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Designing Inclusive Hybrid Learning Using Eye-Tracking and Adaptive UX: A Neuroadaptive Framework

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ABSTRACT

Background. The growing diversity of learners in hybrid education environments necessitates adaptive systems that respond to individual cognitive and emotional states in real time. Traditional user experience (UX) models often fail to accommodate neurodivergent users or those with varying attention patterns and processing styles.
Purpose. This study proposes a neuroadaptive framework that integrates eye-tracking technology and adaptive UX design to create inclusive hybrid learning experiences.
Method. The research aims to examine how real-time gaze data can inform interface adjustments that support engagement, accessibility, and cognitive load management. Employing a mixed-method design, the study involved 58 university students who interacted with a prototype learning platform embedded with eye-tracking sensors and adaptive UX features. Quantitative data from gaze patterns, task completion, and performance metrics were complemented by qualitative feedback through user interviews and think-aloud protocols.
Results. Results indicate that the neuroadaptive interface significantly improved task efficiency, learner focus, and subjective usability across diverse cognitive profiles.
Conclusion. The study concludes that This study demonstrates that real-time biometric feedback can personalize hybrid learning experiences and improve inclusivit.

KEYWORDS

Neuroadaptive Design, Eye-Tracking, Inclusive Learning, Hybrid Education, Adaptive UX

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INTRODUCTION

Hybrid learning has become a dominant educational modality in the wake of digital transformation and global shifts toward more flexible instructional models. The convergence of online and in-person formats allows for dynamic content delivery, broader access, and learner autonomy. However, despite these advancements, hybrid learning environments often remain poorly attuned to learners' moment-to-moment cognitive states and accessibility needs. There is a growing recognition that static learning interfaces-hose which fail to respond in real-time to user behavior-can inhibit concentration, reduce inclusivity, and exacerbate cognitive overload.

User experience (UX) design in educational technology plays a critical role in mediating how learners navigate, process, and engage with content. Well-designed interfaces can enhance clarity, motivation, and flow, while poorly designed systems may create barriers to engagement and performance. For neurodiverse learners, including those with attentional differences or sensory processing variations, the standard "one-size-fits-all" digital experience is especially limiting. Educators and designers alike are therefore increasingly seeking tools that allow platforms to adapt responsively to learners' unique cognitive profiles and attentional states in real time.

Emerging technologies such as eye-tracking and biometric feedback offer new possibilities for developing such responsive systems. Eye-tracking, in particular, provides a non-invasive, real-time measure of user attention, gaze fixation, and cognitive effort. By integrating eye-tracking data into adaptive UX systems, it becomes possible to create neuroadaptive learning environments—platforms that can sense and respond to the learner's mental state (Fairclough, 2023; Grubov et al., 2024; Legeay et al., 2022; Teixeira et al., 2024). The potential of these systems lies in their ability to personalize content delivery, pacing, and layout based on actual learner engagement, thereby promoting deeper learning and greater inclusivity.

Despite the pedagogical promise of hybrid learning, many systems currently in use are not optimized for cognitive variability among learners. Existing platforms often assume a uniform pace and style of interaction, ignoring the differences in attention span, processing speed, and working memory capacity that characterize today's diverse learner populations (Beauchemin et al., 2024; Chohan et al., 2023; Hejrati & Mattila, 2024). These limitations are especially pronounced for neurodivergent learners and individuals with invisible cognitive conditions such as ADHD or dyslexia, who may disengage or underperform in rigid, non-responsive digital environments.

Standard UX principles in educational contexts have traditionally focused on aesthetics, navigation ease, and content accessibility. While these are important, they do not account for the fluid and fluctuating nature of learner cognition during a learning session. Without real-time feedback on user experience, designers are forced to make assumptions about engagement that may not reflect actual user behavior. This disconnect results in systems that appear functional on the surface but fail to support optimal cognitive processing for a wide range of users.

Designing educational technology that can adapt in real time to learner attention and emotional states remains an unresolved challenge. While adaptive learning platforms exist, most are algorithmically driven by performance metrics such as quiz scores or page views, rather than neurophysiological indicators. These systems, therefore, lack sensitivity to immediate cognitive fatigue, distraction, or overload. There is an urgent need for new design frameworks that integrate neuroadaptive feedback into the user experience to support inclusive and cognitively responsive hybrid learning.

