Use of IDHEAS to Generalize Human Performance Data for Estimation of Human Error Probabilities

Jing Xing, Y. James Chang
US Nuclear Regulatory Commission

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U.S.NRC
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Protecting People and the Environment

What's next in human reliability analysis – DATA, DATA, DATA

- Existing human error data – from various fields, in different formats, varying context and levels of details

- Data generalization and use for human reliability analysis - the Integrated Human Event Analysis System (IDHEAS) has an inherent structure for generalizing and integrating human error data

Human error data: The ideal world and reality

$$\text{HEP (failure mode under specific context)} = \frac{\text{\# of errors (failure mode)}}{\text{\# of Occurrence (under the context)}}$$

- Ideal world:

- The same task for a failure mode is repeated thousands of times with the same people under the identical context;
- Do this for all possible contexts

Failure modes	# Occurrence	Context	Variety
✓ Well-defined failure modes	✓ Known, sufficient number of task occurrences	✓ Context clearly defined and repeated	✓ Sufficient data for all failure modes and contexts

Human error data: The ideal world and reality

$$\text{HEP (failure mode under specific context)} = \frac{\text{\# of errors (failure mode)}}{\text{\# of Occurrence (under the context)}}$$

- Reality:

X Failure modes unknown
X Number of occurrences not reported
X Context undocumented and/or unrepeated
X Lack of variety – limited failure mode / context tested
X Not talking to each other

Type of human error data	Failure modes	# Occurrence	Context	Variety
Statistical	X	X	X	✓
Human error analysis	✓	X	X	✓
Operational database	✓	✓	Unrepeated	Limited
Experimental	✓	✓	✓	X

Examples of statistical data

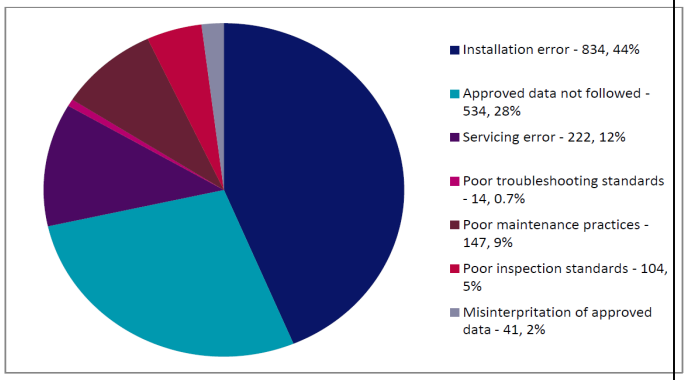
- Statistical study in 2016 - Medical errors are the third leading cause of death in the U.S., after heart disease and cancers, causing at least **250,000** deaths every year (Ref. 1)

- France - Nuclear Power plant replacement of the Dungeness B Data Processing System - The installation team completed 22,000 plant connections to the new system with a less than **2%** error rate. (Ref. 3)

- X Occurrence of the tasks not reported
- X Failure modes unspecified
- X Context undocumented and unrepeated

