On the Role of Users' Cognitive-Affective States for User Assistance Invocation

Celina Friemel, Stefan Morana, Jella Pfeiffer and Alexander Maedche

Abstract User assistance systems are often invoked automatically based on simple triggers (e.g., the assistant pops up after the user has been idle for some time) or they require users to invoke them manually. Both invocation modes have their weaknesses. Therefore, we argue that, ideally, the assistance should be invoked intelligently based on the users' actual need for assistance. In this paper, we propose a research project investigating the role of users' cognitive-affective states when providing assistance using NeuroIS measurements. Drawing on the theoretical foundations of the Attentional Control Theory, we propose an experiment that helps to understand how cognitive-affective states can serve as indicators for the best point of time for the invocation of user assistance systems. The research described in this paper will ultimately help to design intelligent invocation of user assistance systems.

Keywords Assistance · Invocation · NeuroIS · Attentional control theory
Cognitive-affective user states · Affect · Mental effort

C. Friemel (✉) · S. Morana · J. Pfeiffer · A. Maedche
Institute of Information Systems and Marketing (IISM),
Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany
e-mail: celina.friemel@kit.edu

S. Morana
e-mail: stefan.morana@kit.edu

J. Pfeiffer
e-mail: jella.pfeiffer@kit.edu

A. Maedche
e-mail: alexander.maedche@kit.edu

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1 Introduction

Digital assistants like Siri or Alexa, chatbots like the ones on WeChat [1] and other forms of user assistance strongly developed over the last years and the trend towards providing advanced user assistance in digital services is even growing [2, 3]. The common idea of user assistance systems it to support users to perform their tasks better [4]. One of the early attempts to create such an assistant was Microsoft's Clippy. Yet, Clippy is a famous and regularly trending example for the dismal failure of such user assistance [5]. One of Clippy's most severe design mistakes was its proactive invocation mode. Proactively offering assistance at the right point can be a helpful feature in order to relieve the user's effort, ensure successful task performance and avoid errors [2, 6]. Certainly, Clippy appeared in the most inappropriate moments and interrupted users when not required. This led to Clippy's rapid downfall [5], which demonstrates the importance of a careful invocation design of assistance. The example shows that the communication via assistants needs to be well designed and adapted to the user in order to enhance trust and usage, and ultimately performance [7, 8]. Thus, the right timing of assistance invocation is an important design aspect [9, 10]. Invocation design in this context describes how assistance is activated. Some researchers [10] suggest a more advanced invocation which is provided by the system that "monitors the user in some way" (p. 504). However, existing approaches of assistance invocation are mainly dominated by either automatic activation or manual user requests. The automatic provisioning is often designed with static predefined rules by for example applying explicit user modelling, that incorporates the users' goals, needs, or other preferences to detect their need for assistance [11]. Both modes have been proven to not be entirely sufficient [6, 12], possibly because users are not always aware of when they need help and likewise frequently do not know how to use assistance effectively [13–15]. Furthermore, the "right time to intervene is [still] difficult to predict" [16] for the systems and consequently users get annoyed or out of flow when being interrupted at the wrong moments [5, 17]. As user assistance serves to relieve users' mental working memory [10] the system should not additionally burden the user with interruptions at the wrong time.

To address this research gap of providing intelligent invocation of user assistance [18], we argue for taking into account the cognitive-affective states of the user in real-time. With the term cognitive-affective states we refer to user states that involve both affective as well as cognitive activity [19]. These states heavily impact the interaction between humans and technology, users' need for assistance and consequently their task performance [20–23]. User states that influence users' interaction with IT are, in particular, task-dependent negative cognitive-affective states, such as frustration or anxiety [6] as well as high mental effort [24]. Thus, we assume that these user states correspondingly influence users' need for assistance [21, 22]. Drawing on the theoretical assumptions of the Attentional Control Theory [20], we argue that the assessment of the users' negative cognitive-affective states with neurophysiological data is an important design aspect to further improve user assistance invocation [6, 25]. Ultimately, systems can automatically adjust assistance invocation to sensed user states to increase the users' efficiency, performance, and satisfaction [6]. In our research we follow a NeuroIS approach [8, 26]. One major advantage with regard to the outlined problem is the opportunity to observe latent variables, such as the users' need for assistance, "directly from body signals" [27]. Thus, the research question guiding this work is:

> Can we identify users' need for assistance by unobtrusive and real-time measurement and analysis of cognitive-affective states of the user?

