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Preface

NeuroIS is a field in Information Systems (IS) that makes use of neuroscience and neurophysiological tools and theories to better understand the development, adoption, and impact of information and communication technologies. The *Gmunden Retreat on NeuroIS* is a leading academic conference for presenting research and development projects at the nexus of IS and neurobiology (see http://www.neurois.org/). This annual conference has the objective to promote the successful development of the NeuroIS field. The conference activities are primarily delivered by and for academics, though works often have a professional orientation. The conference is taking place in Gmunden, Austria, a much frequented health and summer resort providing an inspiring environment for the retreat. In 2009, the inaugural conference was organized. Established on an annual basis, further conferences took place from 2010-2014.

The genesis of NeuroIS took place in 2007. Since then, the NeuroIS community has grown steadily. Scholars are looking for academic platforms to exchange their ideas and discuss their studies. The *Gmunden Retreat on NeuroIS* seeks to stimulate these discussions. The conference is best characterized by its “workshop atmosphere.” Specifically, the organizing committee welcomes not only completed research, but also work in progress. A major goal is to provide feedback for scholars to advance research papers, which then, ultimately, have the potential to result in high-quality journal publications.

NeuroIS examines topics lying at the intersection of IS research and neurophysiology and the brain sciences. Specifically, NeuroIS studies comprise conceptual and empirical works, as well as theoretical and design science research. It includes research based on all types of neuroscience and neurophysiological methods, spanning techniques such as functional magnetic resonance imaging (fMRI), electroencephalograhy (EEG), transcranial magnetic stimulation (TMS), near infrared spectroscopy (NIRS), brain lesion studies, quantitative and molecular genetics, hormone assessments, galvanic skin response, heart rate, eye-tracking, and facial electromyography.

Analyses of the existing NeuroIS literature shows that contributions often address the following topics, among others: employment of neuroscience and neurophysiological methods and tools to study technology adoption, mental workload, website design, virtual worlds, technostress, emotions in human-computer interaction, ecommerce, social networks, information behavior, trust, IT security, usability, avatars, music and user interfaces, multitasking, memory, attention, IS design science, risk, knowledge processes, and business process modeling and enterprise systems. Moreover, software prototypes of NeuroIS applications, which use bio-signals (e.g., EEG, skin conductance, pupil dilation) as system input, are also a core topic in the field, and many NeuroIS researchers believe that this topic of neuro-adaptive information systems is one that holds significant potential, both from a theoretical and practical viewpoint. Also, the discourse on methodological and ethical issues and evaluation of the status of the NeuroIS field has been the subject of discussion in the extant literature.

This year it is the first time that we publish the proceedings in the form of an edited volume. A total of 29 research papers are published in this volume, and the diversity in topics, theories, methods, and tools of the contributions in this book constitutes a major strength of the NeuroIS field. It will be rewarding to see what insights future NeuroIS research will reveal about the interplay between neurobiology and the development, adoption, and impact of information and communication technologies.

March 2015,

F. D. Davis, R. Riedl, J. vom Brocke, P.-M. Léger, A. Randolph (Editors)

NeuroIS Knowledge Discovery Approach to Prediction of Traumatic Brain Injury Survival Rates: A Semantic Data Analysis Regression Feasibility Study

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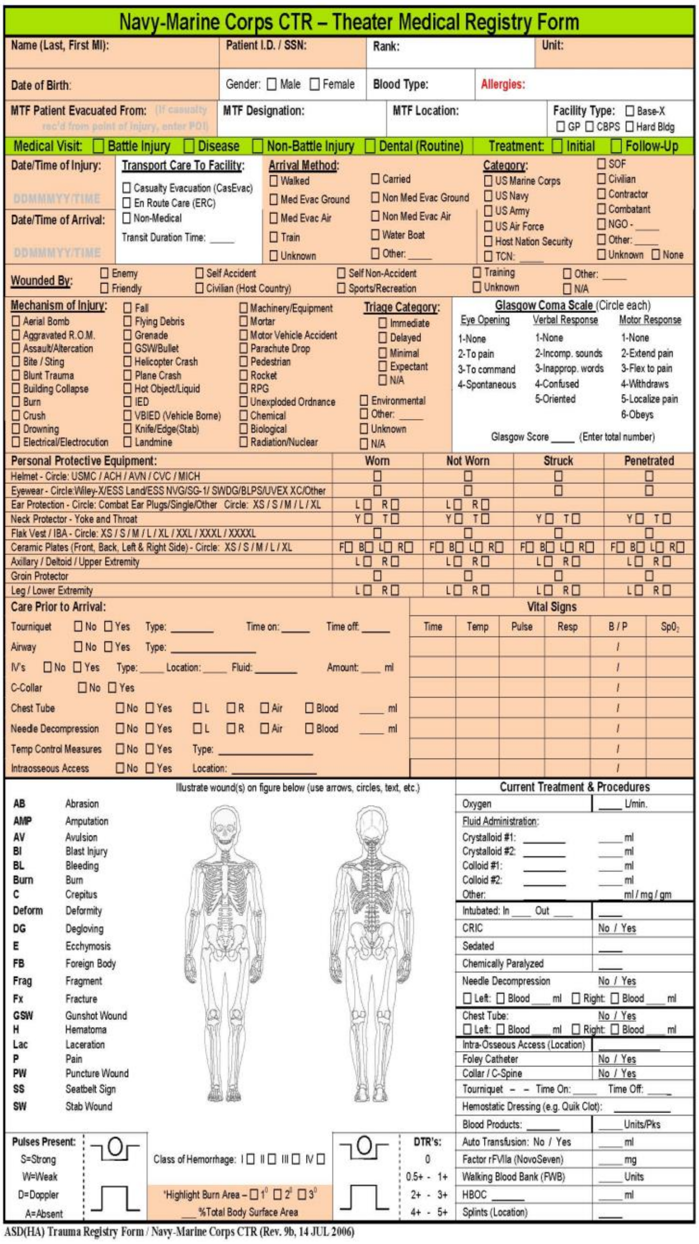
Abstract. The study of Neuro-IS often contains huge amounts of data. While the outcomes of this process are well documented, little has been written about the collection and dissemination of this data. In order to fill this gap, we looked at hospital ships which provide a medical asset in support of military operations. We collected data on three ship variables and four physiological body region injuries (head, torso, extremities and abrasions). We ran an exploratory regression analysis and found a significant relationship may exist ($p<0.000$) for the overall model. In medical diagnosis, it is important to not only maximize correct classifications, but also to minimize Type I and Type II errors. We contend that predicting a patient that does not have TBI, will survive, when in fact the patient does have TBI, is a worse error than when a patient that has been diagnosed with TBI and in reality does not.

Keywords: Decision Support · Traumatic Brain Injuries · Neuro-IS · Apache Hive-Informatics

1 Introduction and Literature Review

The PIPS functional and technical support to the military informatics repository gathers and analyzes data to assist the Navy in preparing for future requirements. PIPS's advanced combat casualty trauma data collection and analysis, paired with an extensive military knowledge of Navy operational medicine, has been the bedrock of theater patient data collection in Iraq and Afghanistan. The objective of PIPS is to define the requirements and functionality of the system. These objectives will serve as the initial baseline PIPS system design and as a reference for determining whether the completed product performs as requested. The PIPS software provides input for medical analysts to support the investigation of blast related data. The analysis then review classified significant event data provided by the intelligence community, identify individuals injured in the significant events and develop medical injury profiles for individuals in the significant events, using information in the PIPS database. This allows for the transmission of medical injury profiles, without individual identifying information to the intelligence community. The medical analysis support encompasses key blast research areas of injury prevention and acute treatment. The tasks include the following medical analyst support areas of combat casualty wounded in action analysis, individual Post Traumatic Stress Disorder (PTSD) research, and (TBI) monitoring. The basis of the medical analysis is to support is the ability to associate the combat casualties to the combat incident. The medical analysis will identify the combat casualty and associate this casualty to the operational incident, usually an improvised explosive device (IED). Synchronization of disparate deployed medical databases with various theater operational reports are used to develop a grading mechanism that provides a high degree of certainty that the combat casualty was truly associated with the combat incident. This process begins with the review of the Iraqi and/or Afghanistan Theater of Operations service reports. Reports provide the operational incident data including: date, time, location, units, personnel casualties (wounded – killed in action – died of wounds), vehicle damage and summary information. The key data elements are documented on the casualty worksheet and validated by reviewing the database. From these theater operational reports, the medical treatment facility may be identified, requiring an extensive working knowledge of the theater regions and the military services and medical treatment facilities in those regions. Once this data is documented on the casualty worksheet, the various medical databases are reviewed. The service casualty report is an additional source of casualty information. This report displays those casualties that are wounded and evacuated to the local medical treatment facility or theater hospitalization capability onboard ship. The medical analyst then reviews databases to associate the combat casualty and to document treatment provided during that time period in the region or subsequent theater hospitalization capability. The ability to associate the casualty to the treatment record at this stage in the process may still have a low degree of certainty, depending upon the multiple sources of information available and the quality of information provided. Due to the intense degree of tactical events occurring during an operational incident, the collection of the patient treatment information is often a low priority, and the service member may be returned to duty on-site when definitive care seems unnecessary. The medical analysis must search through hundreds or thousands of casualty records in the databases, to find a patient match with a high degree of certainty. PIPS has developed and refined various methods to link a group of casualties together for any given enemy encounter. These include matching the unit, time or location of the encounter to injuries reflected in elements of the patient treatment record, and/or gathering the wound pattern information in the database reports and linking them to potential clinical records. All of this information is recorded on the casualty worksheet; and a confidence level score of low, medium or high is given with the match of the following criteria: date, location, unit, service, military vs. civilian, patient identification number, the mechanism of injury and whether the treatment record is documented as a battle injury vs. a non-battle injury or disease non-battle injury. PIPS then passes this information on to a trauma coding form, (Fig 1.) CTR FORM. The resulting medical research and analysis of this archived combat data in the health database is used for re-design of tactical vehicles. This requires specific wounded-in-action – combat incident data to identify vehicle vulnerabilities and methods of improvement to protect the crew and troops in the vehicle. In a textbook NeuroIS example, casualty data collection collaborates with defense scientific and technical information exchange; program harmonization and alignment; and shared research activities to determine the veracity of TBI signs and symptoms.



