Adherence Engineering to Reduce Central Line Associated Bloodstream Infections

Frank A. Drews
University of Utah
IDEAS, VAMC Salt Lake City

Hosted by
Dr. Hugo Sax
University Hospital of Zurich, Switzerland

"Human error in medicine, and the adverse events which may follow, are problems of psychology and engineering not of medicine." John Senders, 1993

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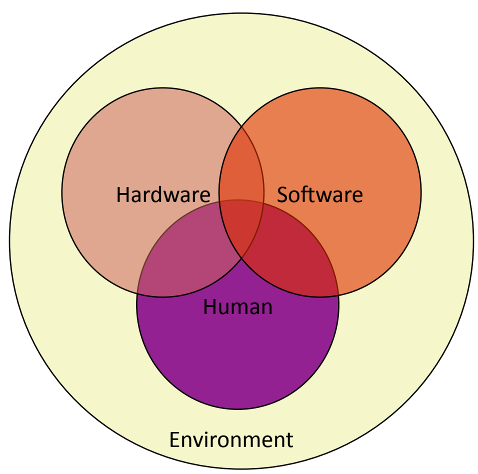
Human Factors

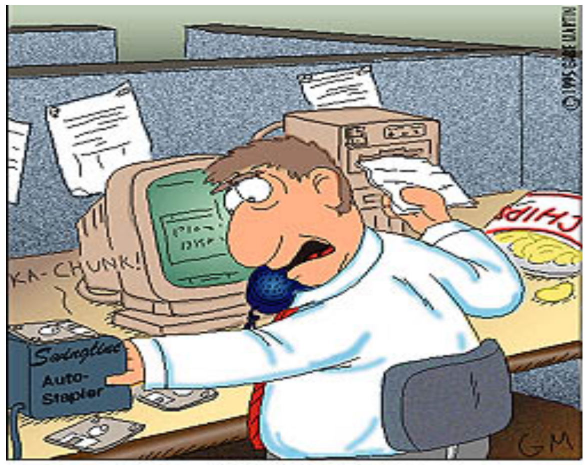
That field involving research into human psychological, social, physical and biological characteristics, maintaining the information obtained from that research, and working to apply that information with respect to the design, operation or use of products or systems for optimizing human performance, health, safety and / or habitability.



2

Human Factors

- Accidents



When multi-tasking breaks down.

3

Human Error

- Human Error
  - 60-90% of causes in major accidents / incidents in complex systems are due to human error

4

Human Factors

- Accidents

5

Field of Human Factors

– Role of human factors
  - Breakdown in interaction between humans and system
    – Usually the systems work well
  - Provides diagnosis and solution

Luckily, Phil's computer was equipped with an airbag and he was able to walk away from this system crash.

6

Field of Human Factors

– Goals of Human Factors
- Reduce error
- Increase productivity
- Enhance safety
- Enhance comfort

7

Field of Human Factors

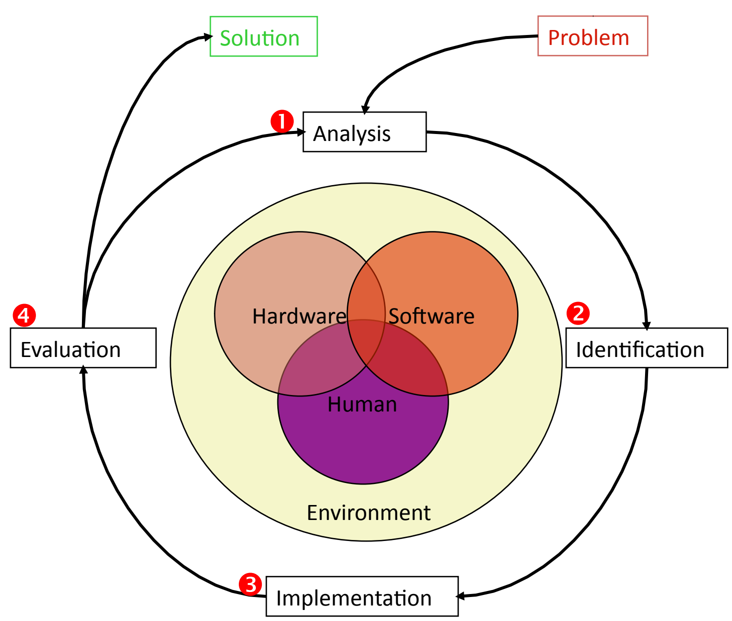
– Applying Human Factors
- Steps in the cycle of human factors
  – Problem
  – Analyze the causes
    » Task analysis
    » Statistical analysis
    » Incident and accident analysis
  – Identify the problems and deficiencies in the human-system interaction

