An Experiment Study on the Influence That Failure Number, Specialization, and Domain have in Predicting System Failures

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Motivation

" Electronically Controlled Infinitely Variable Pressure Control for Chuck or Tail Stock of CNC Lathe"

Project Duration : 3 months

Team Members

- 4 Undergraduates
- 3 Shop floor maintenance personnel
- 2 Senior Hydraulic Engineers
- 1 Senior Sales Engineer

Hydraulic Power Unit

Observations from Design Review

- Assessing criticality of the design issues was the primary target
- Team members often did not agree on assessing the importance of failure modes
- Failure modes were assessed individually with the most critical failure mode addressed first
- Reliance on the remarks made by experienced personnel

O: Chance for Occurrence; S: Seriousness; D: Chance for Detection

Function or Item	Potential Failure	Potential Reason for Failure	Effects of Potential Failure	O	S	D	Score (RPN)	Action
Shaft	Break	Fatigue	Complete Failure	1	10	10	100	Oversize Shaft
		Yielding	Complete Failure	1	10	3	30	None
Seal	Leak	Bolts elongate	Pressure not maintained	3	3	1	9	None
…	…	…	…	..	…	…	…	…

Would the same decision been made on criticality issues if only undergraduates were considered?

What effect does considering multiple failures at the same time have on decision making?

Research Questions

1. *When multiple failure modes are considered at a given time, what effect does it have on failure mode assessment?*
2. *Does the level of domain awareness or knowledge have an effect on failure mode assessment?*

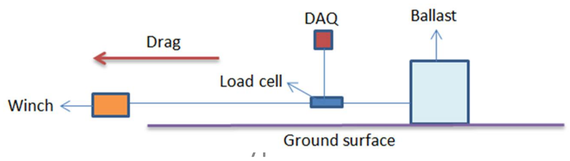
Research Goal

- Develop a method to calibrate assessment of failure modes by individuals in the design team
- Understand the confidence engineers impart on decision making during the assessment of multiple failure modes

Experiment Problem: Tent Testing - IFAI

Objective: To develop test equipment and testing protocol to collect data on the movement resistance of different ballast types, with different surface conditions, and different modifying interfaces.

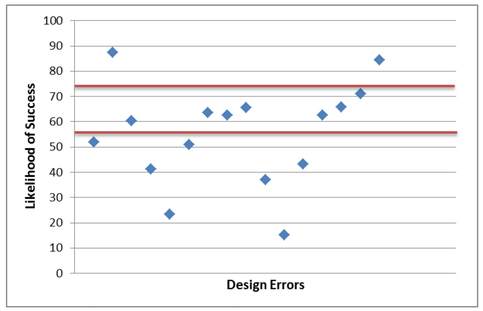
Testing Setup



1. The participants' confidence in the tent testing mechanism will decrease as the number of presented design errors increases
2. Decrease in confidence will be smaller when the design errors are presented with their associated controls (Solutions)

Design Error Pruning and Selection

- An experiment was conducted to select equivalent failure modes out of the 16 failure modes generated by FMEA of the tent testing mechanism
- Participants were instructed to provide their confidence in the success of the mechanism for individual design errors
- 5 random errors were presented to 29 senior engineering students



Assessment of Likelihood of System Success for Each Design Error

Experiment Design

Primary Independent Variable ⟶ # of design errors

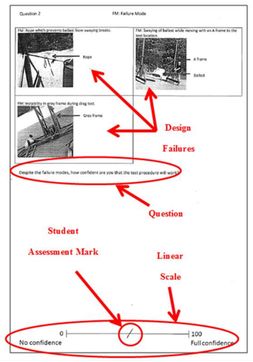
Secondary Independent Variables ⟶ Controls for errors and Domain

Participants : **117** Domain generalists (freshmen general engineering students)• **23** Domain specialists (graduate mechanical engineering students) • **43** Non-domain generalists (junior psychology students)

