ResilientGrid

EE379K/EE394V Smart Grids: The Human Factor in the Grid

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February 7, 2019

Guiding Principles

"All organizations are perfectly aligned to get the results they get."

Arthur W. Jones

Guiding Principles

"Ensuring a resilient electric grid is particularly important since it is arguably the most complex and critical infrastructure, and the one upon which other sectors depend to be able to deliver their essential services. "

– Department of Energy

Guiding Principles

Humans are like components of the grid. Interconnect them well, and allow them to operate within their tolerance ranges, and you have an efficient system.

Interconnect them poorly or let them operate outside of tolerances, and you create inefficiency, heat, and the occasional explosion.

Quick Introduction

- A baseball and bat together cost $11. The bat costs $10 more than the ball. How much does the ball cost?

- Did you say $1 for the ball?
  - Most people do, but:
  - The correct answer is $0.50:
  - $10.50 - $0.50 = $10.00

- Why do many of us make these kinds of mistakes?
  - Mental shortcuts tend to shorten the amount of time it takes us to come up with an answer, but doesn't necessarily work in all situations.

Outline

- The role of humans and the grid
- Cognitive biases
- Human Factors Engineering
- Visual Attention
- Situational Awareness
- Behavioral Economics
- Human Error
- Fatigue
- Organizational Management

Humans and the Grid

- Across layers of the electric power space, one can view real-time consumption as the aggregation of:
  - Human behavior based on their needs
  - Human behavior resulting from policy decisions and financial incentives
  - Devices facilitating human behavior
  - Human behavior in control rooms, policy decision making, and in the residential and consumer spaces.
  - Technical changes to the system as understood by humans

Humans and the Grid

- Therefore, in order to understand and better model the state of the system, one must better understand human behavior!
  - This is an engineering activity: applying engineering principles to knowledge derived from psychology, neuroscience, sociology, and anthropology.
  - This is akin to the way that physics, chemistry, mathematics and computer science knowledge is applied to the engineering of the grid's physical components and operation.

Humans and the Grid

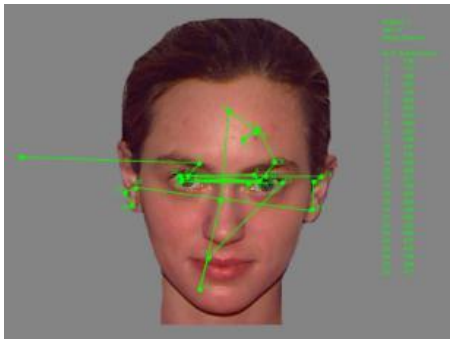
- Human behavior is observable across all layers of the grid, and in several emerging areas. Some examples:
  - Software/firmware development for "smart"/IoT devices
  - Real-time and day-ahead control room operations
  - Individual consumer behavior
  - Policy making around PTC/ITC, and other incentives

Cognitive biases

- Where do they come from:
  - Brain's limited processing capabilities
    - Heuristics (mental short-cuts)
    - Distractions, stress, pace
  - Emotional, moral, and social sources
  - Physiological arousal
  - How we feel (e.g., hungry, tired)

