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Neuroassessment and monitoring of higher cognitive functions in naturalistic contexts: the case of organizational neuroscience

Davide Crivelli[1,2] **- Michela Balconi**[1,2]

[1] *International research center for Cognitive Applied Neuroscience (IrcCAN), Università Cattolica del Sacro Cuore, Milan, Italy*
[2] *Faculty of Psychology, Università Cattolica del Sacro Cuore, Milan, Italy*

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davide.crivelli@unicatt.it

ABSTRACT

Naturalistic neuroassessment has emerged as a transdisciplinary applied neuroscience approach aimed at evaluating cognitive and socio-affective processes in ecologically valid contexts. By integrating methods from cognitive neuroscience, psychology, and behavioural sciences, this framework enables the monitoring of neural and physiological correlates of complex functions – such as decision-making, problem-solving, and attentional control – during realistic tasks. Within organizational contexts, neuroassessment supports the field of neuromanagement by providing objective insights into cognitive effort, self-regulation, and executive functioning involved in managerial and team-based activities. Multimodal approaches combining electroencephalography (EEG), autonomic markers (e.g., heart rate variability and electrodermal activity), and eye-tracking allow for real-time assessment of cognitive load and emotional arousal. The increasing availability of wearable technologies further enhances ecological validity by enabling continuous monitoring in workplace environments. Beyond diagnostic profiling, neuroassessment can inform training, leadership development, and organizational design. However, its implementation requires careful consideration of methodological rigor, user acceptance, and ethical issues related to privacy and employee autonomy.

Keywords: neuroassessment; organizational neuroscience; cognitive load; self-regulation; wearables

1. INTRODUCTION

Naturalistic neuroassessment has evolved as a transdisciplinary approach combining methods and models from cognitive neuroscience, psychology, and behavioural sciences with the goal of measuring and interpreting neurofunctional and physiological data for the sake of evaluation or profiling of individual cognitive and socio-affective skills in applied, often non-clinical, contexts. One of the key motivations for this evolution is the growing recognition that complex cognitive processes such as decision-making, attentional control, and problem-solving unfold differently in dynamic real-life scenarios than in static laboratory conditions. This has prompted a shift toward ecological validity and the development of tools capable of capturing brain and behaviour interactions in real-world environments and with realistic tasks.

From its origins in clinical neuropsychology, neuroassessment has evolved by integrating insights and methods from cognitive neuroscience, bioengineering, and biomedical disciplines to create more complex protocols for monitoring and evaluation of cognitive processes, now progressively embedded into fields such as education, healthcare, human performance, and organizational sciences. By embracing a multimethod approach and adopting a multifaceted perspective on human performance, neuroassessment protocols grounds on the assumption that by using multiple tools and metrics it is possible to better capture the complexity of such phenomenon and to properly consider the various covert and overt ways it manifests itself. Let's take problem-solving as an example.

Problem solving can be defined as a complex, goal-directed cognitive process wherein an individual identifies a discrepancy between a current state and a desired goal state and engages in a series of mental operations and action plans to bridge this gap. Psychologically, this involves stages such as problem representation, strategy formulation, execution, and evaluation, often employing heuristics or algorithms to navigate toward a solution. From a neuroscientific standpoint, problem solving engages a distributed network of brain regions (Barbey, 2018; Bartley et al., 2018; Kounios & Beeman, 2014). To sum up: (i) the dorsolateral prefrontal cortex (DLPFC) is crucial for maintaining goal representations and managing working memory; (ii) the anterior cingulate cortex (ACC) monitors for conflicts and errors, facilitating adjustments in strategy; (iii), the posterior parietal cortex contributes to attentional control and the manipulation of information. Additionally, the default mode network (DMN) may be involved during periods of insight or creative problem solving, reflecting the integration of internally generated information. Also, during problem-solving, autonomic nervous system (ANS) responses show fluctuations based on cognitive demand and emotional arousal. Heart rate variability (HRV) may decrease as task complexity and mental effort increase, reflecting sympathetic activation and reduced parasympathetic regulation (Forte et al., 2022; Thayer et al., 2009). Similarly, skin conductance increases in response to cognitive load and emotional intensity, signalling heightened arousal and attentional engagement (Dawson et al., 2007).

