Making sense of human capability and workload

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Summary

In the world of process safety and loss prevention, we often speak of "failure points". For example, the pressure or temperature at which the structural strength of a vessel or pipework reduces so that a loss of containment may occur. Adding a safety margin allows us to operate within a range of pressures and temperatures where we have confidence that structural integrity will be maintained.

It is tempting to use a similar approach to human mental or cognitive capability. We know that people can be overwhelmed by information, leading to an increased likelihood of error. But unlike mechanical systems, there is no clearly defined failure point. Humans are fallible but also remarkably adaptive. We make errors even when conditions are good but can successfully handle periods of information overload and complexity. People can show amazing levels of resilience by responding flexibly to unexpected situations, but this should not be relied on for safety.

Keywords: Human factors, cognitive workload, alarm management, situational awareness

References

Humans have a range of coping strategies that lead to performance that is often good but less than perfect. Examples include:

1. *Optimisation:* Stop doing non-essential activities and pay less attention to information perceived as secondary. Focus on what makes the biggest difference to the core mission.
2. *Simplification:* Redefine the situation so that it makes sense. Use this to narrow the scope of situational awareness. Ignore information that is outside of this scope.
3. *Short-cutting:* React to signals (e.g., an alarm or a flashing light) without attempting to understand the underlying causes.

Understanding observed behaviour

When observing someone handling a complex situation it seems reasonable to believe they are being successful if the system keeps running, output is maintained and tasks are completed. However, this gives no direct indication of the quality of decision making or attention to detail. It may be the case that:

- The approach has been successful so far, but may not be suitable as the situation develops;
- The capability to cope is reaching capacity and if the situation goes on much longer, failure is likely;
- The current amount of information is manageable but any slight increase may lead to a catastrophic loss of control.

Equally, if they made an error it is not possible to determine if this was due to information overload or the result of another human error mechanism.

Measurement challenges

Observations of people working does not allow accurate measurement of workload. Simulation appears to offer a solution but in practice it is difficult to create suitable scenarios that provide data that can translate to the real world. Studies using simulation often require measurable data that has to be physical and observable, such as the number of times a button is pressed or the sequence of control actions made. But it is the cognitive activity taking place inside the brain that is most important.

People can be asked to subjectively rate their workload during scenarios. This may be after a genuine event or by pausing a simulation. However, it is very difficult to calibrate subjective ratings to any meaningful measure of workload or to correlate the findings with human performance. Someone may perceive low levels of workload because they did not recognise that a situation required their attention or they may have initiated a successful response using a short cut that worked on that occasion but is not appropriate for all situations (i.e. they were lucky). They may report a workload peak that lasted a very short time and had very little impact on their overall performance.

Practical applications

The following examples illustrate how understanding human limitations and capabilities can lead to better solutions.

Alarm rates

One topic that generates a lot of interest, and may appear to be amenable to simulator studies, is alarm rate. In particular, the number of alarms an operator can handle per hour during normal operations and upset conditions.

Industry guidance from the Engineering Equipment and Materials Users Association (EEMUA)[1] and International Society of Automation ISA[2] suggest that six alarms per hour and 10 alarms in the first 10 minutes of an upset are manageable. This means that the workload created by the alarm should not detract from the main goal of the operator role of acting proactively to keep plant within defined limits and responding quickly and effectively when things go wrong.

Other sources suggest that the figures in the guidance are either too optimistic or pessimistic. Data from the nuclear industry[3] is often referred to on this matter. It says that there

knowledge and competence

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is a 90% likelihood of successful diagnosis of an alarm within 10 minutes, rising to 99% after 20 minutes. If this is the case operators would be fully engaged with alarm response if they are occurring six times per hour, and would be misdiagnosing 10% of them.

On the other hand, the Center for Operator Performance (COP) has carried out simulator studies and concluded that operators are able to handle a higher rate of alarms[4] with up to 20 in 10 minutes appearing to be manageable. Operators continue to manage the situation at higher rates up to 30 in 10 minutes by delaying their response to low priority alarms.