With this we want to expand and add value to NeuroIS literature as well as user assistance research by investigating psychophysiological correlates that reliably and timely detect the users' need for assistance and the IT-related behavior of assistance usage [26]. The research described in this paper will ultimately help to design intelligent invocation of user assistance systems.

2 Conceptual and Theoretical Foundations

2.1 Assistance and Invocation Modes

Assistance systems are provided in order to support users to perform their tasks better [4]. Assistance tends to become more and more tailored to the users' needs in order to increase performance at the right time and in the right context [2, 4]. Moreover, varying in their degree of system intelligence (e.g. provision of context-aware assistance) and interaction enabled by the system (e.g. offering highly sophisticated dialog interfaces), assistance systems can exhibit different maturity levels in terms of sensing the users' current environment and activities [4].

One critical design aspect when providing adequate user assistance is to determine when a user actually wants or needs assistance [16]. The right point of interrupting users has been studied extensively in the context of notifications [13, 28, 29]. Badly timed interruptions can cause deteriorated performance and decision-making, negative user states (like annoyance, frustration, cognitive overload) and ultimately distrust in the systems' competency and usage [28–31]. Correspondingly, the timing or invocation of assistance is crucial for the assistance's success. Recent research examining the right time to provide assistance agrees that it should be guided by the users' characteristics, needs, and context [6, 16, 25, 32]. First approaches of such user modeling [11, 16] did not provide accurate determinants for assistance invocation [12]. In line with other research [6, 33–35], we argue that users' cognitive-affective states determine the need for assistance. Modeling approaches on this new determinants exists [6, 35]. Yet, they focus on user modeling, or use manually pre-determined thresholds for assistance invocation. This reveals the lack of efficient timing to intervene with assistance that acts on the sensing of users' cognitive-affective states in real-time.

2.2 Theorizing on Invocation Determinants: A NeuroIS Perspective

Assistance and NeuroIS. In order to gain a better theoretical understanding of human behavior, NeuroIS research [36] is eager to find psychophysiological and neural correlates for already established IT constructs [26]. Especially in the context of offering user assistance, the traditional IS research methods like surveys and interviews encounter difficulties of reliably predicting users' need of assistance [15].

As users have been found to either not always be aware of when they need help, underestimate their need for assistance, or occasionally do not want to admit that they need assistance [13, 15, 37], a NeuroIS research approach can potentially shed light on this issue. However, objective measurement methods for users' assistance need in an objective and unobtrusive way are still absent. Neurophysiological tools offer great potential for new insights on user states by measuring direct responses to stimuli from the human body [27]. Applying this approach enables to capture unconscious processes that users might not be able to introspect or to gain insights on determinants of behavior that users are uncomfortable to report on [26]. Moreover, the possibility of obtaining real-time as well as continuous data enables analysis of temporal aspects and the measurement of simultaneous processes of constructs [26]. Consequently, this helps to design adaptive IT artifacts that consider user states which determine IT behavior [38].

With regard to designing assistance invocation, this integration of psychophysiological determinants for users' assistance needs is absent in existing research. First attempts to include affective user states into invocation determination of user assistance exist [6, 35, 39, 40]. Yet, these studies primarily address this issue only from a theoretical view. Particularly, to our knowledge, there exists no published research on determining assistance invocation by empirically integrating psychophysiological measurements in order to monitor users' states. However, not only from a NeuroIS perspective but also from a psychological view this approach can unlock great potential for reliably detecting users' need for assistance.

Attentional Control Theory (ACT). For decades now, researchers agree that affective as well as cognitive states have motivational properties that lead to observable behavior in IS [38, 41, 42] as well as non-IS contexts [20, 43].

In their psychological theory, Eysenck et al. [20, 44] offer valuable insights into the effects of affect and cognition on users' need for assistance. It describes the influence of especially negative affective states on people's task performance and related behavior, in particular, their coping strategies. In order to prevent a performance loss due to experienced negative affect and increased cognitive effort, people adjust their behavior with, for instance, searching for assistance. Eysenck et al. revealed that provoked anxiety impairs peoples' processing efficiency when working on a goal-directed task because people shift their attentional focus from the current task to the threatening stimulus. This increases their cognitive resource utilization. When responding to this change, people need additional resources (internal or external) to cope with the situation in order to not experience a loss in performance effectiveness. However, this leads to a decrease in processing efficiency. One possibility to prevent people from such an efficiency loss caused by negative affective states is the provision of auxiliary processing resources [20], for example by offering assistance.