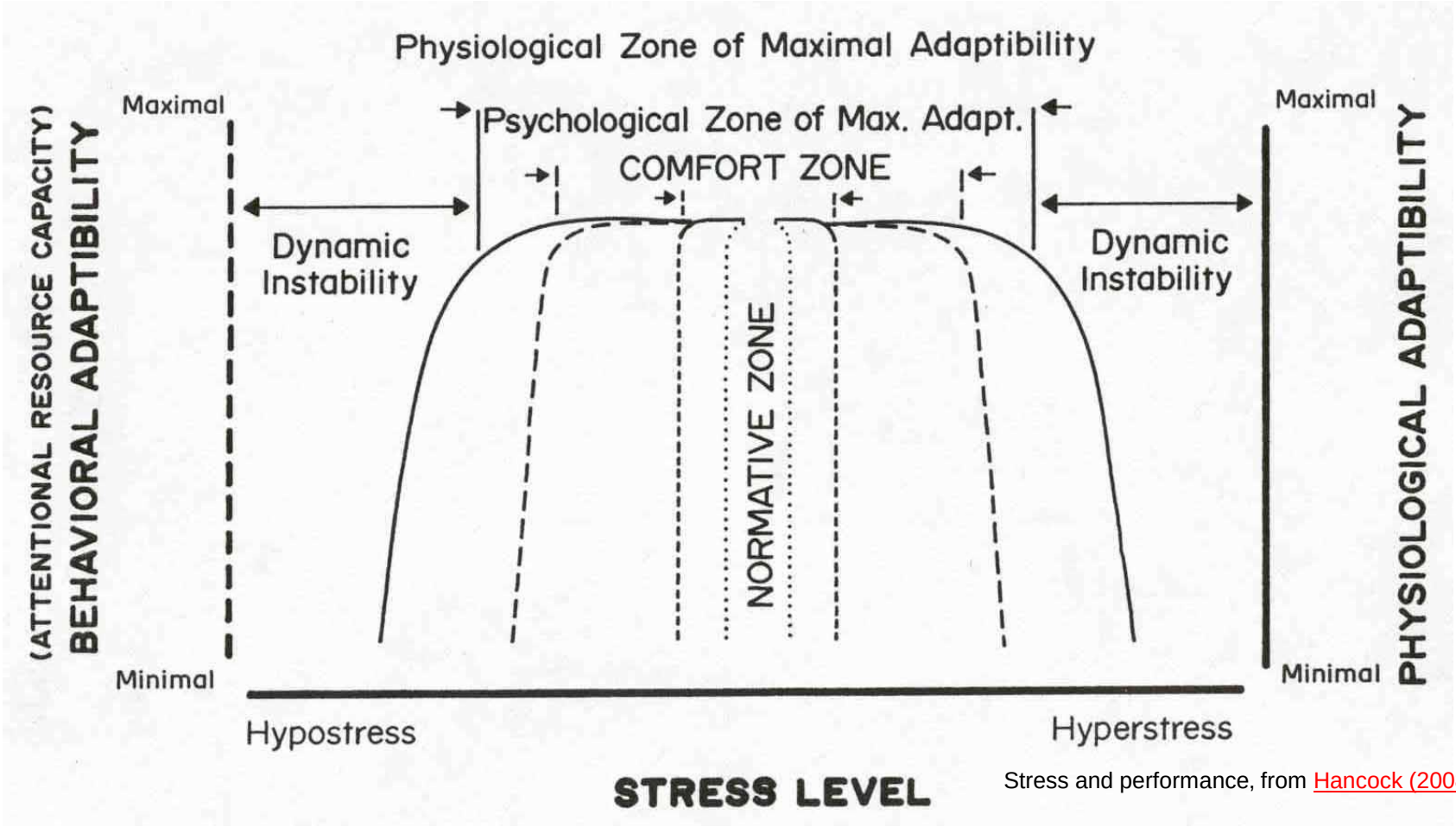
Cognitive biases

- How we respond in ambiguity
- A deviation in judgment – non-logical functioning
- Predictable, but not rational
- May be adaptive (e.g., speeding up decisions)
- Some biases prejudicial



