Preventing Technology-Induced Errors in Healthcare: The Role of Simulation

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Technology-Induced Error

- Health care information technology if not designed properly can introduce <u>new</u> types of error
- Kushniruk et al. (Medinfo 2004) – "technology-induced" error in healthcare
- Koppel et al (2005) – "technology-faciliated error"
- Ash et al. – "unintended consequences"

- Much of this work focuses around aspects of <u>human-computer interaction (HCI)</u> and <u>system usability</u>

Usability

Measures of "ease of use" and usage of a system

1. Learning
2. Effectiveness
3. Efficiency
4. Safety
5. Enjoyability

Usability engineering - scientific methods to improve system usability

Predictive Methodologies – i.e. Ways to Predict Error

- Usability testing
- Usability inspection (e.g. heuristic evaluation)
- Clinical simulations
- Computer-based simulations
- Combination of clinical and computer-based simulations

Background: Simulations in Healthcare Information System Evaluation

- **Used in many disciplines**
  - aviation
  - space exploration
  - military training
  - nuclear industry
  - business
  - medical education

- Need to be applied in health information system evaluation to
  - Predict error that might be inadvertently caused by systems
  - Determine impact of systems on workflow

Clinical Simulations

- An extension of usability testing approaches in healthcare
  - Study representative users doing representative tasks using a system
- To be as realistic as possible
- We typically create realistic scenarios (tasks) and may conduct them in actual setting of system use
- May involve study of individuals or group interaction

Combining Two Different Forms of Simulation for Predictive Analysis

- How can clinical simulations (involving use of realistic task scenarios and real people) be enhanced through use of computer-based (i.e. “in the box”) simulations?

- Motivation of current work to use outputs of clinical simulation studies as inputs into mathematical modelling

Current Research Program

- Phase I
  - Collection of empirical data from conducting clinical simulations of user behavior (with subjects in laboratory setting)
  - Analysis of data from phase I to come up with parameters to predict system impact (e.g. error rates in using a system)
- Phase II
  - Use of computer-based simulations to predict error rates and patterns in real contexts (e.g. use of system in large hospital) -- based on inputs from Phase I
- Phase III
  - Assessment of predictions in real settings (using naturalistic data)

<u>Phase I:</u> Clinical Simulation of Single Users Interacting with a Hand-held Application

- Builds on work been involved with over past fifteen years
- Studies of usability of health care IT
  - Video based analyses
    - EMR, decision support, guidelines, PDA ...
- Extension of usability coding categories (Kushniruk & Patel, 2004)
  - E.g.
    - Navigation
    - Display Visibility
    - Search Capability
    - Content

Categories for Analysis of Medication Error

- Extension of these categories
  - Errors and slips (Norman, 1981; Zhang et al. 2003)
  - Modified categories
    - Slips – errors in medication entry that are "caught" by the user before prescription is finalized
    - Mistakes – errors in medication entry that are not caught by the user (would appear in the prescription)

Usability and Handheld devices
(Kushniruk, Triola, Stein, Borycki, Kannry, MedInfo 2004)

- A particularly good area to study relation of usability to error introduction
  - – Small size of screen
    - Usability issues
  - – Complexity of applications and uses in real contexts

