Stress and Cognitive Function: The impact on Quality in Manufacturing Environments

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Bovis brings a unique blend of industrial expertise and neuroscience to the table, having mastered the art of driving change and enhancing operational efficiency in manufacturing organisations around Europe through a near 40-year career. In recognition of his achievements in industry and his creation of the innovative BTFA™ (Believe-Think-Feel-Act) model, a framework that helps to transform organisational culture and leadership decision-making processes, he was granted a Masters in Applied Neuroscience from the Institute of Organisational Neuroscience (ION) in 2022.

Abstract:

This paper investigates the intricate relationship between stress and cognitive function within manufacturing environments, emphasising the significant impact of chronic stress on operational performance and product quality. By analysing neurobiological pathways, particularly the roles of cortisol and brain-derived neurotrophic factor (BDNF), the study elucidates how stress disrupts cognitive processes. This paper combines the latest discoveries from neuroscience with lived experience spanning more than 30 years in manager and director roles within the manufacturing sector, to highlight the cognitive and quality-related challenges posed by stress in high-demand industrial settings. Using a combination of qualitative and quantitative data, the findings reveal that elevated cortisol levels impair critical brain regions, leading to diminished decision-making and memory functions essential for quality control. The study concludes that understanding and mitigating stress in manufacturing environments is crucial for enhancing cognitive function and maintaining high standards of operational quality.

Keywords: Neuroscience, Cognitive Function, Culture, Productivity, Performance, Quality.

1. Introduction

In the pursuit of operational excellence, the cognitive well-being of employees is paramount, particularly in environments as demanding as manufacturing. Stress, a pervasive aspect of everyday life in the 21st century, and specifically in modern manufacturing operations, is not merely a personal health issue but, to the discerning leader, root-cause of operational and strategic concerns, reported in terms of attrition rates, lost skills, re-training costs, inefficiency, poor quality and reduced profits. Therefore, reducing stress offers a panacea of opportunity for improvement. This paper explores the profound impact of uncontrollable [chronic] stress on the cognitive function of people in a variety of roles, and consequently, the impact upon the quality performance achieved in manufacturing processes, which are designed, maintained, and executed as an output of brain function, within a manufacturing environment. It elucidates the neurobiological mechanisms of stress, presents real-world implications for manufacturing operations, and suggests interventions to mitigate these effects.

2. The Neurobiology of Stress and Its Impact on Cognitive Functions

2.1 Detailed Neuroendocrine Mechanisms of the Stress Response

The stress response is a sophisticated neuroendocrine mechanism that begins in the central nervous system and extends to various endocrine glands, ultimately preparing the body to face potential threats. This response is orchestrated by the hypothalamic-pituitary-adrenal (HPA) axis, which involves a hierarchical series of hormonal signals.

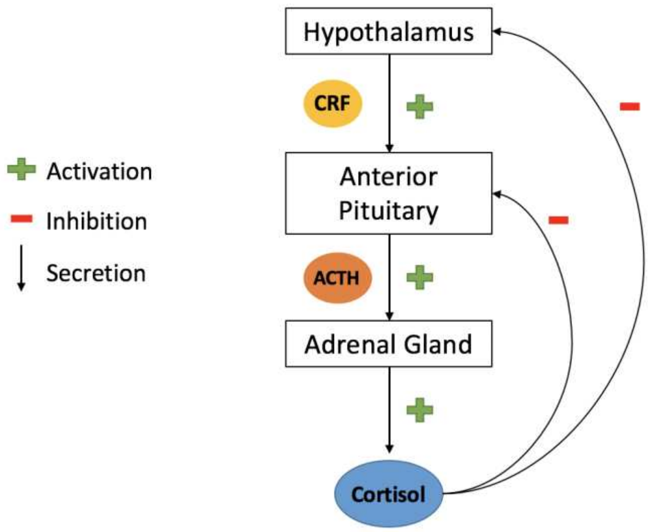
Upon the perception of stress, the paraventricular nucleus of the hypothalamus synthesizes and secretes corticotropin-releasing factor (CRF), also known as corticotropin-releasing hormone (CRH)*, into the hypophyseal portal system, a system of blood vessels in the microcirculation at the base of the brain, connecting the hypothalamus with the anterior pituitary gland.

*The difference in nomenclature: ‘factor versus hormone’, primarily reflects historical usage and different research traditions, with "factor" often used in earlier literature and "hormone" reflecting its recognised role in signalling between organs.

CRF acts on the anterior pituitary gland, prompting the release of adrenocorticotropic hormone (ACTH) into the systemic circulation. ACTH is a polypeptide tropic hormone synthesized from the precursor molecule pro-opiomelanocortin (POMC) and is essential for the activation of the adrenal cortex.

Upon reaching the adrenal cortex via the bloodstream, ACTH binds to specific receptors on the surface of adrenal cortical cells, stimulating the synthesis and release of glucocorticoids, primarily cortisol in humans. Cortisol, the 'end product' of HPA axis activation, exerts numerous physiological effects aimed at mobilising the body's resources to manage and withstand stress. These effects include increasing blood glucose concentration, modulating immune function, and suppressing non-essential physiological processes to prioritise the fight-or-flight response.

The HPA axis is regulated by a negative feedback loop where high levels of cortisol inhibit the release of both CRF and ACTH, ensuring that the stress response is proportionate to the severity of the stimulus and preventing excessive hormone levels that could be detrimental to the organism [1] (McEwen, 2007) [2] (Smith, S. M., & Vale, W. W. 2006).