Once taken such complex definition into consideration, focusing our analysis only on covert, explicit, behavioural markers of performance at solving problems would surely provide a glimpse on the efficacy and proficiency of the examinee, but leaves much of the picture outside of the frame. As examples, measuring and keeping track of neurofunctional activations linked to DLPFC and ACC regions would provide valuable information on the number of neural resources that the examinee allocate while facing the task, with the possibility for fine-grained conclusions concerning the consumption of working memory vs. error monitoring efforts. Again, collecting real-time data on his/her autonomic arousal offers the possibility to assess the impact of task-related distress on the effectiveness of problem-solving skills or on the ability to manage the stress response during a challenging task. An integrated neuroassessment routine, especially when implemented in naturalistic contexts and with real-life (or realistic) tasks, enables the evaluation of how individuals psychologically and physiologically adapt to task features such as difficulty, uncertainty, or time pressure.

As a further critical point, contemporary models propose that neuroassessment should not only serve diagnostic purposes but should also support processes of monitoring, intervention, and empowerment while considering real-life manifestations of target cognitive and socio-affective skills. High-dimensional neuropsychological assessments (Parsons & Duffield, 2020), as an example, aim to capture the interplay of multiple cognitive, emotional, and contextual factors. These approaches acknowledge that cognition cannot be separated from the socio-environmental conditions in which it is expressed. Thus, emerging neuroassessment models call for context-sensitive metrics that reflect the fluctuating demands placed on individuals in their real-world roles – including the organizational and managerial domains.

The adoption of neuroscientific frameworks in organizational settings has led to the emergence of neuromanagement, which seeks to apply principles of neuroscience to leadership, decision-making, team dynamics, and employee engagement (Balconi, 2021; Butler et al., 2016; Senior et al., 2011). This integration paves the way for neuroassessment methods that are specifically designed to evaluate cognitive and affective load in management-related tasks. For example, Zak (2018) emphasizes the central role of trust and oxytocin-mediated social bonding in organizational behaviour, which can be assessed using neurobiological and psychophysiological measures.

Ultimately, neuroassessment as an applied approach recognizes the importance of integrating real-time, context-aware, and user-centred evaluation techniques. Whether through wearable sensors, digital simulations, or adaptive feedback systems, the future of neuroassessment lies in its capacity to deliver actionable insights into how people think, decide, and perform in the environments that matter most.

2. METHODS AND CASE HISTORIES FOR NEUROSCIENCE APPLICATION TO ORGANIZATIONAL CONTEXTS

Neuroscientific frameworks have begun to elucidate complex social interactions and cognitive functioning within organizations. The concept of Organizational Cognitive Neuroscience (OCN), introduced by Senior et al. (2011), raised the attention on the significance of studying brain activity in organizational contexts to understand underlying behavioural mechanisms. This perspective shifts the focus from purely behavioural analyses to the neural processes that inform decision-making, communication, and leadership styles. By examining how neurobiological factors influence organizational behaviour, researchers aim to uncover insights into executive functioning, trust dynamics, and employee engagement, emphasizing a somatic interpretation of organizational phenomena (Balconi, 2021; Becker et al., 2011; Butler et al., 2016; Senior et al., 2011).

Moreover, Zak (2018) discusses the neuroscience of trust, positing that interpersonal trust within organizations significantly impacts performance. By engaging neuroscientific assessments, organizations can pinpoint interventions that foster trust and enhance collaborative efforts, taking advantage of neurobiological insights into motivation and social connectivity. Neuroimaging techniques, such as functional Near-Infrared Spectroscopy (fNIRS), can provide empirical data on brain activation patterns associated with trust, enabling leaders to develop evidence-based strategies for establishing a high-trust work environment (Balconi, Fronda, & Vanutelli, 2019; Balconi & Fronda, 2020b; Balconi & Molteni, 2016).

