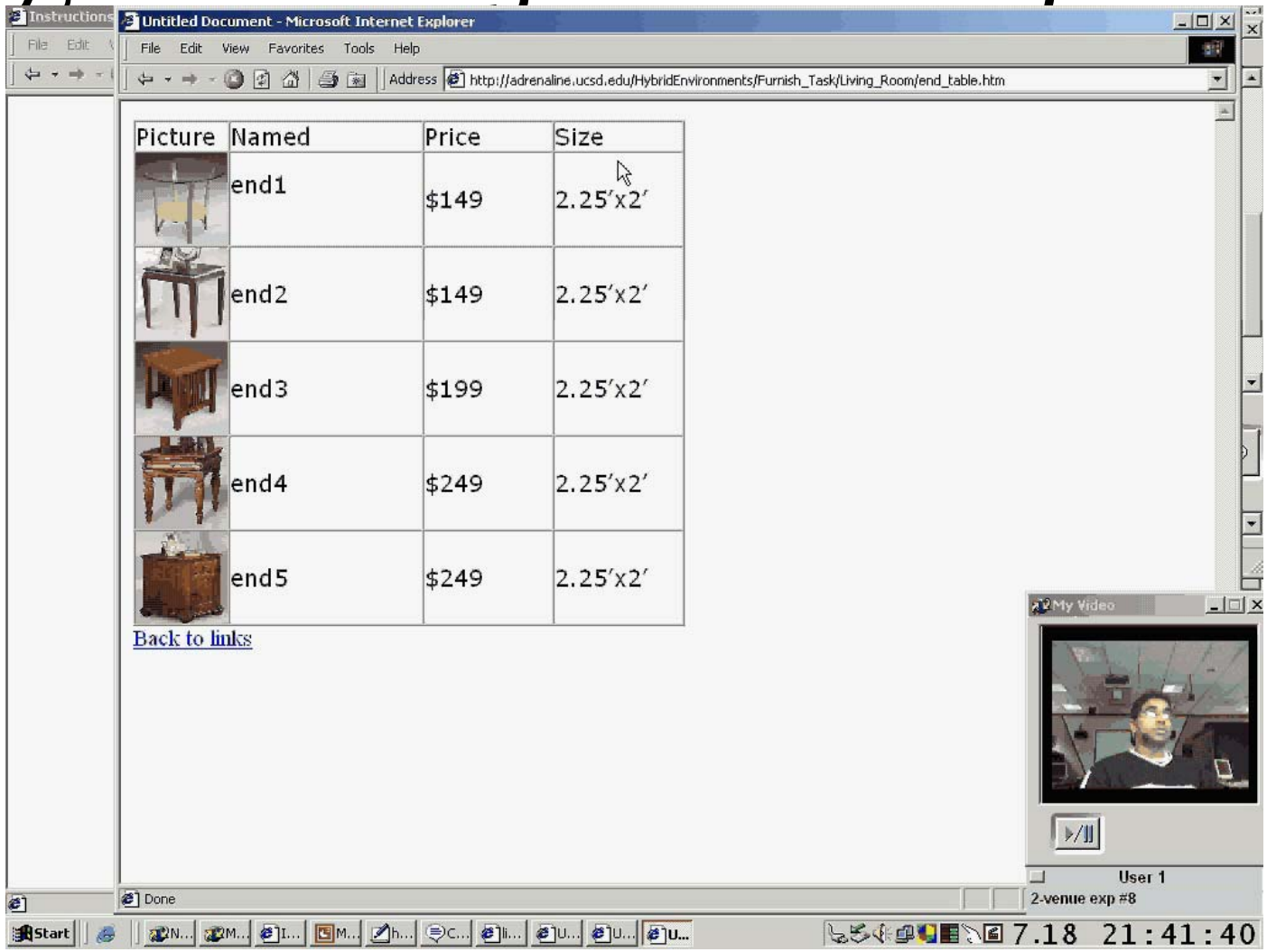
Immediately *offloads task* to someone else

Returns to task with binder.