This study aims to design and evaluate a neuroadaptive framework that integrates eye-tracking data and adaptive UX mechanisms to enhance inclusivity and learner engagement in hybrid learning environments (Conrad & Newman, 2022; Zhao et al., 2023). The framework is intended to enable real-time adjustments to content layout, pacing, and interaction design based on users' gaze behavior and attentional patterns. The objective is not only to improve performance outcomes but also to ensure a sense of cognitive and emotional resonance between learners and their digital environment.

The study investigates the feasibility and effectiveness of implementing eye-tracking-informed UX adaptations in a prototype hybrid learning platform. Specifically, it examines how gaze-based metrics such as fixation duration, saccadic movement, and pupil dilation can be mapped onto UX changes like dynamic highlighting, pacing adjustment, or scaffolded prompts. These adaptations are designed to address lapses in attention, cognitive fatigue, or user confusion, thereby offering real-time, non-disruptive support to learners across neurodiverse profiles.

Another goal of the study is to assess user perceptions of such a neuroadaptive system. Through a combination of usability testing, self-report feedback, and performance analytics, the research explores how learners interpret and respond to real-time UX adaptations driven by biometric data. The findings are expected to inform the development of more human-centered learning technologies that prioritize responsiveness, personalization, and inclusivity in hybrid digital education.

Current literature on adaptive learning and intelligent tutoring systems emphasizes algorithmic personalization based on user behavior over time. These systems typically use performance history or preference data to tailor content, yet rarely incorporate neurophysiological indicators to detect momentary changes in user attention or mental load. While such methods offer general personalization, they do not capture the immediacy of cognitive engagement needed for real-time instructional adaptation.

There is limited empirical research on integrating eye-tracking data into UX design in educational contexts, particularly in hybrid learning environments. Most eye-tracking studies remain within the realm of usability testing or marketing research, focusing on heatmaps and gaze paths rather than pedagogical interventions (Fabrikant, 2023; Gao et al., 2024; Shao & Ye, 2022; Xiang et al., 2025). Furthermore, existing adaptive platforms often lack transparency and learner agency, raising concerns about over-automation and ethical design in educational technologies.

This study fills a critical research gap by proposing a real-time, neuroadaptive UX framework specifically tailored for inclusive hybrid learning. It contributes not only to the literature on adaptive systems and human-computer interaction but also to the evolving discourse on accessibility and universal design for learning (UDL) (Adam et al., 2024; Sarkar & Deb, 2024; Weber et al., 2024). By focusing on real-time adaptation through biometric feedback, the study offers a novel methodology for enhancing digital learning environments based on how learners actually interact-cognitively and emotionally-with digital content.

The proposed study introduces a novel neuroadaptive framework that integrates eye-tracking data with dynamic UX design to personalize the hybrid learning experience. Unlike traditional adaptive systems that rely on retrospective data or predictive algorithms, this framework responds in the present moment to the learner's cognitive state, creating a continuous feedback loop between user and interface. This level of immediacy represents a significant shift in how digital learning can be conceptualized and delivered. The novelty lies in merging biometric sensing with adaptive UX design to create a responsive learning environment rooted in human-centered principles.

The research offers methodological innovation by combining biometric sensing, user-centered design, and experimental hybrid learning environments into a unified investigative model. The framework is not merely theoretical but tested through an interactive prototype, ensuring both conceptual rigor and practical relevance. This integrative approach provides an empirical foundation for the future development of neuroadaptive educational systems, with direct implications for both software development and instructional design.

The justification for this research is grounded in the growing demand for inclusive, responsive learning technologies in a world increasingly shaped by neurodiversity and digital complexity. Learners must be supported not just in terms of content access but also in terms of cognitive alignment and emotional engagement. By leveraging real-time eye-tracking to inform adaptive UX, the proposed model sets a new standard for inclusivity and personalization in educational technology, aligning digital design with the cognitive realities of diverse learners.

RESEARCH METHODOLOGY

The study employed a mixed-methods experimental design to evaluate a neuroadaptive hybrid learning prototype. Fifty-eight university students were purposively sampled to reflect diversity in gender, academic major, and cognitive profile. Participants were randomly assigned to control (static UX) and experimental (adaptive UX) groups. Quantitative data (task time, cognitive load, SUS scores) were analyzed using t-tests; qualitative data from think-aloud and interviews were thematically analyzed using Braun & Clarke's (2006) framework. Ethical protocols included informed consent, anonymization, and IRB approval (Hashim & Vamvoudakis, 2024; Shahvali et al., 2023). The experimental intervention was implemented using a prototype learning platform designed specifically to adapt UX elements based on live eye-tracking data.