[Fig.1]

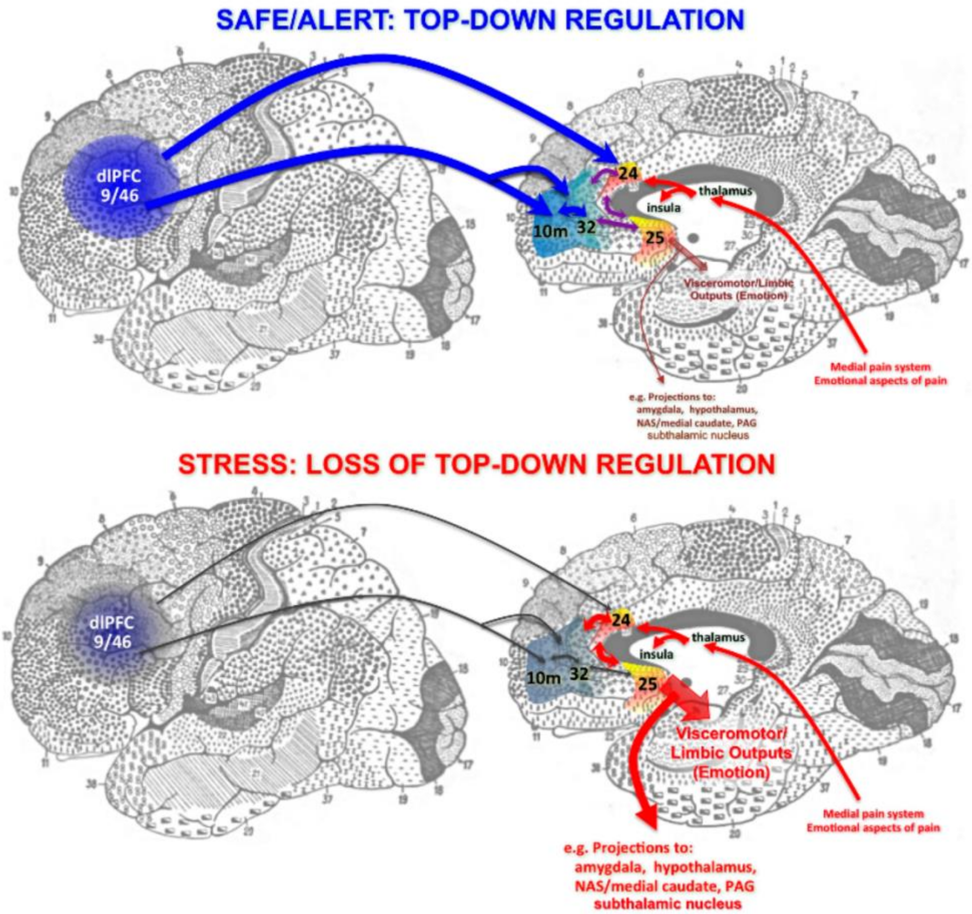
2.2 Cortisol's Impact on Cognitive Regions

Cortisol exerts its influence on multiple brain regions, notably the prefrontal cortex (PFC), hippocampus, and amygdala, which are pivotal in the orchestration of cognitive processes. In the PFC, responsible for executive functions such as strategic planning and judgment, elevated cortisol levels lead to alterations in synaptic plasticity and neurotransmitter release, thereby impairing working memory and flexible thinking, both crucial for quality decision-making in manufacturing operations [3] (Arnsten, 2009). For example, when evaluating the integration of a new technological process, method or approach on the production line, (such as Lean methods being introduced to an historically batch & queue / command and control environment), the stressed brain might struggle with weighing the long-term benefits against the short-term costs, potentially leading to either riskaverse stagnation (Often referred to as Resistance to change) or reckless innovation (Historically referred to as Kamikaze Kaizen).

The hippocampus, vital for learning and memory consolidation, becomes less effective in synaptic signalling under high cortisol conditions, disrupting the formation of new memories and the retrieval of existing knowledge necessary for process improvement and error reduction in manufacturing settings [4] (McEwen, 2000). Meanwhile, the amygdala, which processes emotional responses, shows increased activity, sometimes culminating in heightened perception of threat and emotional reactivity, which can manifest as unhelpful psychological coping strategies such as denial or projection [5] (Pessoa, 2013) [6] (H. Okon-Singer 2016). This amygdala hyperactivity in response to environmental stress triggers, can skew the social dynamics within the workplace, fostering an environment in which such defensive responses are elevated over time, (a 'blame culture' in the vernacular), which in turn, deflects accountability and amplifies stress among colleagues.

Further, the deleterious effect of cortisol on the anterior cingulate cortex (ACC), an area implicated in error detection and conflict monitoring, compromises the ability to recognise mistakes and rectify them before they escalate to quality issues [7] (Bush et al., 2000). The interplay between elevated stress responses, characterised by heightened beta and gamma brain wave activity, and increased energy consumption in these regions can significantly detract from the neural resources allocated to the PFC, thus diminishing critical thinking capacities. This diminished capacity impairs the individual's ability to surmount cognitive biases and to process factual information objectively, untainted by fear or stress-induced self-concept issues. Employees with a stressed self-concept may misinterpret performance metrics and KPI pressures as personal threats rather than motivators, leading to compromised problem-solving and decision-making that could be crucial for maintaining the stringent quality standards required in manufacturing operations.

In sum, the pervasive impact of cortisol on neural functionality across these key brain regions not only alters individual cognitive processes but also has the potential to create a ripple effect that can disrupt the collective cognitive climate of a manufacturing environment, leading to broader implications for quality and the sustainability of improvement activities introduced in pursuit of operational excellence.



[Fig.2]

2.3 Chronic Stress and Neural Plasticity

Chronic exposure to elevated cortisol profoundly impairs the brain's structural and functional plasticity by downregulating the production of brain-derived neurotrophic factor (BDNF). BDNF, is a neurotrophin which plays a vital role in the survival, growth, and differentiation of neurons and in the formation and plasticity of synaptic connections. In the milieu of a manufacturing environment where adaptability and learning are essential for process optimisation and error minimisation, BDNF's role becomes even more critical.