Concept

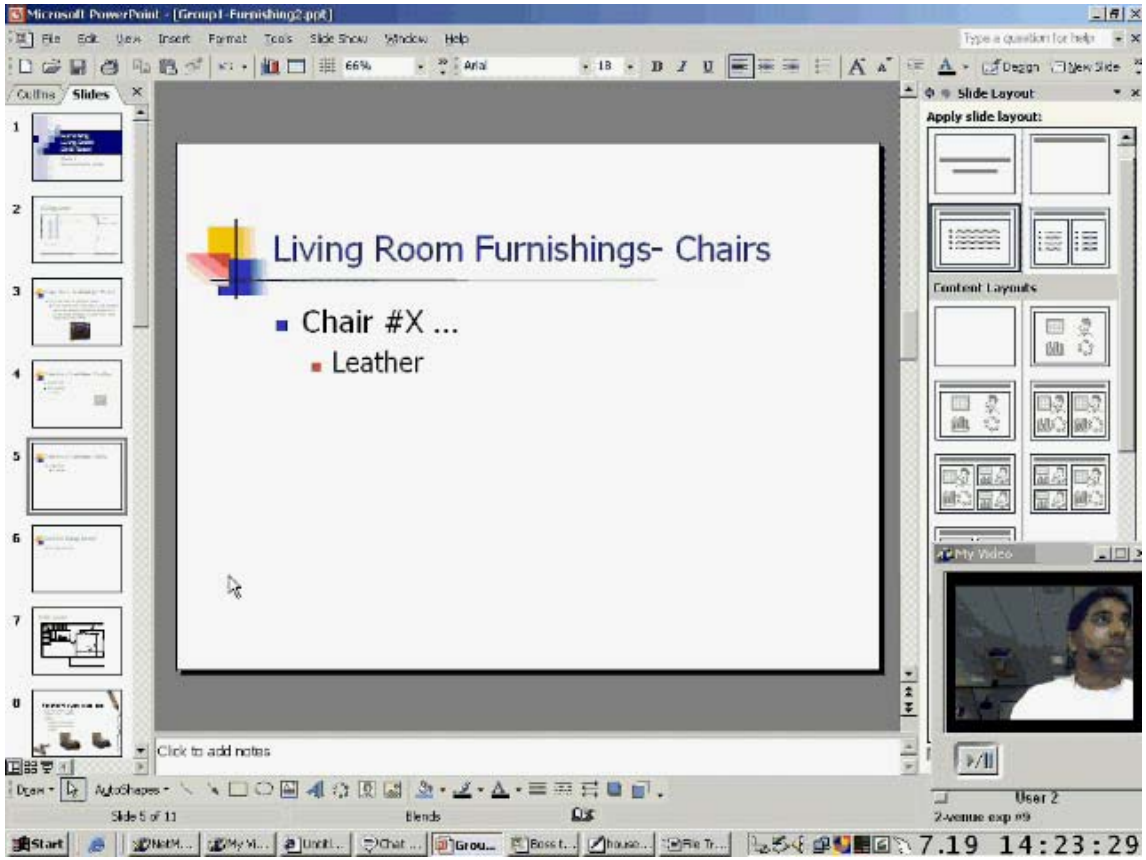
Stabilization in groups

‘Okay, but not right now. *Keep it there*’.



- Thomas tells Shailo to hold onto the information that he passes on because Thomas is busy with something else and does not want to be bothered (13 sec)