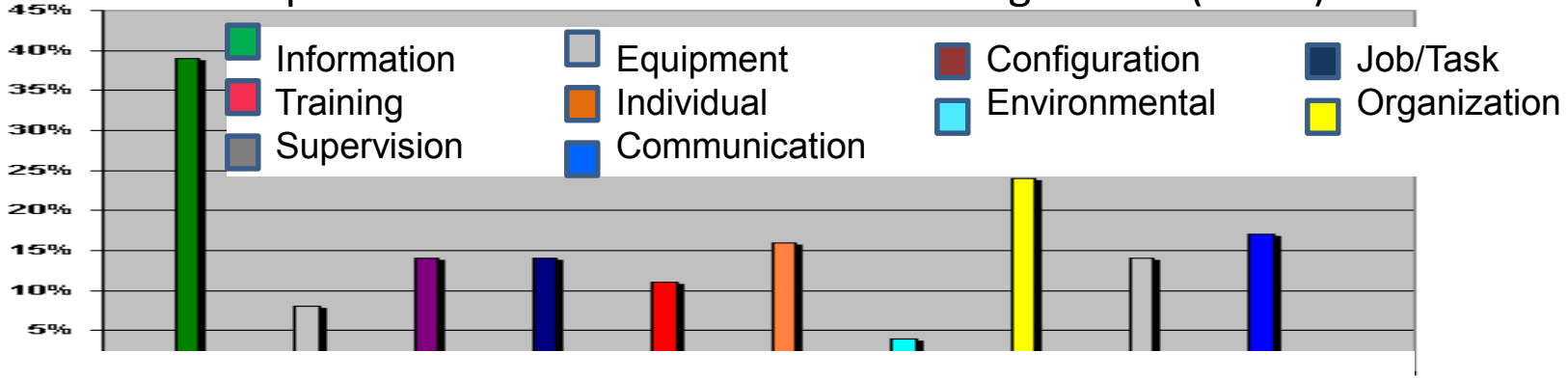
Examples of human error analysis / root causal analysis

- Percent of error types (failure modes) – Airplane maintenance errors (Ref. 6)



Installation error - 44%
Approved data not followed - 28%
Servicing error - 12%
Poor troubleshooting standards - 0.7%
Poor maintenance practices - 9%
Poor inspection standards - 5%
Misinterpretation of approved data - 2%

- Percent of Airplane maintenance error contributing factors (Ref. 7)



- ✓ Failure modes / contributing factors classified and ranked
- X Occurrence of the tasks not reported
- X Relation between failure modes / contributing factors unspecified

Examples of observed human error rates in operations (human performance databases)

- Error rates for nuclear power plant maintenance tasks (Ref. 4):
  - **1/7** for transporting fuel assemblies with the fuel handling machine
  - **1/48** for removing a ground connection from a switchgear cabinet
  - **1/888** for reassembly of component elements

- Reported error rates in medical pharmacies (Ref. 5):
- **5%** for failure to select ambiguously labeled control/package
- **2%** for failed task related to values/units/scales/indicators
- **0.6%** for procedural omission

- ✓ Human error rates reported for the failure modes
- X ✓ Relation of failure mode / contributing factors (maybe) unspecified

Example: Human error rates in experimental studies

The effect of incomplete information on decision-making in simulated pilot de-icing (Ref.8)

Task: Make decision on de-icing in flight simulation under icing weather

Failure mode: Incorrectly select or use information for decision-making

Context: Incomplete or unreliable information (30%), time pressure

Results: Providing additional accurate information improves handling of icing encounters. Performance drops below the baseline when inaccurate information (high uncertainty) is provided in the decision-aid.

% error

	Accurate and additional information	Accurate and incomplete information	Inaccurate additional information
% Stall	18.1	30	89
% recovery	26.7	63.8	75

- ✓ Failure modes, error rates, and specific context reported
- ✓ Quantitative impact of specific context factors reported
- X Not generalized for more complex context with multiple factors