The population of the study consisted of undergraduate students enrolled in hybrid learning courses at a mid-sized university. A total of 58 participants were selected using purposive sampling to ensure a diverse representation in terms of gender, academic discipline, and cognitive learning profiles, including participants with self-identified attentional or neurodivergent conditions. Each participant had prior experience with digital learning platforms but had not previously used biometric-enabled educational technology. Informed consent was obtained, and participants were randomly assigned into control and experimental groups.

The instruments used included an eye-tracking interface integrated into the learning platform, a standardized usability questionnaire (System Usability Scale), a cognitive load self-assessment scale, and a task performance tracking module. Gaze data-such as fixation duration, saccade frequency, and blink rates-were collected using a Tobii Pro Fusion eye-tracking device embedded into each participant's workstation. Qualitative data were gathered through semi-structured interviews and concurrent think-aloud protocols during the learning tasks to explore users' perceptions of adaptivity, cognitive effort, and inclusiveness.

The research procedure was conducted in four phases: orientation, baseline assessment, intervention, and post-assessment. During the orientation phase, participants were introduced to the platform and calibrated for eye-tracking accuracy. Baseline data were collected as participants completed identical learning modules without adaptive features. In the intervention phase, only the experimental group interacted with the neuroadaptive interface, which dynamically altered font size, visual emphasis, pacing cues, and help prompts in response to eye-movement patterns indicative of attention or confusion. The control group used a static version of the same module. In the final phase, all participants completed post-task surveys, and select participants participated in debriefing interviews. Quantitative data were analyzed using inferential statistics, while qualitative data were examined using thematic coding to identify recurring patterns related to user experience and system responsiveness.

RESULT AND DISCUSSION

Table 1 presents descriptive statistics comparing the performance, cognitive load, and usability scores between the control group (static UX) and the experimental group (adaptive UX informed by eye-tracking). The mean task completion time was shorter for the experimental group (M = 14.8 minutes, SD = 2.1) compared to the control group (M = 18.4 minutes, SD = 2.7). The experimental group also reported lower perceived cognitive load on a 10-point scale (M = 4.1, SD = 1.2), whereas the control group reported a mean of 6.3 (SD = 1.6). Usability scores from the System Usability Scale were higher in the adaptive condition (M = 85.2, SD = 5.4) compared to the static group (M = 72.6, SD = 7.1), indicating stronger perceived ease of use and user satisfaction.

Table 1.
Comparison of Performance, Cognitive Load, and Usability Between Groups

Metric	Control Group (Static UX)	Experimental Group (Adaptive UX)
Task Completion Time (min)	18.4 (2.7)	14.8 (2.1)
Cognitive Load (1–10 scale)	6.3 (1.6)	4.1 (1.2)
SUS Score (0–100 scale)	72.6 (7.1)	85.2 (5.4)

The eye-tracking data revealed notable differences in visual behavior between groups. Participants in the adaptive UX condition demonstrated shorter fixation durations and fewer regressive saccades, suggesting more fluent information processing. The system-triggered adaptive responses-such as highlighting relevant text or simplifying layout in real time-corresponded with moments of cognitive hesitation or increased blinking. These adaptive interventions appeared to support better attentional alignment, particularly during complex or multi-step tasks.

Participants in the experimental group also exhibited higher task accuracy, completing an average of 92% of comprehension questions correctly compared to 76% in the control group. Think-aloud data further showed that learners interacting with the neuroadaptive interface verbalized fewer instances of confusion or disorientation. Qualitative responses emphasized the perceived helpfulness of dynamic pacing and visual guidance, particularly for students who reported challenges with sustained attention or information overload in traditional digital learning environments.

Inferential analysis using independent samples t-tests confirmed statistically significant differences between groups across all primary variables. The difference in task completion time was significant ($t(56) = 5.62$, $p < .001$), as was cognitive load ($t(56) = –5.11$, $p < .001$), and SUS usability scores ($t(56) = 6.78$, $p < .001$). Effect sizes were large for all measures (Cohen's $d > 0.8$), indicating that the adaptive UX based on eye-tracking had a substantial impact on learner efficiency, perceived mental effort, and user satisfaction.

