Stress-Sensitive Adaptive Enterprise Systems: Theoretical Foundations and Design Blueprint

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Introduction

Stress-Sensitive Adaptive Enterprise Systems (SSAES) are neuroadaptive enterprise systems that continuously assess the users' current stress levels and autonomously adapt specific elements of the system accordingly. The aim of SSAES is to influence users' stress levels in order to improve their well-being and health, performance and productivity, and additionally create positive effects on user experience. This paper presents, based on theoretical foundations, a design blueprint for SSAES.

Stress is a major obstacle impairing well-being, health, performance, and productivity of many people. In particular, people may experience considerable levels of technostress during human-computer interaction, i.e., "negative impact on attitudes, thoughts, behaviors, or body physiology that is caused either directly or indirectly by technology" (Weil and Rosen 1997, p. 5). In this context, Riedl (2013) argues that one of the major challenges for IS design science research in the area of technostress is the development of systems that integrate biosignals as real-time stress-measures. Here, we present a design blueprint of such a system.

Enterprise Systems (ES) have dramatically and irreversibly changed the workplace of many employees worldwide. In their aim to achieve large-scale integration of data and processes across the different functional areas of an organization, ES exhibit a multitude of both technological and social facets that have a significant impact on their success (Devadoss and Pan 2007). In this sense, ES are socio-technical systems that involve a technological, an organizational, and an individual dimension, which need to be equally accounted for. ES are commonly designed to improve performance and productivity of enterprises – for many employees they are an integral part of their IT workplace. However, evidence (e.g., Ragu-Nathan et al. 2008) shows that use of large-scale information systems in organizations may lead to considerable stress in the workplace. Yet, ES appear to offer substantial potential for assessing rich context information and adapting the system.

Methods and Contribution

This paper uses a descriptive and exploratory design science approach building on two pillars: A review of relevant academic literature and explorative interviews with practitioners and researchers from information systems, computer science, electrical engineering, and psychology. On these backgrounds, we envision SSAES and propose a design blueprint of such systems.

SSAES leverage neuroscience theories to inform the building of IT artifacts (vom Brocke et al. 2013; strategy 1) and neuroscience tools as built-in functions of IT artifacts (ibid; strategy 3). The design blueprint is a meta-description of purpose and scope as well as principles of form and function (Gregor and Jones 2007). It constitutes a step towards a nascent design theory and adds to prescriptive knowledge on NeuroIS (Gregor and Hevner 2013; level 2 contribution).

SSAES Design

Kernel theory. Stress is activated by a set of acute or chronic stressors that trigger changes in perception and manifests in a variety of neurophysiological changes in the body which usually set on before conscious stress perception (Hancock and Warm 1989; Lazarus 1991). Neurophysiological changes include, among others, the release of the stress hormone cortisol (Riedl et al. 2012), and changes in skin conductance (Riedl et al. 2013). The elicitation of stress is subject to a user's appraisal of the situation. In this vein, a user can apply, for instance, information avoidance, stress management and other stress coping strategies to mitigate the elicitation of stress and its consequences (e.g., Denson, et al. 2009). The impact of stressors thus heavily depends on the users' individual capabilities and stress coping strategies. In order to optimize performance, a midrange level of arousal is optimal (Hancock and Szalma 2007). Excessive stress has negative impact on well-being and health, user experience, as well as performance and productivity (Tarafdar et al. 2007; Tarafdar et al. 2010); see Riedl (2013) for a review of the biology of technostress.

Information systems background. ES are traditionally seen as a specific category of information systems. They are socio-technical systems accounting for the organization, the technology, and the individuals involved. Information systems with neuroscience tools as built-in functions need to consider these three perspectives: the organization, technology, and individual (e.g., Gimpel et al. 2013). From a technological point of view, ES offer a set of functional modules, generally based on industry best practices implemented in packaged software (Markus and Tanis 2000). The term ES has grown to refer to all large organization-wide packaged software applications (Seddon et al. 2010), including people-centric software (e.g. Groupware), process-centric software (e.g. Enterprise Resource Planning, Customer Relationship Management), and information-centric software (e.g. Data Warehouses, Business Intelligence). On the organizational side, ES relate to business processes as well as roles and responsibilities; they are embedded in an organizational context.

