Designing Operator Tasks to Minimize the Impact of Heuristics and Biases

aeSolutions Technical Team
10375 Richmond Ave. Suite 800
Houston, TX 77042

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aeSolutions Technical Team
10375 Richmond Ave. Suite 800
Houston, TX 77042

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Abstract

Often times when a person is blamed for "not thinking," the reality is they were thinking, but were not aware of it. This is the theory of System 1 (i.e., Fast) versus System 2 (i.e., Slow) thinking that explains we are really two people: Our conscious aware selves (System 2 thinking), and a dominant "fast" subconscious making most of our decisions (System 1 thinking) without being consciously aware of it in the moment (to the point that some have argued there is no such thing as "free will"). The heuristics (i.e., mental short cuts) we use to think in System 1 are necessary to make it through a day (it is exhausting to maintain a continuous conscious stream of thought), and often lead to good outcomes. However, System 1 thinking can make us vulnerable to systematic biases (i.e., mental traps) that arise from the use of those heuristics. It is necessary to be aware of the traps System 1 thinking can create, because often times that is our only defense against them. In this respect, "fast thinking" represents one of the fundamental limits to achieving safe operation. In addition to awareness, there is a need where possible to design operator tasks and the interfaces they use to minimize the likelihood of systematic bias occurring when thinking in System 1. Lastly, it would be useful to provide designs that could increase the potential for the operator to engage System 2 thinking (consciousness) when required, which is less susceptible to biases.

This paper proposes a combined approach of discussing the cognitive psychology behind System 1 and System 2 thinking, the types of heuristics we use, the biases that result, and operator task and interface design that can minimize the likelihood of systematic bias. The paper will incorporate the learnings from 5 years of safety critical Task Analysis performed for field and control room tasks. A practical operator response to abnormal situation model will be described that will link the heuristics used and potential biases that may occur, as well as design features to minimize the likelihood of those occurring.

1 Introduction

Achieving process safety success is fundamentally a human endeavor, from the front-line worker to the PHA room and beyond. But the human must work within a System (i.e., organization, environment, technology, etc.). To operate safely, both must considered, human and System. And so it is with Situation Awareness (see **Figure 1**), both the human and the System must be taken into account when designing for Situation Awareness. It is often rightly said that "the System must be designed to match the capabilities and limitations of the human" (not the other way around). But no System design is a 100% perfect match to a human, if for no other reason than the natural variation between humans that use the System. We are then left with the human to close the gap.

Situation Awareness
1. What? (Become aware of a problem)
2. So what? (Interpret and Diagnose)
3. What now? (Project to future state)

Figure 1. The Elements of Situation Awareness (SA), after Mica Endsley **[1]**.

Human thinking, more specifically how we think, plays an important role in Situation Awareness. Each of the three elements of Situation Awareness asks a question, that must be answered by the human brain. It is slightly more complicated than that, as shown in **Figure 2**, humans have one brain but three minds.

The unconscious mind controls basic life support functions, breathing, heart rate, etc. (we don't have to remember to breathe), and while this is biologically important, it is not relevant to process safety. The subconscious mind is where the majority of the action takes place regarding decision making and task execution, as we spend 95+% of our day in the subconscious state **[2]**. Our subconscious is fast and effortless. The conscious mind (i.e., the conscious being you call "I"), thinks it is the "star" of the show (i.e., in control). In reality, our conscious mind is only in hot-standby, ready to engage when a problem has been detected. It is slow and laborious. This is all good and well, except that our subconscious mind is more prone to systematic error and bias in decision making, because it uses heuristics (i.e., mental shortcuts) when making decisions (see **Section 2**). This is the trade-off for fast effortless thinking.

Some people don't like to accept the fact that our conscious self is not in control. But this is in fact our conscious mind fooling us. Consciousness takes energy, and it is nearly impossible to maintain a continuous conscious stream of thought for more than a few seconds. What is happening is our mind is continually reverting back to its subconscious, to conserve energy. This is the human factors principle of least energy at work. Humans will seek to minimize the amount of energy (physical and mental) expended on a task. Task design should take this into account. Humans will always find a short-cut (physical and mental). For those still not convinced that your subconscious is actually in control, the field of neuroscience has more recently demonstrated through brain scans that people's subconscious is active several seconds before our conscious mind becomes active, during decision making experiments. In other words, your subconscious is making the decision, and your conscious self only becomes aware of it several seconds later. Your conscious self will not question it, because it thinks it made the decision (i.e., it is the star of this movie**[3]**)!