Navy-Marine Corps CTR – Theater Medical Registry Form

Name (Last, First MI): | Patient I.D. / SSN: | Rank: | Unit:

Date of Birth: | Gender: ☐ Male ☐ Female | Blood Type: | Allergies:

MTF Patient Evacuated From: (If casualty rec'd from point of injury, enter POI) | MTF Designation: | MTF Location: | Facility Type: ☐ Base-X ☐ GP ☐ CBPS ☐ Hard Bldg

Medical Visit: ☐ Battle Injury ☐ Disease ☐ Non-Battle Injury ☐ Dental (Routine) | Treatment: ☐ Initial ☐ Follow-Up

Date/Time of Injury: DDMMMYY/TIME
Date/Time of Arrival: DDMMMYY/TIME

Transport Care To Facility: ☐ Casualty Evacuation (CasEvac) ☐ En Route Care (ERC) ☐ Non-Medical; Transit Duration Time: ____

Arrival Method: ☐ Walked ☐ Med Evac Ground ☐ Med Evac Air ☐ Train ☐ Unknown ☐ Carried ☐ Non Med Evac Ground ☐ Non Med Evac Air ☐ Water Boat ☐ Other: ____

Category: ☐ US Marine Corps ☐ US Navy ☐ US Army ☐ US Air Force ☐ Host Nation Security ☐ TCN: ____ ☐ SOF ☐ Civilian ☐ Contractor ☐ Combatant ☐ NGO - ____ ☐ Other: ____ ☐ Unknown ☐ None

Wounded By: ☐ Enemy ☐ Friendly ☐ Self Accident ☐ Civilian (Host Country) ☐ Self Non-Accident ☐ Sports/Recreation ☐ Training ☐ Unknown ☐ Other: ____ ☐ N/A

Mechanism of Injury: ☐ Aerial Bomb ☐ Aggravated R.O.M. ☐ Assault/Altercation ☐ Bite / Sting ☐ Blunt Trauma ☐ Building Collapse ☐ Burn ☐ Crush ☐ Drowning ☐ Electrical/Electrocution ☐ Fall ☐ Flying Debris ☐ Grenade ☐ GSW/Bullet ☐ Helicopter Crash ☐ Plane Crash ☐ Hot Object/Liquid ☐ IED ☐ VBIED (Vehicle Borne) ☐ Knife/Edge(Stab) ☐ Landmine ☐ Machinery/Equipment ☐ Mortar ☐ Motor Vehicle Accident ☐ Parachute Drop ☐ Pedestrian ☐ Rocket ☐ RPG ☐ Unexploded Ordnance ☐ Chemical ☐ Biological ☐ Radiation/Nuclear

Triage Category: ☐ Immediate ☐ Delayed ☐ Minimal ☐ Expectant ☐ N/A ☐ Environmental ☐ Other: ____ ☐ Unknown ☐ N/A

Glasgow Coma Scale (Circle each)

Eye Opening	Verbal Response	Motor Response
1-None	1-None	1-None
2-To pain	2-Incomp. sounds	2-Extend pain
3-To command	3-Inapprop. words	3-Flex to pain
4-Spontaneous	4-Confused	4-Withdraws
	5-Oriented	5-Localize pain
		6-Obeys

Glasgow Score ____ (Enter total number)

Personal Protective Equipment:	Worn	Not Worn	Struck	Penetrated
Helmet - Circle: USMC / ACH / AVN / CVC / MICH	☐	☐	☐	☐
Eyewear - Circle:Wiley-X/ESS Land/ESS NVG/SG-1/ SWDG/BLPS/UVEX XC/Other	☐	☐	☐	☐
Ear Protection - Circle: Combat Ear Plugs/Single/Other Circle: XS / S / M / L / XL	L☐ R☐	L☐ R☐		
Neck Protector - Yoke and Throat	Y☐ T☐	Y☐ T☐	Y☐ T☐	Y☐ T☐
Flak Vest / IBA - Circle: XS / S / M / L / XL / XXL / XXXL / XXXXL	☐	☐	☐	☐
Ceramic Plates (Front, Back, Left & Right Side) - Circle: XS / S / M / L / XL	F☐ B☐ L☐ R☐	F☐ B☐ L☐ R☐	F☐ B☐ L☐ R☐	F☐ B☐ L☐ R☐
Axillary / Deltoid / Upper Extremity	L☐ R☐	L☐ R☐	L☐ R☐	L☐ R☐
Groin Protector	☐	☐	☐	☐
Leg / Lower Extremity	L☐ R☐	L☐ R☐	L☐ R☐	L☐ R☐

Care Prior to Arrival:

Tourniquet ☐ No ☐ Yes Type: ____ Time on: ____ Time off: ____
Airway ☐ No ☐ Yes Type: ____
IV's ☐ No ☐ Yes Type: ____ Location: ____ Fluid: ____ Amount: ____ ml
C-Collar ☐ No ☐ Yes
Chest Tube ☐ No ☐ Yes ☐ L ☐ R ☐ Air ☐ Blood ____ ml
Needle Decompression ☐ No ☐ Yes ☐ L ☐ R ☐ Air ☐ Blood ____ ml
Temp Control Measures ☐ No ☐ Yes Type: ____
Intraosseous Access ☐ No ☐ Yes Location: ____

Vital Signs

Time	Temp	Pulse	Resp	B / P	SpO_2
				/	
				/	
				/	
				/	
				/	
				/	
				/	

Illustrate wound(s) on figure below (use arrows, circles, text, etc.)

AB	Abrasion
AMP	Amputation
AV	Avulsion
BI	Blast Injury
BL	Bleeding
Burn	Burn
C	Crepitus
Deform	Deformity
DG	Degloving
E	Ecchymosis
FB	Foreign Body
Frag	Fragment
Fx	Fracture
GSW	Gunshot Wound
H	Hematoma
Lac	Laceration
P	Pain
PW	Puncture Wound
SS	Seatbelt Sign
SW	Stab Wound

Current Treatment & Procedures

Oxygen ____ L/min.
Fluid Administration:
Crystalloid #1: ____ ____ ml
Crystalloid #2: ____ ____ ml
Colloid #1: ____ ____ ml
Colloid #2: ____ ____ ml
Other: ____ ml / mg / gm
Intubated: In ____ Out ____
CRIC No / Yes
Sedated ____
Chemically Paralyzed ____
Needle Decompression No / Yes
☐ Left: ☐ Blood ____ ml ☐ Right: ☐ Blood ____ ml
Chest Tube: No / Yes
☐ Left: ☐ Blood ____ ml ☐ Right: ☐ Blood ____ ml
Intra-Osseous Access (Location) ____
Foley Catheter No / Yes
Collar / C-Spine No / Yes
Tourniquet - - Time On: ____ Time Off: ____
Hemostatic Dressing (e.g. Quik Clot): ____
Blood Products: ____ Units/Pks
Auto Transfusion: No / Yes ____ ml
Factor rFVIIa (NovoSeven) ____ mg
Walking Blood Bank (FWB) ____ Units
HBOC ____ ____ ml
Splints (Location) ____

Pulses Present: S=Strong W=Weak D=Doppler A=Absent
Class of Hemorrhage: I ☐ II ☐ III ☐ IV ☐
*Highlight Burn Area – ☐ 1° ☐ 2° ☐ 3°
____ %Total Body Surface Area
DTR's: 0 0.5+ - 1+ 2+ - 3+ 4+ - 5+

ASD(HA) Trauma Registry Form / Navy-Marine Corps CTR (Rev. 9b, 14 JUL 2006)

Fig. 1. CTR FORM

In this section, we plan to discuss basic concepts, widely used algorithms, and some real-world applications in NeuroIS healthcare involving Big Data analytics. Hazen et al. [1] point out that today's supply chain professionals are inundated with data, and they propose methods for monitoring and controlling data quality while addressing the importance of highlighting interdisciplinary complementary theory. Edwards et al. [2] demonstrate various applications of MapReduce that can be adopted to analyze patterns of load distribution using parallel node calculations, which can later be scaled up to match the requirements for the power utility sector. Their paper shows the impact of data analytics on big data smart grids. In a similar vein, Shina et al. [3] point out that big data analytics can enable timely and accurate insights using machine learning and predictive analytics, to make better decisions. They developed a proof-of-concept, using open platform solutions including MapReduce, Hadoop Distributed File System (HDFS), and a machine-learning tool in order to present an example of big data analytics modeling in the metal cutting industry. Similar to our model utilizing SDA and regression, Seera and Lim [4] proposed a hybrid intelligent system that consists of the Fuzzy Min–Max neural network, the Classification and Regression Tree, and the Random Forest model as a decision support tool for medical data classification. Their experimental outcomes positively demonstrated that the hybrid intelligent system was effective in undertaking medical data classification tasks. In much the same way, we utilized Hive, Hadoop and Azure to drill down to find TBI injuries in the ship databases. Esfandiari et al [5] postulate that data mining is a powerful method to extract knowledge from data by handling various data types in all formats. This paper also was relevant to our study, because it emphasized the fact that data mining works in the context of knowledge extraction from medical data and provided some guidelines to help medical practitioners. Garcia-Randolph and Gilbert [6] investigated impaired cognitive functions and provided the therapist with dynamic decision support information for assigning the most appropriate rehabilitation plan to each patient. Data mining techniques were used to build data-driven decision making models similar to those proposed in our model. Marcano-Cedeño et al [7] contend that acquired brain injury (ABI) is one of the leading causes of death and disability in the world and is associated with high health care costs as a result of the acute treatment and long term rehabilitation involved. This mirrors the road to recovery for the TBI military personnel in our study. They propose a novel application of data mining (DM) techniques to predict the outcomes of cognitive rehabilitation in patients with ABI and generate three predictive models that allow them to obtain new knowledge to evaluate through the application of decision tree (DT), multilayer perceptron (MLP) and general regression neural network (GRNN) which have allowed for increased knowledge about the contributing factors of an ABI patient recovery and to estimate treatment efficacy in individual patients. Hatiboglu et al [8] postulated that the outcome of patients with intracranial aneurysm could be predicted by a fuzzy logic approach. This study is similar to our TBI mortality and survival results, because two hundred and forty two patients with the diagnosis of intracranial aneurysm were analyzed and the results showed that that the outcome of the patients with an aneurysm can be accurately predicted by a fuzzy logic approach. Guler et al [9] purposed a study to develop a diagnostic system todetect the severity of traumatic brain injuries using artificial neural networks. Similar to our SDA research, thirty-two patients with traumatic brain injuries in different age and gender were studied. They found a significant relationship between the findings of neurologists and systems output for normal, mild, moderate and severe electroencephalography tracing data. Lu et al [10] investigated results utilizing the Glasgow Outcome Scale (GOS) as the primary endpoint for efficacy analysis of clinical trials in traumatic brain injury (TBI). They believe that accurate and consistent assessment of outcome after TBI is essential to the evaluation of treatment results, particularly in the context of multicenter studies and trials, as found onboard ships. They further believe that the inconsistent measurement or interobserver variation on GOS outcome, or for that matter, on any outcome scales, may adversely affect the sensitivity to detect treatment effects in clinical trial. Their research concluded that nondifferential misclassification directly reduces the power of finding the true treatment effect and that an awareness of this procedural error and methods to reduce misclassification should be incorporated into TBI clinical trials. Kao et al [11] state that Symbolic data analysis (SDA) has gained popularity over the past few years because of its potential for handling data having a dependent and hierarchical nature, much like the data in our study. They also used graphical and visualization tools for SDA including zoom star, closed shapes, and parallel-coordinate-plots. We also employed these tools to present a snap shot picture of our overall approach. Guo et al [12] believe that SDA is a new data analysis technique which captures the value of a variable with a symbolic representation. They conducted a simulation study to evaluate their standardization method by using clustering analysis in which they do not require the assumption of uniformly distributed data in the interval.