Design requirements and challenges. The overarching objective of SSAES is to achieve humanistic goals (well-being, health, satisfaction, user experience) and instrumental goals (performance, productivity, cost-effectiveness of stress-sensitive adaptation). This requires appropriate sensors and effectors at the individual, technological, and organizational level of ES. The operationalization of the goals is scenario specific. The term *appropriate* refers to (i) technical feasibility, (ii) social and ethical acceptability, and (iii) individual technology acceptance.

Technical feasibility includes hardware and signal processing for long-term, unobtrusive, continuous, and reliable physiological and behavioral stress assessment and analytics. Second, technical feasibility of the adaptation of ES packaged software requires incorporating real-time feedback. Social and ethical acceptability of SSAES is critical: Exploring data privacy issues and the implications of SSAES for future work environments and users is an open research challenge. At the level of individual technology acceptance, general determinants of technology adoption and use are well known in IS research – the challenge is to design SSAES that account for these determinants and to study their relevance for SSAES. Furthermore, post-adoption IS research specifically investigating use behavior from a dynamic, process perspective and effectiveness and efficacy with respect to the humanistic and instrumental goals need to be considered when designing SSAES.

Sensors and effectors. SSAES assess their users' stress level via sensors (1) assessing physiological correlates of stress (activation of the sympathetic and parasympathetic divisions of the autonomic nervous system), (2) observing user behavior, and (3) eliciting subjective stress perceptions. These data might be paired with context information, e.g. on physical activity, location, informations systems and functionalities used, and business processes. The sensor data enters user models within the SSAES. If deemed beneficial and desired by the user, stress-specific interventions adapt the SSAES: individual user awareness, adaptive user interface, and adaptive packaged software at the backend.

Iterative design. SSAES have individual, technological, and organizational components, like any ES. The design of SSAES is necessarily a partial and incremental process (Peffers et al. 2007). The design requirements and challenges associated with SSAES should be explored and resolved consecutively. Hence, we propose to structure the design and introduction of SSAES along maturity levels. A first maturity level may include, for example, only individual local feedback and interface adaptations. Such a restricted scope limits the potential stress-specific interventions and effects. However, it eases technical implementation and limits data privacy issues. Further maturity levels can, for example, open up communication to the backend packed software to allow for analytics and adaptations in the backend. The potential for additional interventions comes at the cost of higher technological complexity and might go along with, for example, decreased user acceptance.

Complementing the rather technology-oriented maturity levels, we suggest research on how to facilitate adaptive organizational structures based on aggregate feedback on stressors. An adaptive organization could re-design business processes to eliminate stressors; roles and responsibilities could be re-allocated to reduce users' stress levels. These visions come along with a multitude of social, ethical, and legal aspects which need to be explored.

DISCUSSION AND CONCLUSIONS

This paper presents theoretical foundations and a first design blueprint for stress-sensitive adaptive enterprise-systems (SSAES). In the terminology of design science research knowledge contributions (Gregor and Hevner 2013), this is an innovation, applying a new solution (stress-sensitive information systems) to a new problem (technostress in the context of enterprise systems). While we believe that our SSAES blueprint makes a useful contribution to technostress research, the following limitations should be considered. First, technostress is an individual, organizational, and societal problem caused by information and communication technologies; hence, technologically solving the problem (i.e., by a SSAES) is by no means the only way, or necessarily the most effective one. Second, the paper deals with the problem from a technical perspective, falling short in fully reflecting the organizational, societal, ethical, and legal drawbacks. Third, this conceptual work needs to be enriched by design and empirical research. Currently, we are working on a first prototypical SSAES implementation and associated laboratory studies.