Practical applications of neuroscientific approaches to organizational issues have been realized in various domains, particularly in strategic management. Caneppele et al. (2022) highlight how neuroscientific tools can predict organizational phenomena with greater accuracy than traditional methods, facilitating a deeper understanding of constructs such as leadership and teamwork. Waldman et al. (2011) propose applying neuroscientific methods to improve leadership effectiveness. Their work suggests that leaders who embody cognitive and emotional competencies, as revealed through neuroassessment, can significantly enhance their followers' performance and satisfaction. These notes underscore the potential of neuroscientific assessments in leadership development programs, moving beyond psychometric tests to more dynamic and responsive evaluations. Furthermore, in service recovery contexts, Vaerenbergh et al. (2018) explored the emotional journey consumers undergo and its implications for service recovery strategies. By implementing neuroscientific assessments, organizations could better design service experiences that resonate emotionally with customers, thereby improving recovery outcomes. This possible development exemplifies how neuroassessment can be leveraged not only for internal management but also to enhance customer relationship management and service design.

As the field of organizational neuroscience expands, methodological considerations become imperative for effectively integrating neuroassessment tools within organizational studies. Karmarkar and Plaßmann (2017) advocate for the careful selection of psychophysiological methods, emphasizing the need for clarity about the constructs under investigation and the neurobiological implications of specific assessments. Their remarks moved from the field of consumer neuroscience, but they could and should be extended to all contexts in which psychometric and cognitive evaluation is improved by using neuroscientific tools. For instance, the differentiation between intrinsic and reflexive brain activities must be acknowledged when interpreting neurofunctional data, as such distinctions can significantly influence research outcomes (Waldman et al., 2019).

Challenges related to the application of neuroscience tools are addressed in the work of Lindebaum and Zundel (2013), who argue for transparency and rigor in research designs that utilize neuroscience technologies. They highlight the importance of avoiding over-reliance on neurological evidence while still integrating such findings meaningfully into organizational theories. This perspective resonates with the overall discourse advocating for balanced approaches that synthesize traditional behavioural studies with neuroscientific insights, thereby fostering comprehensive organizational theories.

The evolving field of neuromanagement stands as a crucial intersection between neuroscience and organizational behaviour, providing the theoretical and practical frameworks necessary to implement neuroscientific approaches in management practices. As proposed by Butler et al (2016), neuromanagement can refine our understanding of managerial decision-making by contextualizing neurocognitive research within practical organizational settings. This integration can potentially lead to more refined managerial strategies that align with innate human behaviour rather than conventional managerial theories that may not fully encapsulate human cognitive and emotional realities.

Furthermore, scholars such as Murray and Antonakis (2019) emphasize the role of neuroscience in informing leadership development and team dynamics, advocating for methods that consider neurobiological influences on managerial behaviour and interpersonal relations within teams. By forming a coherent understanding of how cognitive processes underpin work-related relations and inter-actions, organizations can design training programs that not only elevate leaders' awareness of their own cognitive styles but also optimize interactions with their teams, leading to enhanced performance and collective efficacy.

3. NEUROASSESSMENT IN ORGANIZATIONS

Within the broader context of organizational neuroscience, neuroassessment can then be deemed as a strategic tool. Its application in neuromanagement is predicated on the idea that complex professional functions – such as multitasking, prioritizing under pressure, navigating uncertainty, and regulating interpersonal dynamics – can be better understood and improved by examining the neural and physiological mechanisms underpinning them. By offering a window into the real-time neural and psychophysiological correlates of cognitive and emotional processes, neuroassessment makes it possible to identify patterns of effective (or maladaptive) work-related behaviours and to design evidence-based interventions.

Naturalistic neuroassessment is typically conducted in ecologically valid settings using portable technologies such as EEG, fNIRS, autonomic monitors, and/or eye-tracking systems. These tools allow for real-time data collection while the examinees engage in realistic complex tasks and/or simulate work-related scenarios. Such assessments enable the identification of cognitive bottlenecks, stress responses, or attentional lapses, which can then inform targeted cognitive training, executive coaching, or organizational redesign.

Additionally, neuroassessment data can feed back into team-level optimization strategies. For example, synchronized EEG, hemodynamic, or heart rate data across team members can indicate alignment and effective communication, while physiological mismatches might signal conflict or breakdowns in shared attention (Balconi, Angioletti, & Cassioli, 2023a, 2023b; Balconi & Fronda, 2020a; Czeszumski et al., 2020; Léné et al., 2021; Nozawa et al., 2016; Balconi & Pozzoli, 2005). In this regard, neuroassessment not only supports individual self-awareness but also enables systemic insights into group processes and organizational dynamics.