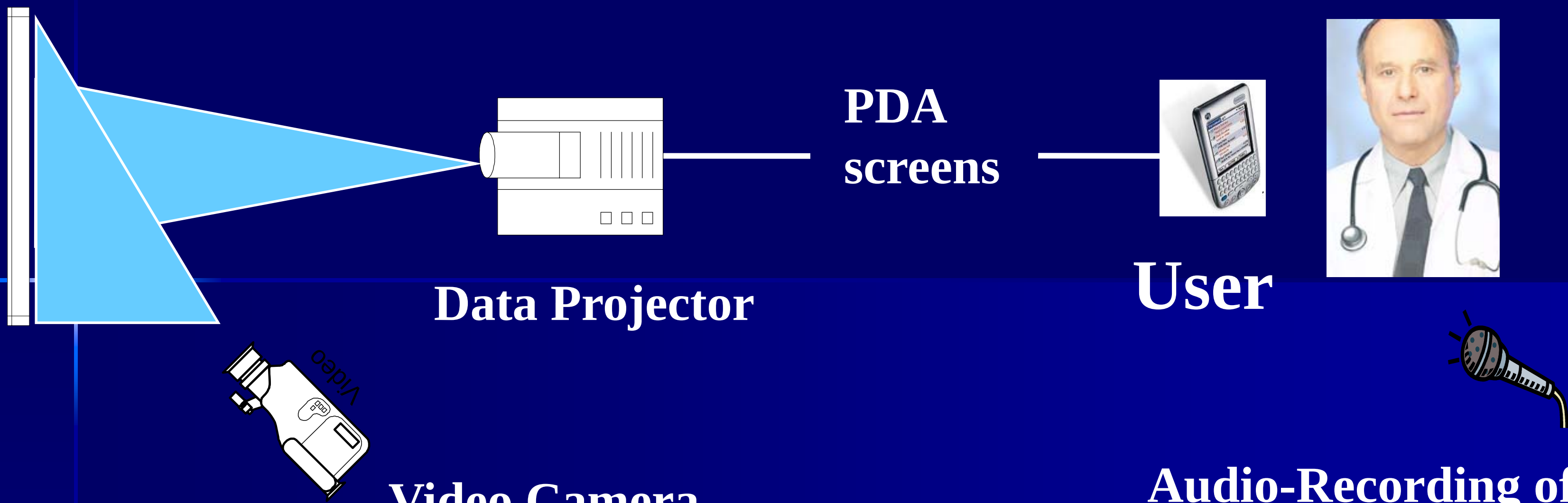
Materials

- **Software**
  - A handheld prescription writing program
  - contains a database of 8,000 medications
  - Allows user to enter and store medications, print and process them

- **Hardware**
  - Visor Pro (Handspring Inc) running Palm OS
  - Also used *Presenter-to-go* to connect to a data projector (or alternatively, directly to a VCR) for video recording sessions

Evaluation Design

- **Subjects**
  - 10 physicians who were all experienced PDA users but who had not used the program being studied
- **Procedure**
  - Each subject received training on use of the program
  - Subjects were then asked to
    - Enter medications from a paper list (as accurately as possible)
    - Read a clinical scenario involving patient cases and enter medications
  - Subjects were asked to “think aloud”
  - All screens of the device were video recorded



1. Data Collection

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2. Data Analysis

Tape of PDA screens

plus "think aloud"

- coding of usability problems
- coding of prescription errors

Fig. 1 Portable Handheld Usability Laboratory
(Kushniruk, Triola, Borycki, Stein, & Kannry, IJMI, in press)

Example of Coded Transcript (of subject "thinking aloud" while entering a medication)

02:26 "Amoxillin, 250 capsules, po, two times a day, is that one of our options q8, darn, q8 hours times 7 days"

SUBJECT ENTERS 250 mg tid X 7 days (30 dispensed)

02:30 "Oh wait, I wanted to dispense, come back. Let me think about that, 7, 8, 24. He just got 6 extra tablets!"

USABILITY PROBLEM #1 – DISPLAY VISIBILITY – not clear that a drop down menu should be used in order to enter "q8h"

ERROR #1 MISTAKE – "tid" entered instead of "q8h"

USABILITY PROBLEM #2 – DEFAULT INAPPRORIATE

ERROR #2 SLIP – 30 dispensed instead of 21

Analysis and Results

- **The transcripts were coded in two independent passes**
  - To identify usability problems
  - To identify medication errors
- **Total number of coded usability problems – 73**
  - most frequent were problems related to display visibility (19), procedure (11), and data entry (9)
- **Total number of errors in entry of meds – 27**

- **37% of the identified usability problems were associated with a medication entry error**
- ***All*** **of the errors were associated with a coded usability problem**
- **Can predict how often usability problem will result in an actual error (for each class of problem)**