Cognitive-Affective States. The ACT mainly focuses on anxiety as negative affective state which impairs attentional control on a current task and ultimately efficiency and resulting performance [20]. Nevertheless, the theoretical implications of ACT have already been applied in the IS context and expanded to negative affective states, in general, that evidently influence IT-related behavior [42, 45]. By definition, an affective state arises from an individual's reaction to an event and influences cognitive, physiological, as well as behavioral components [6, 46]. Especially in the context of human–computer interaction, affective states play an important role when explaining user behavior [19, 21, 47]. Moreover, user states of high cognitive activity are often related to emotional responses; either in parallel or as interacting occurrences [26]. Monitoring user states that involve both affective as well as cognitive activity can reveal new insights on the users and their needs [26]. Baker et al. [19] refer to the latter as cognitive-affective user states. Within the context of assistance invocation especially negative cognitive-affective states are assumed to reveal important insights [23]. They are characterized by a negative affective valence, which can be assessed with the help of facial electromyography tools or facial expression analysis [48]. Examples of negative cognitive-affective user states are frustration or boredom [49]. Likewise, anxiety can be categorized as such a cognitive-affective state [50]. As antecedents of negative cognitive-affective user states certain stressors such as time pressure caused by dropped network connections and high task complexity have been found to increase the need for assistance [37].

3 Research Propositions

Drawing on ACT, we assume that negative cognitive-affective user states influence the related users' behavior in general and specifically the usage of assistance. This assumption is based on the influence of negative cognitive-affective user state on the users' attention focus. As this focus will shift from executing the task to coping with the affect-evoking stimuli the user has to invest more cognitive resources [20]. This increase in resource utilization is represented by users' mental effort, respectively the amount of cognitive resources that is required to manage the workload demanded by a task [51]. As users experience a negative cognitive-affective state, we therefore assume that their level of mental effort increases accordingly:

Proposition P1: A negative cognitive-affective state increases users' mental effort.

This increase in mental effort leads to potential loss in users' efficiency and ultimately task performance [20]. In order to prevent them from this undesirable outcome users are hypothesized to utilize coping strategies to decrease mental effort, respectively to increase efficiency and performance [20, 52, 53]. In the case of our research project, this is represented by the usage of a user assistance system that offers additional information [54, 55]:

Proposition P2: Increased mental effort increases assistance usage.

4 Proposed Methodology

In a first step, we propose to examine the effect of negative cognitive-affective user states on the users' IT-related behavior (in this case the usage of the offered user assistance). To test whether the theoretically derived propositions proof to be valid we plan to conduct a laboratory experiment.

We measure the users' cognitive-affective state with a combination of psychophysiological tools. We assess users' emotional valence via facial expressions with webcams [48] and users' mental effort via heart rate with ECG [8, 38]. ECG is one possibility to assess mental effort among others and has been found to be a reliable predictor for peoples' mental effort [56]. Furthermore, compared to other methods, such as EEG [57], it constitutes a minimally invasive measurement method [26]. Together with existing technical restrictions, this led to our decision of approximating mental effort via ECG measures. As the experimental context, we chose a travel booking scenario and formulate this as a goal-directed task according to the ACT [20] by providing participants incentives for a successful task execution. The experimental task will compromise the configuration of a travel with specific constraints with respect to budget and time. The participants' task is to configure the optimal travel in order to fulfill the experiments' objective. A virtual travel agency will offer the assistance that the user can consult manually, if needed. The participants will be randomly assigned to one of two treatment groups and a control group. The treatment structure will be composed of a *low negative affect* condition and a *high negative affect* condition. The treatments differ with respect to the amount of task features that stimulate negative cognitive-affective states. We then observe when they use the assistance and how this depends on the treatment.

5 Expected Contribution and Future Work

In the next steps, we will finalize the experimental design and carry out the experiment. Conducting the experiment and subsequently evaluating the experimental data will reveal valuable insights on the determinants of users' assistance needs. With this, we will gain first design knowledge on the appropriate invocation timing of user assistance systems. We aim at validating the two suggested constructs of user states as neurophysiological correlates for assistance need in order to design neuro-adaptive invocation of user assistance in later stages of this research [26]. The final objective is to test and evaluate the resulting derived design knowledge in a follow-up experiment. Thereby, we contribute to collecting initial design knowledge towards finding the right moments for user assistance invocation. With ultimately testing the effects of such an invocation on the user, we will further contribute to research on user assistance in general. The hypothesized positive outcomes by applying timely user assistance [6] as well as possible negative effects caused by interrupting the user with the assistance itself [58] will be identified. Conceivably, the expected results will identify the optimal time to offer user assistance even before the user experiences any negative cognitive-affective state. User assistance in the future can then be designed to detect if the user is trending towards a negative cognitive-affective state in order to prevent any associated performance loss by offering timely user assistance.