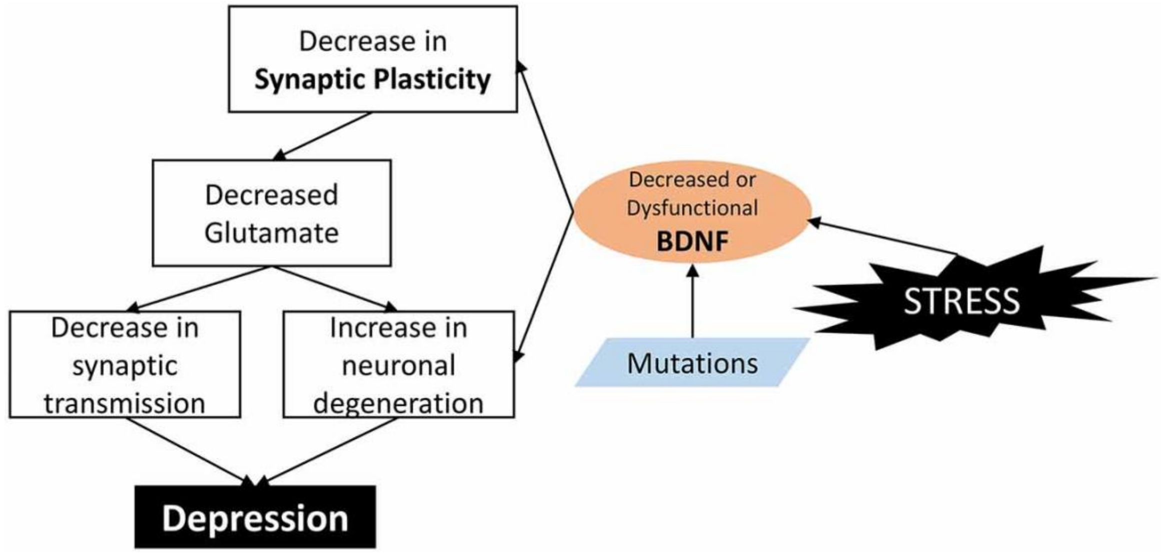
Within the brain's neuroarchitecture, particularly in regions such as the hippocampus and the PFC, BDNF facilitates long-term potentiation (LTP), a cellular correlate of learning and memory. Elevated cortisol interferes with this process, leading to synaptic regression and atrophy, which in turn results in compromised cognitive agility [8] (Bekinschtein et al., 2008). Such cognitive rigidity can manifest as a reduced capacity to assimilate new procedural protocols or to reconfigure production strategies in response to market shifts or technological advancements, often referred to as a lack of flexibility or adaptability in organisational terms, thereby impeding operational efficiency, where failing to adopt improved methods often has direct links to quality control challenges and quality metrics.

Moreover, diminished levels of BDNF are linked to the atrophy of the dentate gyrus and CA regions of the hippocampus, affecting not only memory formation but also the regulation of emotional responses [9] (Duman and Monteggia, 2006). In the context of manufacturing, this may lead to a workforce less capable of emotionally neutral decision-making, prone to overreaction to routine stressors, such as equipment malfunctions or tight deadlines, exacerbating systemic stress.

The effects of compromised BDNF synthesis extend to the frontal lobe, where strategic thinking and problem-solving reside. A workforce battling stress-induced reductions in BDNF may display a tendency toward decision-making that relies on heuristic shortcuts (Firefighting) rather than analytical evaluation (root-cause problem solving), culminating in a greater incidence of production errors or safety oversights. This heuristic bias can be further aggravated by cortisol's impact on the amygdala, biasing the individual toward emotional reasoning, a liability in the precise and calculated world of manufacturing, particularly where such a stress-induced perturbance of judgement, precedes the assumptions and behaviours witnessed in those with power and the authority to make decisions, i.e. Senior / executive leaders.

The perturbations in BDNF-mediated neural circuitry can also attenuate the cognitive elasticity required to navigate and rectify the complex, multivariate problems often encountered on the manufacturing floor. The diminished neuroplasticity hinders individuals' ability to restructure their cognitive approaches to problems that deviate from the norm, limiting their proficiency in troubleshooting and innovation.

These alterations in brain chemistry and physiology underscore the profound necessity of maintaining a work environment that nurtures cognition. By fostering practices that reflect an understanding of human brain function, leaders can strategically and tactically mitigate stress, to promote neurogenesis, so manufacturing settings are purposefully designed to sustain the cognitive health necessary for maintaining high standards of quality and adaptability in a rapidly evolving industrial landscape.



[Fig.3]

Counter to the oft promoted advice of introducing practices such as cognitive training and mindfulness techniques, (which have a place, but are far from a solution), the author encourages leaders to recognise it is often one's own attitude, assumption, action and decision making process, inhibited by the stress response described herein, which provide the conditions in which the human brains around us are able to function optimally or, sub optimally in response to the elevated levels of stress we ourselves create.

This awareness requires leaders develop a high degree of self-awareness, such that they have agency over their own emotional predisposition and choose to lead by example in emotional as well as technical terms, in pursuit of high-quality standards and Operational Excellence. Such awareness can be accelerated where a working knowledge of neuroscience is established, providing a window into one's own and other people's primary drives and subsequent behaviours.

3. Implications of Stress in Manufacturing Practices

3.1 Example Case: Cognitive Overload when Changing Material / Supplier

In pursuit of improved quality performance, it is often the case in a manufacturing environment that one must instigate a material and/or, supplier change. This is a complex task that requires meticulous planning, coordination across several departments, quite often, adherence to project management protocols and, an ability to 'report out' to senior leaders.

When a project manager embarks on this journey, they are not simply engaging in a logistical exercise; they are navigating a labyrinth of technical, social, and cognitive challenges that can be compounded by stress. This process involves a series of intricate steps, each demanding a significant cognitive load, which becomes metabolically taxing and thus, susceptible to the detrimental effects of stress on brain function.

