

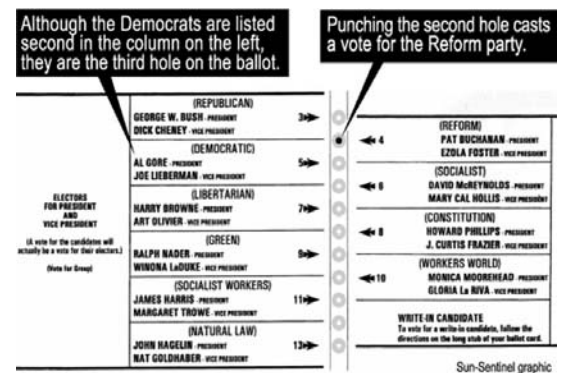
CMPE 233: Human Factors



Human Errors



The Butterfly Ballot



Why did this error happen?

- ▶ Ballot violates conceptual model
- ▶ Ballot violates S-R compatibility (natural mappings): no collocation or congruence between stimulus and response
 - Arrangement of holes (response) incongruent with arrangement of names (stimulus)
 - Visual momentum from reading left-to-right suggests response to the right of the name
 - Violation to Gestalt principles of proximity: separating bar lead democratic vote to second punch hole
- ▶ Ability to detect and correct errors limited
 - No feedback to check response
 - No easy way to correct errors



How common?

- ▶ Human operator accounted for over 90 % of the documented air traffic control system errors
- ▶ Over 50 % of all technical medical equipment problems are due to operator errors
- ▶ Up to 90 % of accidents both generally and in medical devices are caused by human mistakes
- ▶ A study of 23000 defects in the production of nuclear components revealed that approximately 82 % of the defects were due to human errors
- ▶ During the period from June 1 1973 to June 30 1975, 401 human errors occurred in US commercial light water nuclear reactors

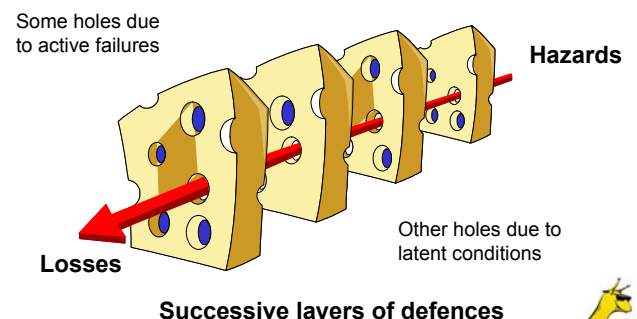


What is human error?

- ▶ Sanders & McCormick (1976)
 - Inappropriate or undesirable human decision or behavior
 - that reduces, or has the potential for reducing, effectiveness, safety, or system performance
- ▶ Reason (1990, 1997)
 - Occasions in which a planned sequence of mental or physical activities fails to achieve its intended outcome
 - and when these failures cannot be attributed to the intervention of some chance agency
 - *Local trigger* or *active failure*: final event (in a series of events) that leads to a disaster
 - *Resident pathogens* or *latent conditions*: collection of factors that represent an accident waiting to happen (because resources are diverted to more immediate needs)