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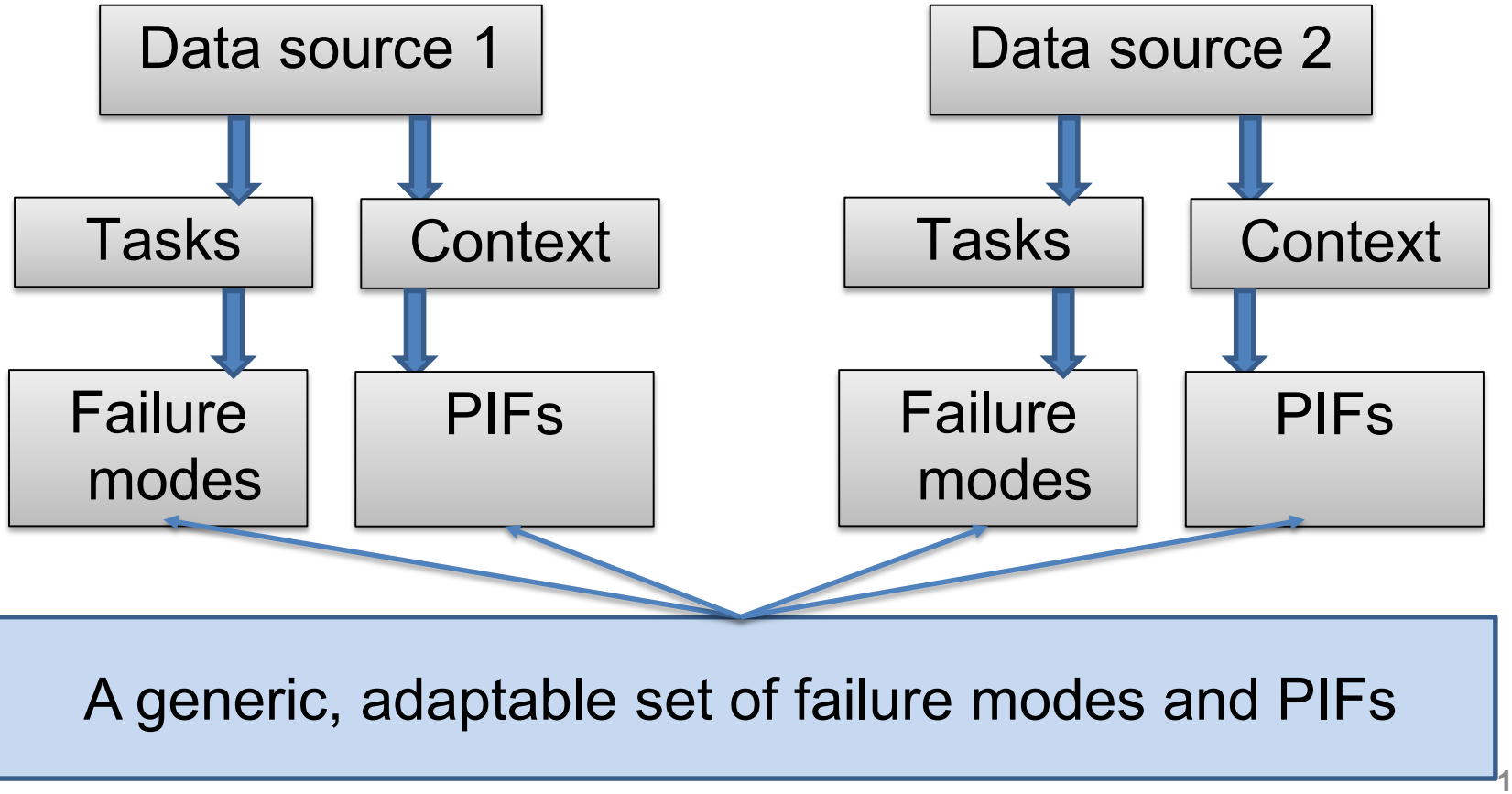
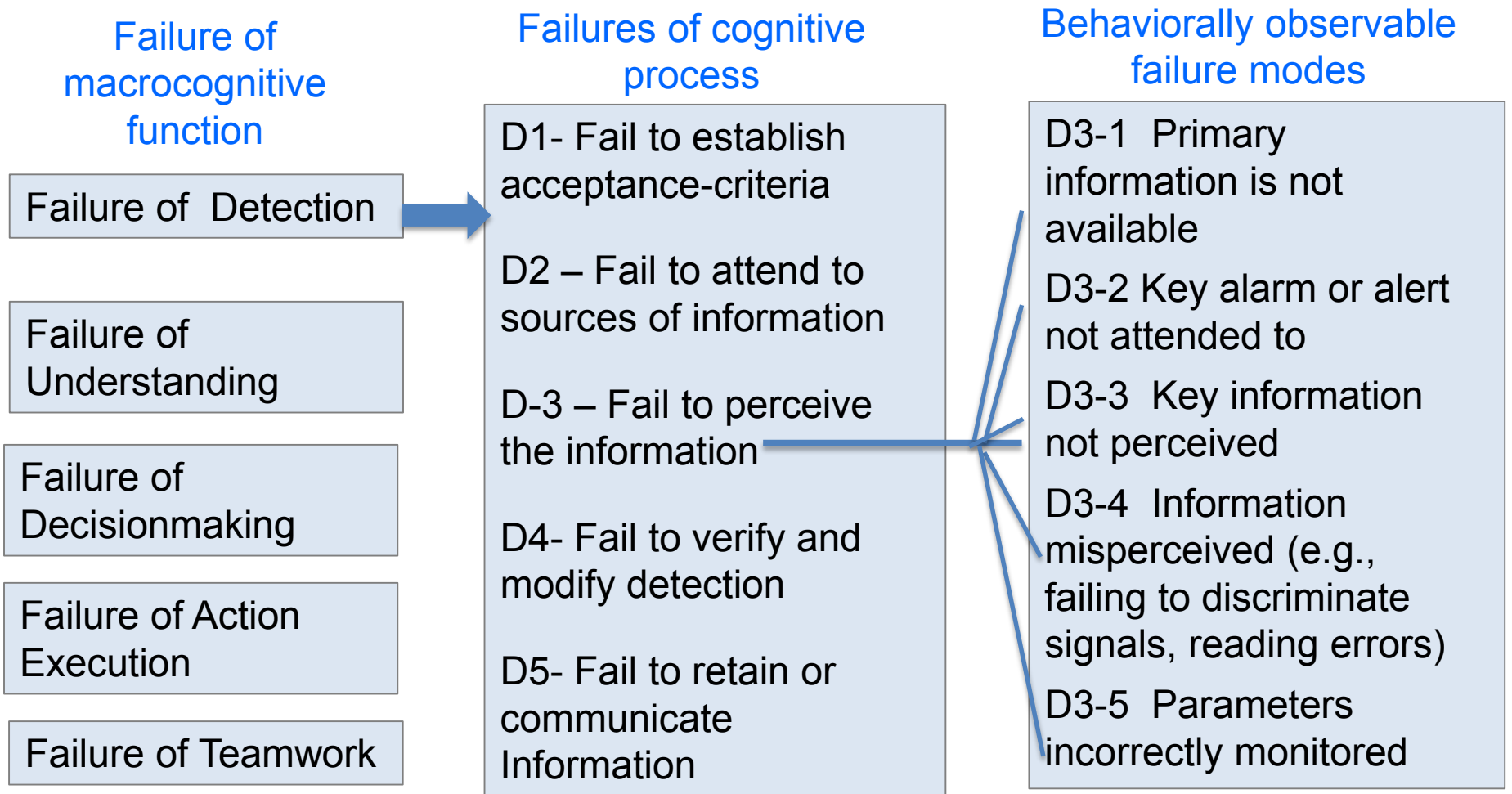
Generalizing human error data to inform human error probability estimation