Below I explore an example that details examples of the steps required and link them to project management methodologies, while also considering the impact of cognitive functions:

3.1.1 Initiation of Material Change:

Project Management Protocol: According to PRINCE2, the initiation stage involves assembling the project brief and plan. This is when the project manager must evaluate the business case for changing the material type, which involves an assessment of risks, benefits, and resource requirements. Other methods employed at this stage might be the coordination of a cross functional engineering team to carry out a Process Failure Modes and Effects Analysis (PFMEA), in and of itself, a cognitively taxing exercise few enjoy.

Cognitive Impact: The decision-making process here requires a high-functioning prefrontal cortex (PFC), capable of strategic planning and judgment. Conversely, thinking through a PFMEA, requires imagination, often associated with the Default Mode Network (DMN), a system within the brain that increases in activity when we 'daydream' and glucose energy consumption rates are reduced in other areas while the DMN is active. This is one example of where process steps, which appear to be 'practical', demand the brain works counterintuitively within itself, reducing efficacy of either function.

Additionally, in such situations, timelines are often imposed for financial reasons. Where finance directors and those looking at market forces remain detached from the reality of conducting such an exercise, the targets to attain improved outcomes can often seem arbitrary to the project manager and the team-members faced with executing the task.

Overarching time pressures which seem unrealistic can act as a major stress trigger, setting the tone and urgency for the entire project. This can lead to increased perceptions of pressure and the initiation of the fear response, further increasing and perpetuating stress levels. Under such elevated cortisol conditions, the compromised PFC may struggle to regulate stimulus passing to the amygdala and the ACC may realise reduced capacity for risk assessment, detrimentally impacting the quality of the business case, even during its development phase.

3.1.2 Stakeholder Analysis and Management:

Project Management Protocol: Stakeholder management, as outlined in methodologies like ITIL (Information Technology Infrastructure Library) and PMBOK (Project management Body of Knowledge), requires identifying and understanding the expectations and influence of all stakeholders, including the incumbent and potential suppliers, internal departments, and regulatory bodies. The challenge, from a neurological perspective, is that the term 'understanding expectations' is systematically underestimated in the absence of a working knowledge of neuroscience. *Expectations* from a neurological perspective engage multiple brain regions and constructs, to include subjective concepts such as goal seeking, predictive risk assessment and perceptions of benefit, determined not only by individual life experience and context, but also by the brain assessing risk within the current conditions, determined also by personal ambition and self-concept (relative to what is imprinted / conditioned as 'good' [for self] over time / through life). Such subjective terms are proxies for inbound sensory stimulus and neurological activation in various areas of the brain. This view of 'expectations' is rarely considered in the curriculum or language register employed in 'best-practice' project management, or quality (QC / QA) education.

Cognitive Impact: Stress can hinder the hippocampus's ability to form and retrieve memories, as we see in studies surrounding long term potentiation (LTP) and can thus impact a project manager's recall of past stakeholder interactions and learning from previous supplier changes. Failing to recall details under stress, can lead to errors of judgement that might otherwise be avoided where memory function is not inhibited due to the biological impacts of the stressor hormone, Cortisol. In worst case, previous projects / changes, emotionally charged by unrealistic leader expectations can lead to uncontrollable stress, which in turn leads to higher attrition rates, seeing project managers exit the organisation, which loses intuitive knowledge, established through experience, with no hope of that knowledge being replicated in systems or 'knowledge management' searchable databases as effectively as it can be retrieved by a non-stressed human brain. The absence of such knowledge often leads to mistakes being made before similar knowledge can be re-established in the brains of the team members.

3.1.3 Quality and Compliance Assessment:

Project Management Protocol: ADKAR's (Awareness, Desire, Knowledge, Ability, Reinforcement) 'Awareness' stage, calls for understanding *the need* for change. Some may assume this necessitates engaging obvious parties like the quality and compliance departments to ensure the new material meets regulatory and company standards. However, an awareness of the need for change, a reason why (purpose), and the potential benefits that are associated to the change, must be understood by all human brains involved and affected by the change. This can demand the project manager consciously considers the development of neurons in brains, which will need to grow and integrate into the existing neural network (via neurogenesis) to represent the new interactions, such that a positive emotional response is cultivated, *before* the changes are introduced in practice. Failing to provide this opportunity for neurological adjustment and reasoning can lead to the neurological adaptation processes consuming glucose energy during the normal cycle of the day's activities, thus reducing available energy in those brain function areas required to perform the task at hand. This can see 'change' lead to an increase in mistakes being made, detrimentally effecting quality performance in teams and departments.

Example employees who will need to have an opportunity to develop such awareness [neurological representation of the new elements they will experience] may include the operators who will use or be involved with the new materials e.g.

- *Lathe operators for new metals:* different cutting speeds/feeds and carbide tips may be required, and will need to be investigated, tested, added to the consumables list with the purchasing department and ordered.
- *Moulding technician, experiencing a change to the plastic granules used for a moulded product:* may need to trial the new material to develop different setting sheets to detail updated temperatures, pressures, screw speeds, open/close and ejection speeds etc.
- *Procurement and finance team members:* may be losing access to relationships with friends in existing suppliers while expected to forge new relationships, requiring the development of trust (also a neuro-chemical state attained in response to stimulus over time [experience]).

This is a very typical account of what it can mean to be 'Aware'. Where leaders, setting timelines and budgets are too detached from this experience, 'expectations' can seem unrealistic seeing projects doomed to difficulty over extended time periods from their very inception. A lack of awareness can lead to elevated stress levels, cognitive error and mistakes that impact quality, cost and delivery performance.