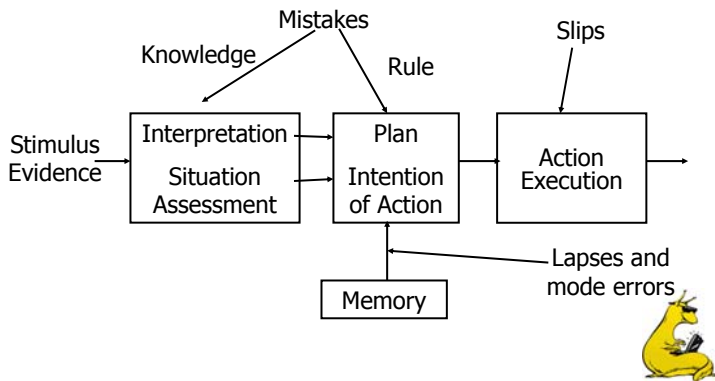


James Reason's Swiss Cheese model of organizational accidents



Taxonomy of Human Error

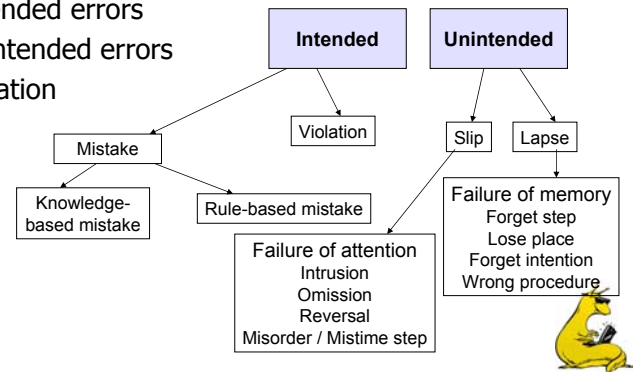
- What type of error did people commit with the butterfly ballot?



Error classification

- Errors of commission
- Errors of omission
- Intended errors
- Unintended errors
- Violation

Rasmussen's SRK model



SB, RB and KB errors

Dimension	SB errors	RB errors	KB errors
type of activity	routine actions	problem-solving activities	
focus of attention	on something other than the task in hand	directed at problem-related issues	
control mode	mainly by automatic processors (schemata)	(stored rules)	limited, conscious processes
predictability of error types	largely predictable (actions)	(rules)	variable
ratio of error to opportunity to error	though absolute numbers may be high, these constitute a small proportion of the total number of opportunities for error	absolute numbers small, but opportunity ratio high	
influence of situational factors	low to moderate; intrinsic factors (frequency of prior use) likely to exert the dominant influence	extrinsic factors likely to dominate	
ease of detection	detection usually fairly rapid and effective	difficult, and often only achieved through external intervention	
relationship to change	knowledge of change not accessed at proper time	when and how anticipated change will occur unknown	changes not prepared for or anticipated

(Reason, 1990, *Human Error*)

RB failure modes

- RB = tackling unfamiliar anticipated problems by stored rules which are learned by explicit training and by experience
- Misapplication of good rules:
 - First exceptions (*first-but-now-wrong rule*)
 - Signs, countersigns and non-signs
 - Information overload
 - Rule strength
 - General rules
 - Redundancy
 - Rigidity
- Application of bad rules:
 - Encoding deficiencies in rules
 - Action deficiencies in rules

- ERRORS OF OMISSION**
 - Omits entire task
 - Omits a step in a task
- ERRORS OF COMMISSION**
 - Selection error
 - Selects wrong control
 - Misposition of controls
 - Issue wrong command on info
 - Errors of Sequence
 - Timing Errors
 - Too Early
 - Too Late
 - Qualitative Errors
 - Too Little
 - Too Much

SB failure modes

- SB = effortless routine actions that take place as smooth, automated and highly integrated patterns of behavior
- Inattention (omitted checks):
 - Omissions following interruptions
 - Delay between intention and execution
 - Perceptual confusions
 - Interference errors
- Over-attention (mistimed checks):
 - Omissions
 - Repetitions
 - Reversals

KB failure modes

- ▶ KB = tackling unfamiliar unanticipated problems through reasoning to diagnose and solve problems, identify deep features about a situation, adapt plans and responses to the needs of the situation in the absence of pre-packaged solutions



KB failure modes

- ▶ Selective processing of information
- ▶ Limitation of space in working memory
- ▶ Availability heuristic (*out of sight out of mind*)
- ▶ Confirmation bias
- ▶ Overconfidence
- ▶ Biased reviewing
- ▶ Halo effect (*expecting based on previous response*)
- ▶ Hindsight bias (*I knew it all along*)
- ▶ Problems with complexity:
 - Problems with delayed feedback
 - Insufficient consideration of processes in time
 - Difficulties with exponential developments
 - Thematic vagabonding (*flitting from one topic or area of a problem to another without sufficient time or effort being expended to resolve the problem*)
 - Encysting (*paralysis by analysis*)

