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Special Issue in Remembrance of Joel Warm

P. A. Hancock and James L. Szalma. *Sustained Attention to Science: A Tribute to the Life and Scholarship of Joel Warm*. S. 365–373.

Objective: To provide an evaluative synthesis of the life and scientific contributions of the late Joel Warm. **Background:** As the doyen of vigilance research, Joel Warm expanded our understanding and horizons concerning this critical response capacity. However, he also made widespread and profound contributions to many other areas of perception and applied psychology, as we elucidate here. **Method:** Using archival sources, personal histories, and analysis of extant literature documenting Warm's own productivity, we articulate his life in science. **Results:** Our synthesis illustrates the continued, broad, influential, and expanding impact that one individual can exert on diverse fields of study. Whole bodies of understanding of human behavior have been illuminated by his exemplary career. **Application:** By understanding his path to success in applied experimental psychology, we anticipate that others will be motivated, inspired, and guided to replicate and even outstrip a lifetime of such seminal and influential contributions. The presence of individuals such as Warm serves as a primary motive in enhancing Humans Factors/Ergonomics Science.

- **Keywords:** vigilance, sustained attention, psychophysics, perception

P. A. Hancock and Gerald Matthews. *Workload and Performance: Associations, Insensitivities, and Dissociations*. S. 374-392.

Objective: The aim of this study was to distill and define those influences under which change in objective performance level and the linked cognitive workload reflections of subjective experience and physiological variation either associate, dissociate, or are insensitive, one to another. **Background:** Human factors/ergonomics frequently employs users' self-reports of their own conscious experience, as well as their physiological reactivity, to augment the understanding of changing performance capacity. Under some circumstances, these latter workload responses are the only available assessment information to hand. How such perceptions and physiological responses match, fail to match, or are insensitive to the change in primary-task performance can prove critical to

operational success. The reasons underlying these associations, dissociations, and insensitivities are central to the success of future effective human–machine interaction. **Method:** Using extant research on the relations between differing methods of workload assessment, factors influencing their association, dissociation, and insensitivity are identified. **Results:** Dissociations and insensitivities occur more frequently than extant explanatory theories imply. Methodological and conceptual reasons for these patterns of incongruity are identified and evaluated. **Application:** We often seek convergence of results in order to provide coherent explanations as bases for future prediction and practical design implementation. Identifying and understanding the causes as to why different reflections of workload diverge can help practitioners toward operational success.

- **Keywords:** cognitive workload, physiological reactivity, subjective perception, association, insensitivity, dissociation

Ashley M. Hughes, Gabriella M. Hancock, Shannon L. Marlow, Kimberly Stowers, and Eduardo Salas. *Cardiac Measures of Cognitive Workload: A Meta-Analysis*. S. 393-414

Objective: We aimed to provide an assessment of the impact of workload manipulations on various cardiac measurements. We further sought to determine the most effective measurement approaches of cognitive workload as well as quantify the conditions under which these measures are most effective for interpretation. **Background:** Cognitive workload affects human performance, particularly when load is relatively high (overload) or low (underload). Despite ongoing interest in assessing cognitive workload through cardiac measures, it is currently unclear which cardiac-based assessments best indicate cognitive workload. Although several quantitative studies and qualitative reviews have sought to provide guidance, no meta-analytic integration of cardiac assessment(s) of cognitive workload exists to date. **Method:** We used Morris and DeShon's meta-analytic procedures to quantify the changes in cardiac measures due to task load conditions. **Results:** Sample-weighted Cohen's *d* values suggest that several metrics of cardiac activity demonstrate sensitivity in response to cognitive workload manipulations. Heart rate variability measures show sensitivity to task load, conditions of event rate, and task duration. Authors of future work should seek to quantify the utility of leveraging multiple metrics to understand workload. **Conclusion:** Results suggest that assessment of cognitive workload can be done using various cardiac activity indicators. Further, given the number of valid and reliable measures available, researchers and practitioners should base their selection of a psychophysiological measure on the experimental and practical concerns inherent to their task/protocol. **Applications:** Findings bear implications for future assessment of cognitive workload within basic and applied settings. Future research should seek to validate conditions under which measurements are best interpreted, including but not limited to individual differences.

- **Keywords:** mental workload, cognition, cardiac activity, meta-analysis

Kelly Satterfield, Amanda E. Harwood, William S. Helton, and Tyler H. Shaw. *Does Depleting Self-Control Result in Poorer Vigilance Performance?* S. 415-425.

Objective: To investigate whether depleting self-control prior to vigilance results in a steeper vigilance decrement. **Background:** The resource-control theory of vigilance asserts that an inherent bias toward self-generated mind-wandering draws attentional resources away from the primary task. This study seeks to test whether depleting self-control, the potential mechanism of self-generated mind-wandering, results in poorer vigilance performance. **Method:** This study featured a between-subjects design where participants either completed a typing task that depleted self-control resources or a standard typing task that did not require self-control before performing a vigilance task.