2 Results

Table 1. Model Summary[b]

Mol	R	R Sq	Adj R^2	Std. Err	DW
1	.507[a]	.257	.223	253.902	1.811

a. Predictors: (Constant), minimal, Byrd, Head, extrimity, Torso, Kersage, Boxer
b. Dependent Variable: mortality

Table 2. ANOVA[a]

Model	SS	df	Mn Sq	F	Sig.
Reg	3384704	7	483529	7.5	.000[b]
Res	9798860	152	64466.1		
Tot	13183565	159			

a. Dependent Variable: mortality
b. Predictors: (Constant), minimal, Byrd, Head, extrimity, Torso, Kersage, Boxer

Table 3. Coefficients[a]

Model	Unst Coeff		St Cof		
	B	Std. Er	Beta	t	Sig.
Cont	-6.1	24.3		-.251	.802
Byrd	.00	.016	.018	.097	.923
Box	.02	.063	.234	.461	.645
Kers	-.02	.026	-.382	-.825	.411
Head	.16	.051	.271	3.22	.002
Torso	.01	.077	.013	.154	.878
extr	-.09	.039	-.198	-2.30	.022
surv	-.42	.076	-.453	-5.53	.000

a. Dependent Variable: mortality

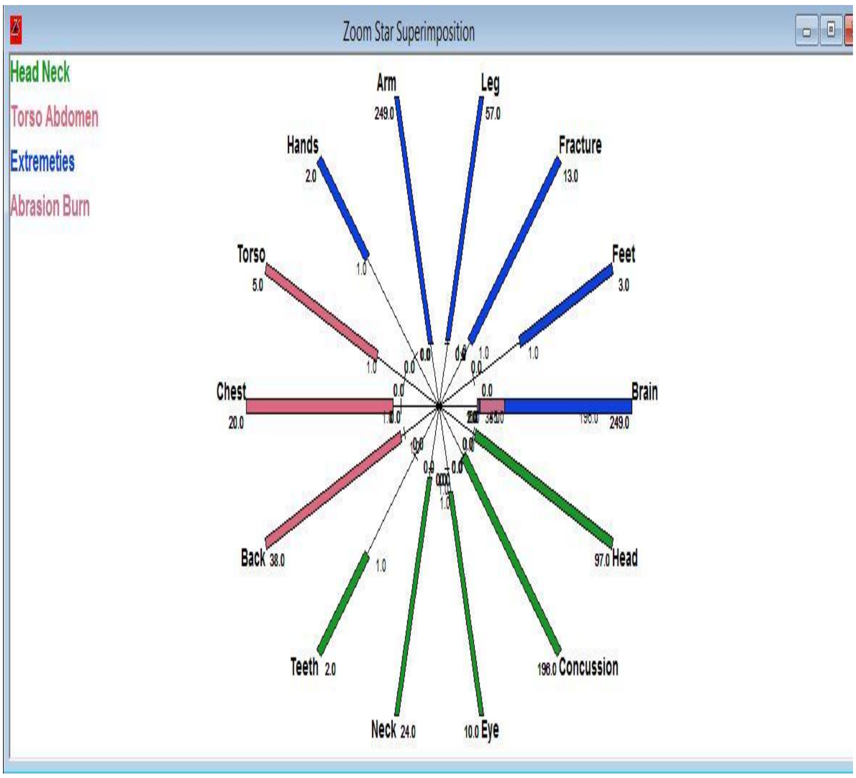


Fig. 2. Physiological Variables

3 Conclusions, Recommendations and Future Issues

In Table 1 we see that the R square for our model was 25.7%. This indicates that there may be other variables that need to be investigated that impact mortality rates. Our results also gives insights that there may be evidence that a significant relationship ($p<0.000$) exists for the overall model of ship and type of injury impacting mortality, as seen in Table 2. Table 3 demonstrates that there were also individual contributions between the mortality rate and extremities ($p<0.022$). Torso injuries were not significant ($p=.878$), perhaps indicating that these cases never reached the ships for treatment, due to their extensive and instantaneous impacts. The mortality rate and head injuries were significant ($p<0.002$). Although this relationship makes sense, SDA indicates that some head injuries may have been misclassified as torso injuries, neck injuries or even as concussions. Since we suspected discrepancies in the classification of the variables and mortality rates due to misdiagnosis of TBI, concussion, and other head, torso and extremity wounds, we decided to investigate further by SDA. In Fig. 2, SDA was used to compare the three symbolic ship dimensions to the 17 injuries which were found to fit into four categories, head/neck, torso abdomen, extremities and abrasion/burn. The SDA confirms that the TBI (brain) were classified as being part torso (red) and part extremity (blue). This misclassification may also potentially be confirmed by running future discriminant results which may have resulting impacts on the reported morbidity and survival results for TBI. Survival rates were also significant ($P<0.000$) and the Beta was negative at -.453. None of the three ships contributed significantly to the mortality rate (.097, .461 and -.825). While the Kersage had a negative t value indicating that as more patients were assigned to this ship the mortality rate went down, this relationship was not significant and also provides evidence that patients who were not transported to the ship either died outright or had minimal injuries and returned to duty, without treatment onboard ship. This may also have to do with the types of injuries that were assigned to each of these ships, as the minimal injuries to the extremities also had a negative t value. The regression gave evidence that further study of TBI misclassifications are feasible and that we should develop our proposed Patient Informatics Processing Software Hybrid Hadoop Hive (PIPSH^3) Data Mining and a Symbolic Data Analysis Canonical KNN Means Discriminant Analysis Nearest Neighbor Misdiagnosis Minimization Approach (MMA) algorithm. In future, we intend to further employ Apache Hive as a data warehouse infrastructure built on top of Hadoop for providing data summarization, query, and analysis to identify TBI as well as other injury cases. Finally canonical correlation will be used to analyze the new data. We are interested in how the set of collection variables relates to the body injuries. Two dimensions or canonical variables may be necessary to understand the association between the two sets of variables (survival vs mortality). Discriminant analysis can be used to predict the percent of TBI injured patients that will survive, once they reached the primary care medical treatment on board the ships. If there are a large number of ungrouped cases, this may be due to the misclassification of TBI cases, as indicated by the regression feasibility SDA results. In our paper we demonstrated the feasibility that survival, mortality and morbidity rates can be derived from the superset of MO data and used for future decision making and planning on TBI patients, to minimize misclassification errors.

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The Status Quo of Neurophysiology in Organizational Technostress Research: A Review of Studies Published from 1978 to 2015

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Abstract. We report on the status quo of neurophysiology in organizational technostress research, showing how neurophysiological tools have been applied in technostress studies with a focus on the organizational level of analysis. Based on a review of research published in peer-reviewed journals, we found that neurophysiological tools have seen relatively frequent application, particularly in early technostress studies (1970s – 1990s), but have since then been on the decline. We also found that contemporary organizational technostress research relies heavily on survey-based approaches to study the nature, causes, and effects of this phenomenon, almost completely neglecting prior successful applications of neurophysiological tools.

Keywords: Technostress · Measurement · Review · Organization · Stress · NeuroIS

1 Technostress and Neurophysiology

With the advent of information and communication technologies (ICT) it has become clear that individuals and organizations can not only benefit from the application of ICT, but that there is also a negative side of ICT use (e.g., [1]). One major negative aspect of ICT use is *technostress* (e.g., [1-4]), a phenomenon that can arise from "direct human interaction with ICT, as well as perceptions, emotions, and thoughts regarding the implementation of ICT in organizations and its pervasiveness in society in general" [1]. Though researchers had started to investigate this phenomenon empirically (e.g., [5,6]) even before the term "technostress" was coined in a publication in 1982 [7], it has received increased attention from IS researchers in the more recent past (e.g., with publications in mainstream journals such as MIS Quarterly, Information Systems Research, Journal of Management Information Systems, or Journal of the Association for Information Systems). This increased level of IS publication is not surprising due to several technological developments (e.g., mobile technologies) that are likely related to user stress. Thus, technostress is a phenomenon of high prevalence in modern society, and it may have detrimental effects (e.g., affecting personal well-being with symptoms such as anxiety [8,9], fatigue [9,10] or exhaustion [2], or work-related outcomes such as reduced job satisfaction [3,10-14], reduced performance [10,13,15], or reduced organizational commitment).

To investigate these effects and the occurrence of technostress in general, neurophysiological tools are essential in order to gain a more complete understanding of the phenomenon. It has been shown, for example, that subjective reports of the experience of technostress alone are not sufficient, as actual physiological stress reactions can deviate significantly from individual accounts (e.g., [1,10,16]).