Human Factors Engineering

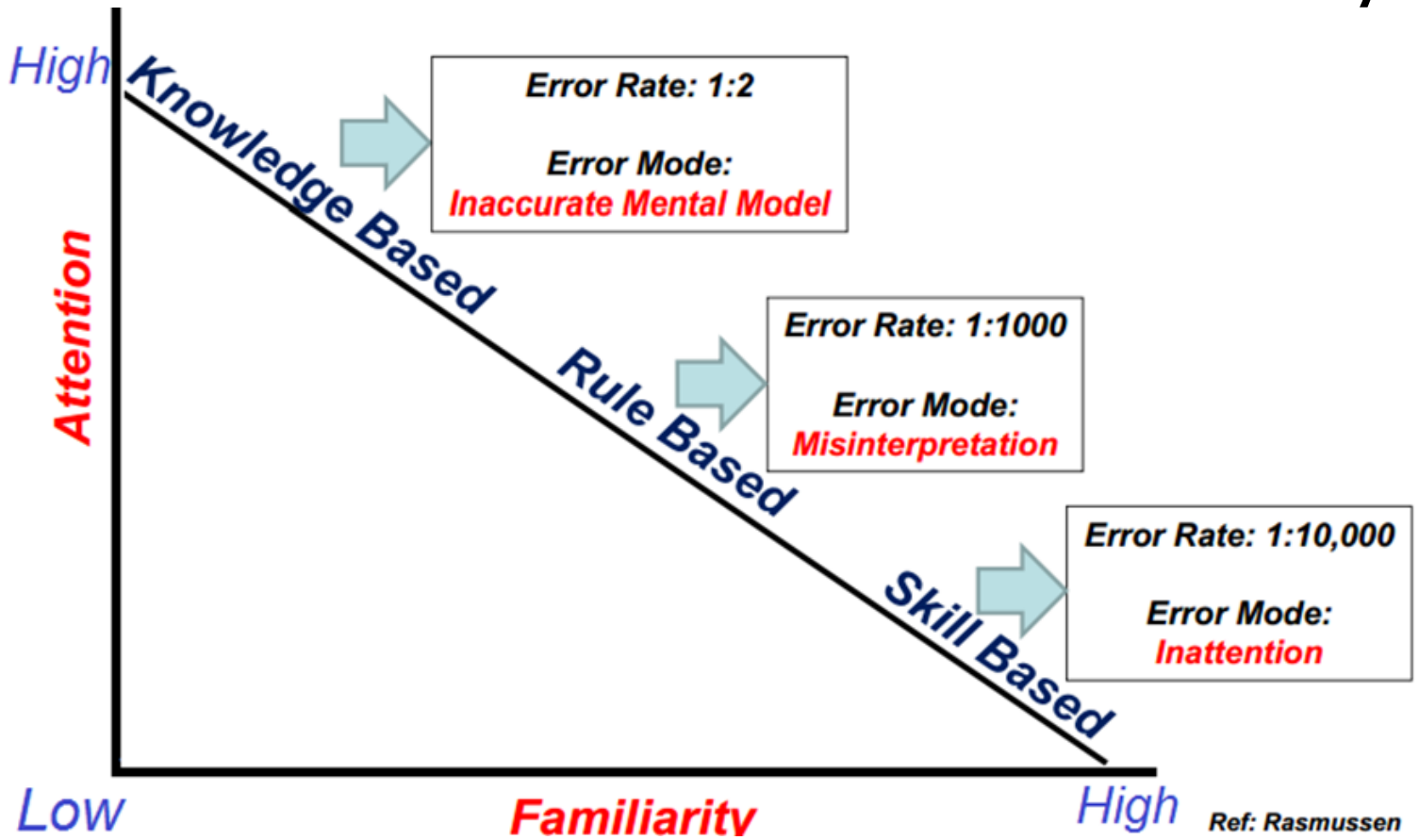
- Human Performance Under Stress



Stress and performance, from Hancock (2008)