Correlational analysis also revealed strong relationships between gaze behavior and system performance indicators. There was a significant negative correlation between mean fixation duration and task accuracy ($r = –.58$, $p < .01$), suggesting that users with smoother visual processing performed better. Positive correlations were found between usability ratings and adaptive system responsiveness ($r = .66$, $p < .001$), indicating that learners valued the system's capacity to respond to their attentional needs in real time.

A case study analysis of two participants-Student A (neurotypical) and Student B (self-identified ADHD)-provides further insight into the system's inclusivity. Student A interacted with the adaptive system with minimal intervention, benefiting primarily from pacing adjustments and contextual cueing. Student B, however, triggered more frequent adaptivity events, including layout simplification and focus prompts. Despite initial hesitation with the eye-tracking setup, Student B reported higher comfort and lower frustration levels in post-task interviews, citing that "the interface seemed to understand when I was stuck."

Both participants completed the learning module with high accuracy, but Student B's performance represented a notable improvement from prior course assessments. Observational data showed reduced blinking rates and more focused gaze behavior as the task progressed, indicating increasing engagement. These outcomes suggest that neuroadaptive UX systems can help level the learning experience for students who typically struggle with digital concentration and interface complexity.

User feedback gathered from exit interviews highlighted the importance of real-time feedback and interface personalization. Participants in the experimental group consistently reported feeling more "in control" of their learning process and better supported during moments of uncertainty. Many described the system as "intuitive" and "comforting," particularly during cognitively demanding segments. In contrast, control group participants noted distractions and difficulty navigating dense content without guidance or adaptive cues.

The overall results indicate that the integration of eye-tracking and adaptive UX contributes to a more inclusive and cognitively responsive learning environment. Learners benefited from system behaviors that matched their cognitive needs in real time, leading to improved performance, reduced cognitive strain, and enhanced usability. These findings support the viability of neuroadaptive frameworks in hybrid education and underscore their potential to support diverse learner populations more effectively.

The results of this study demonstrate that integrating eye-tracking technology with adaptive user experience (UX) design in hybrid learning environments significantly improves user engagement, performance, and perceived cognitive load. Participants in the experimental group completed learning tasks more efficiently, reported lower mental effort, and rated the system as more usable compared to the control group. Gaze behavior analysis confirmed that the adaptive UX interface promoted smoother visual processing and sustained attentional focus (Florence et al., 2022; Gkintoni et al., 2025). The neuroadaptive system responded effectively to cognitive cues such as prolonged fixations and saccades, offering timely interface adjustments that enhanced the learning experience for diverse users.

The findings are consistent with previous research on adaptive learning and attention-aware interfaces, particularly studies highlighting the role of real-time biometric feedback in improving learner-system interaction. Prior works by D'Mello et al. (2012) and Shute & Ventura (2013) have demonstrated that systems capable of detecting affective or attentional states can positively impact learning. However, this study extends the field by applying these principles in a hybrid learning context using a UX-centered framework rather than content sequencing alone. Unlike earlier models focused solely on content adaptation, the present research emphasizes the importance of responsive interface behavior as a pathway to inclusivity and cognitive alignment.

These results signal a paradigm shift in how educational systems might be designed to accommodate cognitive diversity. The improved outcomes for participants with attentional challenges suggest that neuroadaptive interfaces hold significant promise for supporting neurodivergent learners. The ability of the system to detect cognitive strain and respond non-intrusively indicates a move toward truly learner-responsive environments (Nath et al., 2023; Yang et al., 2023). The outcomes reflect a broader recognition that personalization in education must extend beyond content delivery to include dynamic interaction and accessibility at the interface level.

The implications of these findings are critical for instructional designers, educational technologists, and policy-makers seeking to implement inclusive hybrid learning frameworks. Adaptive UX informed by real-time physiological data offers a means to reduce cognitive barriers and improve educational equity. Eye-tracking-enabled systems can support early identification of attention lapses, reduce frustration, and scaffold engagement without explicit user input. This positions neuroadaptive technology as a valuable tool in universal design for learning (UDL), supporting not just learner choice but also learner need as it dynamically emerges during the learning process.

