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Validity and Rationality of Using Neuroergonomics Concept in Exploring Worker Mental Issues in Systemic-Activity Theoretical Research

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ABSTRACT

This paper critically examines the dynamics of workers systemic activity undertakings in neuroergonomic studies and the argument that despite the expansion of the number of useful analytical approaches used in neuroergonomics research, the systemic dynamics of functional brain connectivity and network topology of workers engaged in tasks performance is largely unknown. Arguing from the established knowledge that the field of human factors and ergonomics has benefitted from the inclusion of neuro-based methods and techniques, it is posited that the application of neuroergonomics concepts in the systemic structural activity theoretical approach, is theoretically valid and rational. It is established that neuro-indices of cognitive workload, discussed in the context of human mental load and working memory, has provided a pathway for understanding the systemic association between a worker's ability to recall and process stored information for decision-making and problem-solving and his/her ability to engage in efficient and effective systemic structural activity performance.

Keywords: Systemic structural-activity theoretical research, Neuroergonomics, Neuropsychology, Conceptual validity, Conceptual Rationality

INTRODUCTION

The field of social neuroscience related to human factors and ergonomics is generally accepted as an emerging sub-field that explores on how people process, store, and apply social information about human-machine systems on a continuum from automation to autonomy. Special interest groups, such as the frontiers in social neuroergonomics, have outlined that understanding the neuropsychological underpinnings of human social cognition and interactions toward automation and autonomy can help in the development of more efficient automated and autonomous systems for naturalistic and everyday settings. In this stead, the study of mental workload is viewed as fundamental to understanding the intrinsic limitations of the human information processing system (Dehais, Lafont, Roy and Flairclough, 2021). However, according to de Andrade (2021), the field of behavioral and neurophysiological synchrony should open up promising paths for studies of human–human and human–machine interactions in organizations and work environments.

Arguing from the perspectives of neuroscience and psychology at work, especially, analytical conditions in the field of work and organizations, de Andrade (2021), situated neuroergonomics as combining the behavioral and cognitive phenomena related to the ways that the engineering of neurosciences and their neurophysiological products works. In this respect, and based on the purview that this field of investigation is currently on the rise, de Andrade (2021), sought to explain, at the conceptual level, the workings of the worker's brain by identifying the importance of markers at the neurophysiological, physiological, and behavioral level of mental states linked to the performance of workers.

Mapping of Human Brain Connectivity to Human Activity

It is a known fact that the brain is the most complex organ in the human body. Over the last few decades, mapping human brain connectivity to human activity has gained considerable attention in the areas of cognitive neuroscience and human factors. The field has benefitted greatly from the inclusion and integration of neuroscientific methods and theory, with the argument that synergistic success of such integration could work in the other direction with the inclusion of neuro-field methods in human factors, such as neuro-psychology or neuroergonomics., which incorporates knowledge on the dynamics between human cognition and work performance. Thus, human factors and ergonomics, as a field, has benefitted from the committed inclusion of neuro-based methodologies, which knowledge area has advanced in various ways. In this wise, continuous efforts in the neuroergonomics field have been devoted to studying brain signals relative to human systemic activity work settings. Though the number of useful analytical approaches used in neuroergonomics research has rapidly expanded, there is the argument that the functional brain connectivity and network topology in the context of neuroergonomics is largely unknown. Hence, modern network science, entailing a synergetic mix of dynamic systems theory, graph theory, and statistics, is applied in studying the functional and structural brain connectivity network under various states and conditions. There is correlation in such synergistic relationship, with human factors and neuroergonomics methods and measures benefitting other disciplines, such as the Systemic Structural Activity Theory (SSAT) approach (Bedny and Karwowski, 2007, Sanda et. al., 2014). SSAT establishes that knowledge derived from ergonomics and activity theory is uniquely capable of engaging with different ways of knowing the world of work, generating new knowledge, and helping stakeholders understand and incorporate the results or lessons learned (Bedny and Karwowski, 2007, Sanda et. al., 2014). Even though previous studies have succeeded in quantifying a great variety of cognitive and physical measures of human tasks, the SSAT approach has been used to understand the mental and physical systemic activities entailed in human dynamic temporal interactions during everyday tasks. This therefore brings to the fore the debate on the rational and valid adaption of neuroergonomics concept to explore mental issues in systemic-structural activity theoretical research. In SSAT studies using the neuroergonomics approach, cognitive workload is a

multidimensional construct and a widely invoked concept, whose assessment is of great interest.