8

Field of Human Factors

- Steps in the cycle of human factors
  - Implementation
    - » Task design (no manual lifting)
    - » Equipment design (readable labels)
    - » Training (physical and mental skills)
    - » Environmental design (lighting, noise, organizational climate)
    - » Selection (no colorblind pilots)
  - Evaluation

9



10

Field of Human Factors

- Successful applications of Human Factors
  - Aviation
  - Nuclear Power Plants

11

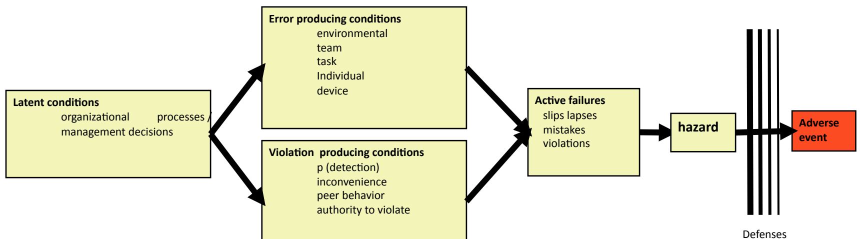
Background

- Two types of performance breakdowns
  - Human Error
    - Planning, memory, and execution
    - Cognitive under-specification
  - Violations
    - Whenever there are standards, rules, regulations
    - People experience them as cumbersome
    - People invent “better” ways of performing a task
    - Cognitive over-specification

12

Background

Contributors to performance breakdowns



13

Background

- Violations
  - Inconvenient to comply, easy to violate, low likelihood of detection (p=0.42; range=0.28-0.58)
  - Compliance fairly important, but chance of detection of violation low (p=0.38; range=0.21-0.55)
  - Socially unacceptable, chance of detection high, chance of bad outcome high (p=0.0001; range=0.00002-0.003)

14

Background

- Conditions that increase the likelihood of violations
  - Low likelihood of detection
  - Inconvenience
  - Authority to violate
  - No disapproving authority figure present
  - Male

15

Background

- When we want people to adhere to best practices, we need to control performance
  - Internal control
    - Training, certification, etc.
  - External control
    - Standardization, protocols, evaluation of performance

16

Adherence Engineering

- Adherence Engineering
  - Conceptual framework to reduce violations and increase protocol adherence
  - Complementary approach to others (e.g., training)
  - Seven guiding principles

Table 1. Adherence Engineering Principles, Implementation Goals, and Implementation

Principle	Goal	Implementation
Affordances	Make use intuitive	Tabs to open kit, visibility of flaps of pockets
Task-intrinsic guidance	Provide structure and preview of task sequence	Sequential order of pockets; when multiple items, then additional information about sequence of use
Nudging	Support adherence by suggesting desirable actions/excluding undesirable actions	Providing hand gel in pockets, providing pen to remind to date the dressing
Smart defaults	Help select desirable actions/ material to perform activity	Selection of materials that if used follow best practices (StatLock, bio patch, site scrub, chlorhexidine scrub)
Feedback	Allow easy resumption and assessment of current performance	Pockets are empty after completion of step, supporting resumption
Minimizing cognitive effort	Support the execution of a task by reducing the required cognitive resources	Chunking of related activities, icons and labels as reminders, structured sequence, reduction in planning needs for procedure, elimination of potential for omission
Minimizing physical effort	Make adherence convenient	Reduction of walking requirements (e.g., to hand gel dispenser, supplies room to pick up missing items); no repeated need to get forgotten materials

17

Adherence Engineering

- Principles
  - Object affordance (Norman, 1988)
    - Create object affordance (a quality of an object/environment allows the performance of an action).

18

Adherence Engineering

- Principles
  - Task intrinsic guidance (Drews et al., 2005)
    - Provide structure
    - Provide preview
  - Nudging (Thaler & Sunstein, 2008)
    - Provide optimized choices
    - Opt-in vs opt-out
  - Smart Defaults
    - Eliminating, minimizing number of choices
    - People are easily overwhelmed with too many choices

19

Adherence Engineering

- Principles
  - Provide feedback (Norman, 1988; Durso & Drews, 2010)
    - Create visibility (e.g., catheter hub swabbing vs capping)
    - Feedback about effectiveness of performance and protocol adherence
    - Permits adherence audits
  - Reduce cognitive effort required for task performance (Fiske & Taylor 1984; Tversky & Kahneman, 1974)
    - People are cognitive misers – they try to minimize cognitive effort whenever possible
    - Extensive planning requirements make it more likely that people do not adhere with procedure
    - But: Yerkes-Dodson law

20

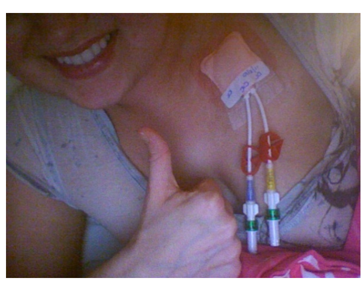
Adherence Engineering

– Principles
- Reduce physical effort required during task performance
  – People do not like to engage in physically effortful activities
  – We try to minimize effort whenever possible
    » Think: When choice between elevator and stairs, what do you take?