The positive effects observed in this study can be attributed to the synergy between biometric input and interface responsiveness. Real-time adaptation allowed the learning system to function as an extension of the learner's attentional rhythm, rather than as a fixed digital space. Participants experienced fewer cognitive disruptions because the system provided subtle cues and layout adjustments precisely when attentional shifts or confusion were detected. The ability to externalize internal states via eye-tracking allowed for a form of invisible scaffolding, which proved especially useful for learners with reduced metacognitive awareness or attentional control.

The success of the adaptive UX model also stems from its non-invasive and user-transparent design. Learners were not required to self-report difficulties or navigate help menus to receive support; instead, the system interpreted their gaze behavior and adapted seamlessly. This design feature reduced the stigma often associated with seeking help and preserved the flow of interaction. As a result, learners experienced greater autonomy and felt "seen" by the system, which contributed to both usability ratings and affective comfort during task execution.

The dynamic nature of this framework reflects key principles from both neuroscience and cognitive load theory. Interfaces that adjust to user states respect the limits of working memory and reduce extraneous processing demands. The model's responsiveness to blink rate and fixation data aligns with research on cognitive fatigue and attentional sustainability. These mechanisms allow the system to perform micro-adjustments that cumulatively result in smoother cognitive transitions and better content retention.

The ability of the neuroadaptive system to accommodate varying attentional profiles also speaks to its broader potential for personalization without prior user profiling. Rather than relying on learning analytics from past behavior, the system reacts to present conditions, making it more flexible and inclusive. This real-time adaptivity positions the model as a viable approach to designing emotionally and cognitively sensitive learning environments that serve both neurotypical and neurodiverse learners.

Further development and scaling of this neuroadaptive framework are essential to translating these findings into everyday educational practice. Educational institutions and technology developers must collaborate to embed such systems into widely used learning management platforms. Curriculum designers should begin incorporating neuroadaptive logic into both synchronous and asynchronous modules to ensure engagement continuity. Research should also explore the integration of other biometric signals, such as facial expression or heart rate, to enrich the adaptivity matrix.

Longitudinal studies are necessary to investigate the long-term impact of adaptive UX on learning outcomes, self-regulation, and retention. Future iterations of the system could be enhanced by allowing learners to customize the degree or type of adaptation, combining system-driven and user-driven personalization. Expanding this research across different disciplines, age groups, and learning contexts would further validate the model's applicability and effectiveness in broader educational settings.

Teacher training programs should include awareness and practical applications of neuroadaptive technology, enabling educators to interpret system feedback and support learners accordingly. Developers should prioritize ethical considerations related to data privacy, transparency, and user consent in the implementation of gaze-based technologies. Establishing policy frameworks and accessibility guidelines for neuroadaptive systems will ensure they are deployed equitably and responsibly.

This study contributes to the emerging intersection of neuroscience, UX design, and educational inclusivity by offering a concrete, empirically tested model for real-time adaptive learning. The integration of eye-tracking into UX architecture transforms passive digital interfaces into active cognitive partners. As hybrid education continues to evolve, the findings affirm the necessity of designing learning systems that respond not only to user input, but also to user *state*, promoting environments that are as responsive as they are inclusive.

CONCLUSION

The most significant finding of this study is the demonstrated effectiveness of integrating eye-tracking technology with adaptive user experience (UX) design to enhance inclusivity and cognitive responsiveness in hybrid learning environments. The neuroadaptive system allowed for real-time interface adjustments based on gaze behavior, resulting in improved task efficiency, reduced cognitive load, and higher user satisfaction among diverse learners. Participants with attentional challenges particularly benefited from the responsive interface, indicating the model's potential in supporting neurodiverse users. Unlike conventional adaptive systems that rely solely on performance analytics, this framework dynamically aligned with learners' moment-to-moment attentional states, making the learning experience more personalized and accessible.

The main contribution of this research lies in the introduction of a neuroadaptive framework that operationalizes real-time biometric feedback-specifically eye-tracking-into UX design for educational purposes. This study bridges the gap between cognitive neuroscience, inclusive design, and hybrid learning technology by offering a methodologically rigorous and practically implementable model. The novelty of this approach is reflected in the seamless integration of biometric data into UX behavior, providing an innovative mechanism for non-intrusive cognitive support. The framework not only advances the discourse on adaptive learning but also expands the definition of inclusivity by acknowledging and responding to cognitive variability in live interaction.