In the SSAT approach, the neuro-indices of cognitive workload have been discussed relative to a task performer's mental load and work memory, especially how he/she process and store information (Bedny and Karwowski, 2007, Sanda, 2020). In the workplace, such process require the manipulation and recall of information for decision-making and problem-solving. In this wise, this paper argue on the validity and rationality of using neuroergonomics concept in the SSAT approach, which has been used in many situations to establish the relation between a task performer's ability to recall and store information associated with to fatigue, stress, and workload, which in turn affects the performer's situational awareness and attention levels that lends to his/her learning performance.

BRAIN FUNCTIONALITY AND ACTIVITY PERFORMANCE

Studies on how the brain works to inform the exertion of force in an activity has gained a promising significance in ergonomics research (Ismail et al., 2022). This understanding, according to Ismail et al., 2022), cannot be gained by studying the function of the brain regions in isolation. The interactive patterns of these regions are now understood and conceptualize as a complex network system (Ismail et al., 2022). This is because, the confluence of network science, modern network modelling, advanced computation paradigms, and developments in neurophysiological technologies has highlighted new ways of studying complex intracortical interactions (Ismail et al., 2022). This development has made it feasible to quantify the connectivity patterns in brain (Ismail et al., 2022), guided by the following approaches outlined by Friston (2011); (i) structural connectivity, which is determined from anatomical brain links; (ii) functional connectivity, which is estimated from statistical dependencies between different brain regions; and (iii) effective connectivity, which reflects causal relations between activated brain areas (Friston 2011). These three approaches have enabled the emergence and application of several techniques with different properties and capabilities in studying systemic activity performance (Bedny and Karwowski, 2007), functional connectivity estimation (Ismail and Karwowski, 2020), and the evaluations of communication patterns to understand information processing and brain functional organization during the execution of a motor task (Jiang et al., 2012).

SSAT AND NEUROERGONOMICS CONCEPTUAL INTERPLAY

Neuroergonomics, Neuropsychology, and Workload

Hardy's (2021) overview of neuroergonomics, entailing personal reminiscences of Raja Parasuraman, highlighted the recognition and inclusion in ergonomics, theoretical and methodological concepts from neuroscience. Arguing from the perspective of Parasuraman (2003), neuroergonomics is contextualized as the study of brain and behavior during task performance, which require investigations on the performer's neural-influenced perceptual and cognitive functions, such as deciding, remembering, seeing, hearing,

planning, and attending, relative to associated technologies and task-settings (Hardy, 2021). This synergistic success indicates that the methodological and theoretical concepts of human factors can be integrated in enhancing knowledge in corresponding neuro-fields, such as neuropsychology (Hardy, 2021). Based on this perspective, it could be implied that the inclusion of workload theory and concepts in neuropsychology research can be beneficial. In this regard, Neuroergonomics and Neuropsychology are related in that they both, broadly construed, involve the application of psychological science and neuroscience to real-world situations Hardy (2021). While the human engaged in work activity is the prime focus of neuroergonomics, the human, as a patient, with a nervous system is the prime focus of neuropsychology (Hardy, 2021). This categorization is underscored by the argument that both fields are underlined by reliability and validity principles. In this wise, and arguing from the perspectives of Parasuraman and Rizzo (2007). the reliabilities relate to the repetitiveness of the behavioral measures of these concepts relative to a person's involved in a work activity, while the validities relate to the real outcome of the person's brain-behavior complementary dynamics when engaged in the work activity. This observation has brought to the fore an argument by Hardy (2021) that though knowledge advancement in neuroergonomics has led to methodological refinements in human work and behaviour assessment, it is imperative that normative procedures and associated guidelines and standards are also established, and thus require additive attention. Arguing from neuropsychological perspective, Hardy (2021) posited such standards will make visible the existing tensions among various testing techniques. Making visible these tensions are of interest and highlights the need for expansive research that could provide the path to developing innovative systemic and structural work-oriented activities. Human factors concepts and theories have complimented that of neuroergonomics to establish standards for data assessment (Hardy, 2021). This, therefore, manifest the applied scientific characteristics of neuroergonomics in the SSAT approach in which emphasis is centred on the comparative analysis of multi-factors that constitutes the measured outcomes of an individual engaged in systemic activity. Thus, from developmental perspective, SSAT is a more dynamic discipline whose theories and concepts associate with that of other disciplines (Bedny and Karwowski, 2007; Sanda, 2014). In this respect, the inclusion of neuro-based methods and techniques and the concept of cognitive resources and its relatedness to cognitive workload is considered very relevant (Bedny and Karwowski, 2007; Sanda, 2020; Hardy, 2021). Thus, SSAT outlines a pathway for differentiating the behavioral state of a task performer and his/her internal state informed by the task's required effort and cognitive demand, and the degree of frustration in the task performance. Therefore, the SSAT approach offers a rational and valid pathway for conceptualizing and assessing the dynamic interrelatedness of a task performer. The SSAT approach is a valid neuropsychological approach that facilitates the exploration of task performers' neurocognitive state, using both outward test performance/brain measures and workload measures.

