Context

Why are dashboards important in industrial environments?

Dashboards are crucial for operators in environments like chemical plants and refineries because they help them make timely, critical decisions about system operations and statuses.

What issues do excessive display clutter and

poorly designed indicators cause? Excessive clutter and poorly designed indicators can slow down operators' ability to interpret data quickly, potentially leading to mistakes that affect safety and operational efficiency.

What is the goal of this study?

This study explores how different types of visual indicators—specifically dial and bar indicators—and varying levels of clutter affect operator performance, such as reaction time and situational awareness.

How will this study help improve operator performance?

By identifying the most effective display configurations, the study seeks to optimize dashboards for better decision-making, improving operator safety, accuracy, and efficiency in highpressure environments.



Definitions:

Bar Indicator: A visual tool that represents data using a bar, where the length or fill of the bar indicates the value being measured, making it easy to compare and interpret values quickly.

Dial Indicator: A visual tool that displays data using a circular dial with a needle or pointer that moves to indicate the value being measured, similar to a traditional gauge.



<u>Clutter:</u> The presence of unnecessary or excessive visual elements in a display that can make it difficult to focus on important information. In the context of dashboards, clutter can include overlapping graphics, excessive lines, or irrelevant data that increase cognitive load and hinder effective decision-making.



Analog Bar vs Dial Indicators in the Presence of Clutter

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Background

Beville Operator Performance Specialists is a consulting firm in human factors and engineering with a focus on operator performance analysis within refinery and petrochemical industries. They partnered with our team to study how indicator design and visual clutter affect operator performance in real-world control environments.

Methodology

- Sample Size: 20 participants
- Testing Duration: 30 minutes
- **Display Setup: 4 simulations**



Bar Indicator: Low Clutter



Dial Indicator: Low Clutter

Bar Indicator: High Clutter



Dial Indicator: High Clutter

Survey : \bullet

This survey gathered feedback from operators to evaluate the effectiveness of different dashboard display configurations in industrial environments. It focused on how varying levels of visual clutter and indicator types (dial vs. bar) impact key performance metrics such as reaction time, accuracy, and situational awareness. The responses provide valuable insights into operator preferences and highlight the importance of clear, clutter-free displays for improving decision-making, reducing errors, and enhancing overall safety in high-pressure settings.

For ide Dial	For each of the simulations please indicate the level of difficulty you experienced to identify errors. Dial Indicator: Clutter What was the level of difficulty when completing this task?																		
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Very Low	,																		Very High
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Very Low	,																		Very High
Ana	alog	Bar:	Clut	tter V	Vhat	was	the I	evel	of dif	fficult	ty wh	en o	omp	leting) this	task	?		
I	I				I	I	I	I						I	I	I	I	I	
Very Low	2																		Very High
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Very Low	;																		Very High

experience In other wo	of workle	ad during this run. h of the pair made the task <i>hard</i> e							
			- ·						
	1	Dial Indicator: Clutter	Dial Indicator: No Clutter						
	2	Analog Bar: Clutter	Analog Bar: No Clutter						
	3	Dial Indicator: Clutter	Analog Bar: Clutter						
	4	Dial Indicator: Clutter	Analog Bar: No Clutter						
	5	Dial Indicator: No Clutter	Analog Bar: Clutter						
	6	Dial Indicator: No Clutter	Analog Bar: No Clutter						
Survey Que	stions: ou feel t	here was significant stress when	experimenting with the simulation	ns?					
2) Wer If Ye	e there a s, please	ny challenges or issues you ence explain)	ountered during this experiment?	(Ye					
3) Dog pref	Do you have a preference between indicator types? (Yes/No- If yes, please circle yo preference) Analog Bar <u>QR</u> .Dial Indicator								
4) Doy thro pref	Do you have a preference in the amount of static information(referred to as clutter throughout the study) displayed on the screen? (Yes/No- If Yes, Please circle your preference)								
Mini	Minimal Static Information(No Clutter) <u>OR</u> Maximum Static Information (Clutter)								

Figures present the user performance data across different display conditions. It includes key metrics such as the total number of actions logged, valid response time entries, average and median response times, as well as the minimum and maximum response times observed.

The bar indicator exhibited higher variability, with standard deviations of 682 ms under low clutter and 717 ms under high clutter, indicating a wider range of response times.

The table provides a high-level overview of the different conditions, showing that the dial indicator has the highest average response time, indicating a better response time for bar indicators over dial indicators.

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Results





	Bar In	dicator	Dial Indicator			
	Low Clutter	High Clutter	Low Clutter	High Clutter		
Total Files	20	20	20	20		
Total Actions Logged	1939	2010	1674	1699		
Valid Response Time Entries	720	720	720	720		
Errors (Reached 100% without response)	61	120	248	305		
Average Response Time (ms)	3973.28	3917.26	5500	5700		
Median Response Time (ms)	3926.3	3021.95	5515.82	5631		
Min Response Time (ms)	200.37	275	2763.44	2952.37		
Max Response Time (ms)	7850.92	9966.1	8287.55	8812.97		

Test Bar Indicators High/Low	Statistic	P-Value	Interpretation
T-Test	0.375	0.707	No significant difference
Anova	0.141	0.708	No significant difference

The results of the statistical tests indicate no significant difference between low and high clutter conditions, These findings suggest that the visual complexity of the interface did not significantly affect user performance when using the Bar Indicator.



Bar Indicator outperforms the Dial Indicator in both low and high clutter conditions, with fewer errors overall.

Based on the NASA-TLX data for subjective workload comparison across different conditions, several key trends emerge.



Participants consistently reported that dial indicator simulations were more challenging to interpret compared to bar indicators. Additionally, for both indicator types, high-clutter conditions were perceived as more difficult than low-clutter conditions, indicating that visual complexity significantly impacted user experience.

This study found that bar indicators consistently outperformed dial indicators in both low and high clutter environments. Bar indicators led to faster response times, fewer errors, and lower mental workload. Participants also rated them as easier to use. In contrast, dial indicators were more difficult to read—especially in cluttered conditions and caused higher workload and frustration. These results highlight the importance of user-centered design and support using bar indicators in cluttered industrial settings to improve safety, accuracy, and efficiency

We would like to express our gratitude to our advisor, Dr. Mumtaz Karatas and our client, David Strobhar from Beville Operators Performance Specialists.

Results cont Box plot shows the distribution of errors for each condition, where the Bar Indicator demonstrates relatively lower variability in errors compared to the Dial Indicator. The high clutter condition for both indicators shows a broader spread of error rates, indicating that increased clutter contributed to greater inconsistency in user performance.

Survey Results

Conclusion

Acknowledgments