21

An application

- Applying Adherence Engineering: Central Line Associated Bloodstream Infections (CLABSI)



22

An application

- CLABSI facts
  - In US approx. 250,000 patients develop CLABSI annually
  - Excessive length of stay (LOS) = 7 days
  - 4-20% mortality rate
  - Costs: $35,000 - $56,000
  - 1/3rd of all preventable death in HC
- Solution: Checklists
  - Pronovost, et al., 2006; Gawande, 2009

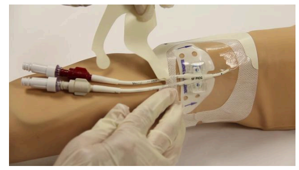
23

An application

- Problems with checklists
  - Require multi-tasking or additional staff to supervise
  - Increase in overall cognitive task load
  - Lead to checklist fatigue
  - Facilitate expectation driven perception
  - Domain of application: Engineered vs. natural systems

24

An application



- Central line maintenance (CLM)
  - A "brittle" procedure
    - Timing of CLM
      - Based on need
      - Identification of last CLM; often missing date on dressing
    - Complexity of CLM
      - Maintenance more than 25 steps
      - If provider error rate is p(error)=.01
        - » 25 step task p(successful execution) = 0.77
    - Performance
      - Novice nurse performance increases likelihood of CLABSI three-fold
      - CLABSI risk increases five-fold with inappropriate central line care

25

An application

- Equipment
  - Current equipment does not support clinicians; nurses spend approx. 5% of their work time searching for equipment
  - Opportunity to redesigning the task / equipment applying Adherence Engineering

26

An application

- Building an alternative: Applying AE

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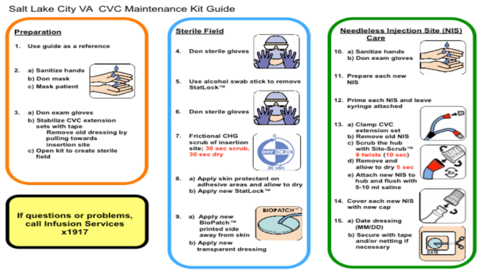
  - Goal: Making adherence effortless

27



28

An application

- Method
  - Observational method (time-motion paradigm)
    - Data collection on tablet PC in ICUs
    - Trained observers (2 ICU nurses)
      - 2 weeks of training
      - Inter-rater reliability >95%
  - 16 month (5 month pre-intervention; 11 month post-intervention) data collection
  - Participants
    - 95 nurses (85 female)
    - Mean experience = 6.7 years
    - All participant nurses received training on kit use
  - Patients
    - n = 151
  - Total of 218 CLM procedures

29

An application

- Results
  - CLABSI rates

	Line Days	CLABSI	CLABSI RATE/1000 line days
Pre-Intervention	7253	**16**	**2.21** (95% CI: 1.26-3.58)
Post-Intervention	4570	**0**	**0.0** (95% CI: 0-0.81)

Incidence Rate Ratio = 0 (95% CI: 0-0.41); **P<.001**

30

An application

- Results
  - Aseptic technique
    - Adherence to best practice
      - Hand sanitization and maintaining aseptic conditions

	Pre-intervention			Post-intervention			
	n	Mean	Median	n	Mean	Median	P
Composite score	128	2.8	3.0	90	4.1	4	**<.0001**

(Composite score max=8)