Rationality in Goal-Formation for Systemic Activities

Actors at the workplace are known to engage in activities entailing several actions and operations that constitute practices and whose performances leads to the actors attaining habitual accomplishment of specific tasks. In this wise, actors are cognitively influenced by their psychosocial interaction with the work context, starting from their goal formulation process and cognition in strategizing for the pending activity towards considering possible outcome decisions. Thus, activities that actors engage in at the workplace is viewed to occur in the macro-contexts that provide commonalities of action, and the micro-contexts in which action is highly localized (Sanda, 2020). The interaction between the micro and macro contexts makes visible the uncertainties associated with the activity (Sanda, 2016; Bedny and Karwowski, 2007) as well as provide the avenue for formulating practice that is adaptive (Sanda, 2019; Sanda et al., 2014). Since uncertainty in an activity is indicative of both the objective (i.e., complexity) and subjective (i.e., difficulty) characteristics of an organizational activity (Sanda, 2016; Bedny and Karwowski, 2007), the same complex task can be evaluated by different actors as either difficult or not, based on their cognition, skills and individual features (Sanda, 2016; Jarzabkowski, 2003). A study of graduate students preparing for examination activity by Sanda (2017) has shown that the conscious goal-directed processes of an actor are influenced by the actor's experiences on previous task engagements and his/her subjective perception of complexity in an impending task. Also, when the actor is preparing to engage in a pending organizational activity, different cognitive-oriented activities occur in the transition of the actor's conscious goal-directed processes to the emergence of thoughtfully mastered learning activity of the actor (Sanda, 2017). The transitional dynamics in such cognitive-oriented activities is shaped by the psycho-characteristics of the activity goal formation, in terms of the actor aiming for a "best goal" or setting the "highest goal" (Sanda, 2017). Thus, (Sanda, 2017). firstly, concluded that "in the emergence of an actor's thoughtfully mastered learning when readying for a best-goal-oriented task, his/her characterization of the goal as "best" in his/her activity goal formulation will mediate the influences that the actor's consideration of activity strategies has on his/her considerations of decision outcomes. Secondly, when the actor's characterization of the goal as "highest" in his/her activity goal formulation will moderate the influences that the actor's consideration of activity strategies has on his/her considerations of decision outcomes (Sanda, 2017).

Validity of Goal-Directed Systemic Processes and Activity-Strategies

In the design processes of an actor's activity, it is important to identify and distinguish the complexities associated with the activity's cognitive attributions, as informed by the specificity of its information processing, and its emotional-motivational attribution, as informed by its energetic aspects (Jarzabkowski, 2003; Sanda, 2019). Making visible these attributions of complexity will enable the designers of actors' activities to understand the practice enhancing strategies used by actors to mediate the cognitive difficulties and the emotional-motivational challenges inherent in their designed

activities (Jarzabkowski, 2003; Sanda, 2019). Key variable in self-regulation is goal-setting (Sanda et al., 2014). Hence, in understanding the dialectical complexities of an activity, there is the need to consider the existence of multiple goals (Jarzabkowski, 2003). This is because an actor's activity cannot be adequately interpreted that it is organized around a single, neatly identifiable goal (Jarzabkowski, 2003). Instead, multiple goals, that are often in interaction and sometimes in conflict, are typically involved (Jarzabkowski, 2003; Sanda, 2019). A goal is what an actor is trying to accomplish, and thus manifest the object or aim of an action, which is similar in meaning to the concepts of purpose and intent (Locke and Latham, 2019). Thus, in the approach towards identifying factors that influence practices evolving from actors' activities in organizations, it is important to understand the practices that are entrenched in an actor's conscious goal-directed processes that leads to the emergence of the actor's thoughtfully mastered learning activity (Sanda, 2017). As such, in preparing for complex tasks, actors must choose appropriate strategies (Sanda, 2017), and must have the ability to attain or at least approach their goals (Locke, 1969).