Human Factors Engineering

- Human Performance Based on Familiarity



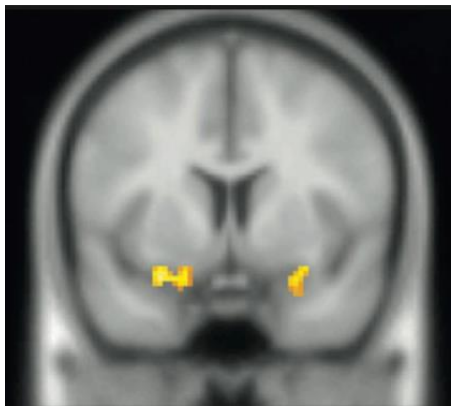
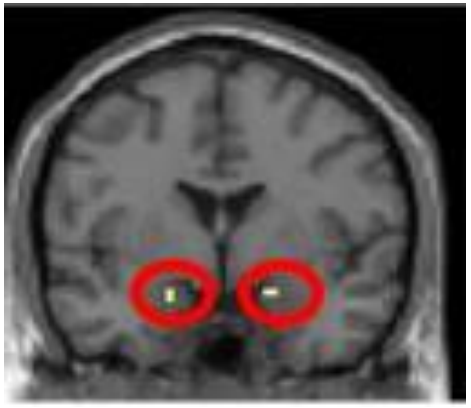
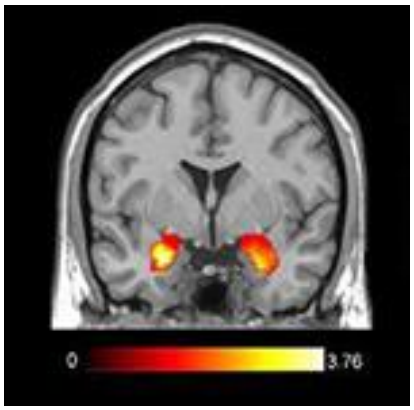
From: NERC Cause Analysis Methods

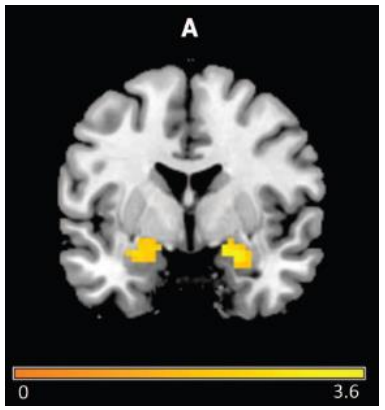
Human Factors Engineering

- Ego Depletion:
  - Self-control is a limited resource, and like a muscle, it tires out.

Human Factors Engineering

- Most difficult to process information under extreme stress
- Humans make 3 – 7 mistakes per hour awake, 11-17 under extreme stress.
- Working memory decreases under stress (from 7±2 chunks to 3-5 or lower, with long term damage)