Stabilization if recorded, but not



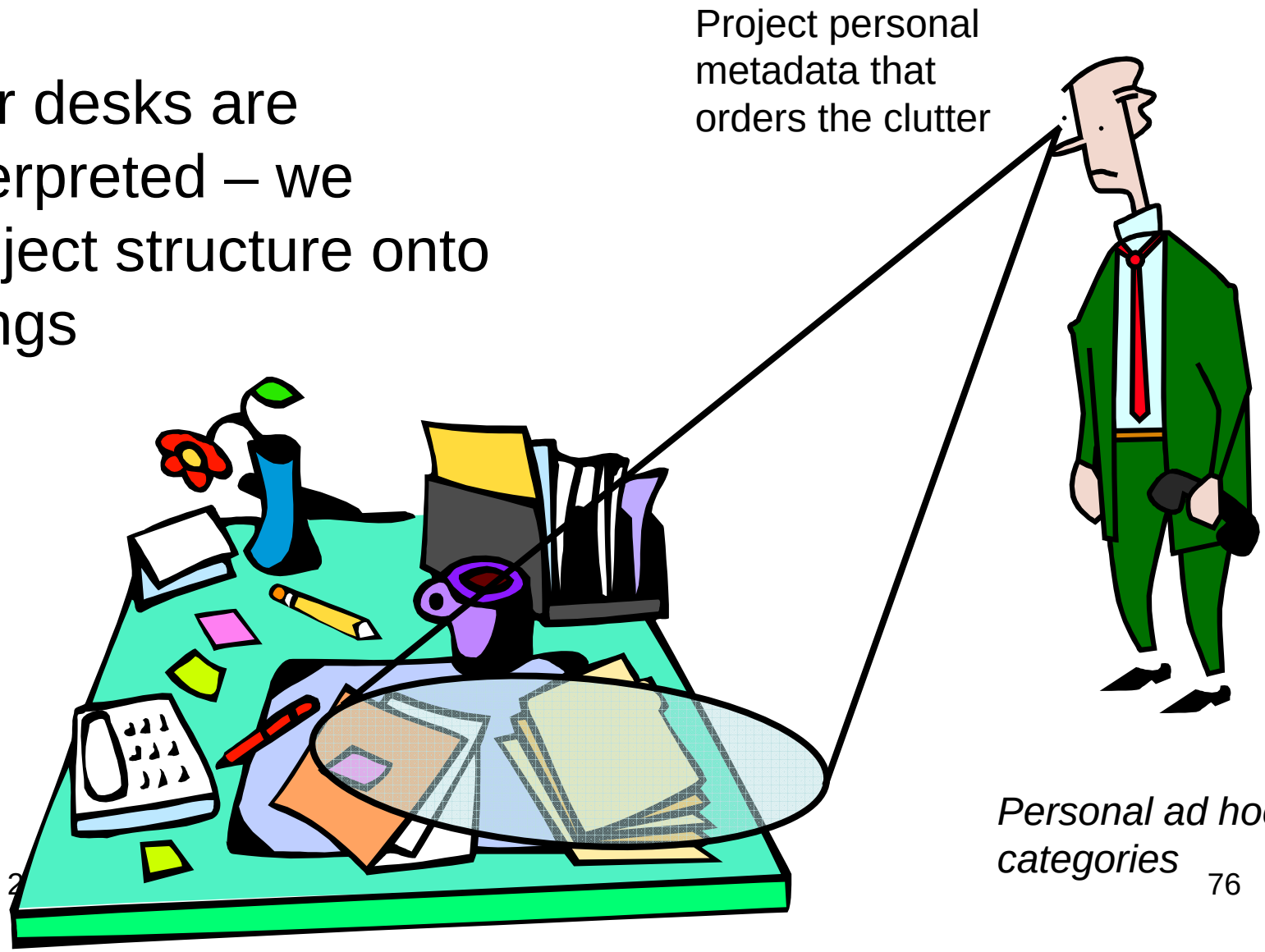
- S creates a schedule for when they are going to discuss certain aspects of each task (video is 19 sec)
  - “T and I are going to work on the presentation”
  - “We’ll get back to you in 5 minutes”

Concept

Personal Metadata

Personal Metadata

- Our desks are interpreted – we project structure onto things



Personal Metadata

- Example metadata
  - The docs that Mike gave me (history)
  - The files I have to sign (tagged by a to do)
  - The files I was working on when John came in
  - The files I need for the meeting today
- Each task and each Operational space frames certain metadata
  - Post-its connected to invoice I was doing yesterday
  - My contact sheet for purchasing

Our workspace is superposition of work layers

- Multiple tasks
- Multiple interests
  - work, social
- Interrupted tasks

Sharing Personal Metadata

- Great design question:
  - How to facilitate ‘getting on the same page’
  - How can we design better environments to make it easier to share our personal metadata when we are working together

Presentations and Articles

Relevant Presentations at Technical Venues

- Upcoming Speaker at Conference on Evolution of Routines, Jan 2005
- Workshop speaker at Computer Supported Cooperative Work 2004 – Methodologies for Evaluating Collaboration Behavior
- Main speaker at 3rd Annual MIT - UCI Knowledge and Organizations Conference 2004 – Coordination and Negotiation
- Lecturer and seminar leader at UCSD lecture series on Cognitive Ecology – Methodologies for Studying Collaborative Behavior
- Main speaker at 2nd Annual MIT - UCI Knowledge and Organizations Conference 2003 – Role of Representation in structuring activity.
- Cognitive Science Society Virtual Colloquium Series 2003 – Cognitive Principles of Interactivity and Design

Relevant Recent Publications

- Kirsh, D. & Conein B, How routines alter the cost structure of activity space. 2005 conference article (in press) journal article to follow in special issue on Routines,