As observed by Locke (1969), strategy development is motivated by goals, with the mechanism itself being cognitive, and involving either skill development or creative problem-solving. Since a goal is the object or aim of an action, it is possible for the completion of a task to be a goal (Locke and Latham, 2019). According to Locke (1969), in most goal-setting studies, the term goal refers to attaining a specific standard on task proficiency, usually within a specified time limit. This makes it imperative to know how a person's goal affects his/her task performance (Locke, 1969; Sanda, 2017). Thus, Locke (1969) views goal setting primarily as a motivational mechanism, even though cognitive elements are necessarily involved. Goals, according to Locke (1969) seem to regulate performance most predictably when such goals are expressed in specific quantitative terms or as specific intentions to take a certain action rather than as vague intentions to "try hard" or as subjective estimates of task or goal difficulty (Locke, 1969). In this regard, there is the notion that specific challenging (difficult) goals lead to higher output than vague goals (Locke, 1981). No differences were found by Locke (1969) in studies on tasks whose actors have no-goals, and that in which actors are explicitly told to do their best. According to Locke (1969) actors with no-goal, typically will try to do as well as they can on their assigned task. As found by Sanda et al. (2014) actors automatically use the knowledge and skills they have already acquired that are relevant to goal attainment, when confronted with task goals. Similarly, if the task for which a goal is assigned is new to actors, they will engage in deliberate planning to develop strategies that will enable them to attain their goals (Locke, 1968; Locke and Latham, 2019). SSAT has thus, enabled the description of (i) how a person creates a goal, (ii) subjective cognition of the situation, (iii) type of the exploratory actions and operations to utilize, (iv) types of possible mental models developed, and (v) how a subject selects preferable mental models. In this stead, Bedny and Karwowski (2012) established that the orienting of self-regulation activity does not lead to the transformation of the real situation, but rather creates a mental representation of situation that precedes execution. Bedny

and Karwowski (2012) explained that in the course of task performance, cognitive processes are integrated to attain specific purpose of activity self-regulation. This insight has helped explain how cognitive processes enable the formation of functional mechanisms of self-regulation which are now understood to be constant, but whose contexts changes constantly (Bedny and Karwowski, 2012).

One important feature of systemic-structural analysis is the hierarchical description of activity. This calls for different stages and levels of analyses (Bedny and Karwowski, 2007). Transition from one stage and level of activity description to another has a loop structure of organization, implying that the result of analysis from one stage or level may require reconsideration of the preliminary stage and levels of analysis (Bedny and Karwowski, 2007). Self-regulation is not a psychological notion, but a cybernetic one. Bedny and Karwowski (2012) define self-regulation as an influence on the system that derives from the system itself in order to correct its behavior or activity. The concept of self-regulation is also meaningful only when the self-regulation model is presented and defined in terms of functional mechanisms or function blocks as highlighted by Bedny and Karwowski (2012).

CONCLUSION

Concepts, according to Stroh et al. (2003) are neither just in the mind nor just in reality, but are the form in which the human minds grasps reality beyond the perceptual level. Stroh et al. (2003) viewed concepts that pertain to consciousness to be based on introspection, whereby one can observe both mental contents and mental processes. Thus, in the formation of concepts of processes, such as perception, judgment, evaluation, imagination, thinking, and emotion, one observes similarities among certain processes that differentiate them from other processes. Similarly, one can omit measurements of the content and intensity of the process, but assumes that both exist (Stroh et al. 2003). To ensure conceptual clarity, Stroh et al. (2003) proposed the importance of holding in mind that the purpose of a definition is not to impress others or to follow the crowd but to identify the essentials of the concept. By essentials, Stroh et al. (2003) meant the most fundamental characteristic that distinguishes it from other concepts and accounts for the most other characteristics of the concept, as argued by Rand (1990, p. 45). Though there are justified research boundaries in different scientific disciplines, such differences have now waned with the advent of multidisciplinary research, of which neuroergonomics and SSAT are cases in point. Thus, the cross adaption of neuroscience theoretical concepts and methodologies has resulted in further advances in the application of the SSAT approach to understand human performance (see the edited book by Bedny and Bedny, 2019). The implication is that, in the SSAT approach, the application of such multi-theoretical conceptions and methodologies in understanding human work activity is valid and rational. The SSAT approach, therefore, enables a person's cognition and behavior, which are shaped and influenced by the state and function of the person's brain to be properly situated when preparing to undertake a work activity. The rational and valid payoff of its applicability is the enablement

of understanding how neuro-constructs mediates the impact of a person's cognitive processes on his/her goal formation (Sanda, 2019) and workload (Hardy (2021) that lend to the person's formation of mental representation of a systemic structural work for achieving activity self-regulation that precedes execution (Bedny and Karwowski, 2012).

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