Furthermore, the proposed experiment has some limitations that open up opportunities for future work on the results. As we will use an ECG measurement approach for assessing participants' mental effort, future research on the topic could evaluate other measurement methodologies in comparison. The approach of Eye-Fixation Related Potential (EFRP) proposed by Léger et al. [59] could offer further insights into participants' mental effort during task execution and help to identify when to offer user assistance. Moreover, we are aware of the fact that not only users' negative cognitive-affective states might constitute a need for user assistance. Other factors apart from these should be investigated in future research on the topic. Positive affective states have been found to influence task performance, too [60]. Together with examining the role of users' attention, this could complement the proposed research of finding the optimal timing for offering user assistance.

References

1. Mou, Y., Xu, K.: The media inequality: comparing the initial human–human and human–AI social interactions. Comput. Hum. Behav. **72**, 432–440 (2017)
2. Sarikaya, R.: The technology behind personal digital assistants: an overview of the system architecture and key components. IEEE Sig. Process. Mag. **34**, 67–81 (2017)
3. Baig, E.C.: Personal digital assistants are on the rise (and they want to talk). http://www.usatoday.com/story/tech/columnist/baig/2016/05/08/personal-digital-assistants-rise-and-they-want-talk/83715794/
4. Maedche, A., Morana, S., Schacht, S., Werth, D., Krumeich, J.: Advanced user assistance systems. Bus. Inf. Syst. Eng. **58**, 2–5 (2016)
5. Veletsianos, G.: Cognitive and affective benefits of an animated pedagogical agent: considering contextual relevance and aesthetics. J. Educ. Comput. Res. **36**, 373–377 (2007)
6. Liao, W., Zhang, W., Zhu, Z., Ji, Q., Gray, W.D.: Toward a decision-theoretic framework for affect recognition and user assistance. Int. J. Hum. Comput. Stud. **64**, 847–873 (2006)