- Kirsh, D. “Metacognition, Distributed Cognition and Visual Design”. To appear in Cognition, Education and Communication Technology (eds.) Peter Gardinfors & Petter Johansson, Lawrence Erlbaum 2004

- Kirsh, D. “Implicit and Explicit Representation” in Encyclopedia of Cognitive Science, 2003

Publications: In preparation

1. INTERACTIVITY, Oxford University Press (Book contracted and in preparation)
2. Cognitive Principles of Interactivity and Design (in preparation)
3. Negotiating Consistency in the Collaborative use of representations (in preparation)
4. Operational spaces (in preparation)
5. Coordination Theory, the central role of representations (in preparation)
6. DESIGNING ENVIRONMENTS: Cognitive Principles underlying a science of design. Oxford University Press. (Book contracted and in preparation)

Completion Criteria

Completion Criteria

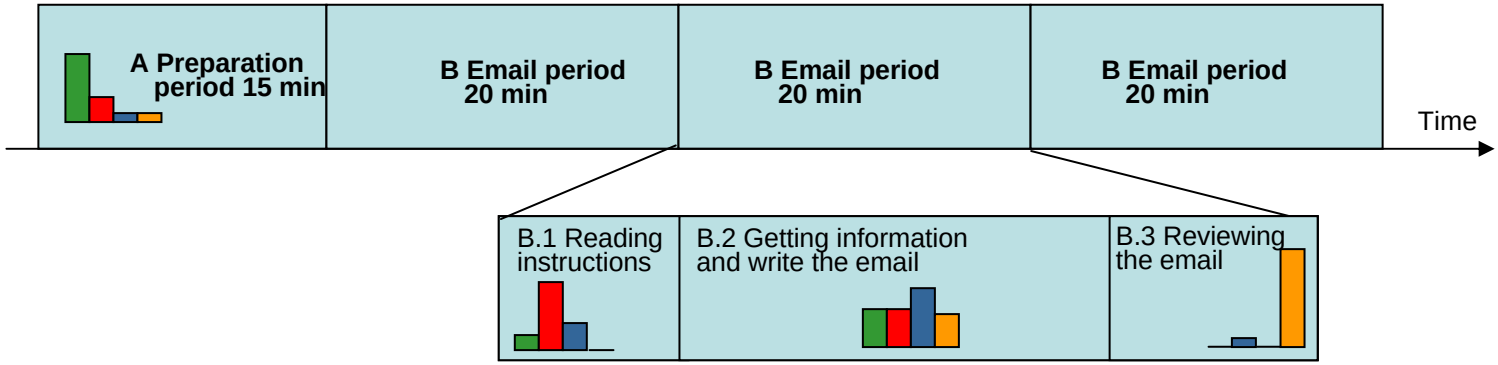
- Modular distributable software package for capture and analysis of distributed collaborative activity
- Analysis of operational spaces and their role in distributed collaborative environments
- Guidelines for effective setup of distributed venues and for collaborative preparation of such venues

Contribution to Resolving CKM Technical Issues

Contribution to structural team collaboration model

- Collaboration model recurses so that elements of each part are found in each stage
- Our major research areas provide insight into the mechanisms of
  - MetaCognition – vigilance, coordination, representation use
  - Information Processing - coordination
  - Knowledge Building -
  - Communication – signaling, communication structures

Application of structural model



Travel trip	A. Preparation period	B.1 Read instructions	B.2 Get information	B.3 Review the email
	Subjects familiarize themselves with the websites	*Subjects receive their task instructions*	*Subjects look for the information and write the*	*If they have time, subjects check over their email*
Individual knowledge construction	Subjects explore webpages	Subjects match the instructions with the information they have seen	Subjects get more knowledge while looking for the information	
Collaborative team problem solving	Subjects use the resources and requirements lists to discuss and specialize	Create a list to help define and share the tasks	Subjects comment on their findings and on the problems they encounter	The subjects discuss what they have found
Team consensus	Team agrees on who will do what. Usually a leader suggests roles	Team distributes tasks, according to specializations and strategic issues (location, budget)	Experienced members are trusted to decide themselves what info to send to leader	
Outcome, evaluation and revision	Requirements list helps subjects decide what they still have to learn		Check task requirements, triage or reallocate effort according to remaining time	Check the form and content of the email

The End