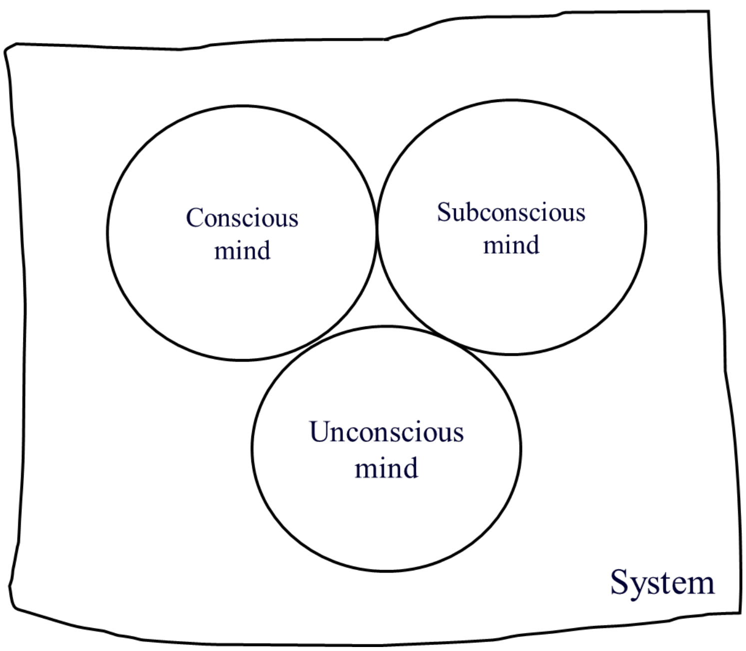

Figure 2. One brain, three minds, after Cristian Sylvestre **[2]**. Along with the System (technology, organization, etc.), this forms what is known as a "Socio-technical" system.

Back to Situation Awareness. The three elements of Situation Awareness are best performed by the conscious mind. The conscious mind is more rational and less error prone than our subconscious mind. In addition, only our conscious mind can "see" Risk (i.e., severity + likelihood). Our subconscious can't. However, it takes effort to "turn on" our conscious mind and that doesn't always happen when needed. Therefore we need to also look at how we might make better decisions using our subconscious mind. See **Figure 3** for an overview of the characteristics of each type of mind and the thinking associated with it (i.e., System 1 or "fast" thinking, and System 2 or "slow" thinking).

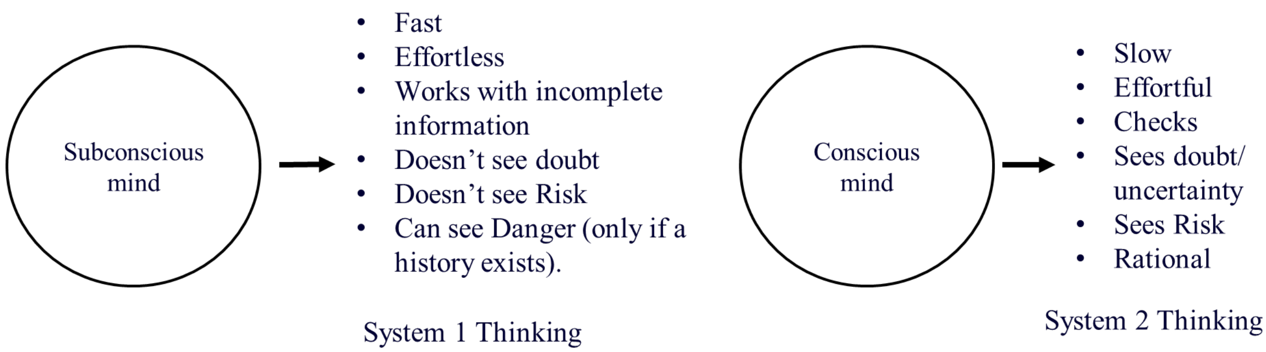

Figure 3. One person, two minds, after Daniel Kahneman **[3]**. Recognizing that humans spend 95% of our working day in our subconscious mind, can explain a lot of behavior. For example, if a potentially dangerous task or operation is performed many times without incident, our subconscious stores a pattern of said task that doesn't include that it's dangerous. When something bad happens, the worker(s) may be blamed for being "complacent" (i.e., not thinking). However, this is just human nature, i.e., using our subconscious mind. It will do little good to tell workers to "pay more attention" next time.