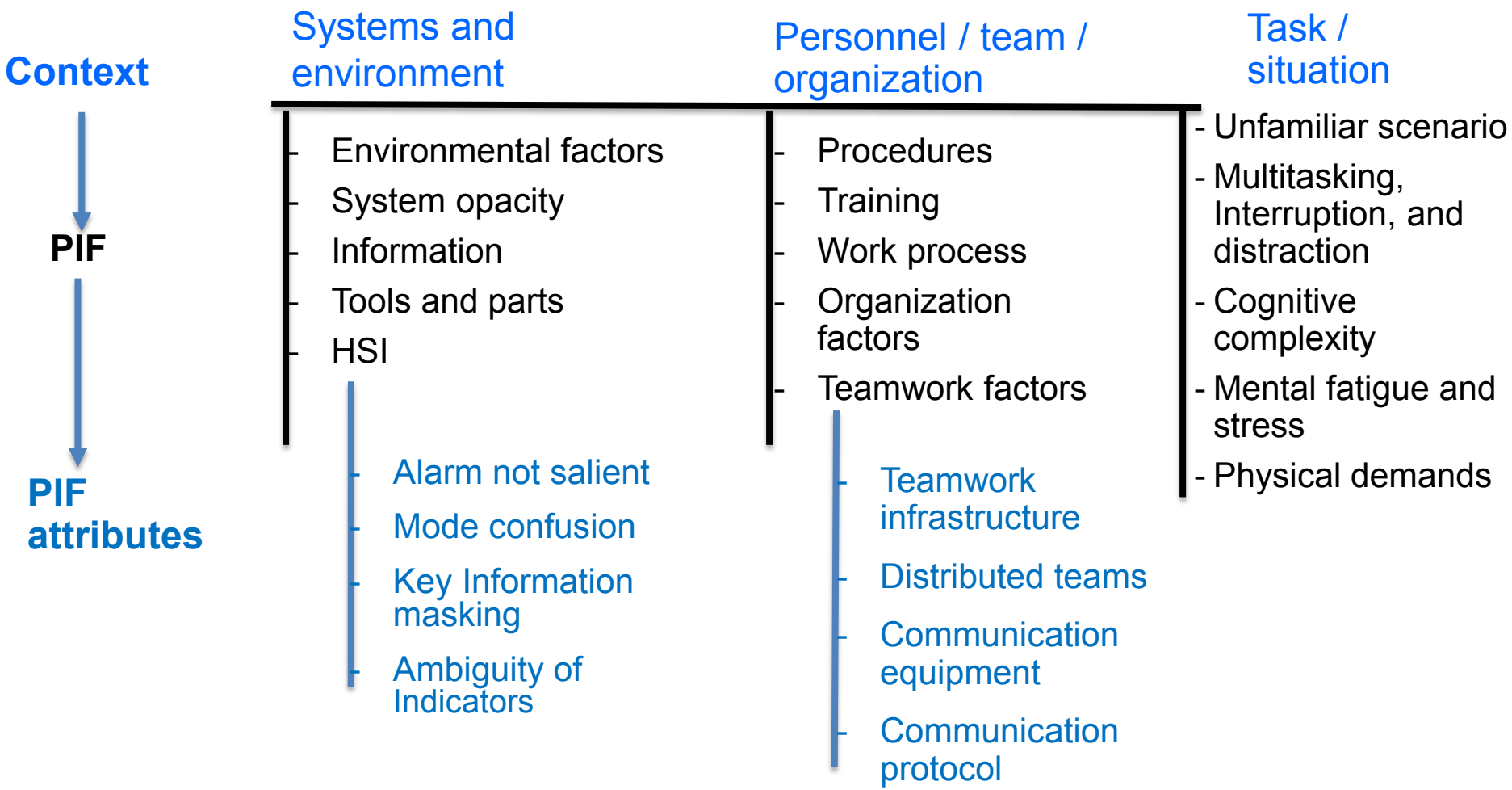
HEP = *f*(states of performance influencing factors)