Cognitive Impact: Stress-induced reductions in BDNF can affect the neuroplasticity needed to adapt to anything new, from compliance requirements to new machining methods to new relationships … ideally such considerations would be effectively integrated into the project plan, so brains are provided the opportunity to make the adaptations required to map the new stimulus into its existing neural network, mitigating so far as possible, any negative emotional reactions to the change. i.e. Leaders would 'Believe' that engagement and rapid adoption is a prime emotional step in attaining the required logical outcome objective. However, in the absence of a working knowledge of neuroscience many 'best practice' project management methods fail to educate in these neuroscientific terms.

3.1.4 Cross-Functional Team Coordination:

Project Management Protocol: ASAP7's focus on teamwork comes into play as the project manager must coordinate with procurement, IT, R&D, production engineering, and design departments, ensuring that all teams are aligned and the change is reflected in ERP systems, procurement contracts, and product documentation. As we've detailed above, each brain involved must establish a neuro-chemical balance in response to the suggestion of the change, if one is to facilitate an awareness, that ensures the brain retains capacity to function optimally and beyond that, alters its chemical state in the positive, to experience 'Desire' i.e. a positive Neuro-psychological response, often described as 'wanting to', and assumed when using terms like discretionary effort or intrinsic motivation, all of which are neuro-chemical states triggered by the environmental stimuli the individual brain perceives and is surviving in the moment.

Cognitive Impact: Such enormous coordination efforts place a substantial burden on working memory and executive function, which can be impaired by cortisol's impact on the PFC and ACC, potentially leading to errors in communication and task prioritisation as just two examples among many.

3.1.5 Change Implementation and Monitoring:

Project Management Protocol: During the change implementation phase, methodologies like PRINCE2 and ITIL emphasise the need for monitoring and controlling project progression. This involves overseeing the delivery and inspection of the first-off samples, ensuring that production does not falter during the transition.

Cognitive Impact: The ACC's role in error detection is crucial here. Stress can compromise the ACC's ability to detect and respond to discrepancies, increasing the risk of quality lapses during implementation.

3.1.6 Training and Communication:

Project Management Protocol: The ADKAR model's desire and knowledge stages highlight the necessity for training and communication. Throw-away phrases like **"Employees need to understand the change and be competent in their roles post-change"** abound in the literature surrounding change and change management and are also to be found amongst 'advice' freely shared on business-based networking platforms like LinkedIn, however, once we start to break such 'advice' down semantically, through the neuroscience lens, we find:

- **'Need'** is a descriptive word for a psychological state, that links to dopamine release and the seeking mechanism
- **'Understand'** is a description of the formation of new neurons, neurological pathways or adaptation and new firing sequences through existing pathways.
- **'Change'** to anything a human does (e.g. execute a process differently / behave differently) has a neurological process at its core, often described with words like neuroplasticity / neurogenesis.
- **'Competent'** is an outcome of 'Long Term Potentiation', requiring the individual brain is exposed to sufficient stimulus over time to ensure myelin around axons on neurons has thickened through repeated stimulus and will be maintained with high action potential over time, following lesser stimulus from conscious processing activities.

Once considered as brain function, it is apparent that many of the conditions leaders create and advocate under the banner of 'best practice', justified in pursuit of reduced timelines to effective outcomes, are in fact, counterproductive, detracting from the timeliness of change and adoption of new processes, but also, from the culture of the organisation.

Cognitive Impact: Chronic stress can hinder the ability of the hippocampus to acquire new knowledge, making it challenging for anyone surviving the environment, like a project manager and the cross-function team members in this example, to learn, and then effectively convey the nuances of the new material to the wider audience around the organisation.

3.1.7 Evaluation of Change Effectiveness:

Project Management Protocol: Upon project completion, PRINCE2 advocates for reviewing project outcomes against the initial plan to measure effectiveness and learn for future projects. However, in the absence of any consideration of feelings / emotions and their impact on performance, such 'logical' instruction systematically fails to recognise the impact of brain function on performance and learning. All such project outcome assessments therefore remain focused on quantifiable data collected within the existing paradigm, i.e. from the standard output of systems coded via logic, whose design is aligned to the logic-based assumptions embedded into the education landscape, which, to date, has ignored the neurological / emotional component, which so often detracts from performance and rate of adaptation.

Cognitive Impact: Under duress, from time considerations and leadership 'expectations' i.e. to report only successes upwards in the hierarchy, the associated stress levels can affect the project managers and teams' cognitive flexibility and openness to feedback. That coupled with a pre-determined language register that omits consideration of the human emotional state in response to imposed control and change, potentially biases the evaluation of the project's success, negatively impacting lessons learned for future changes, while confirming existing methods as valid. This education-best-practice loop has remained self-perpetuating in the absence of any challenge.

3.2 The Systematic Oversight of Brain Function in Project Management, Change management and Leadership education.

While project management protocols provide structured methodologies, and similar change management models have been added to the portfolio of training options leaders can opt to take for their own development, there is a systemic capacity to overlook the impact of brain function and stress on these processes. These methodologies largely treat project management and change management as a logical sequence of tasks, undervaluing the complex neural processes that underlie each emotional decision and subsequent action any human being takes. It is understandable that historic (20th century) models fail to integrate a working knowledge of neuroscience, as advances in the field have only recently started to bridge the gap between academia and the world of business, however, this oversight can be detrimental to project outcomes, as stressed cognitive systems are less adept at navigating the intricate, multifaceted challenges people face, as presented in the previous example, of material and supplier changes in manufacturing environments.

To enhance the effectiveness of project management and change management in such cognitively demanding scenarios, it is imperative to incorporate an understanding of the neurobiological impacts of stress. By doing so, organisations can create more resilient project management practices that account for the human element, optimising both individual and project performance, leading to better processes, performance, and key metrics like, Quality, Cost, Delivery, Growth, Safety and Morale (QCDGSM).

3.3 Stress-Induced Errors in Manufacturing Execution

Stress can lead to both cognitive and physical errors on the front line. For instance, under high stress, workers may misinterpret complex machinery readings or overlook critical safety checks, resulting in increased accident rates and defects in product quality.