Scenario	Design Errors Presented to Students
Scenario 1	**1 design error** Error A
Scenario 2	**3 design error** Error B Error C Error A
Scenario 3	**5 design error** Error D Error E Error B Error C Error A
Scenario 4	**7 design error** Error F Error E Error D Error E Error B Error C Error A

Student Package	Control	Scenario			
		1	2	3	4
1	No	A	BCA	DEBCA	FGDEBCA
2	Yes	G	ABG	CDABG	EFCDABG
3	No	B	CDB	EFCDB	GAEFCDB
4	Yes	F	GAF	BCGAF	DEBCGAF
5	No	C	DEC	FGDEC	ABFGDEC
6	Yes	E	FGE	ABFGE	CDABFGE
7	No	D	EFD	GAEFD	BCGAEFD
8	Yes	D	EFD	GAEFD	BCGAEFD
9	No	E	FGE	ABFGE	CDABFGE
10	Yes	C	DEC	FGDEC	ABFGDEC
11	No	F	GAF	BCGAF	DEBCGAF
12	Yes	B	CDB	EFCDB	GAEFCDB
13	No	G	ABG	CDABG	EFCDABG
14	Yes	A	BCA	DEBCA	FGDEBCA

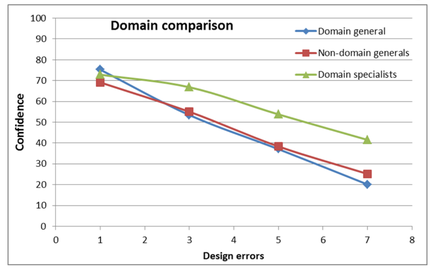
Data Collection



"Despite the failure mode, how confident are you that the procedure will work?"

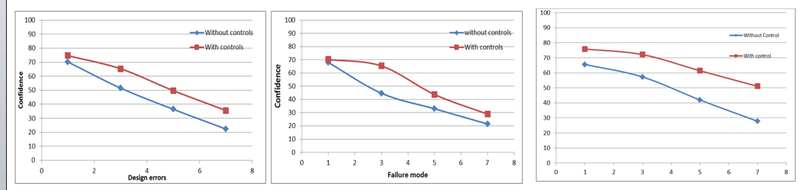
- Each participant rates their confidence on the performance of the mechanism on a linear scale
- Participant goes through 4 scenarios, and each scenario has question mentioned above

Results on Domain and Design Error Interaction



# design errors	Domain generals	Non-domain generals	Domain specialists	P-value
1	75.26	69.13	72.86	0.3456
3	53.45	55.04	66.84	0.0793
5	37.09	38.38	53.79	0.0198
7	20.12	25.19	41.54	0.0002

Results on Domain and Design Error Interaction



Error	Population	Average Percent confidence without control	Average Percent confidence with control
1	Domain General	74	76
3		50	57
5		32	42
7		15	25
1	Non-domain	68	70
3		45	65
5		21	33
7		16	22
1	Domain Specialist	66	76
3		57	72
5		42	62
7		28	51

Domain	Design Error	% decrease in confidence	p-value
Specialists	1-3	6.1	0.2802
Specialists	3-5	13	0.0211
Specialists	5-7	12.2	0.0301
Non-domain	1-3	14.1	0.0002
Non-domain	3-5	16.7	<0.0001
Non-domain	5-7	13.2	0.0005
General	1-3	21.8	<0.0001
General	3-5	16.4	<0.0001
General	5-7	16.9	<0.0001

Conclusions

- The mean confidence for the domain specialists is higher than domain and non-domain generals for three, five, and seven design errors
  - *Domain specialists showed a more optimistic point of view of system success (higher confidence) in making the decision with design errors*
- The rate of confidence decrease is the least for domain specialists
  - *Considering their experience and knowledge in the domain, this perhaps suggests that they are more optimistic of the system performance based on their deeper understanding of the functionality of the system*
- Use of controls proved to be more significant for the domain specialists
  - *Domain specialists can understand better the implications of the use of controls to reduce the risk or prevent the errors*

Acknowledgments

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