2 Heuristics and Biases – a brief Tutorial

As explained in **Section 1,** our subconscious mind uses heuristics which can result in biases when making decisions under uncertainty (all process safety decisions involve uncertainty). Often our decisions turn out to be correct. However, the field of Behavioral Economics has studied many situations where our heuristics can produce systematic error in our decisions.

The following are some ways a decision bias can be described:

- A mental trap
- A distortion (the difference between what is seen and what is there)
- A systematic error (i.e., one that will skew statistical calculations such as averages)
- Predictable. Has the potential to be corrected for if it can be identified.

A heuristic is a shortcut that bypasses conscious thinking. Different heuristics provide the short-cut mechanism. We expect conscious thinking to be less biased.

Some examples of heuristics and their bias that have relevance for front-line workers include **[3]**:

<u>Confirmation bias</u> – People will seek information to validate what they already believe to be true.

<u>Commitment bias (capture error)</u> – Tunnel vision. Not considering alternatives.

<u>WYSIATI (what you see is all there is)</u> – Making decisions using only the information that is immediately available. Not only this, but also filling in gaps in the narrative (the "story") with information of unknown validity. Humans will not work to find information.

Substitution effect – Substituting an easier question for a more difficult one.

Framing and Loss Aversion – People will work twice as hard to avoid a loss than they will to achieve an equivalent gain, and framing the loss/ gain decides which side wins.

Next, we look at under what conditions humans move from the subconscious to the conscious mind to help reduce the impact of systematic bias.

3 Turning ON our Conscious Mind

Switching from subconscious (System 1thinking) to conscious (System 2 thinking) takes effort. This effort is generated by what is called "cognitive strain" **[3]**, i.e, colloquially referred to as a "problem." System 2 becomes mobilized when there is problem that moves System 1 out of its comfort zone, as shown in **Figure 4**. System 1 automatically carries out the following type of assessment to determine if System 2 is needed. In terms of neuroscience our subconscious mind is reviewing its stored pattern library looking for matches (i.e., cognitive ease). If no match is found, it kicks out to our conscious mind.

- Is anything unfamiliar?
- Are things going well?
- Is more effort needed?
- Should I redirect attention?
- Is there an imminent threat?

Heuristics such as Substitution and WYSIATI (what you see is all there is) can create a short bypass back to System 1. But if the transition to System 2 thinking is successful, System 2 is more likely to reject any "fast" answers that are suggested by System 1 thinking.

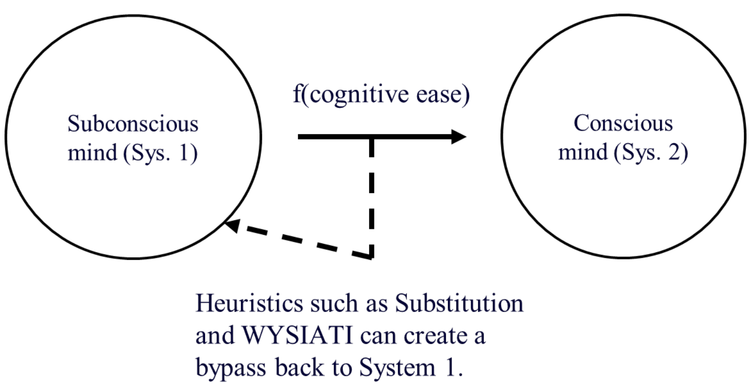

Figure 4. Transitioning between System 1 thinking to System 2 thinking is a function of cognitive ease, which has a scale range between "easy" and "strained." Colloquially, we can refer to this as "detecting a problem." System 2 thinking is considered more reliable as it is less prone to systematic bias compared to System 1 thinking.