This is usually an issue highlighted by events in high profile environments, such as the Southwest Airlines Flight 1455 which travelled from Las Vegas to Burbank, California. During the landing approach, cockpit warning signals alerted the captain and first officer that flight speed and angle of descent were outside of the glide path. These warnings were ignored. As a result, the plane overran the runway, crashed through a fence and wall coming to rest in a neighbourhood narrowly missing a set of gas station pumps.[10]

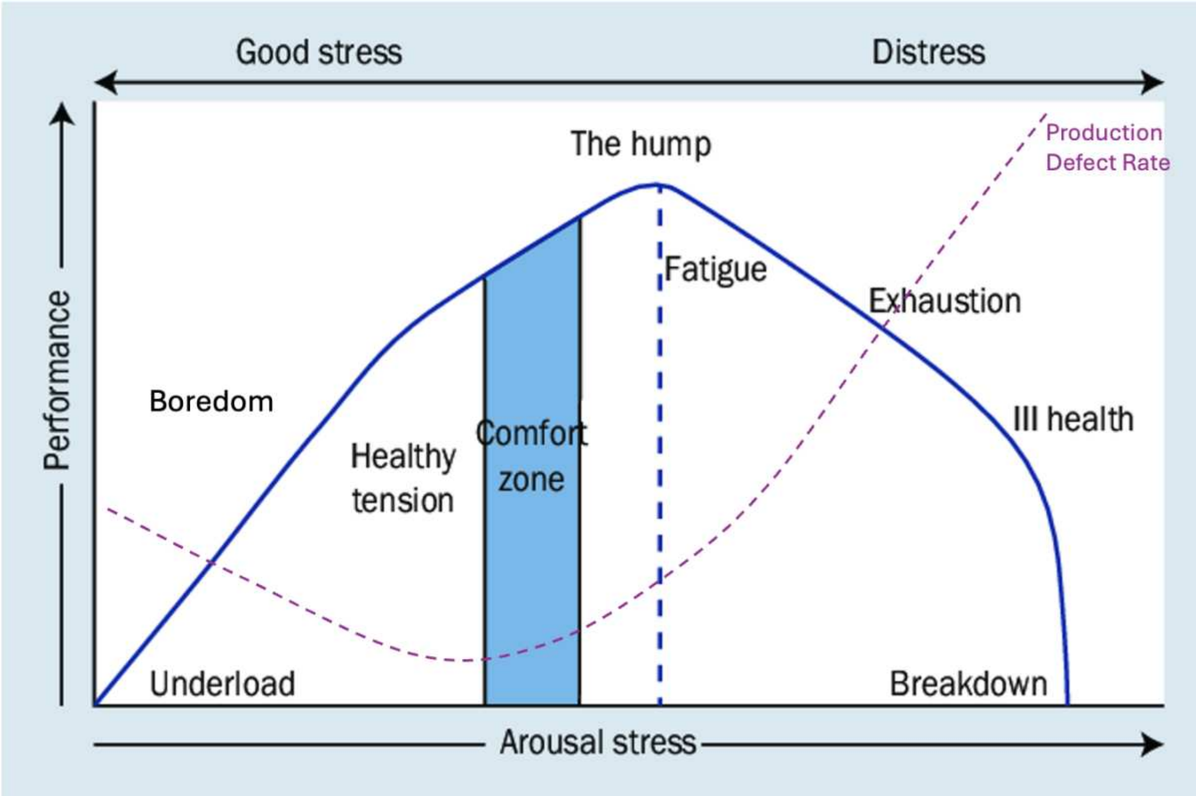
In fact, this same article states, *"In private or general aviation, loss of aircraft control by the pilot is the number one cause of plane and helicopter crashes. Even commercial airline flights are not immune from these issues, with recent statistics calculating that at least 50 percent of major airline crashes are related to human factors."*

Other accounts include The Three Mile Island Unit 2 reactor, near Middletown, Pa., which partially melted down on March 28, 1979. A combination of equipment malfunctions, design-related problems and worker errors led to TMI-2's partial meltdown.

This helps to highlight a perennial focus on human error is a conscious consideration in high-risk environments, particularly prevalent in industries such as aerospace, nuclear power, mining and medical… incidents are reported when things go wrong, but rarely is human error linked explicitly to stress as a function of CRF/CRH/ACTH – i.e. the HPA Axis, that ultimately leads to cortisol being released into the bloodstream and crossing the blood brain barrier to negatively alter cognitive function as part of the fight-flight mechanism being activated in the modern workplace, which ironically, evolved to keep us safe in natural surroundings.

In recent years there is increasing awareness surrounding this issue, accelerated by advances in neuroscience. The subject is now better translated into language that businesspeople in all sectors can understand. One such supporting study [11] carried out in Malaysia in 2014, reported that almost 90% of accidents in the workplace are a result of human error and, that 4 major influencers, namely stress, repetition, fatigue and environment can explain 48.8% of all such human error. This is an interesting view as repetition, fatigue and environment can all be considered 'stress triggers' so far as the 'human brain surviving its environment' is concerned at a neurological level.

In the absence of such studies yet linking those neurotransmitters associated to stress, with production error rates, we might posit the outcome of any such analysis might look something like the following diagram, which shows the lowest production defect rates will most likely correlate to neurological homeostasis where thinking is clear, due to the brain not processing stimulus that triggers a fear response, and that error rates will be more common where people are bored (disengaged through apathy) and will significantly increase when chronically stressed (disengaged through the fear-based survival response).