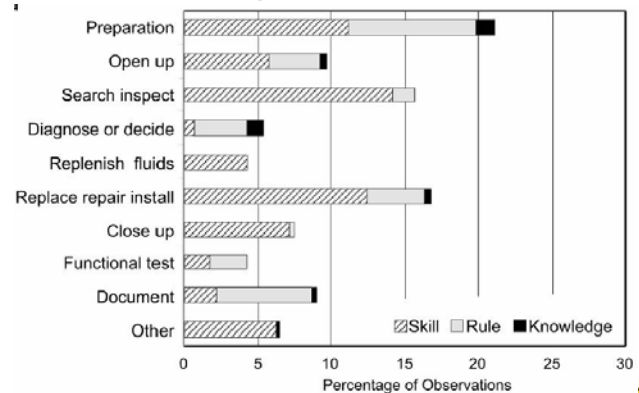


Study of aircraft maintenance

- ▶ Hobbs & Williamson, 2002, *Ergonomics*
- ▶ Observations of the work of 25 aircraft mechanics:
 - Activity sampling technique
 - Task analysis checklist
 - 666 observations
- ▶ Interviews with 72 maintenance workers:
 - Using critical incident technique
 - 101 critical incidents reported
 - 3 categories of incidents:
 - ▶ Behavioral events: error / acceptable behavior
 - ▶ Environmental events
 - ▶ Equipment-related events



SRK performance



Outcomes of 101 critical incidents

Number of cases

Incidents with airworthiness implications

Aircraft returned to operations with maintenance-induced anomaly	17
Damage to aircraft	16
Correction of maintenance-induced anomaly before aircraft returned to operations	12
Potential damage to aircraft	8
Flight delay	5
Failure to correct pre-existing anomaly during maintenance	1
Total incidents with airworthiness implications	59

Incidents with worker health and safety implications

Potential hazard	35*
Actual hazard	16
Total incidents with health and safety implications	51

*Nine cases of potential hazard also had airworthiness implications (5 potential damage to aircraft, 3 damage to aircraft, 1 flight delay).



Errors and opportunities for errors

Table 5. Errors, opportunities for error, and ratio of errors to opportunity for error for non supervisory mechanics.

Performance level	Percent of errors at each level*	Percent of task analysis observations at each level**	Ratio of errors to opportunity for error */**
Skill	45.5	64.9	0.70
Rule	47.5	31.5	1.51
Knowledge	7.1	3.5	2.03



Human error occurrence types

- **Design errors:** the result of inadequate design, eg the placement of controls and displays so far apart that an operator is unable to use them in an effective manner
- **Operator errors:** the result of operator mistakes and the conditions that lead to operator errors include lack of proper procedures, complex taxonomy, poor training and operator carelessness
- **Assembly errors:** occur during product assembly due to humans
- **Inspection errors:** occur because of <100% accuracy of inspectors
- **Maintenance errors:** occur in the field due to oversights by the maintenance personnel
- **Installations errors:** occur due to various reasons including using the wrong installation related blueprints or instructions
- **Handling errors:** occur because of inadequate storage or transportation facilities



Causes for the occurrence

- Poor motivation of involved personnel
- Poor training or skill of concerned personnel
- Poor equipment design
- Inadequate or poorly written equipment operating and maintenance procedures
- Poor job environment: poor lighting, uncomfortable temperature, high noise level, crowded work space, ,etc
- Inadequate work tools
- Complex tasks
- Poor work layout



Where errors happen in the process

- **Decision error:** occur when the wrong decision is made after considering the situation
- **Action error:** are the result of no action ,incorrect action ,or the performance of correct action on the wrong object when required
- **Transmission error:** occur when information that must be passed or to others is not sent, sent incorrectly, or sent to the wrong destination
- **Checking error:** occur when system require checks, the incorrect checks are made ,checks are omitted ,or correct checks are made on the wrong object
- **Diagnostic errors:** are the result of misinterpreting the actual situation when an abnormal event occurs
- **Retrieval errors:** occur when required info either from an individual, an individual memory, or from any other ref source is not received or the incorrect info is received



More Psychological Categories

- Perception error: mis/not heard, mis/not seen

Internal Error Mode	Internal Error Mechanism
Perception	
Mishear Mishearing information.	Expectation Perceptual errors driven by expectations.
Mis-see Misreading, misperceiving, or misidentifying visual information.	Confusion Misidentifications and misperceptions due to similar or confusable of appearance or spatial position.
No detection (auditory) Failing to detect, or being late to recognise the significance of, information.	Discrimination failure Failing to see or hear something that is vague or of short duration.
No detection (visual) Failing to detect or identify visual information, or detecting information too late to be effective.	Tunnel vision Fixating, tunnelling or 'black-holing' on information, to the exclusion of other relevant information.
	Overload A large amount of incoming information.
	Distraction / Preoccupation Momentary distraction or longer-term preoccupation.