7. Parasuraman, R., Wilson, G.F.: Putting the brain to work: neuroergonomics past, present, and future. Hum. Factors **50**, 468–474 (2008)
8. Vom Brocke, J., Riedl, R., Léger, P.-M.: Application strategies for neuroscience in information systems design science research. J. Comput. Inf. Syst. **53**, 1–13 (2013)
9. Silver, M.S.: On the design features of decision support systems: the role of system restrictiveness and decisional guidance. In: Handbook on Decision Support Systems 2: Variations. pp. 261–293. Springer, Berlin, Heidelberg (2008)
10. Gregor, S., Benbasat, I.: Explanations from intelligent systems: theoretical foundations and implications for practice. MIS Q. **23**, 497–530 (1999)
11. Horvitz, E., Breese, J., Heckerman, D., Hovel, D., Rommelse, K.: The lumiere project: bayesian user modeling for inferring the goals and needs of software users. In: Proceedings of the Fourteenth Conference on Uncertainty in Artificial Intelligence, pp. 256–265 (1998)
12. Antwarg, L., Lavie, T., Rokach, L., Shapira, B., Meyer, J.: Highlighting items as means of adaptive assistance. Behav. Inf. Technol. **32**, 1–17 (2012)
13. Schiaffino, S., Amandi, A.: Polite personal agents. IEEE Intell. Syst. **21**, 12–19 (2006)
14. Babin, L.M., Tricot, A., Mariné, C.: Seeking and providing assistance while learning to use information systems. Comput. Educ. **53**, 1029–1039 (2009)
15. Novick, D.G., Elizalde, E., Bean, N.: Toward a more accurate view of when and how people seek help with computer applications. In: ACM 25th International Conference on Design of Communication, pp. 95–102 (2007)
16. Ginon, B., Stumpf, S., Jean-Daubias, S.: Towards the right assistance at the right time for using complex interfaces. In: Proceedings of the International Working Conference on Advanced Visual Interfaces—AVI '16. pp. 240–43. ACM Press, New York (2016)
17. McFarlane, D., Latorella, K.: The scope and importance of human interruption in human-computer interaction design. Hum. Comput. Interact. **17**, 1–61 (2002)
18. Morana, S., Schacht, S., Scherp, A., Maedche, A.: A review of the nature and effects of guidance design features. Decis. Support Syst. **97**, 31–42 (2017)
19. Baker, R.S.J., D'Mello, S.K., Rodrigo, M.M.T., Graesser, A.C.: Better to be frustrated than bored: the incidence, persistence, and impact of learners' cognitive-affective states during interactions with three different computer-based learning environments. Int. J. Hum. Comput. Stud. **68**, 223–241 (2010)
20. Eysenck, M.W., Derakshan, N., Santos, R., Calvo, M.G.: Anxiety and cognitive performance: attentional control theory. Emotion **7**, 336–353 (2007)
21. Klein, J., Moon, Y., Picard, R.W.: This computer responds to user frustration: theory, design, and results. Interact. Comput. **14**, 119–140 (2002)
22. Picard, R.W.: Affective computing: challenges. Int. J. Hum. Comput. Stud. **59**, 55–64 (2003)
23. Fairclough, S.H.: Fundamentals of physiological computing. Interact. Comput. **21**, 133–145 (2009)
24. Fehrenbacher, D.D., Djamasbi, S.: Information systems and task demand: an exploratory pupillometry study of computerized decision making. Decis. Support Syst. **97**, 1–11 (2017)
25. Yorke-Smith, N., Saadati, S., Myers, K.L., Morley, D.N.: The design of a proactive personal agent for task management. Int. J. Artif. Intell. Tools **21**, 1250004-1-30 (2012)
26. Dimoka, A., Banker, R.D., Benbasat, I., Davis, F.D., Dennis, A.R., Gefen, D., Gupta, A., Ischebeck, A., Kenning, P., Pavlou, P.A., Müller-Putz, G.R., Riedl, R., vom Brocke, J., Weber, B.: On the use of neuropyhsiological tools in is research: developing a research agenda for NeuroIS. MIS Q. **36**, 679–702 (2012)
27. Liang, T.-P., vom Brocke, J.: Special issue: neuroscience in information systems research. J. Manage. Inf. Syst. **30**, 7–12 (2014)
28. Bailey, B.P., Konstan, J.A.: On the need for attention-aware systems: measuring effects of interruption on task performance, error rate, and affective state. Comput. Hum. Behav. **22**, 685–708 (2006)
29. Adamczyk, P.D., Bailey, B.P.: If not now when? the effects of interruption at different moments within task execution. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, vol. 6, pp. 271–278 (2004)