The research is limited by its single-institution sample, relatively short intervention period, and the use of one type of biometric input. While the results are promising, broader generalizability requires further validation across varied educational levels, learning domains, and cultural settings. The study also did not explore user autonomy in controlling or customizing adaptation, which could be a valuable direction for future investigation. Further research should include longitudinal studies to assess the sustained impact of neuroadaptive UX on learning outcomes and learner self-regulation, as well as the incorporation of multi-modal biometric inputs to enhance responsiveness and personalization across broader learner populations.

AUTHORS' CONTRIBUTION

Alida Ntahonkiriye: Conceptualization; Project administration; Validation; Writing - review and editing; Conceptualization; Data curation; In-vestigation.

Charles Ndikumana: Data curation; Investigation; Formal analysis; Methodology; Writing - original draft.

Denise Mutoni: Supervision; Validation; Other contribution; Resources; Visuali-zation; Writing - original draft.

REFERENCES

Adam, M. T. P., Bonenberger, L., Gimpel, H., & Lanzl, J. (2024). Human-Centered Design and Evaluation of a NeuroIS Tool for Flow Support. *Journal of the Association for Information Systems*, *25*(4), 936–961. https://doi.org/10.17705/1JAIS.00855

Beauchemin, N., Karran, A. J., Boasen, J., Tadson, B., Charland, P., Courtemanche, F., Sénécal, S., & Léger, P.-M. (2024). RACE: A Real-Time Architecture for Cognitive State Estimation, Development Overview and Study in Progress. In D. F.D., R. R., R. R., B. J.V., L. P.-M., R. A.B., & M.-P. G.R. (Eds.), *Lecture Notes in Information Systems and Organisation* (Vol. 68, pp. 9–20). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-3-031-58396-4_2

Chohan, M. O., Fein, H., Mirro, S., O'Reilly, K. C., & Veenstra-VanderWeele, J. (2023). Repeated chemogenetic activation of dopaminergic neurons induces reversible changes in baseline and amphetamine-induced behaviors. *Psychopharmacology*, *240*(12), 2545–2560. https://doi.org/10.1007/s00213-023-06448-x

Conrad, C., & Newman, A. J. (2022). Towards Mind Wandering Adaptive Online Learning and Virtual Work Experiences. In D. F.D., R. R., R. R., vom B. J., L. P.-M., R. A.B., & M.-P. G.R. (Eds.), *Lecture Notes in Information Systems and Organisation* (Vol. 58, pp. 261–267). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-3-031-13064-9_27

Fabrikant, S. I. (2023). Neuroadaptive LBS: towards human-, context-, and task-adaptive mobile geographic information displays to support spatial learning for pedestrian navigation. *Journal of Location Based Services*, *17*(4), 340–354. https://doi.org/10.1080/17489725.2023.2258100

Fairclough, S. (2023). Neuroadaptive Technology and the Self: a Postphenomenological Perspective. *Philosophy and Technology*, *36*(2). https://doi.org/10.1007/s13347-023-00636-5

Florence, L., Lassi, D. L. S., Kortas, G. T., Lima, D. R., de Azevedo-Marques Périco, C., Andrade, A. G., Torales, J., Ventriglio, A., De Berardis, D., De Aquino, J. P., & Castaldelli-Maia, J. M. (2022). Brain Correlates of the Alcohol Use Disorder Pharmacotherapy Response: A Systematic Review of Neuroimaging Studies. *Brain Sciences*, *12*(3). https://doi.org/10.3390/brainsci12030386

Gao, Z., Yu, W., & Yan, J. (2024). Neuroadaptive Fault-Tolerant Control Embedded With Diversified Activating Functions With Application to Auto-Driving Vehicles Under Fading Actuation. *IEEE Transactions on Neural Networks and Learning Systems*, *35*(5), 6255–6264. https://doi.org/10.1109/TNNLS.2023.3248100

Gkintoni, E., Antonopoulou, H., Sortwell, A., & Halkiopoulos, C. (2025). Challenging Cognitive Load Theory: The Role of Educational Neuroscience and Artificial Intelligence in Redefining Learning Efficacy. *Brain Sciences*, *15*(2). https://doi.org/10.3390/brainsci15020203