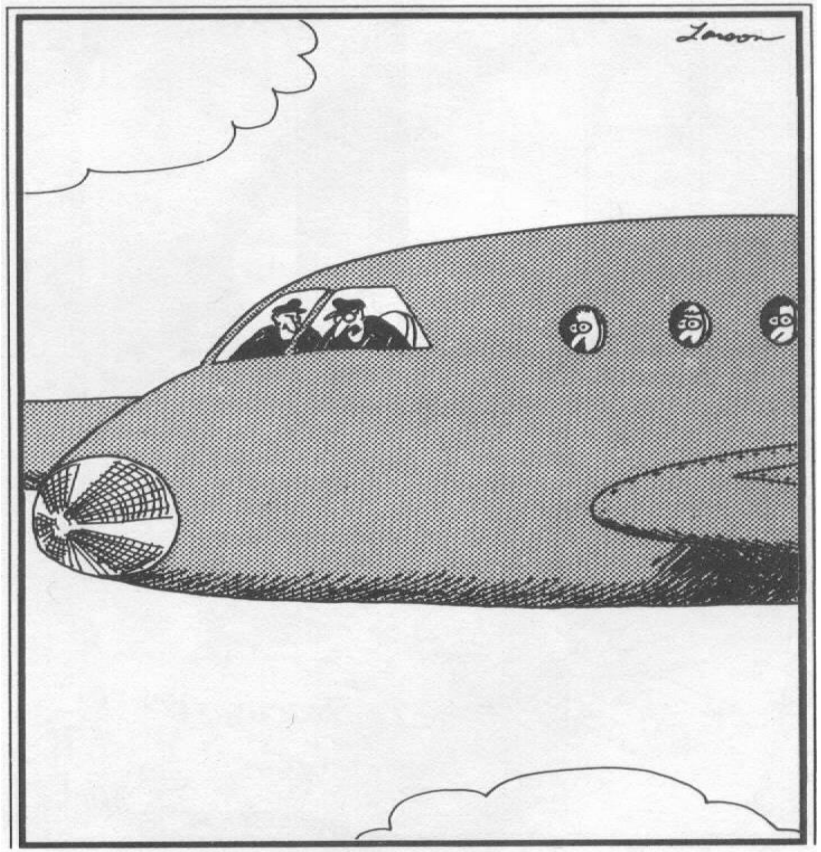
Situational Awareness

Situational Awareness

- "The perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status into the near future" (Endsley, 1988).
- "Continuous extraction of environmental information, integration of this information with previous knowledge to form a coherent mental picture, and the use of that picture in directing further perception and anticipating future events" (Dominguez, 1994).

Situational Awareness

- Three levels of situational awareness:
  - Level 1: Perception
    - What is going on?
  - Level 2: Comprehension
    - What does it mean?
  - Level 3: Projection
    - Where is it going? What am I going to do about it?
- Situational awareness is necessary both in individuals and within teams.



"The fuel light's on, Frank! We're all going to die! ... We're all going to die! ... Wait, wait. ... Oh, my mistake—that's the intercom light."

Source: The Far Side

Situational Awareness

- Three components of situational awareness:
  - Spatial awareness - where you and other objects are in space, orientation to location.
  - System awareness – understanding about the state of the system(s)
  - Task awareness – understanding about the tasks being engaged in

Situational Awareness

- Common pitfalls:
  - Attentional narrowing
    - Attention grabbed, drawing focus away from critical information
  - Data overload
    - More/faster information presented than a human can process
  - Misplaced salience
    - The wrong things standing and catching your attention
  - "Out of the loop"
    - Uncertainty in data and system status not represented to users
  - Short-term memory over-reliance
    - Holding too many chunks, or for too long (> 30 sec)

Situational Awareness

- Complexity Creep
  - Additions to a user interface (UI) or procedure may affect far more than one screen
- Low operator confidence in systems
- Workload, anxiety, fatigue, loss of perceived safety
- Incorrect mental models
- Inattention