Recognizing a problem is speaking to the "What?" of Situation Awareness (see **Fig. 1**). Answering the element of "What?" can best be addressed by System design. Unfortunately, there are not a lot of design options currently available related to process tasks/ operations that will work directly to trigger System 2 thinking. But, to give the reader an idea of what this may look like, the following are examples **[4]**,

- Hi-Vis barricade tape (contrast with the background environment)
- Rumble strips on roads (physical effect on the mind)
- Weight imbalance of a TV remote control (physical effect on the mind)

To be clear, the above examples work directly to alert our conscious mind of a problem. In addition to these, there are a large number of design features that work to increase the likelihood that a problem will be detected. Some examples include,

- Gray-scale graphics
- At-a-glance displays
- Process variable trends
- Rate-of-change trends
- Alarm Management activities in general

Some futuristic version of a Star Wars^{TM} helmet (i.e., an "SA Helmet"), that uses a digital twin to solve the three elements of Situation Awareness, seems far off, even if it's possible at all. The third element of SA (i.e., project to a future state), suffers from what is known as the "Problem of Induction" (i.e., the future can't be known with certainty until it occurs, at which time it has already become the past). Projections across short time scales however does appear more credible, which could be useful for many operational tasks.

4 Better decision making using our Subconscious Mind

It was stated in **Section 1** that "It is the position of this paper that the three elements of Situation Awareness are best performed by the conscious mind." However, we've learned that humans spend 95+% of their working day in System 1 thinking (i.e., subconscious), and that it is difficult to transition from System 1 to System 2 (i.e., it takes continuous effort). For these reasons, it makes sense to evaluate how we can improve decision making using our subconscious minds.

To that end, we evaluate the following:

1) Skill-based intuition **[5]**
2) Habit formation related to critical tasks **[2]**
3) Nudge Theory **[3]**

Each of these uses the subconscious mind.

4.1 Skill-based intuition

The study of skill-based intuition grew out of the NDM (Naturalistic Decision Making) community of scholars and practitioners, led by Gary Klein. Opposed to the NDM school is heuristics-based intuition, led by Daniel Kahneman, which focuses not on human expertise (i.e., getting things right), but instead, on systematic error in decision making.

Putting aside their differences, Klein and Kahneman got together, and defined the conditions under which people develop expert intuition.

Intuition is recognition, i.e., of patterns stored in subconscious memory. Recognizing that your son or daughter has had a bad day at school, a co-worker is tired versus angry, or the way a small child recognizes an animal is a dog, not a cat, are all examples of recognition. Does the same apply to a console or field operator recognizing an abnormal situation? Yes.

Recognition begins with learning a cue (i.e., a signal or prompt) from the environment (i.e., the What? in SA), that then allows access to stored patterns. Beyond that, skill-based intuition develops with:

- a High validity environment (i.e., regular and repeatable)
- an Adequate opportunity to learn it (i.e., via practice with feedback)

High validity does not imply the absence of uncertainty. However, the uncertainties should be somewhat bounded (i.e., known unknowns – "we know what we don't know" - would be considered bounded). This speaks to the What now? element of SA.

One of the most important leading indicators of Situation Awareness in the average and variance of the years of experience of both console and field operators. A minimum baseline of experience needed for skill-based intuition should be determined. For example, a site might determine that 3-5 years console experience is the point at which a board operator develops this intuition. An indicator can be triggered off of this.

4.2 Habit formation related to critical tasks

It takes time and practice to develop skill-based intuition. And for certain high hazards, there may be no operational experience related to responding to said event. For these reasons, developing habits related to safe operation should be developed. Your LOPA scenarios are a good place to identify which tasks safe habits should be developed for, especially the ones that involve operations as initiating event or barrier. Reviewing alarm metrics related to high hazards is also useful. How much practice does the board operator have responding to said alarm? If there is no experience with the alarm, habits should be drilled.

Habit formation involves the following (see **Figure 5**).

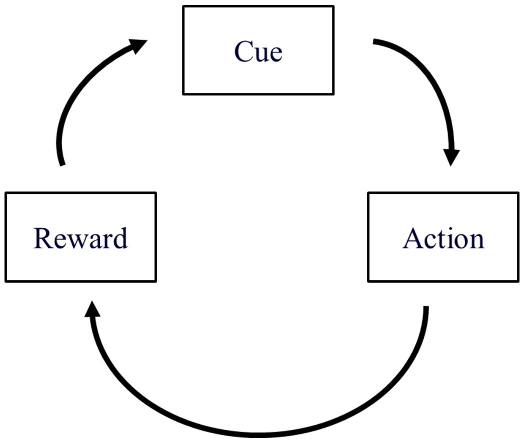

Figure 5. The Habit Loop. Developing good habits is situation specific. Cueing and action are the easiest to drill. Identifying a reward short of "avoiding catastrophe" does require some creativity, however, because the subconscious mind doesn't "see" danger (unless experienced real, or imagined), it is important to visualize the danger when creating habits, since for catastrophic events most of us haven't experienced these first-hand. Nudge theory can help develop proper habits (see **Section 4.3**).