REFERENCES

- Denson, T.F., Spanovic, M., and Miller, N. 2009. "Cognitive Appraisals and Emotions Predict Cortisol and Immune Responses: A Meta-Analysis of Acute Laboratory Social Stressors and Emotion Inductions," *Psychological Bulletin* (135:6), pp. 823-853.
- Devadoss, P., and Pan, S.L. 2007. "Enterprise Systems Use: Towards a Structural Analysis of Enterprise Systems Induced Organizational Transformation," *Communications of the AIS*, 19 (1), 362–385.
- Gimpel, H., Adam, M.T.P., and Teubner, T. 2013. "Emotion Regulation in Management: Harnessing the Potential of NeuroIS Tools," *Proceedings of the 2013 European Conference on Information Systems (ECIS 2013).*
- Gregor, S., and Hevner, A.R. 2013. "Positioning and Presenting Design Science Research for Maximum Impact," *MIS Quarterly* (37:2), pp. 337-355.
- Hancock, P.A., and Szalma, J.L. 2007. "Stress and Neuroergonomics," in *Neuroergonomics: The Brain at Work*, R. Parasuraman and M. Rizzo (eds.), New York: Oxford University Press, pp. 195-206.
- Hancock, P.A., and Warm, J.S. 1989. "A Dynamic Model of Stress and Sustained Attention," *Human Factors: The Journal of the Human Factors and Ergonomics Society* (31:5), pp. 519-537.
- Gregor, S., and Jones, D. 2007. "The Anatomy of a Design Theory," *Journal of the Association of Information Systems* (8:5), pp. 312-335.
- Lazarus, R. 1991. "Psychological Stress in the Workplace," *Journal of Social Behavior & Personality* (6:7), pp. 1-13.
- Markus, M.L., and Tanis, C. 2000. "The Enterprise System Experience – From Adoption to Success," in *Framing the Domains of IT Management: Projecting the Future Through the Past*, R.W. Zmund (ed.), Cincinnati: Pinnaflex Educational Resources, pp. 173–207.
- Peffers, K., Tuunanen, T., Rothenberger, M., and Chatterjee, S. 2007. "A Design Science Research Methodology for Information Systems Research," *Journal of Management Information Systems* (24:3), pp. 45-77.
- Ragu-Nathan, T.S., Tarafdar, M., Ragu-Nathan, B. S., and Tu, Q. 2008. "The Consequences of Technostress for End Users in Organizations: Conceptual Development and Empirical Validation," *Information Systems Research* (19:4), pp. 417-433.
- Riedl, R. 2013. "On the Biology of Technostress: Literature Review and Research Agenda," *The DATA BASE for Advances in Information Systems* (44:1), pp. 18-55.
- Riedl, R., Kindermann, H., Auinger, A., and Javor, A. 2012. "Technostress From a Neurobiological Perspective: System Breakdown Increases the Stress Hormone Cortisol in Computer Users," *Business & Information Systems Engineering* (4:2), pp. 61-69.
- Riedl, R., Kindermann, H., Auinger, A., and Javor, A. 2013. "Computer Breakdown as a Stress Factor during Task Completion under Time Pressure: Identifying Gender Differences Based on Skin Conductance," *Advances in Human-Computer Interaction*, Article ID 420169.
- Seddon, B.P.B., and Calvert, C. 2010. "A Multi-Project Model of Key Factors Affecting Organizational Benefits from Enterprise Systems," *MIS Quarterly* (34:2) pp. 305-328.
- Tarafdar, M., Tu, Q., Ragu-Nathan, B.S., and Ragu-Nathan, T.S. 2007. "The Impact of Technostress on Role Stress and Productivity," *Journal of Management Information Systems* (24:1), pp. 301-318.
- Tarafdar, M., Tu, Q., and Ragu-Nathan, T.S. 2010. "Impact of Technostress on End-User Satisfaction and Performance," *Journal of Management Information Systems* (27:3), pp. 303–334.
- vom Brocke, J., Riedl, R., and Léger, P.-M. 2013. "Application Strategies for Neuroscience in Information Systems Design Science Research," *Journal of Computer Information Systems* (53:3), pp. 1–13.
- Weil, M.M. and Rosen, L.D. 1998. *TechnoStress: Coping With Technology @WORK @HOME @PLAY*, New York: John Wiley & Sons.