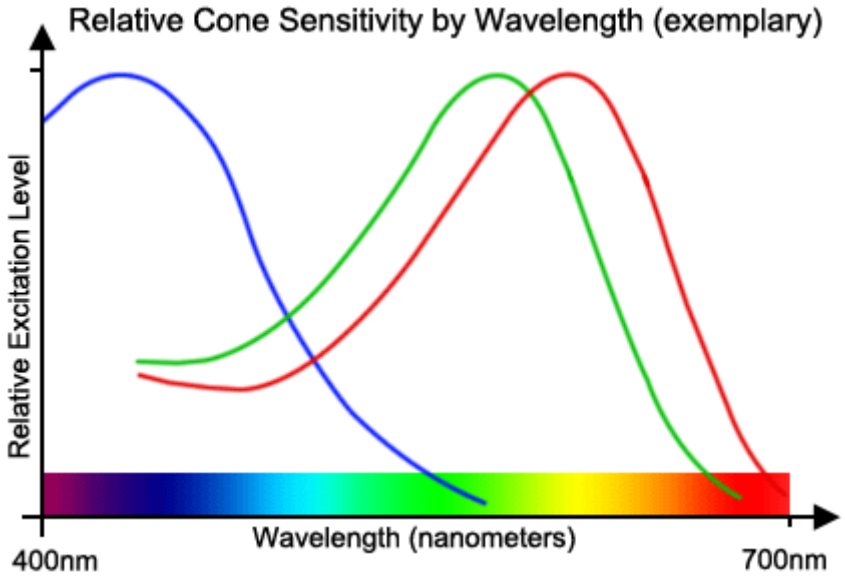
Situational Awareness

Situational Awareness

Situational Awareness

Visual Attention

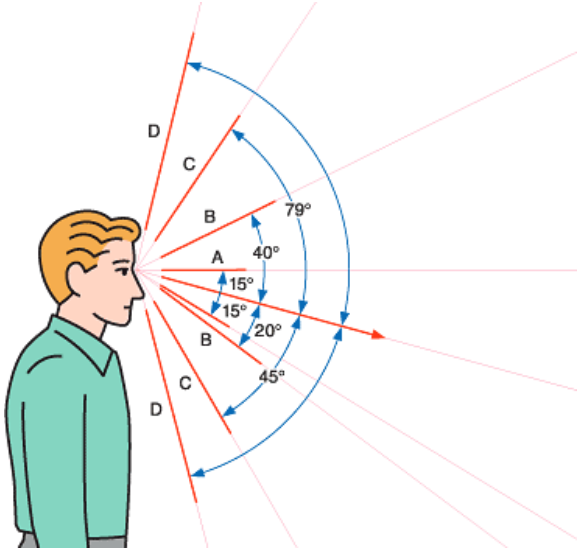
- Color is a fascinating subject
  - Cultural values associated with colors
  - Evolutionary issues
    - Favorite color blue (60% of men, 35% of women)
    - Processing speed increases when large red objects seen
  - In the eye, three types of cones process color signals

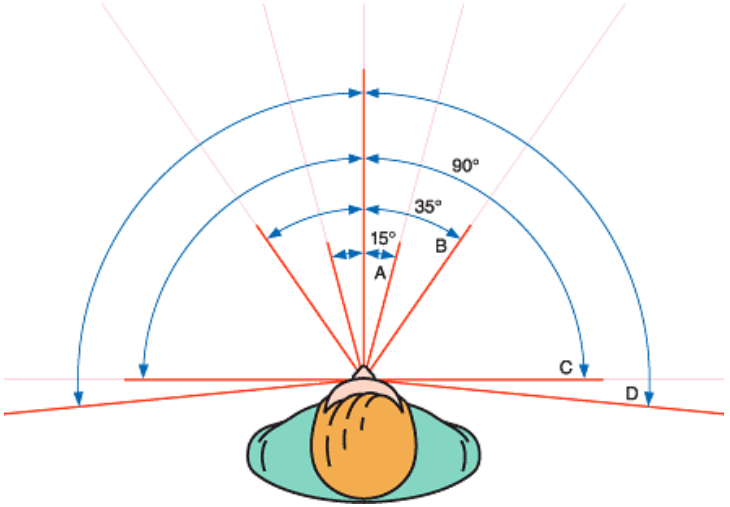


Source: Color Blindness Simulator

Visual Attention

- Resolution on retina highest at center, lower towards periphery.
  - Farther out, you can only detect motion & vague shapes.
  - Motion in the periphery can be distracting