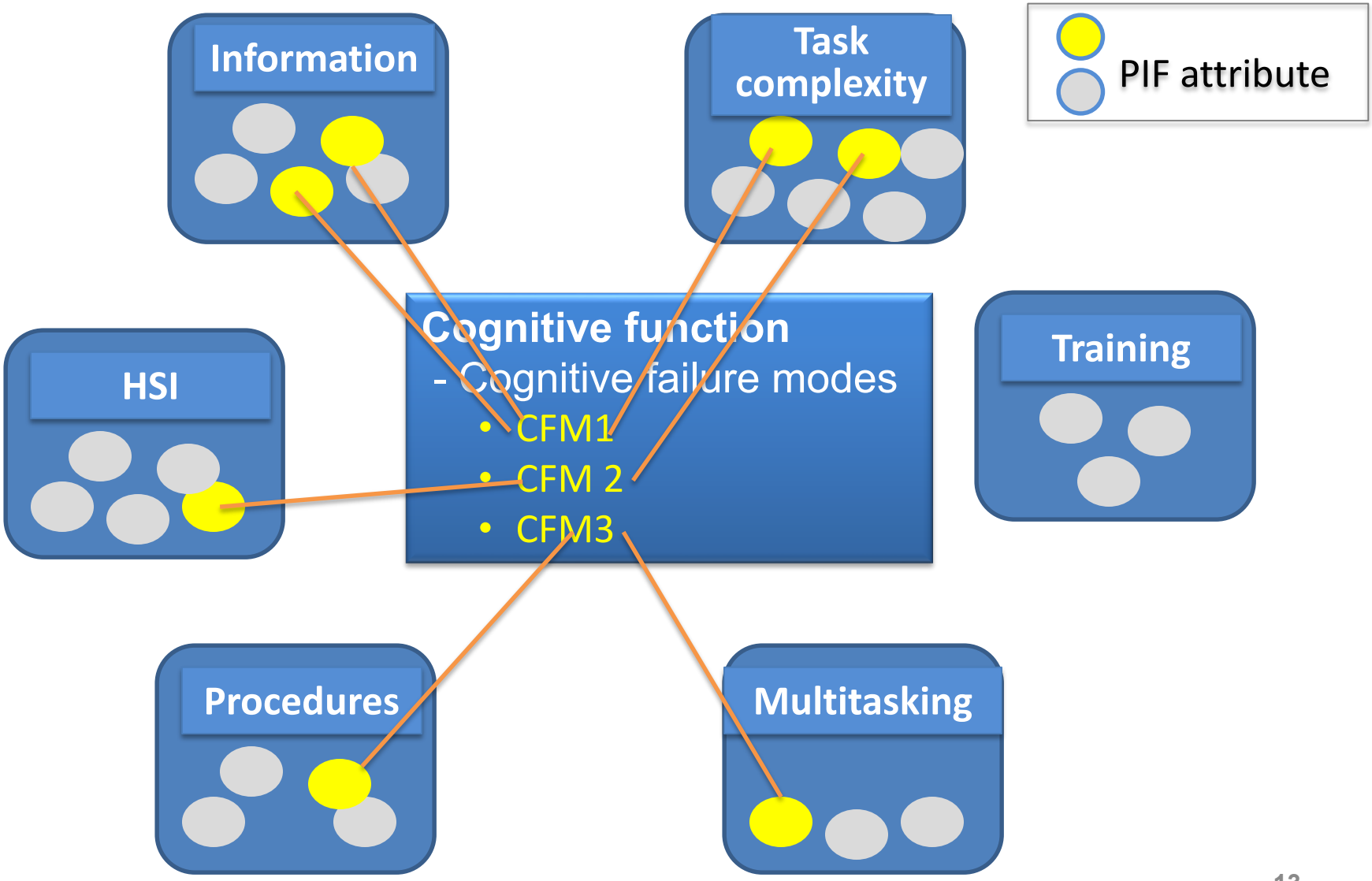
Demonstration of IDHEAS-G cognitive failure modes