As technostress is a phenomenon that results from the interplay between the individual and the environment (e.g., [17,18]), focusing on the individual level of analysis alone (e.g., through experimentation in laboratory settings) limits the generalizability of research findings (external validity issue). Presumably due to the complexity of neurophysiological measurement, application of neurophysiological tools has been avoided at all, or neurophysiological studies of technostress have so far been predominantly conducted in laboratory settings [1]. Thus, technostress research applying neurophysiological tools in the field is urgently needed and has already been shown to be a viable option, particularly in early studies (e.g., [5,6,10,11,19]). In this paper, therefore, we show how technostress research outside of laboratory settings has developed since these early studies. Specifically, we review the different measurement tools which have been applied so far in organizational technostress research.

2 Measurement Tools in Technostress Research

Following the research methodology presented in a recent review of technostress research to identify relevant studies ([1], see appendix)[1], we selected peer-reviewed journal articles which focused on technostress in an organizational context (e.g., indicated by the collection of data from individuals in their roles as professionals acting in organizational settings, e.g., [15]). This process of research and subsequent selection led to the identification of a total of 25 journal articles which were then used as the basis for this review [2–6,9–15,19–31].

When focusing on the chronology and publication outlets, we found that there have been two major periods of technostress research so far. The first period of intensified research started in the beginning of the 1990s and stretched throughout that decade, with research being mainly published in non-IS journals (e.g., journals related to medicine or psychology) [10–12,19–23]. The second major period of technostress research started in the last decade and is ongoing until today. Unlike the studies in the preceding period of research, contemporary technostress articles have mainly been published in IS journals [2,4,9,13–15,24–31].

As shown in Table 1, we observe significant differences with regard to the measurement tools that have been applied in extant literature on organizational technostress research. We identified the application of four main data sources: (A) inter-

[1] Google Scholar search of the term “technostress” on 02/13/2015. Note though that we did not formulate the requirement that a publication must have at least five citations to be included in our study (see [18]).

views, (B) surveys, (C) physiological data, and (D) hormones and related biological substances. We found significant differences in types of collected data between research published in the 1990s and before that period and research published in the 2000s and after that period.

Table 1. Main Measurement Tools Applied in Organizational Technostress Research[2]

	1970s – 1990s								2000s - 2015											
	Johansson and Aronsson 1978 [5]	Johansson and Aronsson 1984 [6]	Berg et al. 1992 [20]; Arnetz and Berg 1996 [21]	Arnetz 1996 [11]	Korunka et al. 1996 [10]	Wastell and Newman 1996 a, b [22,23]	Arnetz and Wiholm 1997 [12]	Boucsein and Thum 1997 [19]	Tu et al. 2005 [24]	Tarafdar et al. 2007-2011 [4,13,14]	Ragu-nathan et al. 2008 [3]	Wang et al. 2008 [25]	Ayyagari et al. 2011 [2]	Barley et al. 2011 [26]	Shu et al. 2011 [27]	Salanova et al. 2013 [9]	D'Arcy et al. 2014 [28]	Sellberg and Susi 2014 [29]	Tarafdar et al. 2014 a, b [15,31]	Maier et al. 2015 [30]
A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
B	X	X	X			X				X	X		X	X	X		X			
C	X	X		X	X	X		X												
D	X	X	X	X	X		X													

Surveys (A) have been applied frequently, mainly in order to measure the perceptional components involved in the experience of technostress. This focus can be attributed to the essential role of individual perceptions in the occurrence of technostress-related discrepancies (e.g., discrepancy between the perceived reliability of computer systems and the desired reliability of computer systems), though it is not sufficient to investigate technostress perceptions alone (e.g., [32]). Interviews (B), in contrast, were mainly used to assess the viability of existing or newly developed measurement scales (e.g., [2,14]), or as complementing data sources (e.g., [23,26]).

The measurement of physiological data (C), such as cardiovascular activity (e.g., [10]) or electro-dermal activity (e.g., [19]), and the measurement of the excretion of hormones (D)[3] such as cortisol (e.g., [10]) or adrenaline (e.g., [11]), were commonly

[2] We merged (i) [20] and [21], (ii) [22] and [23], (iii) [4], [13] and [14], (iv) and [15] and [31] because they share the same empirical basis.

[3] Though the measurement of hormones and related biological substances (D) could be subsumed in category (C) as another source of physiological data, we created an own category

applied in early field studies. Interestingly, despite the substantial research basis published in early studies, we found no journal publications that were published after 1997 which reported on an empirical study (conducted in an organizational setting) applying neurophysiological tools of the categories (C) and (D).

Moreover, brain-imaging tools, an equally important category of measurement tools in NeuroIS research (e.g., [34–38]), have not been applied in any technostress field study thus far. This research gap can be partially explained by the characteristics of brain-imaging tools (e.g., lack of mobility of some tools or their low accessibility in certain areas, [37]), which complicate their application in the field or even render application impossible (e.g., in the case of magnetic resonance imaging). However, the advent of brain-imaging tools which can be applied in field settings more flexibly, such as near-infrared spectroscopy (NIRS) (e.g., [39,40]) or electroencephalography (EEG) (e.g., [41]), indicate significant research potential in this area.

Overall, it seems that a gap regarding the application of neurophysiological tools in organizational technostress studies has emerged in contemporary research. Therefore, in the next section, we will briefly show which neurophysiological measures have been utilized successfully in early technostress research (i.e., period 1970s – 1990s, see Table 1), in order to foster their more frequent application in future studies.

3 Neurophysiological Tools in Early Technostress Research

As a result of a more detailed review of studies which applied measurement tools included in categories (C) and (D) (see Table 1), we created an overview of all neurophysiological measures that have been applied in organizational technostress research so far (see Table 2). Physiological measures (C) that have been applied most frequently are related to cardiovascular activity such as heart rate and blood pressure, while other measures were used less frequently (i.e., body temperature, electrodermal activity, and neck electromyogram). Moreover, measures of ocular activity (e.g., eye movements or pupil dilation) or facial muscular activity (which can be an indicator for emotional valence) were not applied at all, even though they have been introduced as viable tools for NeuroIS studies (e.g., [37,38]).

Hormones and related substances (D) which played a significant role in prior research are mainly stress hormones such as catecholamines (e.g., adrenaline and noradrenaline) and cortisol, and sex hormones such as estradiol or testosterone. Further, prolactin has been shown to be a viable alternative to these substances, as it can also be good indicator of mental and physical arousal [10]. Importantly, studies like the ones by Berg et al. [42] or Arnetz and Berg [21] have demonstrated that there is a wide variety of additional substances that can be measured when assessing the effects of technostress. However, to analyze these substances in most cases blood samples have to be drawn (except for substances such as catecholamines and cortisol which can measured via urine and saliva samples, e.g., [5,6,10]). As blood cannot be collect-

for this data source due to differences in the underlying research methodology (for details, see a recent paper by Riedl, Davis, and Hevner [33]).

ed non-invasively, in contrast to urine or saliva samples, the NeuroIS researcher might perceive a boundary, preventing scholars from collecting blood samples.

Although our results indicate that there is a gap in technostress studies applying neurophysiological tools in the field, neurophysiological tools have been applied in several IS laboratory studies in recent years. For example, Riedl et al. [43] have shown that cortisol excretion significantly increased in response to a system breakdown and, in a follow-up study [44], demonstrated gender differences in reactions to system breakdown based on electrodermal activity. Also, Tams et al. [45], to mention another recent study, demonstrated that measuring the salivary excretion of α-amylase can be a valuable addition to the biological measurement of technostress levels.

Despite the lack of NeuroIS field studies in the domain of technostress research it can therefore be acknowledged that neurophysiological tools are readily applied. However, in order to increase the external validity of existing insights, applications of these tools in more natural settings (e.g., field studies in organizations) should be a valuable extension to contemporary research practices. It will be rewarding to see what insight future research will reveal.

Table 2. Neurophysiological Tools Applied in Organizational Technostress Research

	Johansson and Aronsson 1978 [5]	Johansson and Aronsson 1984 [6]	Berg et al. 1992 [20], Arnetz and Berg [21]	Arnetz 1996 [11]	Korunka et al. 1996 [10]	Wastell and Newman 1996 a, b [22,23]	Arnetz and Wiholm 1997 [12]	Boucsein and Thum 1997 [19]
Physiological Measures								
Blood Pressure		X		X	X	X		
Body Temperature	X							
Electrodermal Activity								X
Heart Rate		X		X	X	X		X
Neck Electromyography								X
Hormones and Related Substances								
ACTH Levels			X					
Catecholamines[4]	X	X	X		X			
Cortisol			X	X	X			
Estradiol			X					
Growth Hormone			X					
Melatonin			X					
Prolactin			X	X			X	
Testosterone			X	X				
Thyroxin			X					

[4] Under "Catecholamines" we subsume Adrenaline (Epinephrine) and Noradrenaline (Norepinephrine).

Related Substances[5]				X				

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The Impact of Interruptions on Technology Usage: Exploring Interdependencies between Demands from Interruptions, Worker Control, and Role-based Stress

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Abstract. Mobile technologies have dramatically increased the number of work-related interruptions. In many organizations, employees have to remain accessible and respond to these technology-mediated (T-M) interruptions even after regular work hours. At the same time, most employees have limited freedom to decide how and when they accomplish their tasks, a work condition that renders the explosion of T-M interruptions problematic. When people have limited control over their work environment, they cannot adapt their work schedules and methods to the additional demands from T-M interruptions, potentially leading them to be stressed and, in turn, to shy away from using the technologies that create these interruptions. Hence, we propose that demands from T-M interruptions negatively affect work-related IT-usage via workers' experiences of stress and that this indirect effect depends on worker control. Psychological and physiological data (salivary cortisol & alpha-amylase) will be collected and analyzed through advanced procedures for testing moderated-mediation effects.

Keywords: Interruptions·Stress·Demand-Control Theory·IT Use

1 Introduction

Mobile technologies expose knowledge workers to an endless stream of interruptions that frequently come during non-work hours; over 75 per cent of workers unlock their phones and use them between 5pm and 8pm [1]. During this peak evening time, the average worker is interrupted 27 times by a mobile device. This time period is also the peak family time, implying that the usage of the phone during this time period is bound to create a strain on family life, entailing role-stress. This role-stress likely has downstream negative consequences for organizations, leading to job-related and behavioral outcomes. We suspect that role stress may eventually lead employees to withdraw from using mobile technologies [2,3]. Thus, this study holds that characteristics of IT that are often experienced negatively, such as frequent interruptions, can reduce the extent to which people are willing to use the IT or to interact with it [4,5].