Several good habits related to a console operator responding to an abnormal situation are listed in **Figure 7**. Good habits related to a field operator task are more task specific. However, a short list of general field task habits is listed in **Figure 6**.

Good Habits

Field Task

1. Pre-Job. Review critical steps, and the danger.
2. Always carry the procedure (even if task is memorized)
3. Cue specific 'pause points' into procedure to perform a mindful (conscious) check.
4. Develop good habits to prevent common error syndromes such as (shortcuts, abandon task, shift change, forget-remember, working on wrong equipment, not believing instrument readings, restoration, etc. **[6]**)

Figure 6. Good habits to develop related to field tasks.

4.3 Nudge Theory

Nudge theory grew out of the Heuristics and Biases (HB) school of thought **[3]**. Nudge theory can be defined as:

> "An intervention in choice-architecture that causes a person to behave in a desired way or to choose a preferred option over alternatives."

Nudges work by taking advantage of our mental short cuts (a.k.a., heuristics).

The "Framing and Loss Aversion" heuristic that was described in **Section 2** is a good candidate for a nudge regarding operator behavior.

For example, production versus safe operation. If, in the operator's mind, production is framed as the "loss," safe operation will lose every time. People will work twice as hard to avoid a loss than an equivalent gain. When building better habits related to operational safety, framing a choice problem is very important.

5 Designing for Situation Awareness (Tying it all together)

Design for Situation Awareness by considering the following four techniques:

1. System Design
2. Develop skill-based intuition
3. Create Safe habits
4. Use Nudge Theory

Figure 7 shows the elements of Situation Awareness and how the concepts discussed in this paper might apply to each element. This is for a console operator response to abnormal situation.

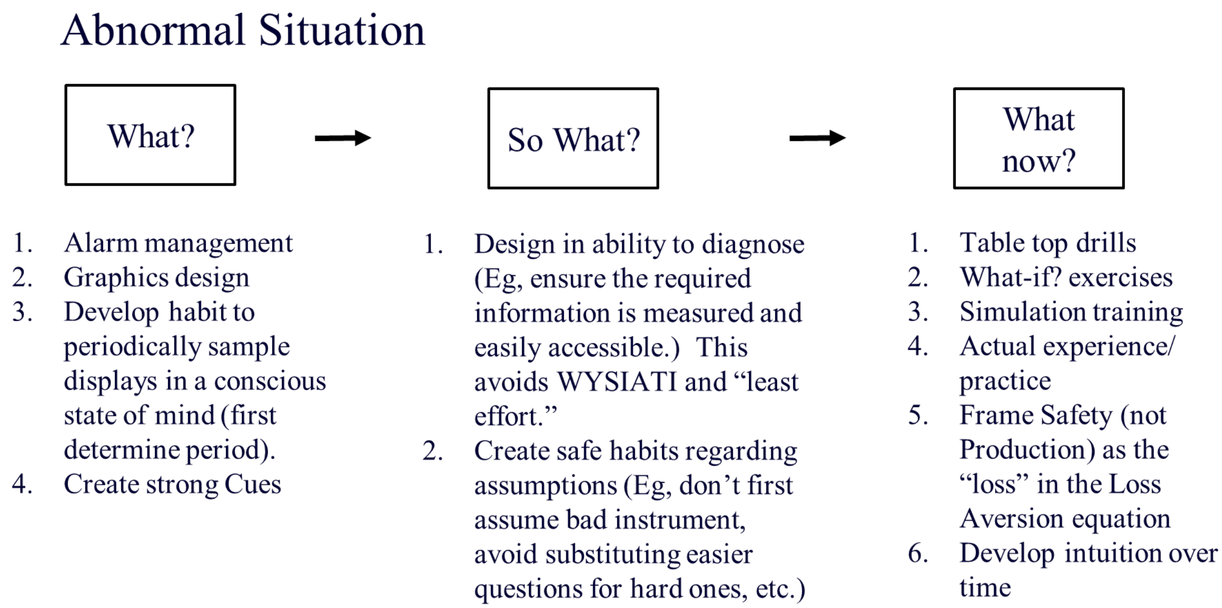

Figure 7. Ways to promote Situation Awareness for a console operator response to abnormal situation.

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