Reply to reviewers – PhD dissertation

Reviewer: Dr. habil. András N. Zsidó, DSc. Institute of Psychology, University of Pécs, Hungary
Title: Human Cognitive Load and Awareness Monitoring Using AI and Biosignals in Assembly Operations
Author: Abdulrahman Khalid Eesee Al-sabaawi
Supervisors: Dr. Tamás Ruppert, Dr. habil. György Eigner

Dear Dr. András N. Zsidó,

Thank you very much for your careful and supportive evaluation, and for your role in helping improve this dissertation from the home defense stage to the final defense. I truly appreciate the time and academic attention you devoted to reading the work so thoroughly.

Your evaluation is especially valuable to me because you highlighted the contribution of the dissertation from several important sides. I truly appreciate your recognition of the relevance of the topic, the theoretical basis of the work, and the care given to the methodology in this interdisciplinary field. I am also very thankful for your positive comments on the literature review, the experimental and analytical work, and your thoughtful reading of the main findings and their contribution. Your supportive words mean a lot to me at this final stage of my PhD.

Thank you again for your kind support and for your contribution to strengthening this dissertation.

Questions for the defense

"*You clearly define what can and cannot be inferred from HRV, EDA, and kinematic signals. You also explicitly state that these are indirect indicators of changes in load-related states rather than direct measures of attention, effort, or awareness. Looking to the future, what kind of empirical validation strategy would be necessary to progress from reliable load tracking to stronger construct validity for higher-level cognitive states, such as situational awareness or monitoring capacity?*"

Response:

Thank you for this important question. My view is that the next step should be a multi-stage empirical validation strategy. I would not try to move directly from HRV, EDA, and kinematic signals to claiming direct measurement of higher-level cognitive states such as situational awareness. In the dissertation, I treat these signals as indirect correlates of load-related state change, not as direct readouts of awareness itself. So, to strengthen construct validity, I would first combine them with more direct and task-specific measures of situational awareness or monitoring performance in controlled experiments where awareness demands are systematically manipulated. Then I would test whether the physiological and behavioral markers converge with those direct

measures in the expected way. After that, I would broaden the sensing set, especially with measures that are closer to attentional allocation, such as eye tracking, and where needed EEG or other cortical measures, because HRV and EDA alone are probably not enough for strong construct-level inference. Finally, I would test the resulting multimodal model in more realistic industrial settings to see whether the same relationships remain stable outside the laboratory. So, for me, the key strategy is controlled manipulation, multimodal convergence, cross-task replication, and then ecological validation.

"*You emphasize that the proposed models are context-dependent and are trained within clearly defined task structures. If the goal were to deploy this system across heterogeneous industrial tasks with different temporal dynamics and attentional profiles, which area of research would you prioritize to enable cross-task generalization without compromising sensitivity?*"

Response:

Thank you for this important question. If I had to prioritize one area of research for cross-task deployment, I would focus on context-aware transfer learning, or domain adaptation, for multimodal human-state models. In my view, the main challenge is not only that tasks differ, but that they differ in temporal structure, movement profile, and attentional demands. Because of that, I do not think a single universal model would be the best solution. I would instead prioritize models that can learn what is shared across tasks while still preserving task-specific adaptation. In practice, that would require collecting multimodal datasets across several heterogeneous industrial tasks, using more explicit task and event annotations, and combining physiological signals with contextual descriptors from the task itself. This fits well with the Extended HAAS idea, where task, worker, and environment are already treated as part of the interpretation. I think this direction would give better cross-task generalization without losing sensitivity, because the model would not ignore context, but would use it directly.

"*Finally, from a future research perspective, how would you investigate the long-term cognitive and behavioral consequences of continuous adaptation based on estimated cognitive load, particularly regarding the risks of overreliance, reduced self-regulation, and altered learning trajectories?*"

Response:

Thank you for this very important question. From my perspective, this would need to be investigated through longitudinal experiments rather than short-term adaptive evaluations only. I would not evaluate such a system only by asking whether it improves immediate performance or lowers estimated cognitive load. I would compare at least three conditions: a non-adaptive baseline, a continuously adaptive condition, and ideally a faded-support condition where the

adaptation is gradually reduced over time. This would allow us to see whether the system is actually supporting learning and self-regulation, or whether it creates overreliance on external adaptation. In addition to immediate performance, I would look at retention, transfer to new tasks, changes in self-regulation behavior, and whether performance remains stable when support is removed or reduced. I would also include subjective and physiological measures over repeated exposure, because a system that looks beneficial in the short term could still alter learning trajectories or reduce independent monitoring in the long term. So, for me, the key future direction is to evaluate adaptation not only as assistance, but also as something that may reshape behavior and learning over time.

Veszprém, 2026.04.16.

Abdulrahman Khalid Eesee Al-Sabaawi
Ph.D. Candidate
University of Pannonia
Department of System Engineering