The differences in data may highlight the challenges with defining human capability for handling complex situations. The figures from EEMUA and ISA are a useful guide to what may be manageable, but do not take into account context and should not be used as simple targets. The NUREG figures may be suitably conservative if credit is being taken for operator response to alarms in safety studies, while the data from COP shows that the rate of alarm is not the only measure that should be used and that other factors are important, including alarm prioritisation.

What is clear is that the physical response to an alarm that can be observed in a control room is not what counts. It will only take seconds for an operator to read an alarm description, operate the accept button and open a graphic page to look for data. But it is the way they understand what is going on and make decisions that is most important. While a poorly designed alarm system can increase the likelihood of human error, well designed systems provide an opportunity to take advantage of human capabilities. "Unwarranted conservatism in the claims permitted for alarms will place a higher burden on other protection layers and may result in more complicated requirements in respect of automated Safety Instrumented Functions"[5].

Data presentation

The way data is presented has a significant effect on the effort required to interpret its meaning. While numerical figures may be considered as most accurate, they require the user to work hard to understand what they mean and identify if action is required. Alternative methods of display can be used, allowing people to update their situational awareness with a quick glance (see Figure 1). For example[6]:

- Analogue dials make it easy to determine if the parameter is within limits
- Bar charts make it easy to compare data points
- Trend displays show historical values with a clear indication of rate of change.

Even when presenting data numerically is appropriate, being overly precise (i.e. using more decimal places than necessary) adds to the workload. The goal should be to present information that matches the user requirements and human capabilities. While human capability for analysis can be limited, their ability to perceive patterns and changes explains why people are still such a critical part of most complex and critical systems.