More Psychological Categories

- Memory error: forgotten, mis/not recalled

Internal Error Mode	Internal Error Mechanism
Memory	
Omitted or late action Forgetting to perform a planned task, or missing a step in a task sequence (including monitoring information/people).	Confusion Other (e.g. similar) information interferes with memory.
Forget information Forgetting information or previous actions.	Overload Too much information to retain in memory.
Misrecall information Misremembering temporary or longer-term	Insufficient learning A learning problem or negative transfer of
	Mental Block A mental block - just cannot recall information.
	Distraction / Preoccupation Momentary distraction or longer-term



More Psychological Categories

- Decision error: planning, decision making

Internal Error Mode	Internal Error Mechanism
Decision Making	
Misprojection Misprojecting or misjudging spatial-temporal information	Misinterpretation Failure to integrate, calculate or understand information.
Poor decision or poor plan Poor decision or inadequate plan.	Failure to consider side- or long-term effects Unforeseen side- or long-term effects.
Late decision or late plan Acceptable decision or plan formed too late to be fully effective.	Mind set Sticking to a faulty plan, belief or interpretation, perhaps even despite evidence to the contrary.
No decision or no plan No decision made or no plan formed	Knowledge problem Lacks required knowledge due to training or learning.
	Decision freeze Decision 'freeze' due to complexity or emotion.



More Psychological Categories

- ▶ Action error: in executing action

Internal Error Mode	Internal Error Mechanism
Action	
Selection error Unintended manual selection or positioning.	Variability Lack of manual precision, fluency or intonation.
Unclear information Transmitting or recording unclear, vague or ambiguous information.	Confusion Selecting an object that looks similar to another, is in a confusable position, or is functionally similar.
Incorrect information Inadvertently transmitting or recording incorrect information.	Intrusion Thoughts, habits or task interference effects cause a controller to do or say something unintended.
	Distraction / Preoccupation Momentary distraction or longer-term preoccupation.
	Other slip Other slip of the tongue, pen, action etc.



Collecting human error data

- ▶ Experimental studies
- ▶ Expert judgments
- ▶ Self made error reports
- ▶ Human data recorder
- ▶ Automatic data recorder
- ▶ Published literature
- ▶ Human error data banks and sources



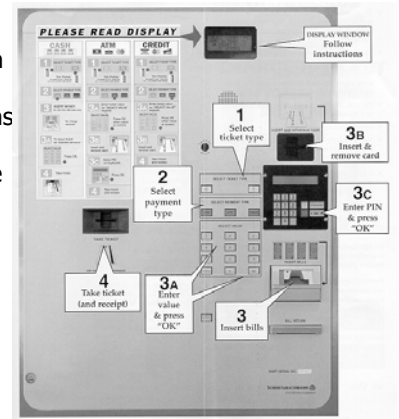
Human error data banks

- ▶ Data store
 - Established in 1962 by American Institute for Research, Pittsburgh and it contains estimates for time and human performance
- ▶ Operational performance recording and evaluation data system
 - developed to collect data on operational human performance by the US Navy Electronics Laboratory, San Diego
- ▶ Nuclear plant reliability data system
- ▶ Aviation safety reporting system
 - developed by NASA and contains information on civil aircraft accidents
- ▶ Safety related operator action program
- ▶ Technique for establishing personnel performance standards



Detecting Error: TAFEI

- ▶ Task Analysis for Error Identification
- ▶ Model of human interaction with products
- ▶ Consider possible transitions for each state
- ▶ Ask whether transitions are 'legal', (needed to fulfil specific goal)



Error Remediation

- ▶ Task Design: perform a Task Analysis
 - identify potential performance bottlenecks (eg, high working memory or attentional loads, stressors, etc)
 - eliminate these bottlenecks by changing the human component of the task
- ▶ Equipment Design:
 - minimize perceptual confusion, make components distinctive (bad eg, space shuttle)
 - Design systems to be error-tolerant (feedback, error correction)
 - forcing functions: physical constraints that prevent operators from committing an error (eg, transmission locks)
 - Reminders (eg, "lights are on")
 - Avoid multi-mode systems
- ▶ Train for Errors: during training make sure some errors happen--learn the hard way!