A potentially pertinent amplifier in this context is that–while knowledge workers are expected to be accessible at all times–many of them have limited freedom to decide whether, how, and when they accomplish their work [6]. This work condition renders the explosion of T-M interruptions especially problematic. Decision-making freedom allows workers to fit the task of responding to T-M interruptions in their other work responsibilities [7,8]; lack of it, however, implies that people have limited control over their work and cannot adapt their work schedules and methods to the additional demands from T-M interruptions, potentially leading them to be stressed and, in turn, to shy away from using technologies [9]. Yet, despite the practical significance of the demands from T-M interruptions, research focusing on their negative effect on technology usage and the dependence of this effect on worker decision-making freedom (i.e., the extent of control that employees have over their work) is nascent. Therefore, our second goal is to examine–when employees are required to be accessible–does it matter whether they are given a certain level of control over how and when they use their mobile technologies? In summary, *the present study examines whether demands from T-M interruptions impact work-related technology usage via increased perceptions of role-based stress – and whether this mediated impact of T-M interruptions depends on the extent of control that employees have over their work.*

We contribute to research on technostress in several ways. Most importantly, we include the work environment and job design characteristics (i.e., worker control) as a moderator in our study to advance understanding of how technostress can be managed [7]. Additionally, we establish work-related IT usage as an important consequence of technostress. Further, we enrich understanding of the precise effects of demands from T-M interruptions on technostress. Finally, we will evaluate stress using both psychological and physiological measures to generate more holistic explanations of technostress [10]. The next section provides the study background and develops the hypotheses that probe our research objective. The third section briefly outlines the general methodology to test our research model and provides concluding thoughts.

2 Background and Hypotheses

In the paragraphs that follow, we integrate the concepts of *demands from T-M interruptions*, *stress*, and *work-related technology usage*.

2.1 Demands from T-M Interruptions

Despite the prevalence of T-M interruptions and their generally negative consequences for work-related behaviors, research into their effects is nascent, particularly in the context of technostress [11]. In IS, two pioneering studies by Speier and colleagues [11,12] highlighted the importance of exploring their negative consequences in more depth. Three later review papers [13,14,15] supported this notion, indicating that T-M interruptions cause substantial productivity losses for organizations by leading employees to feel stressed and, in turn, to withdraw from various desirable behaviors.

Consistent with Speier et al. [11], we examine T-M interruptions as stressors that are externally generated and randomly occurring and that break continuity of cognitive focus on another task or obligation. Further, T-M interruptions generally require immediate attention and insist on action so that an individual who is being interrupted generally needs to turn his or her attention toward the interruption [11]. Thus, workers receiving more interruptions than they can effectively process generally consider these interruptions demanding [16]. In line with this notion, in this study we focus on the negative consequences of *demands from T-M interruptions*. These *demands from T-M interruptions* can, ultimately, result in stress [14].

2.2 Role-based Stress in the Context of T-M Interruptions

Given the pervasive, omnipresent nature of such contemporary mobile technologies as smartphones and of the interruptions they mediate, their impacts often transcend work and non-work settings so that individuals' work roles intrude into and interrupt their other roles, creating conflict among the various different role requirements [4], [17]. For this reason and consistent with prior technostress research [4], [17], we conceptualize stress in response to T-M interruptions as role-based stress in the form of inter-role conflict. Role-based stress in the form of inter-role conflict most frequently manifests as conflicting demands of work and family [2], [4], [17], implying a conflict about the allocation of time and attention to both environments [2]. For example, Tarafdar et al. [18] report on the case of Mike, who spends a large part of his annual vacation responding to interruptions from mobile technologies rather than focusing on his family. As a result, Mike overlooks family duties like dinner plans, entailing a major conflict between his job and family roles that may, subsequently, lead him to withdraw from using mobile technologies altogether [2,3], [18].

2.3 Connecting T-M Interruptions and Role-based Stress to Work-related Technology Usage

To inform our understanding of how the relationship between demands from T-M interruptions, role-based stress, and work-related technology usage is structured and of how this relationship may depend on worker control, we use Karasek's [7] demand-control model. This model fits the phenomenon studied in the present paper since it theorizes the interaction between demands (e.g., demands from T-M interruptions) and worker control. More specifically, the demand-control model consists of four basic elements: job demand (i.e., the stressor, such as demands from T-M interruptions), stress (e.g., role-based stress), stress-related negative consequences such as not performing a work-related behavior (e.g., limited technology usage), and control (i.e., the extent of control that workers have over their work) [7], [19,20,21]. According to Karasek's model, we can conceptualize demands from T-M interruptions as a job demand/stressor, role-based stress in the form of inter-role conflict as stress or strain, work-related technology usage as a consequence of this role-based stress, and worker control as a negative moderator of the interruption-stress-usage relationship.

The demand-control model offers two hypotheses: the strain and the buffer hypotheses [19], [21]. While the strain hypothesis suggests that high demands lead to stress and, ultimately, impact employee behaviors, the buffer hypothesis predicts an interaction effect of job demands and worker control, in which control moderates the effects of job demands on stress and subsequent outcomes (i.e., the buffer hypothesis constitutes a specification of the strain hypothesis) [19], [21]. The strain hypothesis implies for the present paper that high demands from T-M interruptions reduce work-related technology usage via increases in role-based stress, while the buffer hypothesis suggests that the strength of this mediated relationship may vary with worker control. Concerning the former hypothesis, research has suggested, albeit not explicitly modeled or empirically examined, that demands from T-M interruptions can lead people to shy away from using the technologies that create these interruptions [11,12], [22]. This negative impact of T-M interruptions on usage has been suggested to occur because interruptions are often considered intrusive and are, thus, experienced negatively, resulting in stress that leads people to attempt to escape from them [11,12], [23]. This notion is consistent with **DeLone and McLean's [24] IS success model** and the **technology-acceptance model [25]**, both of which indicate that the characteristics of a technology can impact the extent to which it is used. Hence:

H1: Role-based stress mediates the negative effect of demands from T-M interruptions on work-related technology usage; that is, there is a negative, indirect effect of demands from T-M interruptions via role-based stress on work-related IT usage.

Concerning the buffer hypothesis that serves to specify H1, the demand-control model can be used to predict that the indirect effect of demands from T-M interruptions via role-based stress on work-related technology usage should be weaker when workers have more control over when and how to accomplish their work and over what kind of work to accomplish [7], [20]. Accordingly, schedule control, method control, and criteria control, which address the when, how, and what, respectively, are pertinent moderators of the indirect effect [8], [26,27]. Specifically, control about scheduling, methods, and criteria affords employees the freedom and flexibility to manage the timing and content of their responses to T-M interruptions so that the demands from T-M interruptions present less of a struggle, reducing inter-role conflict and, thus, role-based stress in the face of these interruptions. Hence (see Figure 1 and Table 1):

H2a: The strength of the mediated relationship between demands from T-M interruptions and work-related technology usage (via role-based stress) depends on the level of schedule control; the negative, indirect effect of demands from T-M interruptions via role-based stress on work-related technology usage is weaker when schedule control is higher.

H2b: The strength of the mediated relationship between demands from T-M interruptions and work-related technology usage (via role-based stress) depends on the level of method control; the negative, indirect effect of demands from T-M interruptions via role-based stress on work-related technology usage is weaker when method control is higher.

H2c: The strength of the mediated relationship between demands from T-M interruptions and work-related technology usage (via role-based stress) depends on the level of criteria control; the negative, indirect effect of demands from T-M interruptions via role-based stress on work-related technology usage is weaker when criteria control is higher.

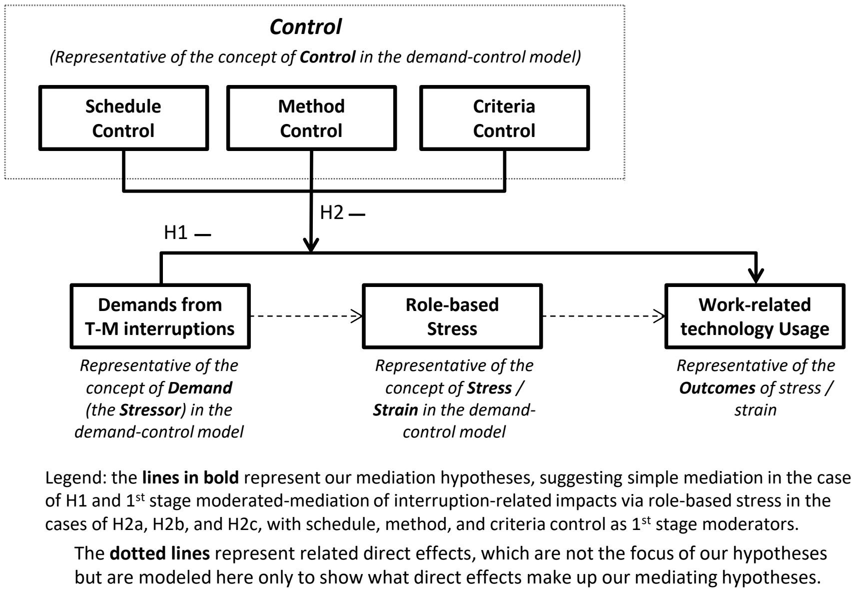

Fig. 1. Research Model

Table 1. Construct Definitions.

Construct	Definition
Demands from T-M Interruptions	The extent to which workers feel overwhelmed because they receive more T-M interruptions than they can process
Role-based Stress	The inter-role conflict that occurs as job demands interfere with the performance of family duties (see the example of Mike)
Work-related Technology Usage	The extent (in terms of intensity and scope) to which individuals utilize a mobile technology
Schedule Control	The degree to which a worker can schedule his or her own work
Method Control	The degree to which a worker can determine the procedures (i.e., methods) to be used in carrying his or her work out
Criteria Control	The degree to which a worker can determine what is to be done (i.e., the objectives of his or her work)

3 Next Steps and Conclusion

We will test the model using a field study and a simulation experiment akin to an in-basket exercise, which will integrate perceptual measures with bio stress measures (cortisol and α-amylase reflecting changes in adrenalin [29]) to yield a more complete picture of technostress [10]. For data analysis, we will use Preacher et al.'s [30] approach to estimate the conditional indirect effects at different levels of the moderators. In doing so, we will expound how, why, and under what conditions the demands from

T-M interruptions impact IT usage, providing implications for work process redesign. For example, workers could be given the freedom to decide about whether, when, and how to respond to a work-related instant message or email after regular work hours.