Usability Problems and their Relationship to Medication Entry Error (using a PDA application)

Problem	# Usability Problems	Errors	% problem associated with error
EASE OF USE:			
Display Visibility	19	16	84.2
Procedure	11	0	0
Data Entry	9	7	77.8
Printing	8	1	12.5
Locating	6	1	16.7
Navigation	4	0	0
Speed	3	0	0
CONTENT:			
Database	8	0	0
Defaults	3	2	66.7
Training Manual	1	0	0

Slips and Mistakes Detected

- 50 % of the errors in entry of medications were caught (and corrected) by the subjects (and therefore coded as "slips")

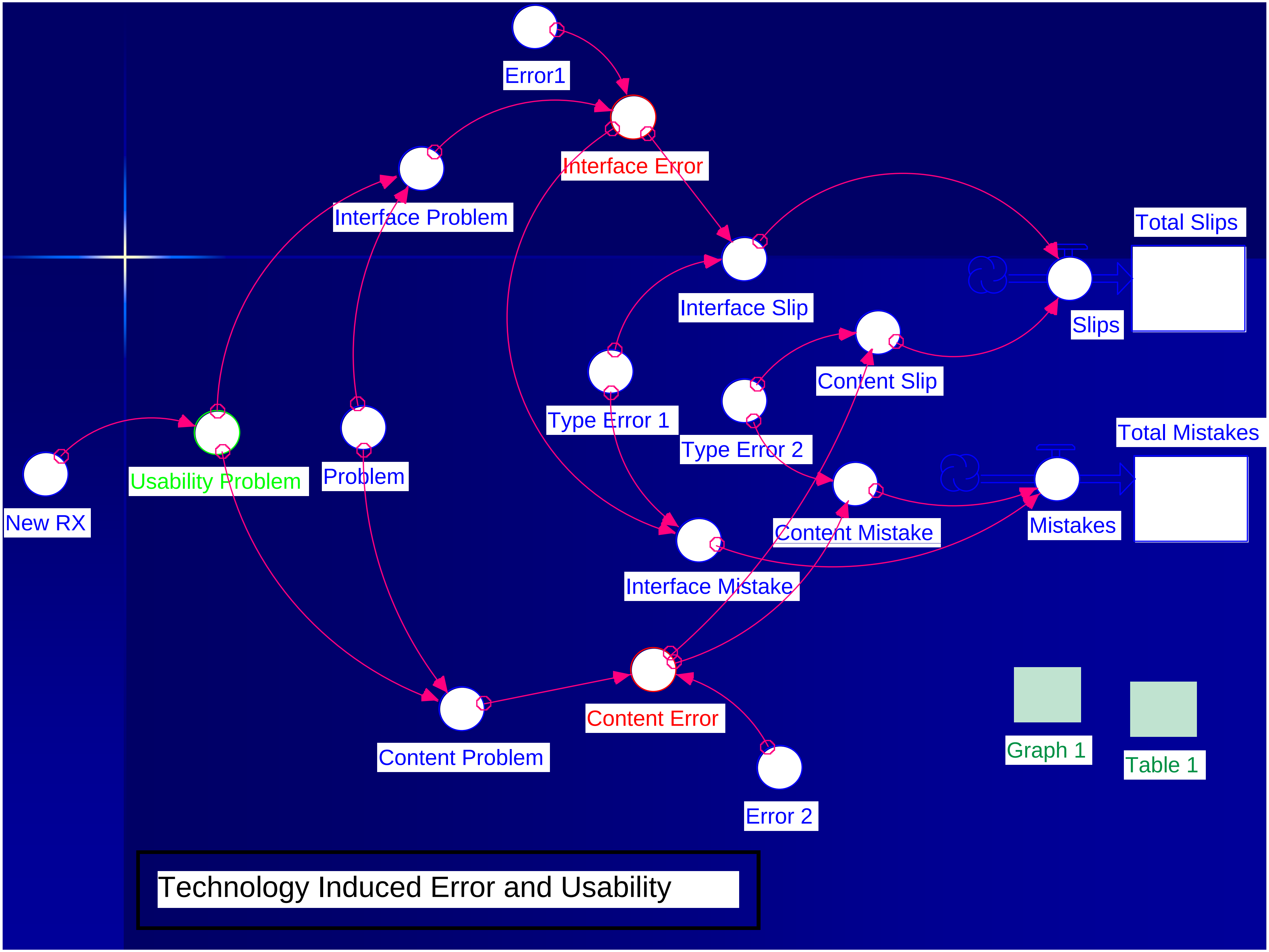
- However, 50% of the errors in the entry of medications were <u>not</u> caught by subjects, resulting in a variety of errors in the final printed prescription