Demonstration of IDHEAS-G PIF structure



Generalizing human error data to IDHEAS-G cognitive failure modes (CFMs) and PIFs



Evaluate data - PIF effects on human errors

Error factor (EF) = Error rate at a poor state of the PIF / error rate at the nominal state

PIF - *Multitasking, Distraction and interruption*

Ref	Context and task	Error rates and impact factor (EF)
Ref .8	Experiment on dual task: Airplane pilots detecting de-icing cue and responding to air traffic control information	Error rate in detecting icing cue alone vs. dual-task: 2.8% vs 21% missing cue EF= **7.2** 5% vs 20% missing changes EF= **4** 1% vs 37% wrong diagnosis EF= **37**
Ref. 9	Effect of interruption on target detection	Accuracy for no interruption vs interruption Simple Spatial .726 (.21) .803 (.11) Complex Spatial . 549 (.254) .441 (.273) EF(weak interruption on detection) =**1.1** for simple task EF(weak interruption on detection) =**0.9** for complex task
Ref. 10	Driving simulation with cell phone conversation	Missing dangerous targets: 2.5% without cell phone distraction 7% with cell phone distraction EF(persistent distraction) = **2.8**
Ref. 11	Experiment on performing sequences of action steps	error rate =0.15 for no interruption, 0.3 for 2.8s interruption, EF(interruption) = **2** 0.45 for 4.4s interruption, , EF(longer interruption) = **3**
Ref. 12	The effect of interruption on driving and fighting in military weapon system	4% for no interruption and 8% with interruption EF(interruption) =**2**