In the self-control depletion condition, participants typed a passage while omitting any "e" and "space" keys. In the standard typing task, participants typed the same passage without skipping any keys. Following both typing tasks, participants in both conditions completed an identical 12-min vigilance task. **Results:** Results demonstrated decreased accuracy and increased reaction times over time for both groups. Depleting self-control did not result in significant differences in accuracy, reaction time, nor a steeper vigilance decrement. **Conclusion:** These results provide evidence against resource-control theory and self-control as an explanation for vigilance, and provide further support for cognitive resource theory as the predominant explanation for vigilance impairments. **Application:** It is still unclear exactly what constitutes a "resource." A better understanding of the nature of these resources can help researchers and practitioners identify how they can be replenished, which could enhance human performance in situations requiring vigilance such as baggage screening.

- **Keywords**: sustained attention, vigilance, self-control, stress and vigilance, resource theory, resource-control theory

Curtis M. Craig and Martina I. Klein. *The Abbreviated Vigilance Task and Its Attentional Contributors*. S. 426-439.

Objective: To measure contributing attentional processes, particularly that of executive attention, to two iterations of the abbreviated vigilance task. **Background:** Joel Warm was at the forefront of vigilance research for decades, and resource theory is currently the dominant explanation for the vigilance decrement. The underlying mechanisms contributing to both overall performance and the decrement are only partly understood. **Method:** Seventy-eight participants answered questionnaires about their attentional skills and stress state, performed the Attention Network Test and two blocks of the 12-min abbreviated vigilance task, with a brief break between the two vigils during which they viewed images intended to affect performance. Changes in oxygenated hemoglobin were measured with functional near-infrared imaging. **Results:** Expected patterns were observed for both iterations of the abbreviated vigilance task, with performance declining after the first 2 min. Manipulations intended to evaluate whether executive processes contributed to vigilance performance failed to observe an effect. Other factors, particularly orienting and alerting attentional networks, task engagement, and subclinical ADHD symptomology were associated with performance. Significant factors for the first and second vigilance blocks were different. **Conclusion:** We suggest that (a) cognitive control is not a predominant factor, at least for the abbreviated vigilance task, and (b) attentional mechanisms and stress states affecting performance on the abbreviated vigilance task change over time. **Application:** Potential applications of this research include the use of breaks for sustained attention tasks involving high sensory load, and implications for the use of the abbreviated vigilance task as a proxy for general vigilance processes.

- **Keywords**: attentional processes, vigilance, stress, effort, neuroergonomics

Victoria L. Claypoole, Daryn A. Dever, Kody L. Denues, and James L. Szalma. *The Effects of Event Rate on a Cognitive Vigilance Task*. S. 440-450.

Objective: The present experiment sought to examine the effects of event rate on a cognitive vigilance task. **Background:** Vigilance, or the ability to sustain attention, is an integral component of human factors research. Vigilance task difficulty has previously been manipulated through increasing event rate. However, most research in this paradigm has utilized a sensory-based task, whereas little work has focused on these effects in relation to a cognitive-based task. **Method:** In sum, 84 participants completed a cognitive vigilance task that contained either 24 events per minute (low event rate condition) or 40 events per minute (high event rate condition). Performance was

measured through the proportion of hits, false alarms, mean response time, and signal detection analyses (i.e., sensitivity and response bias). Additionally, measures of perceived workload and stress were collected. **Results:** The results indicated that event rate significantly affected performance, such that participants who completed the low event rate task achieved significantly better performance in terms of correction detections and false alarms. Furthermore, the cognitive vigil utilized in the present study produced performance decrements comparable to traditional sensory vigilance tasks. **Conclusion:** Event rate affects cognitive vigilance tasks in a similar manner as traditional sensory vigilance tasks, such that a direct relation between performance and level of event rate was established. **Application:** Cognitive researchers wishing to manipulate task difficulty in their experiments may use event rate presentation as one avenue to achieve this result.

- **Keywords:** cognition, information processing, human performance

Samantha L. Epling, Graham K. Edgar, Paul N. Russell, and William S. Helton. *Is Semantic Vigilance Impaired by Narrative Memory Demands? Theory and Applications*. S. 451-461.

Objective: Two verbal tasks were utilized in a dual-task paradigm to explore performance theories and prior dual-tasking results. **Background:** Both the decline in vigilance performance over time, or vigilance decrement, and limited dual-tasking ability may be explained by limited mental resources. Resource theorists would recommend removing task demands to avoid cognitive overload, while mindlessness theorists may recommend adding engaging task demands to prevent boredom. Prior research demonstrated interference between a verbal free recall and semantic vigilance task, but exploring tasks with greater ecological validity is necessary. **Method:** A narrative memory task and semantic vigilance task were performed individually and simultaneously. Relative performance impairments were compared to a previous dual-task pairing. **Results:** The semantic vigilance task caused performance degradation to the narrative memory task and vice versa. A vigilance decrement was not observed, and the interference was to a lesser extent than when the semantic vigilance task was paired with a free recall task. **Conclusion:** Resource theory was supported, though passive learning effects during a semantic vigilance task with novel stimuli may prevent a vigilance decrement. The interference was less than that of a previous similar dual-task pairing, but even tasks as routine as listening to a conversation or story can impair other task performance. **Application:** A better understanding of resource theory and dual-task performance outcomes can help inform feasible task loads and improve efficiency and safety of operators in high-risk and other professions.