Phase II – Input into Computer Simulation
(Kushniruk, Borycki, Anderson & Anderson, 2008)

Parameter	Value
New RX	Random Number (0-1)
Usability Problem	Probability = 1.00
Interface Problem	Probability = 0.84
Content Problem	Probability = 0.16
Interface Error	Probability = 0.41
Content Error	Probability = 0.167
Interface Slip	Probability = 0.52
Interface Mistake	Probability = 0.48
Content Slip	Probability = 0.50
Content Mistake	Probability = 0.50

Simulation Runs (using Stella)

Runs	Probability of Interface Problem	Probability of Content Problem
Run 1	0.84	0.16
Run 2	0.60	0.16
Run 3	0.40	0.16
Run 4	0.20	0.16

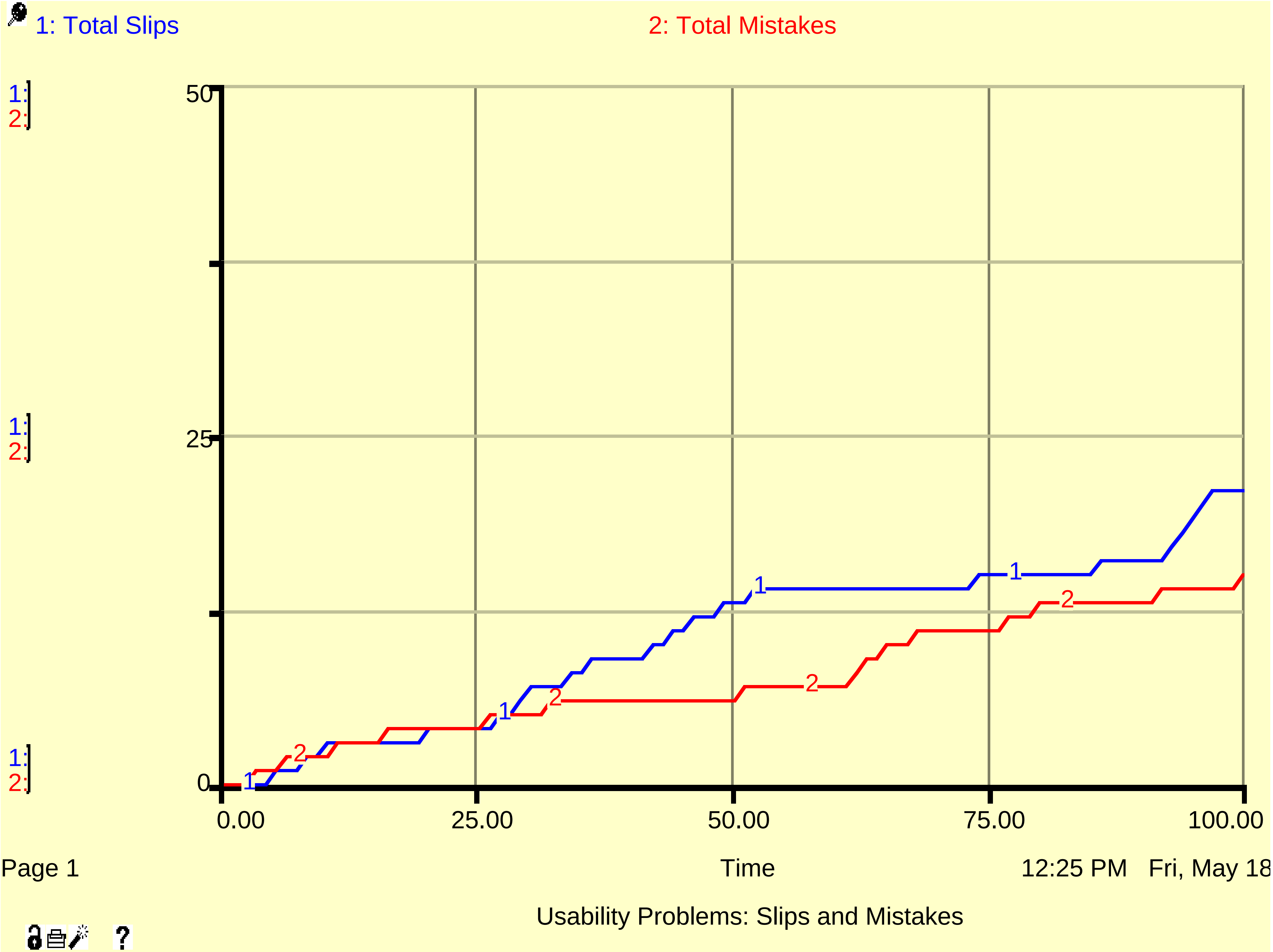

Error1
Interface Error
Interface Problem
Interface Slip
Total Slips
Slips
Content Slip
Type Error 1
Type Error 2
Total Mistakes
Mistakes
Content Mistake
Interface Mistake
New RX
Usability Problem
Problem
Content Error
Content Problem
Error 2
Graph 1
Table 1
Technology Induced Error and Usability