Interpret and represent human error data

PIF - *Multitasking, Distraction and interruption*

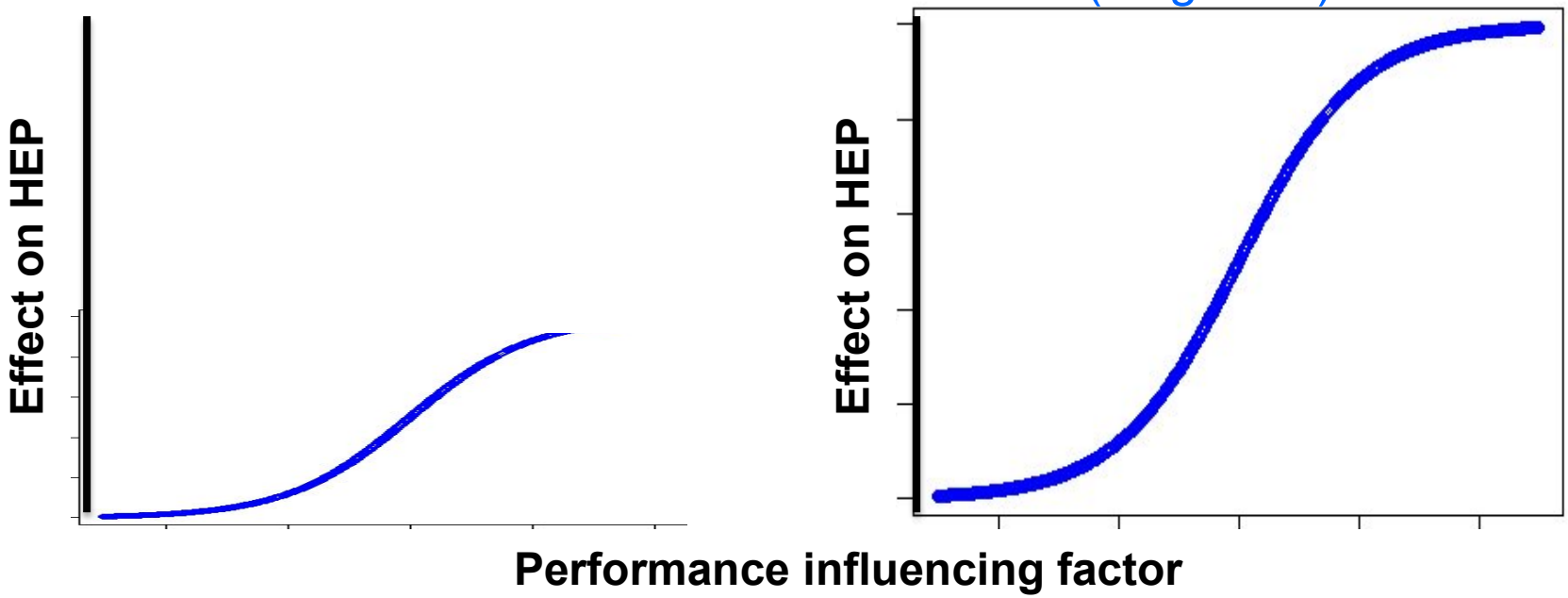
PIF state / Macrocognitive function	Low impact - Distraction - Interruption	Moderate impact - Secondary task - Prolonged interruption	High impact - Intermingled multitasking - Concurrently multitasking
Detection	EF(weak interruption) = **[0.9, 1.1]**	EF(persistent distraction)=**2.8**	EF(dual-task) = [**5, 7.5**]
Understanding			EF(intermingled)=**37**
Decisionmaking	EF(interruption on simple decision) = **1.6** EF(interruption on complex decision) = **1.7**		
Action Execution	EF(2.8s) = **2** EF(4.4s)=**3** EF(interruption)=**2**	HEP (interruption) = **2**	
Teamwork			
Undetermined	EF(interruption)=**2**		