31

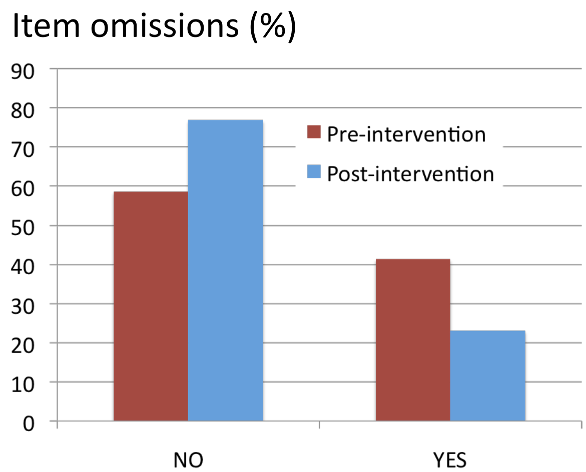
An application

Adherence to best practices

Best Practice	Pre (n=128)	Post (n=90)	Odds Ratio (95% CI)	p
CHG Scrub	102 (81.6%)	80 (96.4%)	**6.01** (1.74-20.7)	**0.005**
Anti-Microbial bandage	114 (97.4%)	79 (93.3)	0.069 (0.14-3.52)	0.66
Hand sanitization	68 (58.6%)	79 (89.8%)	**6.2** (2.83-13.55)	**0.000**
Disinfect catheter hub	30 (28.0%)	63 (76.8%)	**8.51** (4.38-16.53)	**0.000**

32

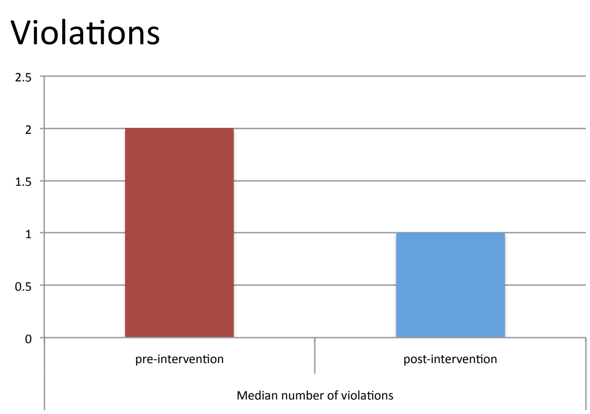
An application



P<0.01

33

An application



P<.01

50% reduction in violations

34

An application

- Changes in kit design based on user feedback

35

An application

- Cost effectiveness of CLM kit
  - Constructed Markov model to compare cost effectiveness of kit compared to standard care (individual collection of items)
  - Assumptions
    - CLABSI cost $45,685
    - Excess LOS
      - » 6.9 ICU days
      - » 3.5 general ward days

36

An application

- Model input data
  - Cost of CLM kit $29.45
  - Cost of separate components $21.82
  - CLABSI rate during observation 0, i.e., 100% reduction
  - Sensitivity analyses
    - Additional analysis with rate reduction ranging from 100% to 1%

		Range		
Description	**Mean**	**Lower**	**Upper**	**Source**
Baseline CLABSI rate[a]	3.1	1.6	5.1	[18]
Reduction in CLABSI rate with CLM kit	100%	0%	100%	[18]
Baseline mortality				
ICU	13.5%	8.0%	19.0%	[31-33]
Ward	2.0%	0.25%	5.5%	[34]
CLABSI-related events				
Mortality rate - RR for CLABSI patients	2.27	1.15	4.46	[35]
Extra days in ICU	6.9	3.50	9.60	[30]
Extra days on hospital ward	3.5	3.40	5.60	[30]
Mean number of central line days per patient[b]	7.14	2.69	13.72	[29]
Utility				
ICU	0.66	0.50	0.80	[36]
Costs				
CLABSI	$46,485	$31,372	$66,201	[30]
Vancomycin	$154	$145	$165	SLCVA
Cost per day (ward)	$3,822	$3,577	$4,068	SLCVA
Cost per day (ICU)	$6,288	$5,003	$7,572	SLCVA
Kit	$29.45	$25	$35	MEDClick
Kit components separate	$21.82	$15	$25	MEDClick

37

An application

- Results
  - 100% reduction of CLABSI rate
    - Kit approach saves $860 / per patient
  - 50% reduction of CLABSI rate
    - Kit approach saves $400 / per patient
  - Sensitivity analysis
    - Kit saves money even with a CLABSI risk rate reduction of 2%

38

An application

- Discussion
  - Elimination of CLABSI beyond study interval for 18 month
  - Kit was adopted in hospital and is currently in use
  - Clear improvement in adherence to best practices, but still space for improvement
  - Fewer item omissions

39

An application

- Discussion
  - Overall a significant cost reduction associated with the use of a CLM kit
    - A dominant strategy to improve care and reduce cost per patient
  - Support for Adherence Engineering framework in the context of infection prevention

40

An application

- Discussion
  - Intervention in conjunction with other approaches
    - Organizational level feedback (providing unit-based performance data)
    - Organizational redesign (weekly, scheduled central line maintenance)
  - Application in other domains (aviation), especially maintenance tasks

41

Contact

http://www.adherenceengineering.org

Frank.Drews@psych.utah.edu

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42

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