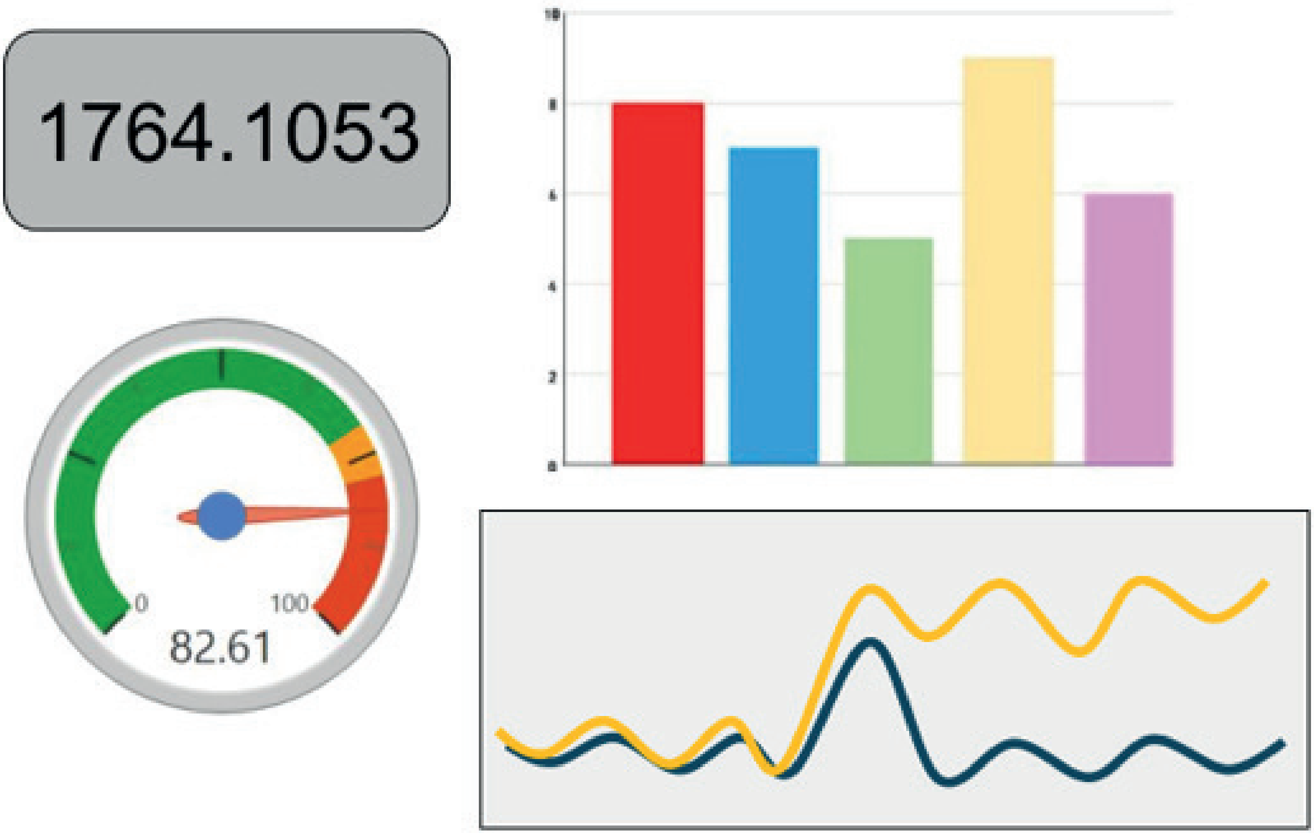

Figure 1 - Different ways of display data

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Procedures and checklists

One of the main reasons for writing procedures is to support people when performing tasks to reduce the likelihood of them making errors. However, using a procedure creates additional workload and so care is required to ensure there is a net benefit. Even simplified checklists can add to a person's workload if they are poorly constructed or poorly applied. They can distract people from the task they are performing and may even increase the likelihood of error[7].

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Figure 2 – Humans do not require text perfection

Step	Description	Role	Additional Information	Done
5.1	Continuously monitor compressor discharge TAHH-30123	CRO	1 High temperature	
5.2	Open recycle V-703	OP	Located on Level 3, behind fuel gas panel	

Figure 3 – Concise procedure steps using description and tag numbers to identify items and a red flag to highlight a significant hazard.

The workload created by procedures and checklists can be justified for some tasks, particularly the ones that are critical, complex and performed infrequently. But expecting people to follow procedures for every task is often counter-productive. Even when justified, the way procedures are written can have a significant impact on how well they support people performing tasks. To balance risk and reward they should be as simple and concise as possible. This means writing for competent people, being ruthless with wording, reducing support information that can detract from the main message and using simple symbology to communicate critical information including hazards and vulnerability to error[8].

As figure 2 illustrates, people do not need text to be grammatically perfect. However, as the word count increases they need to use more effort to understand. A balance is required to simplify as far as possible, without introducing risk. For example, people will often transpose characters in a word, which can be significant if it is being used to positively and accurately identify an item of plant or equipment. Human factors tells us that redundancy of information reduces the likelihood of confusion. Using a description and tag number each time an item of equipment is referred to may increase the word count but is justified by reducing the risk of human error[7].

Examples that illustrate the issues

The Texaco Milford Haven Refinery explosion (1994)[9]

This incident is a classic illustration of how extreme alarm rates can force operators into counterproductive coping mechanisms. In the 11 minutes leading up to the explosion, control room operators were inundated with 275 alarms (an overwhelming rate of 25 per minute). This did not cause an immediate, observable failure. The operators remained at their posts and continued attempting to manage the process upset.

To handle the sheer volume of information, the operators used shortcutting strategies, effectively abandoning active monitoring of the alarm system. While the investigation later found that most of these alarms were of little value, a critical high-level alarm for the flare knockout drum was lost in the noise. If noticed, it could have prompted the operators to take action.

The operators' situational awareness was further degraded by poorly designed graphical displays on the Human Machine Interface (HMI). Critical data was buried within non-essential structural details, and a key parameter, the status of the outlet valve downstream of the debutanizer column, was omitted from the primary screen being monitored, increasing the cognitive effort required to interpret the system's state.