[Fig.4]

4. Strategies to Mitigate Stress and Enhance Cognitive Function in Manufacturing

4.1 Mindfulness, Wellbeing or Create the conditions in which brains can perform at their best?

While cognitive training and mindfulness programs such as those described by Davidson et al. (2003) can indeed play a role in alleviating some symptoms of stress, the ubiquity and variety of stressors present in modern work environments necessitate a broader, more systemic approach to stress management. Such stressors include, but are not limited to:

4.1.1 Micromanagement: Where constant oversight can lead to a sense of diminished autonomy and professional inadequacy.

4.1.2 Bullying and Harassment: Creating a hostile work environment that can result in significant emotional distress.

4.1.3 Imposed System Controls: Rigid adherence to inflexible systems that can stifle creativity and initiative.

4.1.4 High Noise Levels: In industrial settings, persistent noise can disrupt concentration and increase tension.

4.1.5 Unrealistic Deadlines: Leading to a chronic rush and the feeling of always being behind.

4.1.6 Poor Work-Life Balance: Demanding work schedules that encroach on personal time and lead to burnout.

4.1.7 Inadequate Resources: Working with insufficient tools or personnel can escalate workplace stress.

4.1.8 Unclear Job Expectations: Ambiguity can create uncertainty and persistent worry about job performance. NB: Cybersecurity reports some of the highest levels of burnout. [12]

4.1.9 Technological Malfunctions: Frequent equipment or system failures that impede workflow and efficiency.

4.1.10 Organisational Changes: Such as restructuring, which can create an environment of uncertainty and insecurity.

Acknowledging these stressors [and many more besides], underscores the fact that chronic stress is not an isolated problem solvable by treating symptoms alone. Rather, it's a pervasive issue linked to the very fabric of the socio-technical work environment. To truly improve quality and reduce the sources of stress that lead to human error, we must shift our focus upstream and consider the environment itself. This entails designing workspaces that promote a sense of control and autonomy (reducing imposed control), establishing clear communication channels that foster a supportive social environment, and developing organisational systems that are not only technically efficient but also cognitively considerate).

An environment attuned to the neurological realities of its human components, evolves where leaders recognise the brain's need to navigate its surroundings with minimal threat. By reducing stressors, we not only address the root cause of the cognitive and emotional reactions but also allow the brain to operate in a mode that is less about survival and more about thriving and problem-solving. This approach goes beyond symptom management to target root-cause in the form of systemic sources of workplace stress, fostering a culture where quality can flourish as a natural by-product of a well-supported, cognitively healthy workforce.

4.2 Ergonomic and Organisational Changes

Effective workspace design and sound scheduling are techniques adopted to reduce workplace stress and enhance employee well-being. Ergonomic workstations reduce physical strain, which, when left unaddressed, can manifest not just in musculoskeletal disorders but also in mental fatigue that clouds judgment and dampens creativity, for a host of neurological reasons, including issues surrounding chronic stress, especially when induced systematically. The presence of elevated cortisol levels, damages cells and alters the chemical mix in other areas of the brain, detrimentally affecting attention, concentration and logical thinking / decision making. Similarly, schedules that incorporate adequate rest, rather than simply being concessions to human limits, can be informed strategies to maximise cognitive function and sustain attention throughout work cycles.

Moreover, cultivating a culture of inclusion and empowerment is essential for fostering an environment that mitigates stress. When employees are granted meaningful control and ownership over their work processes, they are more engaged and invested, which leads to a sense of personal accomplishment and reduces the stress associated with helplessness and uncertainty.

To expand on these themes, and act, accordingly, requires leaders develop a belief that quality, cost and delivery performance is addressed at source of human function, i.e. leaders must be introduced to and develop a working knowledge of the basics of brain function:

- **4.2.1 Physical and Cognitive Ergonomics:** Aligning the physical aspects of the workplace with human physiological capabilities while also considering cognitive ergonomics, designing tasks that align with human cognitive strengths and limitations.
- **4.2.2 Inclusion Initiatives:** These should extend beyond HR policies and become embedded in the day-to-day operations, e.g. production meetings where meaningful information is shared that people authentically feel they gain benefit from attending, and which gives them a voice when they have concerns. Such ‘standard work’ helps to ensure that every employee feels valued and understood. This reduces social stressors and fosters a collaborative environment.
- **4.2.3 Empowerment through Autonomy:** Providing employees with the autonomy to make decisions relevant to their roles can significantly improve mental well-being, especially where the employees know their line leaders support them and will ‘fight their corner’ when challenges arise. Cultivating such autonomy could mean decentralising decision-making processes or providing clear frameworks within which employees have the freedom to operate. The so called ‘Catchball’ process, core to the effective introduction of Hoshin Kanri as a strategy deployment method recognises the psychological benefits of ‘agency’ and thus promotes inclusion as a mainstay of the overall delivery of ‘respect’, providing all employees an opportunity to check, challenge and change the strategic moves they are asked to support throughout the organisation.

4.2.4 **Stress-Aware Scheduling:** Beyond allowing for rest, work schedules should reflect an understanding of circadian rhythms and allow for flexibility where possible, accommodating personal work styles and life commitments. Scheduling that is based purely upon production requirements, machine capabilities or to mitigate for downtime, poor product supply performance and other such variables, inevitably increases stress and often relies on key operators who will tolerate such a poor quality of life, simply because they don't feel they are worthy of better conditions.

4.2.5 **Training for Stress Management:** Organisations must equip employees with the tools to manage stress effectively, which not only includes training on recognising stress signals and taking proactive steps to manage stressors, but to also recognise the neurological basis of stress, and the thinking patterns within themselves that leads to elevated tension and anxiety, so they can proactively improve their own cognitive capabilities, conduct themselves better and lead change more effectively, from a more informed position and contribute effectively to the creation of conditions in which all brains can work optimally.