Integrating the data to inform PIF quantification

Example PIF – Multitasking, interruption, and distraction

Detection

Understanding (diagnosis)



Evaluate data - PIF effects on human errors

PIF – *Teamwork factors*

ID	Context and task	Error rate
	Nuclear waste handling facility maintenance and operation Supervisor verification error	Check-off sheet, low dependence 1E-1 Check-off sheet, medium dependence 3E-1 Check-off sheet, high dependence and stress 5E-1 EF(independent checking) = **5** for high dependence EF(independent checking) = **3** for medium dependence
	Failure to restore from testing	Two persons, operator check 5E-3 Single person, operator check 1E-2 Single person, no check 3E-2 EF(no team verification) = **2**
	Failure to restore following maintenance	Two persons, operator check 3E-3 Single person, operator check 5E-3 Single person, no check 5E-2 EF(no team verification) = **1.7**
	Experiment of vigilance dual task – detecting targets (responding to visual alarms) and completing jigsaw puzzle.	Paired team, low target presentation speed 19% Single person, low target presentation speed 29% Paired team, high target presentation speed 28% Single person, high target presentation speed 38% EF(team detection) = **1.5, 1.3** for low and high complexity

Evaluate Data - PIF effects on human errors

PIF – *Information completeness and Correctness*

ID	Context and task	Error rate
04	Expert judgment of HEPs for NPP internal at-power event Information misleading	HEP (information obviously incorrect) = 3E-2 IHEP (information not obviously incorrect) =8E-2E-1 HEP(No information misleading) = 1E-3 EF = **30** for Information obviously incorrect EF=**80** for Information not obviously incorrect
40	Experimental study on supporting decision making and action selection under time pressure and information uncertainty in pilots de-icing simulation	Error rate - Percentage of early buffet: Accurate information 7.87% Accurate information but not timely) 20.56% 30% inaccurate information 73.63.% Error rate - Percentage of stall: Accurate information 18% Accurate information not timey 30% (30%) inaccurate information 89% EF = **1.5, 2.5** for accurate but not-timely or not-organized information EF= **5, 9** for 30% inaccurate information

Conclusions

- Human error data are available, not perfect, but can be used to inform quantification of human error reliabilities
- IDHEAS provides a framework to generalize human error data for HRA
- We preliminarily generalized the data to inform the quantification of performance influencing factors on human error probabilities

References

1. Makary MA, Daniel M (2016). Medical error-the third leading cause of death in the US. BMJ. 353:i2139
2. The National Motor Vehicle Crash Causation Survey (2015). Critical Reasons for Crashes Investigated in the National Motor Vehicle Crash Causation Survey. DOT HS 812 115
3. N. N. Chokshi ; J. P. Bailey ; A. Johnson ; D. Quenot ; J. F. Le Gall (2010). Integration testing of safety-related systems: Lessons learnt from Dungeness B DPS replacement project, 5th IET International Conference on System Safety 2010
4. Civil Aviation Authority (2015). Aircraft Maintenance Incident Analysis, CAP 1367.
5. Hobbs A, Williamson A (2003). Associations between errors and contributing factors in aircraft maintenance. Hum Factors. 45(2):186-201.
6. Preischl W, Hellmich M (2013). Human error probabilities from operational experience of German nuclear power plants Reliability Engineering and System Safety, 109:150–159
7. Rovira E, McGarry K, Parasuraman R (2007). Effects of Imperfect Automation on Decision Making in a Simulated Command and Control Task. Hum Factors 49(1):76-87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Thank you!
Jing.xing@nrc.gov