By combining the methodological rigor of neuroscience with the practical aims of management science, neuroassessment for organizational purposes becomes a powerful integrative practice. It enables the design of professional strategies that are aligned with human cognitive and affective capacities, ultimately fostering environments where well-being and performance can co-evolve.

3.1 Neurofunctional and psychophysiological markers of cognitive effort, self-regulation and efficiency of higher cognitive functions

Delving deeper into the applications of neuroassessment, it is relevant to note that understanding cognitive effort, self-regulation, and efficiency of higher cognitive functions (such as problem-solving, strategic planning or decision-making) in real-world settings requires a multimodal assessment approach that integrates neurofunctional and psychophysiological markers. Recent developments in neuroscience and applied psychophysiology have provided tools exploiting especially the collection of EEG, ANS parameters, and/or eye-tracking metrics, which can be employed to monitor these complex processes with increasing ecological validity.

3.1.1 EEG markers of cognitive load and executive function

EEG markers offer a non-invasive, high temporal resolution method for assessing mental effort and engagement. Among the most widely studied markers are frontal theta (4-7 Hz), alpha (8-12 Hz), and beta (13-30 Hz) oscillations, as well as event-related potentials (ERPs) such as the P300 component. Elevated frontal theta activity is strongly correlated with increased working memory load and attentional demands (Cavanagh & Frank, 2014; Lukačević et al., 2023; Sarailoo et al., 2022). Alpha suppression has been shown to indicate higher cognitive engagement and reduced mental relaxation, while beta rhythms are associated with task-related focus and sensorimotor activity (Balconi et al., 2023; Spitzer & Haegens, 2017; Yu et al., 2022).

The application of EEG has been widespread across education, organizational management, and sports. In educational settings, EEG proved to help in detecting engagement levels during learning activities, enabling tailored instruction (Martin, 2014; Vanneste et al., 2021; Xiong et al., 2020). Again, in corporate training and workplace environments, EEG supports monitoring of cognitive states, stress levels, and mental fatigue, thereby optimizing workload management (Anders & Arnrich, 2022; Arpaia et al., 2020; Liu et al., 2023; Sudiarno et al., 2023).

ERP studies such as those examining the P300 component contribute to understanding decision-related attentional processes, while advances in AI and machine learning are enhancing EEG's capacity to classify cognitive load states in real-time (Friedman et al., 2019; Wang et al., 2023). Integration with other modalities (e.g., fNIRS, electrodermal activity) is encouraged to increase reliability and ecological validity (Sazuka et al., 2024).

3.1.2 Autonomic markers: HRV, SL and multimodal integration

ANS responses provide crucial information about both cognitive and affective load. HRV, electrodermal activity (EDA), and pupillometry are reliable indicators of arousal, stress, and attentional effort. Low HRV is typically associated with sympathetic dominance and cognitive overload, while high HRV reflects parasympathetic activation and adaptive cognitive functioning (Thayer et al., 2009, 2012; Xiong et al., 2020).

EDA, particularly skin conductance response (SCR), is a sensitive marker of emotional and cognitive arousal. It increases during complex decision-making, high-stakes problem-solving, and emotionally charged tasks (Dawson et al., 2011; Nourbakhsh et al., 2017). Moreover, studies show that EDA and HRV are responsive to both the difficulty of cognitive tasks and the intensity of emotional experiences (Crone et al., 2004; Saha et al., 2022).

Integration of multimodal physiological signals improves the reliability of cognitive load detection. For instance, respiratory activity, often recorded in tandem with HRV, reflects cognitive effort and is useful for identifying moments of acute mental stress (Grassmann et al., 2016; Oppelt et al., 2022). Adaptive systems that use real-time feedback from autonomic markers are being developed for high-stakes fields such as aviation, surgery, and leadership training (Crivelli et al., 2025; Vanneste et al., 2021; Wang et al., 2020).

Recent findings also underline the relevance of autonomic markers for long-term well-being. Elevated cognitive load without appropriate regulation is associated with nociceptive hypersensitivity and adverse psychological outcomes (Meyers et al., 2023), emphasizing the utility of monitoring systems in preventive organizational health.