The BP-Husky Toledo Refinery fire (2022)[10]

A more recent example of prolonged cognitive strain is the fatal fire at the BP-Husky Toledo Refinery, where a very high alarm rate persisted for over 12 hours. This severely hindered operator communication, delayed critical responses, and led to tragic errors.

When a high level in the fuel gas mix drum level was detected, the operators took a simple decision. The drum was full so it needed to be emptied. They were not prompted to consider why the level was high or what the liquid could be. The normal draining method to the open oily-water sewer was used.

Unfortunately, the liquid was flammable naphtha. The uncontrolled draining allowed a flammable vapour cloud to form, which quickly ignited. The resulting fire killed two operators, brothers Ben and Max Morrissey, who were performing the task together.

Conclusion

Understanding how people deal with challenging situations, including the coping strategies used, can help us to design systems that support human performance and reduce the likelihood of failure. Humans do not perform in the same way as engineered systems and analogies that compare humans to machines are usually flawed.

We rarely have data that tells us whether arrangements will create a manageable level of workload. The solution is to create systems that do not rely on people to handle high volumes of information, and to align designs to how people interpret data and the coping strategies they use.

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The term 'resilience' is often used as a positive feature, suggesting that systems are safer if they can handle complex situations. But too often it means there is a reliance on people responding to difficult situations instead of being in control so that those situations are avoided. Also, just because a task has been completed, it does not mean that the method used will always be safe, especially if people base their situational awareness on a simplified perception of the information available or take short cuts that may be successful most, but not all of the time.

Investigations of incidents and near misses gives us the opportunity to better understand human performance, but only if we collect the right information and use it to gain insight into how people can be better supported to prevent human error. How can information be presented differently? What skills do people need to analyse data? How can people be trained to make better decisions?

Coping strategies provide humans with an ability to handle complex situations using limited cognitive resources. They can contribute to errors but that does not mean that they are a purely negative force. Recognising them as a super-power, with the ability to simplify and optimise exceeding capabilities of the most sophisticated technology available, opens up opportunities for people to do great things.

It may be tempting to look for data that answers our questions about human capability and limitation. But it is important to remember that "Not everything that can be counted counts, and not everything that counts can be counted".

References

1. *Engineering Equipment and Materials Users Association. Publication 191 Alarm systems - A Guide to design, management and procurement. 4th Edition. EEMUA (2024).*
2. *International Society of Automation. ANSI/ISA-18.2-2016, Management of Alarm Systems for the Process Industries. ISA (2016).*
3. *Swain and Guttman. NUREG/CR- 1278 Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications (1983).*
4. *Chemical Processing. How Many Alarms Can an Operator Handle? (2011). Accessed at* ***https://www.chemicalprocessing.com/automation/automation-it/article/11372243/how-many-alarms-can-an-operator-handle-chemical-processing***
5. *Dearden, H. Brazier, A. Jump to it! - A New Model for Safety Alarm Operator Response Time Requirements That Avoids Misplaced Conservatism. Hazards 33. IChemE (2023).*
6. *Engineering Equipment and Materials Users Association. Publication 201 Control Rooms: A guide to their specification, design, commissioning, and operation. 3rd Edition. EEMUA (2019).*
7. *Brazier, A. Pilots use checklists - should tanker drivers and process operators? Loss Prevention Bulletin (2025).*
8. *Brazier, A. Perplexing Persistence of Poor Procedures. Hazards 34. IChemE (2024).*
9. *Health and Safety Executive, 'The explosion and fires at the Texaco Refinery, Milford Haven, 24 July 1994: A report of the investigation by the Health and Safety Executive into the explosion and fires on the Pembroke Cracking Company Plant at the Texaco Refinery, Milford Haven on 24 July 1994' (1997).*
10. *U.S. Chemical Safety and Hazard Investigation Board. Fatal Naphtha Release and Fire at the BP-Husky Toledo Refinery (2024).*

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