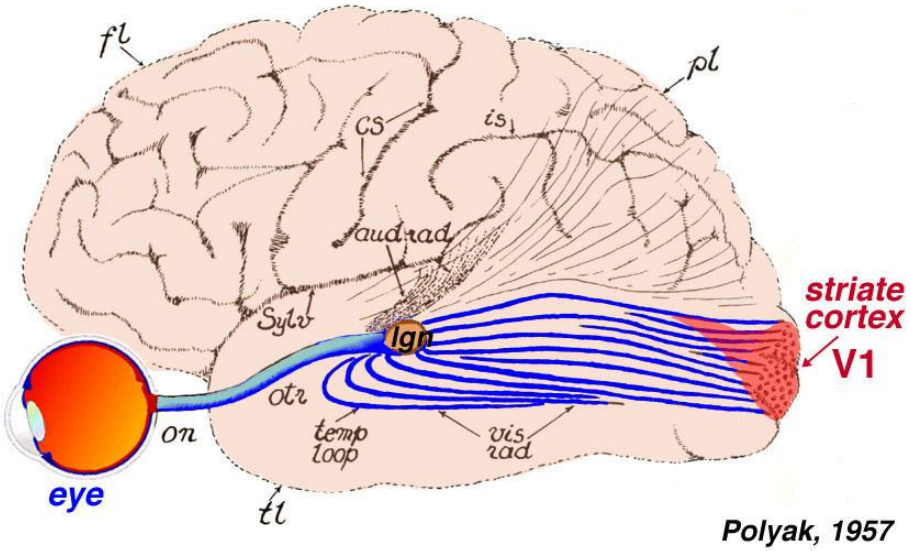
Source: Lean Valley

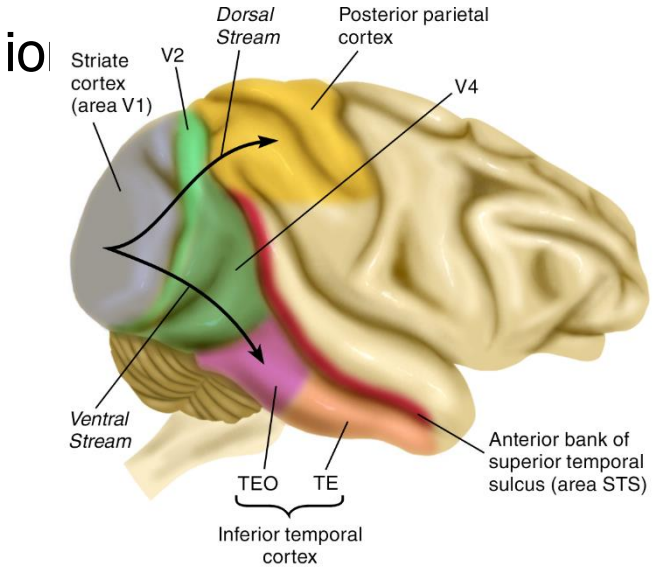
Visual Attention

- Blind Spot
  - Close one eye and stare at the cross (if right eye open) or the dot (if left eye open).

Visual Attention

- Starting small:
  - Eye to lateral geniculate nucleus (LGN) to several areas of brain:
    - "What" system
    - "Where / how" system





Visual Attention

http://youtu.be/vJG698U2Mvo

Visual Attention

- **Change Blindness** – Sometimes we don't see changes in a scene or some critical detail

Human Error

"Human error is a consequence, not a cause. Errors are shaped by upstream workplace and organizational factors… Only by understanding the context of the error can we hope to limit its reoccurrence"

James Reason

Organizational Culture

The case for just culture:

- Traditional management styles lagging research & employee expectations
- Vast amount of work frustration due to inequity and ambiguous signals

Organizational Culture

- High Reliability Organizations:

Photo Montage, Rizwan Shah, Department of Energy

Organizational Culture

- High Reliability Organizations:
  - Preoccupation with failure
  - Reluctance to simplify
  - Sensitivity to operations
  - Commitment to resilience
  - Deference to Expertise