3.1.3 Eye-tracking markers of cognitive and affective load

Eye-tracking provides a window into cognitive processing through metrics such as fixation duration, saccades, and pupil dilation. Fixation patterns and durations reflect attentional allocation and task/stimuli complexity, while pupil diameter is modulated by both cognitive load and emotional arousal (Skaramagkas et al., 2023).

Pupillometric data have shown strong correlations with perceived workload and attentional states, making them valuable for real-time monitoring. In workplace settings, eye-tracking has been used to evaluate cognitive efficiency and decision-making strategies during complex tasks. For instance, prolonged fixations and irregular saccades are often indicative of increased cognitive effort (Król & Król, 2021; van der Wel & van Steenbergen, 2018).

Eye-tracking could also be useful in detecting early signs of cognitive impairment, such as executive dysfunction, through saccadic latency and oculomotor performance (Chehrehnegar et al., 2022). In usability testing and human-computer interaction (HCI), eye-tracking helps designers assess and optimize task interfaces by identifying attention bottlenecks (Novák et al., 2024).

Advanced machine learning techniques are now being employed to classify cognitive states from eye movement data, enabling adaptive systems that respond to user workload and optimize task environments accordingly (Kaczorowska et al., 2021).

3.1.4 Multimodal synergy and future implications

While each modality – EEG, autonomic markers, and eye-tracking – offers unique insights into the way a person manages cognitive and affective loads while executing a task, their integration promises a more holistic understanding. Multimodal systems capable of synthesizing these signals enable real-time, individualized assessments of cognitive readiness and workload management.

Such frameworks are especially relevant for managerial decision-making, where split-second judgments are made under stress and uncertainty. Detection of early signs of overload via converging physiological signals can provide adaptive feedback, prompting users to pause, re-evaluate, or seek support. Integration of these systems with AI tools opens new possibilities for predictive modelling of cognitive decline, training adaptation, and optimized task delegation.

In summary, the combined use of EEG, autonomic markers, and eye-tracking represents a powerful suite of tools for assessing cognitive effort, self-regulation, and executive control. These tools offer actionable insights to support sustainable performance and well-being in cognitively demanding organizational environments.

4. WEARABLES IN NEUROASSESSMENT: MONITORING COGNITIVE AND AFFECTIVE LOADS AT THE WORKPLACE

As discussed above, the integration of wearable technologies in neuroassessment has enabled the real-time and ecologically valid monitoring of physiological responses linked to cognitive and affective states in the workplace. These tools hold great promise for improving decision-making quality, reducing cognitive strain, and optimizing overall managerial performance.

Wearables such as EEG headbands, heart rate monitors, and smartwatches are capable of continuously measuring physiological parameters indicative of cognitive load. HRV has emerged as a reliable index of autonomic regulation and mental workload. Studies such as Smith et al. (2020) demonstrate that HRV patterns change in response to the intensity of cognitive demands, enabling wearables to serve as non-invasive indicators of fatigue and stress in real time. Also, wearables can act as both assessment and intervention tools, providing feedback that allows individuals to adjust their workload, take restorative breaks, or adopt strategies to manage their cognitive effort effectively. Wearable neurofeedback devices, as an example, showed their valuable support in promoting awareness practices for neuroempowerment even outside the laboratory (Balconi, Angioletti, & Crivelli, 2023; Balconi et al., 2019; Balconi, Fronda, & Crivelli, 2019; Crivelli, Fronda, & Balconi, 2019; Crivelli et al., 2019b, 2019a; Crivelli & Vignati, 2025; Vignati & Crivelli, 2025), with users reporting greater awareness of their cognitive states and strategic use of such insight to modulate engagement with complex tasks.

Wearables also support the monitoring and enhancement of executive functioning. For instance, devices that track EEG and electrodermal activity have been used to evaluate attentional control, detect inhibitory processes, and classify levels of distress and arousal (Anders & Arnrich, 2022; Arpaia et al., 2020; Khosravi et al., 2022). Nelson and Allen (2019) showed that reduced HRV in workplace settings correlates with deficits in executive control, indicating that wearable-based HRV monitoring can inform timely interventions aimed at mitigating stress-induced executive impairments.