30. Speier, C., Valacich, J.S., Vessey, I.: The influence of task interruption on individual decision making: an information overload perspective. Decis. Sci. **30**, 337–360 (1999)
31. LeeTiernan, S., Cutrell, E.B., Czerwinski, M., Hoffman, H.: Effective notification systems depend on user trust. In: Human-Computer Interaction—INTERACT 2001 Conference Proceedings, pp. 684–685 (2001)
32. Wang, J., Wang, Y., Wang, Y.: CAPFF: A context-aware assistant for paper form filling. IEEE Trans. Hum. Mach. Syst. 1–6 (2016)
33. Hudlicka, E.: To feel or not to feel: the role of affect in human–computer interaction. Int. J. Hum. Comput. Stud. **59**, 1–32 (2003)
34. Liao, W., Zhang, W., Zhu, Z., Ji, Q.: A decision theoretic model for stress recognition and user assistance. In: Proceedings of Twentieth National Conference on Artificial Intelligence. Seventeenth Innovative Applications of Artificial Intelligence Conference, pp. 529–534 (2005)
35. Li, X., Ji, Q.: Active affective state detection and user assistance with dynamic bayesian networks. IEEE Trans. Syst. Man Cybern. Syst. Hum. **35**, 93–105 (2005)
36. Riedl, R., Davis, F.D., Hevner, A.R.: Towards a NeuroIS research methodology: intensifying the discussion on methods, tools, and measurement. J. Assoc. Inf. Syst. **15**, i–xxxv (2014)
37. Ellis, S., Tyre, M.J.: Helping relations between technology users and developers: a vignette study. IEEE Trans. Eng. Manage. **48**, 56–69 (2001)
38. Riedl, R., Léger, P.-M.: Fundamentals of NeuroIS—Information Systems and the Brain, Springer, Berlin (2016)
39. Dong, J., Yang, H.I., Oyama, K., Chang, C.K.: Human desire inference process based on affective computing. In: Proceedings of International Computer Software and Applications Conference, pp. 347–350 (2010)
40. Frank, K., Robertson, P., Gross, M., Wiesner, K.: Sensor-based identification of human stress levels. In: 2013 IEEE International Conference on Pervasive Computing and Communications Workshops, PerCom Workshops, pp. 127–32 (2013)
41. Gregor, S., Lin, A.C.H., Gedeon, T., Riaz, A., Zhu, D.: Neuroscience and a nomological network for the understanding and assessment of emotions in information systems research. J. Manage. Inf. Syst. **30**, 13–48 (2014)
42. Hibbeln, M., Jenkins, J.L., Schneider, C., Valacich, J.S., Weinmann, M.: How is your user feeling? Inferring emotion trough human-computer interaction devices. MIS Q. **41**, 1–22 (2017)
43. Brown, J.S., Farber, I.E.: Emotions conceptualized as intervening variables—with suggestions toward a theory of frustration. Psychol. Bull. **48**, 465–495 (1951)
44. Eysenck, M.W., Derakshan, N.: New perspectives in attentional control theory. Pers. Individ. Differ. **50**, 955–960 (2011)
45. Anderson, B.B., Vance, A., Kirwan, C.B., Eargle, D., Jenkins, J.L.: How users perceive and respond to security messages: a NeuroIS research agenda and empirical study. Eur. J. Inf. Syst. **2016**, 1–27 (2016)
46. Nass, C., Brave, S.: Emotion in human–computer interaction. In: IEEE Transactions on Pattern Analysis and Machine Intelligence, pp. 77–92 (2007)
47. Scheirer, J., Fernandez, R., Klein, J., Picard, R.W.: Frustrating the user on purpose: a step toward building an affective computer. Interact. Comput. **14**, 93–118 (2002)
48. Ekman, P.: Facial expression and emotion. Am. Psychol. **48**, 384–392 (1993)
49. D'Mello, S., Graesser, A.: The half-life of cognitive-affective states during complex learning. Cogn. Emot. **25**, 1299–1308 (2011)
50. Schlenker, B.R., Leary, M.R.: Social anxiety and self-presentation: a conceptualization and model. Psychol. Bull. **92**, 641–669 (1982)
51. Sweller, J., van Merrienboer, J., Paas, F.: Cognitive architecture and instructional design. Educ. Psychol. Rev. **10**, 251–296 (1998)
52. Peavler, S.W.: Pupil size, information overload and performance differences. Psychophysiology **11**, 559–566 (1974)

53. Paas, F., Van Merrienboer, J.J.G.: The efficiency of instructional conditions: an approach to combine mental effort and performance measures. Hum. Factors **35**, 737–743 (1993)
54. Folkman, S., Moskowitz, J.T.: Positive affect and the other side of coping. Am. Psychol. **55**, 647–654 (2000)
55. Beaudry, A., Pinsonneault, A.: Understanding user responses to information technology: a coping model of user adaptation. MIS Q. **29**, 493–524 (2005)
56. Haapalainen, E., Kim, S., Forlizzi, J.F., Dey, A.K.: Psycho-physiological measures for assessing cognitive load. In: Proceedings of the 12th ACM International Conference on Ubiquitous Computing, pp. 301–310 (2010)
57. Mirhoseini, S.M.M., Léger, P.-M., Sénécal, S.: The influence of task characteristics on multiple objective and subjective cognitive load measures. Presented at the information systems and neuroscience, Springer, Berlin (2017)
58. Jenkins, J.L., Anderson, B.B., Vance, A., Kirwan, C.B., Eargle, D.: More harm than good? how messages that interrupt can make us vulnerable. Inf. Syst. Res. **27**(4), 880–896 (2016)
59. Léger, P.M., Titah, R., Sénecal, S., Fredette, M., Courtemanche, F., Labonte-Lemoyne, É., De Guinea, A.O.: Precision is in the eye of the beholder: application of eye fixation-related potentials to information systems research. J. Assoc. Inf. Syst. **15**, 651–678 (2014)
60. Jung, N., Wranke, C., Hamburger, K., Knauff, M.: How emotions affect logical reasoning: evidence from experiments with mood-manipulated participants, spider phobics, and people with exam anxiety. Front. Psychol. **5** (2014)