- **Keywords:** attentional processes, dual task, resource theory, signal detection theory, vigilance, working memory

Alexis R. Neigel, Daryn A. Dever, Victoria L. Claypoole, and James L. Szalma. *Task Engagement and the Vigilance Decrement Revisited: Expanding Upon the Work of Joel S. Warm Using a Semantic Vigilance Paradigm*. S. 462-473.

Objective: The goal of the present study is twofold: (1) demonstrate the importance of measuring and understanding the relationship between task engagement and vigilance performance, and (2) celebrate the work of Joel S. Warm and expand upon his previous research in two semantic vigilance paradigms. **Background:** The importance of measuring task engagement in cognitive and sensory vigilance tasks has been well documented. But to date, our understanding of the effects of task engagement on semantic vigilance performance is limited. **Method:** Seventy-three participants completed either a standard semantic vigilance task or a lure semantic vigilance task.

Participants also completed subjective measures of workload and stress. **Results:** The results indicated that changes in task engagement are associated with correct detection performance. Changes in task engagement may be related to individual differences in the distress associated with performing semantic vigilance tasks. **Conclusion:** In line with the work of Warm and his colleagues (Dember, Warm, Bowers, & Lanzetta, 1984), participants who reported increased task engagement after the vigil outperformed their peers who noted decreased task engagement upon conclusion of the task. Participants reporting increases in engagement with the semantic vigilance tasks also reported significantly greater distress pretask, but not posttask. Instead, increases in postvigil distress were driven by the task to which participants were assigned, not task engagement. **Application:** The present study has several implications for applied settings that involve long duration semantic processing or semantic target identification. Such real-world tasks include aviation, cyber threat detection and analysis, driving, and reading.

- **Keywords:** attention, engagement, semantic processing, sustained attention, vigilance

Eric T. Greenlee, Patricia R. DeLucia, and David C. Newton. Driver Vigilance in Automated Vehicles: Effects of Demands on Hazard Detection Performance. S. 474-487.

Objective: The current study investigated driver vigilance in partially automated vehicles to determine whether increased task demands reduce a driver's ability to monitor for automation failures and whether the vigilance decrement associated with hazard detections is due to driver overload. **Background:** Drivers of partially automated vehicles are expected to monitor for signs of automation failure. Previous research has shown that a driver's ability to perform this duty declines over time. One possible explanation for this vigilance decrement is that the extreme demands of vigilance causes overload and leads to depletion of limited attentional resources required for vigilance. **Method:** Participants completed a 40-min drive in a simulated partially automated vehicle and were tasked with monitoring for hazards that represented potential automation failures. Two factors were manipulated to test the impact of monitoring demands on performance: Spatial uncertainty and event rate. **Results:** As predicted, hazard detection performance was poorer when monitoring demands were increased, and performance declined as a function of time on task. Subjective reports also indicated high workload and task-induced stress. **Conclusion:** Drivers of partially automated vehicles are impaired by the vigilance decrement and elevated task demands, meaning that safe operation becomes less likely when the demands associated with monitoring automation increase and as a drive extends in duration. This study also supports the notion that vigilance performance in partially automated vehicles is likely due to driver overload. **Application:** Developers of automation technologies should consider countermeasures that attenuate a driver's cognitive load when tasked with monitoring automation.

- **Keywords:** vigilance, vehicle automation, human-automation interaction, driver behavior, fatigue

Ryan W. Wohleber, Gerald M. Vigilance and Automation Dependence in Operation of Multiple Unmanned Aerial Systems (UAS): A Simulation. S. 488-505.

Objective: This simulation study investigated factors influencing sustained performance and fatigue during operation of multiple Unmanned Aerial Systems (UAS). The study tested effects of time-on-task and automation reliability on accuracy in surveillance tasks and dependence on automation. It also investigated the role of trait and state individual difference factors. **Background:** Warm's resource model of vigilance has been highly influential in human factors, but further tests of its applicability to complex, real-world

tasks requiring sustained attention are necessary. Multi-UAS operation differs from standard vigilance paradigms in that the operator must switch attention between multiple subtasks, with support from automation. **Method:** 131 participants performed surveillance tasks requiring signal discrimination and symbol counting with a multi-UAS simulation configured to impose low cognitive demands, for 2 hr. Automation reliability was manipulated between-groups. Five Factor Model personality traits were measured prior to performance. Subjective states were assessed with the Dundee Stress State Questionnaire. **Results:** Performance accuracy on the more demanding surveillance task showed a vigilance decrement, especially when automation reliability was low. Dependence on automation on this task declined over time. State but not trait factors predicted performance. High distress was associated with poorer performance in more demanding task conditions. **Conclusions:** Vigilance decrement may be an operational issue for multi-UAS surveillance missions. Warm's resource theory may require modification to incorporate changes in information processing and task strategy associated with multitasking in low-workload, fatiguing environments. **Application:** Interface design and operator evaluation for multi-UAS operations should address issues including motivation, stress, and sustaining attention to automation.