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An Investigation of the Nature of Information Systems from a Neurobiological Perspective

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Abstract. The purpose of this paper is to investigate how ISs may be conceptualized from an individual, neurobiological perspective. The point of departure is the fact that brains evolved to control the activities of bodies in the world. Based on a number of theoretical contributions bordering between the neural and social realms, a novel IS conceptualization emerges as a dialectical unity of functional organs in the brain and the IT artifact. As a consequence, the IS is conceptualized as intrinsically associated with the individual. I discuss implications of this position for epistemology, ontology, and representation, which are all fundamental aspects of IS research. In conclusion, I claim that a neurobiological perspective on IS has a great potential to advance the discussion of the nature of the IS.

Keywords: IS conceptualization· activity modalities · functional organs · equipment · joint action · common identifiers · integrationism· epistemology · ontology · representation

1 Introduction

The nature of Information Systems (IS) has been a recurrent theme of debate in the IS discipline, so far without reaching closure (see e.g. [1]). It is commonly accepted that IS research lies at the intersection of people, organizations, and technology [2]. However, disagreement remains about how to define a stable foundation from which ISs can be analyzed and exploited in IS design. For example, Lee claims that "Virtually all the extant IS literature fails to explicitly specify meaning for the very label that identifies it. This is a vital omission, because without defining what we are talking about, we can hardly know it" [3, p. 338].

In an attempt to break new grounds for inquiry, the purpose of this paper is to investigate how ISs may be conceptualized from a *neurobiologica*l point of departure. Neuroscientific approaches have recently gained increasingly interest recently in, for example, the NeuroIS initiative [4] and social sciences [5,6,7]. The investigation takes as a fundamental fact that "the mental is inextricably interwoven with body, world and action: the mind consists of structures that operate on the world via their role in determining action" [8, p. 527]. In order to articulate this position, I will briefly recapitulate a number of contributions, which somehow links the neural and social realms;

each from a certain perspective. A preliminary integration of these perspectives lends support to a novel conceptualization of an IS as a dialectical unity of functional organs in the brain and the IT artifact. It follows that the IS is intrinsically associated with the individual; there will be as many ISs as there are individuals engaging with the IT artifact. I discuss implications of this position for epistemology, ontology, and representation, which are all fundamental aspects of IS research. In conclusion, I claim that a neurobiological perspective has a great potential to advance the discussion of the nature of the IS.

2 Some contributions linking mind and action

The activity modalities – predispositions for coordination

Coordination is imperative for life and action: "I do not see any way to avoid the problem of coordination and still understand the physical basis of life" [9, p. 176]. Thus, it is highly plausible that the phylogenetic evolution of the brain and body has brought about some kind of neurobiological substrate, providing prerequisites for coordinating actions in various situations. One indication is Kant, who argued that perception depends on 'a priori ideas or categories' of space and time. These categories cannot be "seen" or sensed externally. Rather, time and space are modes of perceiving the external environment [10]. Taxén has suggested that the dimensions of time and space are elements in a larger set of predispositions called *activity modalities*, which are necessary, albeit not sufficient dimensions for coordinating actions [11]. These modalities are:

- Objectivation – attending to an object around which actions are formed.
- Contextualization – foregrounding relevant things and ignoring irrelevant ones.
- Spatialization – orienting oneself spatially in the situation.
- Temporalization – anticipating actions.
- Stabilization – learning which actions work in a certain type of situation.
- Transition – refocusing attention to another situation.

Since the human neurobiological constitution has not changed significantly since the emergence of early hominids some 3.5 million years ago, these modalities are still at play today whenever we need to coordinate actions.

Functional organs

A key issue is how to conceptualize the relation between phylogenetically evolved morphological features of the brain, and the ontogenetic development of the individual. This problem was a prime concern for the Soviet psychologist Lev Vygotsky and his colleague, the neuropsychologist Alexander Luria. A common tenet in their thinking is that the socio-historical environment an individual encounters during ontogeny, plays a decisive role in the formation of higher mental functions. External, historically formed artefacts such as tools, symbols, or objects "*tie new knots in the activity of man's brain*, and it is the presence of these functional knots, or, as some people call them 'new functional organs' […] that is one of the most important features distinguishing the functional organization of the human brain from an animal's brain" [12, p. 31, italics in original]. This means that "areas of the brain which previously were independent become the *components of a single functional system*" [ibid.].

Equipment

The emergence of a functional organ can be seen as an *equipment* constructing process, where an artefact passes from a state of being *present-at-hand* to *ready-at-hand* [13,14]. In this process, the artefact recedes, as it were, from "thingness" into equipment, when the in-order-to aspect – what the artefact can be used for – takes precedence. Equipment is encountered in terms of its use rather than in terms of its properties. The evolution of artefacts from being *present-at-hand to ready-at-h*and takes place entirely in the brain of the individual. In this process, the artefact may or may not change, depending on the material properties of the artefact.

Joint action

When several individuals coordinate their actions to achieve a common goal, they are engaged in 'joint action' according to Blumer [15]. This term refers to the "larger collective form of action that is constituted by the fitting together of the lines of behavior of the separate participants" [ibid., p. 70]. Joint action cannot be interpreted as participants forming identical functional organs and equipments. Rather, occurs through common, external artefacts called "common identifiers", which provide guidance in directing individual acts so as "to fit into the acts of the others" [ibid., p. 71].

Communication

Concerning communication, which of course is an essential aspect of joint action, the *integrationist* approach provides a relevant perspective [e.g., 16,17,18,19,20,21]. A central axiom of integrationism is: "What constitutes a sign is not given independently of the situation in which it occurs or of its material manifestations in that situation" [20, p. 73]. This means that "[e]very act of communication, no matter how banal, is seen as an act of semiological creation" [20, p. 80]. Contextualization is fundamental for sign making and use: "No act of communication is contextless and every act of communication is uniquely contextualized" [18, p. 119]. In addition, integrationism views all communication as time-bound. Its basic temporal function "is to integrate present experience both with our past experience and with anticipated future experience" [22].

The rationale of the term 'integrated' is "that we conceive of our mental activities as part and parcel of being a creature with a body as well as a mind, functioning biomechanically, macrosocially and circumstantially in the context of a range of local environments" [19, p. 738]. The first relates to the physical and mental capacities of the individual; the second to practices established in the community or some group within the community; and the third to the specific conditions obtaining in a particular communication situation.

The various pieces indicated above may be integrated as follows. Coordination is fundamental for life. The activity modalities denote evolutionary evolved predispositions for coordinating actions. Actions are carried out together with means, which may be intentionally created artifacts. When engaging with means, new ‘knots’ are tied in the brain, resulting in the development of functional organs. The dialectical unity of the individual and artifact can be seen as an equipment forming process. When working together, individuals are engaged in joint action in which individual lines of behavior are fitted together using common identifiers. Finally, integrationism provides a complementary perspective on communication.

3 Implications

3.1 IS conceptualization

In the perspective described, the IS is seen as individual equipment being formed in interaction with the IT artifact. The inevitable consequence is that *ISs become individual specific*. The IT artifact becomes informative only when an individual has made it into equipment for himself. Thus, the IS and the IT artifact are ontologically distinct, albeit dialectically related; they mutually constitute each other, and they do not make sense in isolation from each other. However, the IT artifact remains an artifact; there is no conflation between the individual/social and material as suggested, for example, in the sociomaterial view on IS [see e.g., 23].

3.2 Epistemology

Concerning epistemology, the individual is brought to the forefront: “The mind has as one of its principal functions the contextualized integration of present, past and future experience. That is its constructive role in the evolution of humanity. That is where knowledge comes from, the *fons* et *origo*. There is no hidden or more basic source [20, p. 161; italics in original]. A similar perspective is provided by Polanyi: “[All] knowing is action—that it is our urge to understand and control our experience which causes us to rely on some parts of it subsidiarily in order to attend to our main objective focally” [24, p. 2].

This implies, for example, that knowledge cannot be converted between tacit and explicit forms as suggested in the widely used SECI model [25,26]. The commodity view on knowledge is flawed. Instead of seeing “knowledge” as an object, we need to focus on “knowing” as a process: “every act of speaking, every motion of the pen, each gesture, turn of head, or any idea at all is produced by the cognitive architecture as a matter of course, as a new neurological coordination” [27, pp. 110-111].

3.3 Ontology

A prominent line of inquiry for developing new theories in the IS area has been to rely on a formal and precise ontology i.e., a “theory about the nature of and makeup of the real world” [28, p. 3]. One such ontology is Bunge-Wand-Weber (BWW), which claims, among other things, that “the world is made of things”, and that “things in the world possess properties” [ibid.].

This is in stark contrast to the “ontology” inherent in the neurobiological perspective. The human capability to contextualize implies that we don’t experience things as objectively given. The nature of an object is “constituted by the meaning it has for the person or persons for whom it is an object [15, p. 68]. This meaning is not intrinsic to the object but “arises from how the person is initially prepared to act toward it” [ibid., p. 68-69]. Thus, the world is not “made of things”; neither do these things “possess” properties. Rather, we confer properties onto perceived, actionable objects according to what is relevant in a certain situation.

3.4 Representation

Equally prominent in extant IS research is the notion of “representation”; the idea that we possess an “inner world, that is, a coherent system of detached representations that model the world” [29, p. 89]. Representation is seen as “the *essence* of all information systems” [30, p. viii, italics in original]. The IS “is a representation of a real-world system as perceived by users” [32, p. 88].

However, from a neurobiological point of view, the notion of representation cannot be sustained: “[We] are tempted to say the brain represents. The flaws with such an assertion, however, are obvious: there is no precoded message in the signal, no structures capable of high-precision storage of a code, no judge in nature to provide decisions on alternative patterns, and no homunculus in the head to read a message. For these reasons, memory in the brain cannot be representational in the same way as it is in our devices” [31, p. 77].