Photo Montage, Rizwan Shah, Department of Energy

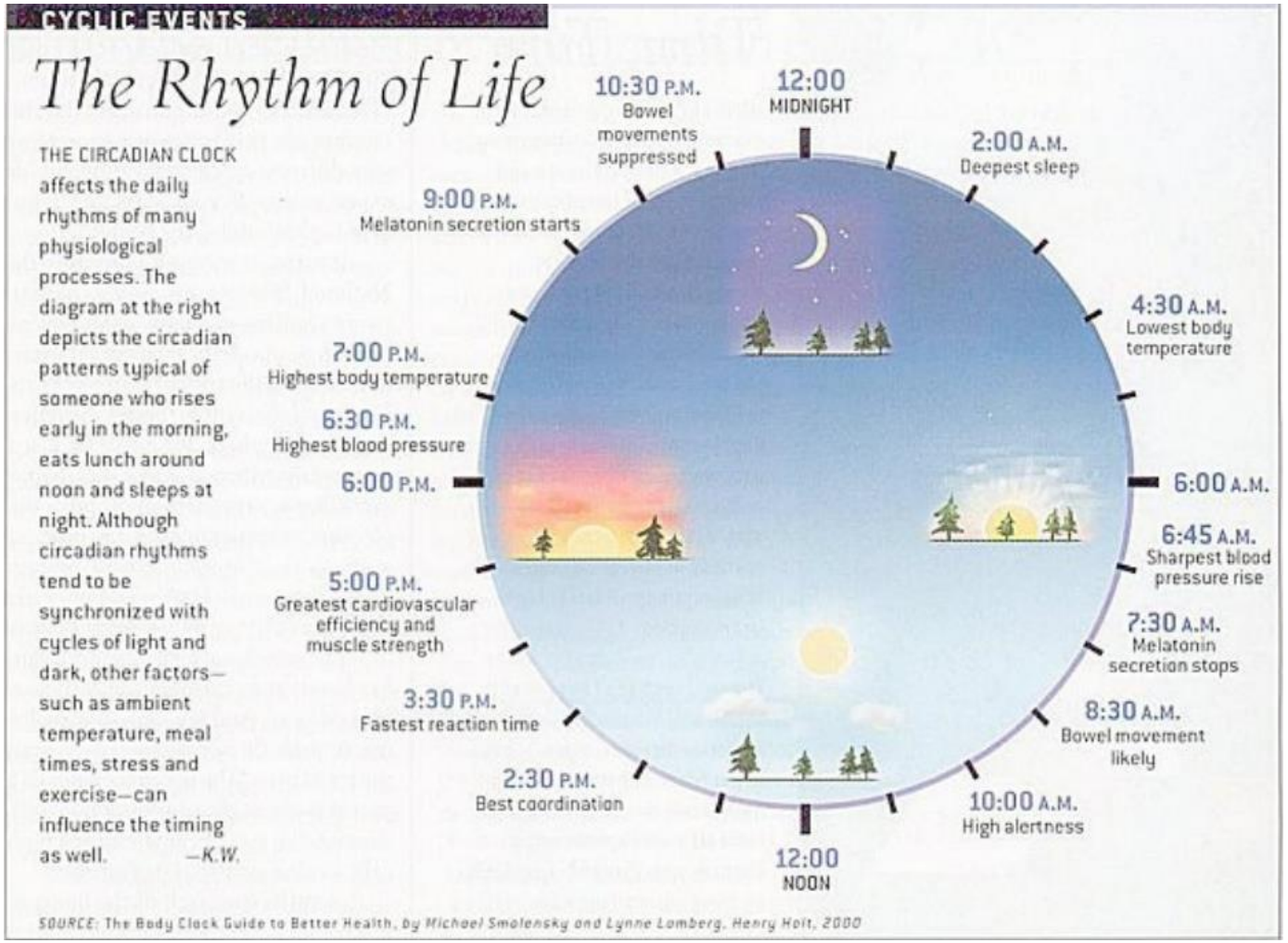
Fatigue

- "After more than 100 years of research on fatigue, we do not really know very much about it" - Hockley
- "A lack of sufficient steady-state energy to power physical and/or cognitive work" – Hancock, Desmond & Matthews
- "Fatigue makes cowards of us all" – Vince Lombardi

Fatigue

- Stark & Ash (1917): "When an error occurs it is followed immediately by other errors and more and more frequently as the period of work continues"
- Fatigue is not boredom!
- Every hour awake after 10 hours, the equivalent of .004% blood alcohol level (BAL) decrease in reaction time (Dawson & Reid, 1997).
- Increased error risk, lowered self-monitoring.

Fatigue



Source: Neuroscience Education Institute

Summary

- Humans are complex; building a resilient grid requires a co-optimization between the physical system, and the humans who manage it, and an understanding how to optimize the future of devices.

Homework Exercises: Due Thursday, Feb. 16

2. Search through news articles for an instance of a human error in electric power operations (e.g., 2003 blackout, three mile island)

3. Review a sampling of cognitive biases and consider how they may have contributed to the human error event you highlighted for (1).