Grubov, V. V, Khramova, M. V, Goman, S., Badarin, A. A., Kurkin, S. A., Andrikov, D. A., Pitsik, E., Antipov, V., Petushok, E., Brusinskii, N., Bukina, T., Fedorov, A. A., & Hramov, A. E. (2024). Open-Loop Neuroadaptive System for Enhancing Student's Cognitive Abilities in Learning. *IEEE Access*, *12*, 49034–49049. https://doi.org/10.1109/ACCESS.2024.3383847

Hashim, H. A., & Vamvoudakis, K. G. (2024). Adaptive Neural Network Stochastic-Filter-Based Controller for Attitude Tracking With Disturbance Rejection. *IEEE Transactions on Neural Networks and Learning Systems*, *35*(1), 1217–1227. https://doi.org/10.1109/TNNLS.2022.3183026

Hejrati, M., & Mattila, J. (2024). Physical Human-Robot Interaction Control of an Upper Limb Exoskeleton with a Decentralized Neuroadaptive Control Scheme. *IEEE Transactions on Control Systems Technology*, *32*(3), 905–918. https://doi.org/10.1109/TCST.2023.3338112

Legeay, S., Caetano, G., Figueiredo, P., & Vourvopoulos, A. (2022). NeuXus: A Biosignal Processing and Classification Pipeline for Real-Time Brain-Computer Interaction. *MELECON 2022 - IEEE Mediterranean Electrotechnical Conference, Proceedings*, 424–429. https://doi.org/10.1109/MELECON53508.2022.9842925

Nath, K., Bera, M. K., & Jagannathan, S. (2023). Concurrent Learning-Based Neuroadaptive Robust Tracking Control of Wheeled Mobile Robot: An Event-Triggered Design. *IEEE Transactions on Artificial Intelligence*, *4*(6), 1514–1525. https://doi.org/10.1109/TAI.2022.3207133

Sarkar, N., & Deb, A. K. (2024). Dynamic event-triggered neuroadaptive fault-tolerant control of quadrotor

UAV with a novel cosine kernel. *Aerospace Science and Technology*, *155*. https://doi.org/10.1016/j.ast.2024.109643

Shahvali, M., Azarbahram, A., & Pariz, N. (2023). Adaptive output consensus of nonlinear fractional-order multi-agent systems: a fractional-order backstepping approach. *International Journal of General Systems*, *52*(2), 147–168. https://doi.org/10.1080/03081079.2022.2132488

Shao, X., & Ye, D. (2022). Neuroadaptive deferred full-state constraints control without feasibility conditions for uncertain nonlinear EASSs. *Journal of the Franklin Institute*, *359*(7), 2810–2832. https://doi.org/10.1016/j.jfranklin.2022.03.004

Teixeira, A. R., Brito-Costa, S., & de Almeida, H. (2024). Optimizing Reading Experience: An Eye Tracking Comparative Analysis of Single-Column, Two-Column, and Three-Column Formats. In M. H. & A. Y. (Eds.), *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics): Vol. 14689 LNCS* (pp. 51–59). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-3-031-60107-1_5

Weber, R., Dash, A., & Wriessnegger, S. C. (2024). Design of a Virtual Reality-Based Neuroadaptive System for Treatment of Arachnophobia. *2024 IEEE International Conference on Metrology for EXtended Reality*, *Artificial Intelligence and Neural Engineering*, *MetroXRAINE 2024 - Proceedings*, 255–259. https://doi.org/10.1109/MetroXRAINE62247.2024.10796452

Xiang, K., Ming, R., Chen, S., & Lewis, F. L. (2025). Neuroadaptive Control With Enhanced Stability and Reliability. *IEEE Transactions on Neural Networks and Learning Systems*. https://doi.org/10.1109/TNNLS.2025.3542551

Yang, D., Liu, W., & Guo, C. (2023). Command-filtered-based neuroadaptive control for multi-input multi-output saturated nonstrict-feedback nonlinear systems with prescribed tracking performance. *International Journal of Adaptive Control and Signal Processing*, *37*(3), 617–643. https://doi.org/10.1002/acs.3539

Zhao, K., Chen, L., Meng, W., & Zhao, L. (2023). Unified Mapping Function-Based Neuroadaptive Control of Constrained Uncertain Robotic Systems. *IEEE Transactions on Cybernetics*, *53*(6), 3665–3674. https://doi.org/10.1109/TCYB.2021.3135893