4.2.6 **Holistic Wellness Programs:** Effective wellness programs [13] must be comprehensive, providing support for physical health, mental well-being, and fostering social connections within the workplace. However, it's critical to recognise that such interventions, particularly counselling services, should not merely act as post-crisis support. While they play a role in addressing individual symptoms of stress, they may not tackle systemic issues. The efficacy of counselling is often compromised in environments where leadership behaviours contribute to a culture of stress. When the origin of stress is internal and institutional, such as a leader who inadvertently fosters a blame culture, counselling services may face an inherent conflict of interest. Their effectiveness is constrained when the structural triggers of stress remain unaddressed, and their focus may inadvertently shift toward enhancing individual coping strategies and reinforcing the self-concept of employees. While these are valuable goals, they cannot substitute for addressing and remedying the underlying organisational stressors. Without modifying the environmental and cultural factors that precipitate stress, the positive impacts of counselling are likely to be transient as the larger issues of workplace well-being remain unaddressed.

4.2.7 **Enhanced Feedback Systems:** Establishing robust feedback mechanisms is not just an exercise in corporate transparency, but a fundamental strategy to combat the psychological impact of voicelessness among employees, which can be a significant source of workplace stress. An effective feedback system must facilitate open, two-way communication and ensure that employee input is not only heard but also acted upon. This includes creating structured channels for employee feedback. These are often considered as something separate, such as regular surveys, suggestion boxes, and forums for open dialogue. However, these systems can be integrated with the company's decision-making processes (e.g. inform Catchball execution practices), ensuring that the insights gathered lead to meaningful changes in principle, practice and even leadership performance and organisational direction where required. It is crucial that employees see the tangible outcomes of their contributions, reinforcing their agency and sense of value, within the organisation. However, the utility of effectively integrated feedback mechanisms extends beyond alleviating stress; they are vital tools for identifying stressors within the workplace itself. They can serve as early warning systems, unveiling issues ranging from workflow inefficiencies to interpersonal conflicts that may not be immediately visible to management.

By actively soliciting and respecting employee feedback, organisations empower their workforce and acknowledge the validity of their experiences and perspectives. This not only nurtures a culture of mutual respect and continuous improvement but also creates a collaborative environment where stressors can be systematically identified and addressed, rather than allowing them to undermine employee well-being and organizational performance.

4.3 Revisiting Performance Metrics

Redefining performance metrics is a strategic imperative for organisations aiming to create sustainable work environments that prioritise well-being alongside productivity. Traditional metrics often fail to capture the complex dynamics of workplace performance, particularly when it comes to the adverse effects of conflicting KPIs and target-driven behaviours.

4.3.1 **Conflicting KPIs:** Key Performance Indicators (KPIs) are often established with a narrow focus, ignoring the interdependencies across various functions and levels within an organisation. For instance, while the production department may have KPIs centred around output within shifts, the executive team might be focused on long-term strategic goals spanning years. These misalignments can lead to cognitive dissonance among employees who are caught between competing priorities and can create a cascade of stress across the organisation. This is exacerbated when KPIs across departments are not harmonised, leading to a tug-of-war for resources and focus that dilutes overall performance.

4.3.2 Target-Driven Behaviours: Targets can drive behaviour, but not always in the desired direction. When incentive structures are tied purely to short-term targets, they can foster unethical practices, such as the manipulation of sales or production figures. The phenomenon of 'gaming the system' for personal gain undermines collective organisational integrity and can erode trust both internally and with external stakeholders. At the operational level, aggressive pursuit of targets may prompt supervisory staff to adopt coercive management styles, heightening stress, and impairing the mental bandwidth necessary for tasks requiring precision and attention to detail. This often leads to a decline in critical performance parameters such as quality due to increased human error.

Leaders in organisations need to holistically reassess their performance evaluation frameworks to ensure they incentivise behaviours that align with ethical standards and long-term organisational health. Performance metrics should be multi-dimensional, capturing not only the quantity but the quality of work, including the ethical conduct of employees and the health of the organisational culture. They should also be adaptive, with the flexibility to evolve as the strategic direction of the organisation shifts and / or be used proactively (leading indicators) to inform the need for such a shift. By aligning KPIs across different functions and levels, and by designing targets that promote ethical and cooperative behaviour, organisations can cultivate a workplace where stress is minimised, and quality is upheld as a cornerstone of operational excellence.

By addressing these areas, organisations can create a more stress-resilient work environment. This entails a recognition that the modern workplace is a complex socio-technical system where stress impacts not only the individual but the intricate interplay between people, processes, and technology. Through deliberate design and policy, we can reduce the sources of stress that lead to error and suboptimal quality, thereby promoting a culture that not only strives for excellence but achieves it through the well-being of its people.

5. Conclusion

The research underscores the critical importance of understanding stress's impact on cognitive function to maintain high standards of operational quality in manufacturing environments.

By synthesizing insights, which have only become available from the world of neuroscience in recent years, as a result of technological advances and connecting these to practical examples from a lifetime leading change and performance improvement in industry, the study highlights the profound effect of chronic stress on brain function, particularly in key regions responsible for decision-making, memory, and emotional regulation, showing personal performance as root cause of productivity and common performance metrics – Quality, Cost and Delivery. These findings have significant implications for both theoretical and practical approaches to stress management in industrial settings. Practically, leaders of organisations should adopt holistic strategies that include environmental design, strategy and change deployment methods which consider stress and brain function, a neurological understanding of relationships between people-process-systems, and enhanced feedback systems to create environments that support cognitive health as foundational to operational excellence. This is imperative if change is to be sustained, alignment is to be achieved over principle based practice and improvements leading to higher engagement, efficiency, productivity and profit are to be maintained culturally. However, the study also acknowledges limitations, such as the variability in individual stress responses and the complexity of isolating stress effects in real-world settings. Future research should explore more granular interventions, for example, to include wearable biometric technology to monitor neurochemical levels in real time (oxytocin / ACTH release) and their impacts on specific cognitive functions required from top-floor to shop-floor, to further refine strategies for mitigating stress and improving performance in manufacturing environments.

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