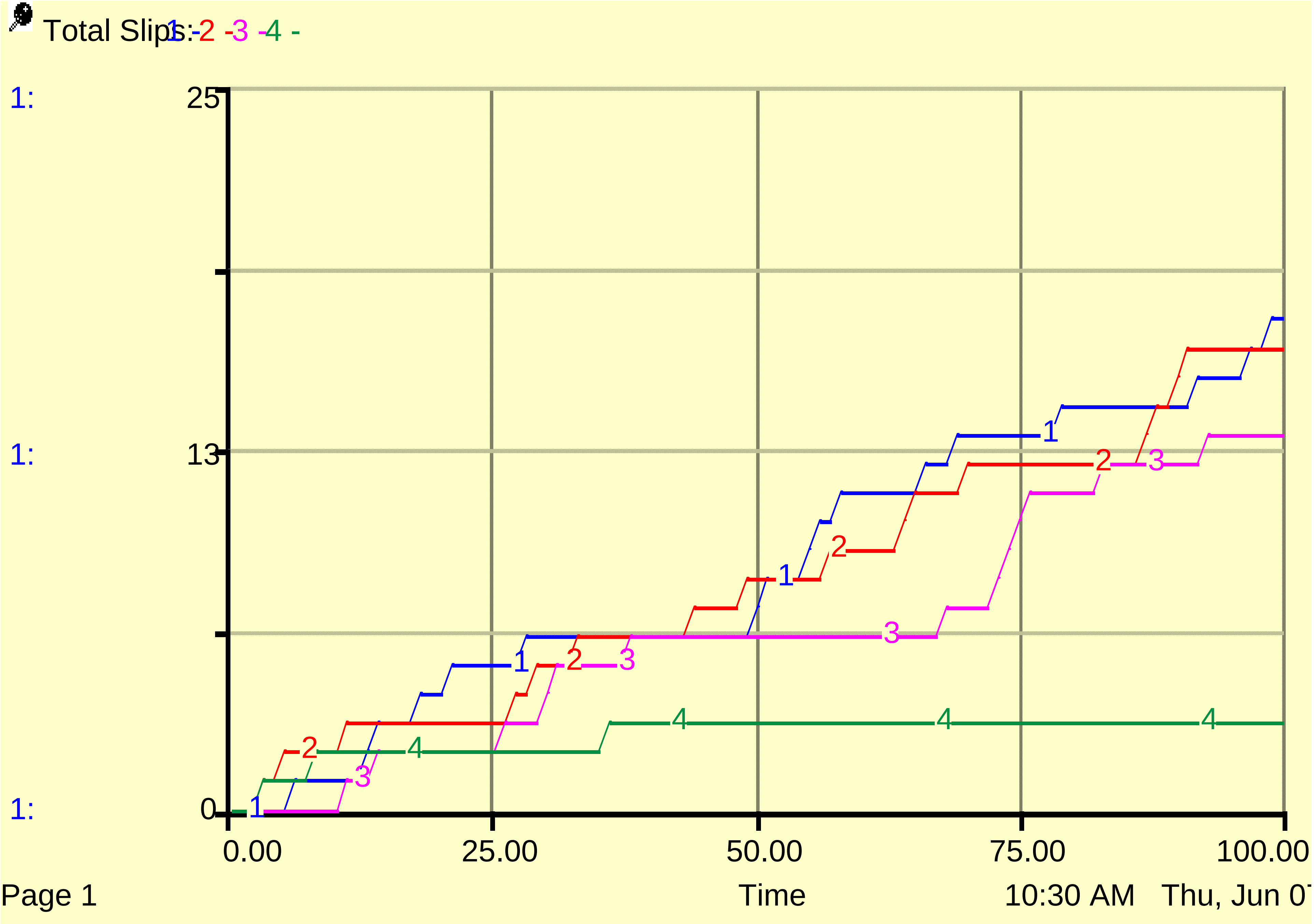
Equations

Total_Mistakes(t) = Total_Mistakes(t - dt) + (Mistakes) * dt
INIT Total_Mistakes = 0

