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A Typical Problem in Fatigue Risk Management: Assessing the System-Wide Risk from Fatigue in Coupled Physical and Cyber Infrastructures in 24/7 Operations with Humans in the Loop
A Key Aspect of Fatigue Risk from Sleep-Deprived Humans in the Loop: Instability in Sustained Attention

Psychomotor Vigilance Test


Lapse threshold
(500 ms)
Sleep Deprivation Degrades Cognitive Processing in Neuronal Circuits Involved in Task Performance

Numerosity Discrimination

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Diffusion Decision Model

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Fatigue may make any cognitive processing harder and less reliable

**Diffusion Decision Model**

A Diffusion Decision Model-Based Metric of the Fidelity of Information Processing: PVT Signal to Noise Ratio (SNR)

\[ SNR \approx \frac{N \left( \sum_{i=1}^{N} w_i S_i \right)^2}{\sum_{i=1}^{N} w_i \left( S_i \sum_{i=1}^{N} w_i - \sum_{i=1}^{N} w_i S_i \right)^2} + 1 \]

\[ S_i = 1 / (RT_i - C), \quad w_i = 1 / (r^2 S_i + 1), \quad C = 100 \text{ ms}, \quad r^2 = 196 \text{ ms}, \]

\( RT_i \) is the \( i \)th response time (in ms), and \( N \) is the number of PVT stimuli
Impact of Sleep Deprivation on PVT SNR in Laboratory Studies

Chavali VP, Riedy SM, Van Dongen HPA. Sleep, 2017, in press.

Medium effect size
\( f^2 = 0.34 \)
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PVT testing with chin rest

Chavali VP, Riedy SM, Van Dongen HPA. Sleep, 2017, in press.
A Baseline-Invariant Version of the PVT SNR Metric

\[ LSNR = 10 \log_{10}(SNR) \]

Large effect size \((f^2 = 0.40)\)

Chavali VP, Riedy SM, Van Dongen HPA. Sleep, 2017, in press.
Conclusions

• The LSNR metric for the PVT quantifies the fidelity of information processing
• LSNR has high sensitivity to fatigue, high degree of statistical normality, and absence of floor and ceiling effects
• A given change in LSNR always has the same meaning regardless of absolute values – a reduction in LSNR of 3 units (i.e., a −3 dB change) represents a 50% drop in the fidelity of information regardless of the starting point
• The SNR baseline value may therefore be freely chosen to anchor the metric (0 dB point), which is helpful for mathematical models of fatigue
• LSNR provides a basis for calculations of the overall reliability of partially automated operational systems with sleep-deprived humans in the loop
• As such, LSNR may be a useful tool for systems-integrated fatigue risk management
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