4 Concluding remarks

This paper is an attempt to instigate a novel line of IS research from a neurobiological perspective. The motivation is simply that any IS approach ultimately need to be anchored in the *sine qua non* conditions for the existence of human life. To this end, I have pointed to some research contributions, which may contribute to the establishment of a solid foundation for neurobiological conception of ISs. Needless to say, this is just a beginning that has to be corroborated on many areas. However, I claim that a neurobiological perspective has a great potential to significantly advance the discussion of the nature of the IS.

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A Hot Topic – Group Affect Live Biofeedback for Participation Platforms

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Abstract. Emotions are omnipresent in our lives. They influence our health, decision making, and social interactions—bilateral as well as multilateral. Hence also modern forms of opinion building and exchange, e.g., on e-participation platforms, should consider the effects of emotions on individual and group level. Previous research on group interactions demonstrated that providing the members with information about the affective state of the entire group, reciprocally influences the affective states of the individuals and can even increase group performance. Hence, in the current short paper we propose group affect live biofeedback (LBF) as a beneficial feature for e-participation platforms. We want to examine how group affect LBF based on the participant's heart rate impacts participation behavior.

Keywords: Group Affect · Live Biofeedback · Participation · Emotion

1 Emotion and Participation

Participation is a fundamental right in our democratic value system. Not only does this basic concept shape our political system, it also affects our social interaction. Today, online participation platforms, or e-participation platforms, are omnipresent and range from crowdfunding websites to participatory budgeting [1,2]. On crowdfunding platforms (e.g., kickstarter.com, indiegogo.com), people can help to fund projects of their interest. Other platforms for participatory budgeting or political opinion forming and decision making (e.g., ffm.de, fixmystreet.com, or democratia.fi) offer the opportunity for open discussion and voting on different political or social issues. However, the design of e-participation platforms still faces major challenges. First, such platforms face the need to improve user engagement since the number of users is still rather low. Most German political participation platforms only reach less than 1% of possible users (e.g., ffm.de, liquid-friesland.de). Furthermore, a study by [3] with 504 participants revealed that more than half of those participants had not been active on a single participation website. Second, previous research identified shortcomings in the (potential) users' general engagement towards social as well as political topics [4]. For example, political frustration and low election turnouts are wide spread in modern society [4]. Finally, the retention rates of e-participation platforms are low, as users often lose interest in the provided topics.

In this context, recent research indicated that emotions are an important driver for participation behavior, i.e. proposing, discussing, evaluating, and rating different topics or ideas in an interactive and multilateral process. Furthermore, users with a higher level of emotionality are demonstrably more active during online participation [5]. By making use of the powerful role of emotions, e-participation platforms could thus be enhanced and participation behavior positively stimulated. In this short paper, we propose a group live biofeedback (LBF) mechanism for e-participation platforms that is based on the group members' heart rate. A person's heart rate is an indicator of their current emotional state and even short measurement periods are suitable for LBF applications [6].

We argue that LBF in form of a group affect parameter at a collective level can improve participation by increasing the users' engagement towards the discussed topics and their user experience. Furthermore, when users are more engaged in a topic, they are more likely to return to the platform. Hence, providing group affect LBF, could increase user attachment to the provided topics and the e-participation platform itself. Finally, users that are more engaged and active could signalize liveliness of an e-participation platform and thus make it more interesting to potential users as well as co-users. We therefore propose the examination of group affect LBF in the context of e-participation platforms. Specifically, we seek to answer the research question, how group affect LBF impacts online participation behavior.

In this work, we define group affect as an "aggregate of individual group members' affective states and traits" [7]. Group affect is a dynamic measure that changes as the group evolves, e.g., new members joining in, others dropping out, and individual changes in behavior and mood. With regular LBF, individuals receive information about their neurophysiological state [8]. Providing group members with a group affect parameter based on neurophysiological measurements, hence brings the idea of LBF to a collective level.

Group affect has shown to be a central element for understanding group dynamics [9–11]. [7] examined group level consequences of group affect and found that it influences several characteristics of group interaction, including (i) attitudes about the group, (ii) cooperation and conflict management within the group, (iii) creativity of the task solving process, (iv) decision making, and even (v) performance. [10] found that providing the group with feedback on aggregated affective experiences of the group members increases the group members' appraisals of future events and experiences. Based on mood-as-input theory, [12] investigated how affect shapes transitions in teams over time, showing that shared team affect influences team performance. Furthermore, [13] developed a cyclical model that describes how the affective state of an individual person sparks emotional reactions of other group members (*affective similarity-attraction*) and how the affective state at a collective level reciprocally influences the individual group members (*affective sharing*).

The degree of bilateral as well as multilateral interaction on online platforms, such as e-participation platforms, is limited to written contribution and discussions. However, in human interaction, non-verbal behavior, e.g., for the expression of emotions, plays an important role [14]. Previous NeuroIS research has shown that neurophysiological processes can be utilized to acquire information about a person's emotional state [15–19]. Therefore, group affect LBF could support the interaction by providing additional emotional feedback based on neurophysiological data to the group. Such additional group information could serve as an emotional spark as described by [13]: group affect LBF corresponds to the idea of affective similarity-attraction, since it aggregates the affective states of the group members. Likewise, it corresponds to the idea of affective sharing by being returned to the group. Research in the domain of group decisions and negotiations found that there exists a positive relationship between a group member's emotions and attitudes towards the group [7]. Based on this evidence, we suggest that group affect LBF holds great potential for improving participation on online platforms by leveraging the power of emotions. We investigate, how affective experiences in groups shape subsequent group experiences and interactions and thus picks up the research gap formulated by [7].

2 Research Agenda

Participation is a living process that evolves over time. Participants have to develop their opinions and discuss their ideas with one another. We are aware of the fact that a laboratory environment would yield more internal validity and possibly higher quality of the measured neurophysiological data. However, we plan to examine the influence of group affect LBF on participation in a field study for the following reason: Only a realistic environment with time constrains that offer enough freedom for ideas to grow and opinions to be formed yields a suitable setting for the examination of group affect LBF in e-participation. The target group for this study will be university students. As part of a concurrent research project, a simple platform for online participation is developed. This platform gives students the opportunity to propose, discuss, and evaluate campus-related projects and measures (e.g., providing extra printing credit to students, etc.). The developed platform can be accessed using a mobile phone application.

We plan to conduct two conditions based on the e-participation platform and their respective applications for mobile devices. The first condition serves as a control condition, where participants use a "plain version" of the platform interface, similar to existing e-participation platforms. The second condition implements the group affect LBF. It contains a group affect LBF parameter that indicates the level of emotional affect. The group affect LBF is based on individual heart rate measurements of the participants. The participant's heart rate will be measured using Eulerian Video Magnification (EVM) by [20], which is open-source [21]. The EVM makes temporal variations in videos visible that are too small to see with the naked eye. It can be applied in real time on a video sequence that is captured by a standard camera device. The algorithm performs spatial decomposition followed by temporal filtering on the respective video sequence. The result is a signal, where changes are amplified and thus, former hidden information, such as a person's blood flow, become visible [20].

For the planned field study participating users require an input device that includes a front camera, i.e. a common smartphone. During interaction with the platform, the users' faces are videotaped. This, of course, requires user consent and some level of cooperation. The respective videos are used for analysis with the EVM algorithm only. Using the captured video, the EVM identifies a location on the user's forehead. Color changes of this region over time are then used to derive the user's heart rate [20]. The participants' average heart rate value is measured while they discuss different topics. For each topic the average heart rates are aggregated on a group level. The aggregated heart rates then are weighted by the number of users that participated in the respective topic leading to a group affect score for each topic. This group affect score will be provided to all participants as LBF revealing information about the affective states of other users.

A crucial characteristic of LBF is the form in which the feedback is provided to its users. We decided to provide visual LBF as demonstrated in previous research by [8, 22–24]. In the planned study, the group affect LBF is visualized in form of a thermometer that displays the current *temperature* of a certain discussion. High temperature indicates that participants currently experience a high level of emotional arousal, while discussing the (hot) topic. Lower temperatures indicate lower levels of emotional arousal, respectively.

As proposed by [25], websites aim for interactivity, which can be measured by the number of first-time visits and the number of returns to the website. Therefore, we propose to use the number of returns of the study participants to the platform and the number of comments as quantitative measures in order to investigate the influence of group affect LBF on participation behavior. Furthermore, users' sentiments significantly impact the discussions and thus the entire participation process. Such sentiments in turn can be extracted by analyzing the users comments [26, 27]. Hence, the sentiments within discussion as well as user satisfaction can serve as qualitative indicators for platform improvement.

We will inspect how group affect LBF influences the IS constructs perceived social presence [28–30], perceived emotions [31,32], perceived usefulness [33,34], and perceived ease of use [33,34]. Recent research has identified perceived social presence as an important component of the user-website relationship and thus must be considered for successful website design [28,29]. Furthermore, it was shown, that that perception of social presence positively influences enjoyment, perceived usefulness and a user's trust in a website leading to more favorable consumer attitudes [28,30]. The accurateness of the perceived emotions are crucial for emotion regulation and thus for beneficial communication [31,32]. Both, perceived usefulness as well as perceived ease of use, are established as fundamental determinants of user acceptance and are significantly correlated with self-reported current usage behavior and self-predicted future usage [33,34]. Hence, we will compare the four previously mentioned IS constructs between both described conditions in order to examine the contribution of group affect LBF.

3 Concluding Remarks

In this short article, we have sketched out how group affect LBF may be used to stimulate a desired behavior, i.e. user participation, in online discussion environments. Technically, we base this idea on unobtrusive access to neurophysiological data such as heart rate, accessed by computer vision and algorithmic recognition of smallest variations of skin color and brightness. Besides the presented approach, other methods are conceivable. The fitbit bracelet, for instance, enables continuous and highly unobtrusive measurement of heart rate [35]. There exist several applications for mobile phones (e.g. Instant Heart Rate [36], Runtastic Heart Rate Pulse [37], Heart Rate Pulse [38]) that measure a user's heart rate at the fingertip using the phone's flashlight and camera. Furthermore, bracelets developed by [23,39] measure a user's electrodermal activity unobtrusively. Also user input devices, such as a standard mouse device can be used to measure the level of emotional affect based on click rate and intensity [40].