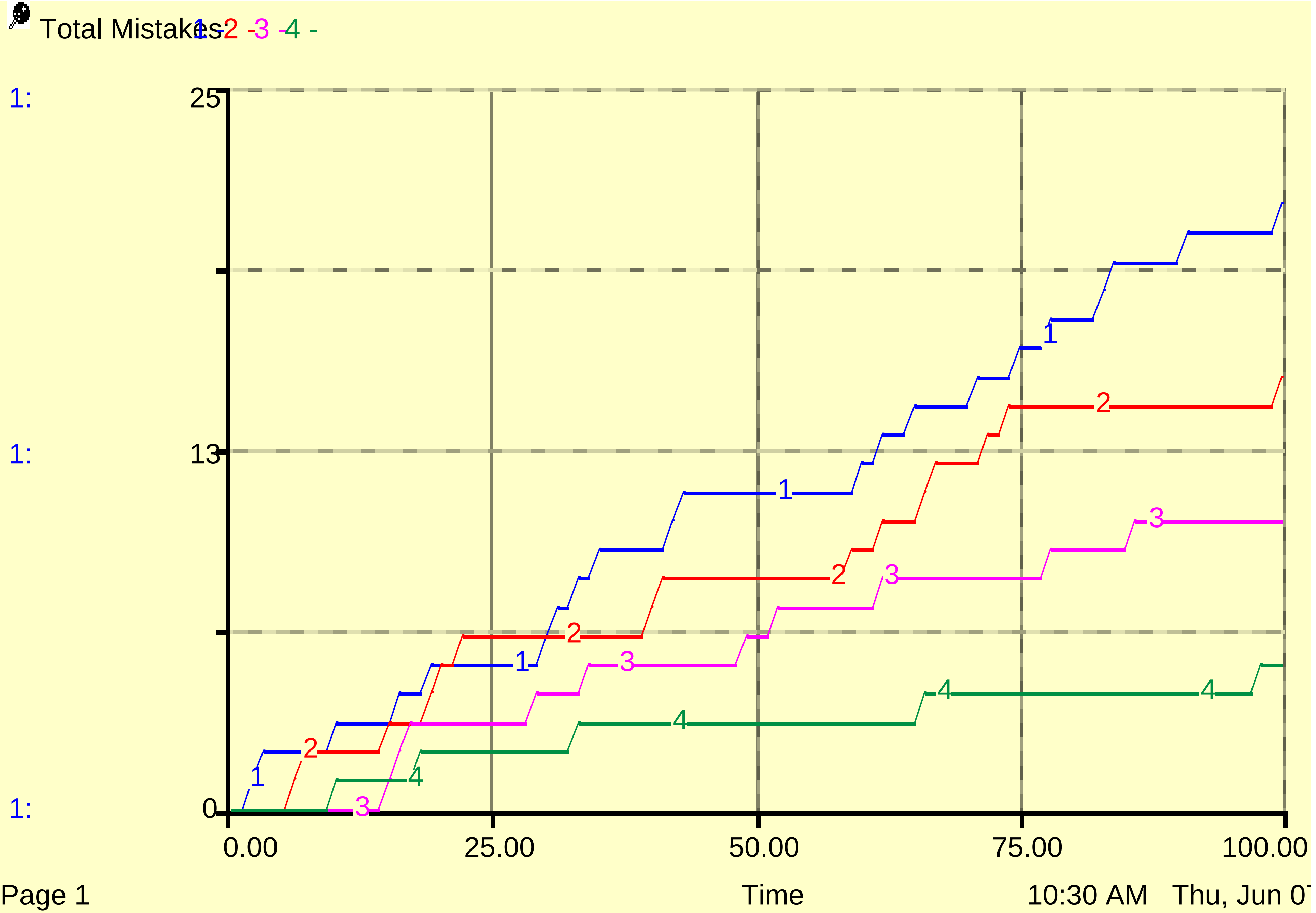
INFLOWS:
Mistakes = Interface_Mistake + Content_Mistake
Total_Slips(t) = Total_Slips(t - dt) + (Slips) * dt
INIT Total_Slips = 0

INFLOWS:
Slips = Interface_Slip + Content_Slip
Content_Error = IF Content_Problem=1 and Error_2<0.167 THEN(1) ELSE(0)
Content_Mistake = IF Content_Error = 1 AND Type_Error_2 > 0.50 THEN(1) ELSE(0)
Content_Problem = IF Usability_Problem =1 AND Problem > 0.84 THEN (1) ELSE(0)
Content_Slip = IF Content_Error=1 AND Type_Error_2<0.50 THEN(1) ELSE(0)
Error_2 = RANDOM(0,1)
Error1 = RANDOM(0,1)
Interface_Error = IF Interface_Problem=1 AND Error1 <0.41 THEN(1) ELSE(0)
Interface_Mistake = IF Interface_Error=1 AND Type_Error_1>0.52 THEN(1) ELSE(0)
Interface_Problem = IF Usability_Problem=1 and Problem<0.84 THEN (1) ELSE (0)
Interface_Slip = IF Interface_Error=1 AND Type_Error_1<0.52 THEN(1) ELSE(0)
New_RX = RANDOM(0,1)
Problem = RANDOM(0,1)
Type_Error_1 = RANDOM(0,1)
Type_Error_2 = RANDOM(0,1)
Usability_Problem = IF(New_RX <1.00) THEN(1) ELSE(0)


1: Total Slips
2: Total Mistakes
50
25
0
0.00
25.00
50.00
75.00
100.00
Page 1
Time
12:25 PM Fri, May 18
Usability Problems: Slips and Mistakes



Comparative Graph of Total Slips



Comparative Graph of Total Mistakes

Conclusions

- Results from usability testing, inspection methods, clinical simulations and computer-based simulations may provide a useful approach to assessing the usability (and error rates) of healthcare systems
- The approach is being refined (and packaged) so that it can be disseminated into healthcare organizations
- Need for combination of approaches to predict, understand and prevent potential negative system impact