In high-stakes decision-making scenarios, wearables are useful for detecting subtle physiological cues that precede or accompany cognitive and emotional overload. For example, wearable photoplethysmography (PPG) and EDA sensors can detect autonomic arousal linked to emotional salience and decision stress (Nelson et al., 2023). Biometric data gathered during decision tasks can inform the emotional and cognitive load influencing managerial choices (e.g., Crone et al., 2004). Moreover, wearable technologies can proactively support decision-making by delivering prompts or alerts when physiological thresholds are exceeded, thereby reducing the risk of error-prone decisions made under stress. Patel et al. (2021) suggest that the inclusion of such wearable-guided interventions contributes to improved workplace decision quality and overall productivity. Notably, given the technological and methodological progress that has led to the progressive increase of feasibility and applicability of hyperscanning protocols in real-life contexts (Balconi, Angioletti, & Cassioli, 2023a; Balconi & Vanutelli, 2017; Dikker et al., 2017; Shamay-Tsoory & Mendelsohn, 2019; Venturella et al., 2017), wearable neurotechnologies can now inform assessment practices even when they are focused on teamwork, joint tasks, and inter-personal dynamics (Crivelli & Balconi, 2023, 2025; Silbert et al., 2014; Zhang et al., 2021).

Nonetheless, it is relevant to stress that, to be effective, wearables must be integrated thoughtfully into workplace dynamics. Factors such as user acceptance, privacy concerns, and perceived surveillance may hinder implementation. Krzywdzinski et al. (2024) underscore that employees' initial perceptions of wearable utility and organizational transparency significantly influence adoption and engagement. Design considerations – including comfort, data ownership, and feedback clarity – are essential for long-term use. Also, despite their advantages, wearable technologies raise ethical questions regarding continuous monitoring, data privacy, and autonomy. Muhl & Andorno (2023) argue for clear regulatory and ethical guidelines to balance the benefits of cognitive monitoring with the rights of employees. The tension between support and surveillance must be carefully managed.

Looking ahead, future developments may include smart textiles, AI-integrated adaptive systems, and multimodal sensors capable of interpreting complex cognitive-affective states in real time (Chalabianloo et al., 2022; Kan & Lam, 2021; Wang et al., 2024) . These technologies could yield more personalized, context-sensitive assessments that improve both individual and organizational outcomes.

5. CONCLUSIONS

Neuroassessment represents a significant advancement in the understanding and application of cognitive neuroscience within organizational contexts. By integrating neurophysiological and psychophysiological data through tools such as EEG, fNIRS, autonomic measures, eye-tracking and pupillometry, researchers and practitioners can gain insights into the underlying mechanisms of cognitive effort, self-regulation and use of mental resources to efficiently support higher cognitive functions such as attention regulation, planning, problem-solving, and decision-making. These insights are particularly relevant for organizations, where decision-making quality, stress regulation and cognitive control are essential to effective performance.

The integration of wearable technologies has further expanded the reach and applicability of neuroassessment. Wearables may already provide continuous, non-invasive, and real-time monitoring of cognitive and affective states, supporting both assessment practices and fine-grained profiling of individual potential, and adaptive interventions to enhance performance and well-being. Their ability to capture physiological signals in naturalistic settings enhances ecological validity and opens the door to novel approaches in workplace optimization, employee training, and organizational design.

However, the implementation of wearable neuroassessment in the workplace also brings ethical considerations to the forefront. Balancing support and surveillance, ensuring transparency, and protecting employee autonomy are critical challenges that must be addressed through clear regulatory frameworks and participatory design practices.

Future directions for research and application include the development of multimodal sensing systems, integration with artificial intelligence for predictive modelling, and the evolution of neuroadaptive interfaces capable of dynamically responding to users' cognitive states. As neuroscience continues to inform organizational theory and practice, the potential for creating cognitively attuned, responsive and ethically grounded work environments grows ever more promising.

Ultimately, neuroassessment and neuromanagement offer a transformative lens through which to understand human performance in complex social systems. By embracing the interplay of brain, behaviour, and context, organizations can foster environments that not only enhance productivity and leadership but also promote cognitive health, emotional well-being, and sustained human potential.

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