Using such sensible information may raise considerable user concern as data privacy and in particular the value of neurophysiological data (e.g., for health insurances) are subject to heated public discussion. We are well aware of this issue. Nevertheless, the *quantified-self* is not a trend of the distant future, but self-tracking applications for fitness, mood, sleep, etc. are ubiquitous and exist today. Future smart phones, bracelets, camera-equipped glasses, and watches will more and more be used to monitor their owner's vital functions for health related reasons. Applications may then ask for access to neurophysiological data in the same manner as they do for location, contact list etc. already today. Despite all justified concerns, it appears likely to us that user resistance will eventually decrease and convenience will lead to interspersion of neurophysiological measurements in everyday life applications.

When it comes to group affect in the context of e-participation, text based sentiment analysis is a further valid and wide spread approach that has to be considered [27, 41]. However, we consider group affect LBF as a complementary method to existing approaches for affect analysis. In future different approaches such as neurophysiological measurements and text-based analysis might be combined in order to acquire more accurate information about user's affective states.

Taken together, real time feedback based on neurophysiological data is a promising opportunity to provide users with additional information on an individual as well as a group level. Especially the case of participation might benefit from such features, since a group member's behavior can be stimulated though information about the affective state of the group [7, 10].

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(Online)-buying Behavior and Personality Traits: Evolutionary Psychology and Neuroscience based

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Abstract. This paper tries to link findings from evolutionary psychology and neuroscience with the aim to adapt traditional buying models and, as a result, shed new light on the different buying behavior. Out of these theories one can derive that (online) buying behavior is in a general sense twofold. *Need-oriented-buying behavior*: We purchase goods because we have a need. Yet, this purchase contributes little to our happiness since it is a sheer necessity. *Want-oriented buying behavior*: Many goods, however, are bought because we "want" and "like" them based on our experience or due to the fact that they are new. Such products generally generate a so-called "incentive salience". By adding the additional dimension of an involvement component, a two-dimensional model with four archetypical types can be established: (a) Extensive buying, (b) effort-minimizing buying, (c) self-indulgent buying, and (d) conspicuous buying.

Keywords: Buying behavior · neuroscience · evolutionary psychology

1. Introduction

We live in a consumer society in which the variety of consumer goods has become incredibly vast. On a daily basis, consumers need to choose from a myriad of products to meet both their requirements and wants. Not only consumers have to make decisions regarding the different product brands but also they can choose which buying channel, an *online shop* or a *bricks-and-mortar store*, fits their requirements best. It is assumed that these decisions highly depend on personality traits and of course on the product per se. This paper will shed new light on these coherences inspired by aspects from evolutionary psychology (EP) and neuroscience (NS).

Referring to Katona [1], buying decisions can generally be distinguished between so called *genuine decisions* and *habitual decisions*. According to his definition, genuine decisions are generally associated with intense cognitive involvement with the product that mainly occurs when considering buying a new product. Habitual decisions on the other hand, are typical of utility articles of daily use where the buyer already has some experience. As a result, cognitive information is not necessarily required and, as such, cognitive effort is low. However, this rough differentiation is insufficient if one seeks to cover all the facets of the buying decision. Buller [2] elaborated on Katona's dichotomy adding a further element, the so-called limited decisions and Weinberg [3] seemed to complement the buying types with *impulsive deci-*

sions. Whereas Howard and Shet position *limited decisions* in terms of their cognitive efforts between extensive and habitual decisions stating that there is already a certain product experience, impulsive decisions tend to be predominantly influenced by emotions triggered by specific, often unintended and spontaneous stimulations at the point of sale (POS). This concept has been drawn on by diverse literature in the field of consumer behavior or marketing and was frequently explained in detail [4]. This notion of buying behavior is also the only source referred to in the German Wikipedia. As aforementioned, this paper intends to enrich this current notion with aspects from EP and NS. Bearing in mind that the comprehensive theoretical coherences can only be touched here on the surface, this paper will result in a new buying behavior model intended to further contribute to the academic debate in this field.

2. Homeostasis and Well-Being

Each organism tries to both survive and reproduce itself. This urge toward survival and reproduction is an evolutionary process already identified by Charles Darwin [5]. Admittedly, while this process seems inappropriate for explaining the entire morphology of mankind, it still sheds light on underlying mechanisms that determine human behavior [6]. In line with this reasoning, it is only logical that the goal of all organisms is to grow old, to stay healthy, to keep their reproductive capacities, and to be perceived as an appropriate reproduction partner. All these behaviors that were particularly advantageous in past for increasing survival and reproduction have proven to be valuable and have been passed on from generation to generation. These experiences finally resulted in a genetic adaptation that helps us and our offspring optimize survival and reproduction [7–10]. These adaptations allow humans to recognize threats such as predators, poisonous insects, dangerous heights, or even strangers [8, 11] and to react quickly [11–13]. This responsiveness is facilitated by the release of neurotransmitters such as norepinephrine, epinephrine, and cortisol that provide energy to escape or possibly engage in a fight [14,15].

Apart from these innate reaction patterns that help us survive, it is also required, as aforementioned, that one finds an appropriate reproduction partner. For this purpose, humans face two challenges: on the one hand, someone needs to be perceived as a selectable partner; on the other hand, he or she has to filter an appropriate partner out of a variety of possibilities. This selection process is based on a perception of a potential partner that corresponds with his or her ability to survive in a hostile and competitive environment and on whether he or she is willing to take care of the offspring. Thus, being healthy, strong, powerful, and possessing the willingness to invest in the partner's and offspring's life are indicators of whether a mate meets these requirements. In contrast, being weak, ill, feeble, and self-interested indicates the opposite [6,10,16,17]. To assess whether a potential partner has sufficient capabilities for survival and qualities for successful common breeding, humans depend on various signals [18]. These signals are related to (a) physical appearance, such as full lips, smooth and firm skin, shiny hair, a favorable fat distribution, symmetrical face, and athletic abilities, which point to a person's reproductive value [8,19–22]; (b) the availability of resources, such as nutriment [23]; and (c) behavioral aspects, such as the extent to which a potential mate behaves cooperatively and altruistically, which are both indices of willingness to invest in a partnership and offspring [24,25]. Undoubtedly, there are some gender differences in terms of attraction signals. For example, Anglophone and European women tend to compete with each other for high-quality men by emphasizing signals that demonstrate reproductive values, such as youthfulness, a small nose, and pale, hairless skin. In contrast, men tend considerably more to communicate dominance by intimidating reproductive rivals, which results in attracting women [19]. That is one reason why men and women choose different signals to reinforce their mating strength. It is important to note that chosen signals, called *self-expression traits* (SETs), highly depend on attainability. If somebody, for example, wants to have a fancy car to signal power, but this car is not affordable for him or her, then the importance of this trait is adapted to reduce cognitive dissonance (see fig.1) [26, 27].

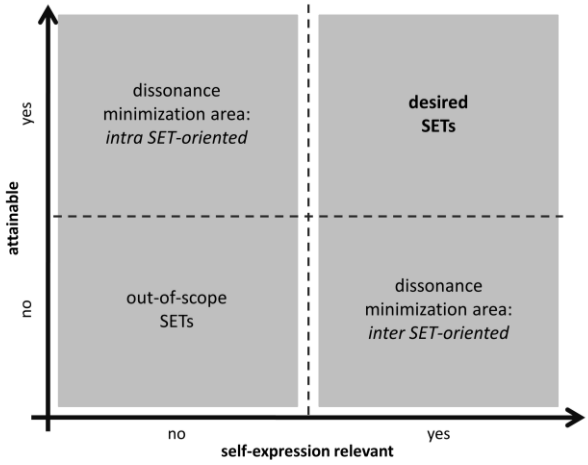

Fig. 1. Self-expression traits

Overall, it can be assumed that objects (in this report, these are human beings, animals, items, or even symbols) are automatically assessed on the basis of innate cues which help survival and selection of appropriate mates. For this assessment different signals are vital. The importance of these signals highly depends on the gender.

An underlying mechanism for these automatic assessments is homeostasis, a process that supports survival and helps identify salient signals [28, 29] homeostasis concerns (a) the inner milieu (e.g., alterations in heart rate, blood pressure, hormonal secretion), (b) the striated muscles (e.g., facial expressions), and (c) cognitions such as focusing attention and/or making decisions [30].

In addition to these innate aspects, mankind learns to assess objects and situations according to the principle of reward and punishment. While a positive effect of this principle is enhanced quality of life resulting in increased individual *well-being*, a negative effect lies in decreased quality of life, leading to pain and/or negative emotions. Consequently, when confronted with a certain object, the brain automatically assesses such objects and triggers reactions that are both innate and based on personal experiences and observations. In the event of an overall positive assessment, such an object and the situation in which the object occurs is “*liked”*. Hence, future perceptions of such, or similar, objects or corresponding situations are considered particularly attractive and effective in obtaining an individual “*incentive salience*” leading to appetency and, thus, to a longing to repeat this experience [29, 31]. In the event of an overall negative assessment, such an object and the corresponding situation are disliked. Therefore, such objects are allocated an individual negative value, which leads to an inherent aversion to the objects and situation [30]. In the event of completely new stimuli, this knowledge based on experiences needs to be established for the first time. Undoubtedly, we pay particular attention to all new and unknown objects [32] that trigger curiosity which, as a result, drive us to explore them in more detail [33]. New and unknown stimuli are crucial for us since they can be either a chance to increase personal well-being or a threat.

3. A new Buying Behavior Model and a Personality Classification

These roughly described mechanisms help us to control our future behavior driven by optimizing survival and reproduction. With these aspects of EP and NS in mind an analogy to the buying behavior can be derived: Goods are purchased because somebody has a need. Yet, this purchase does not contribute to happiness since it is a sheer necessity. Many goods, however, are bought because somebody “wants” and “likes” them based on experience or due to the fact that they are *new* and thus embrace a hedonistic dimension. So we get two different behavior types: A *need-oriented* buying behavior type and a *want-oriented buying* behavior type. By adding an *involvement* dimension [34] a two-dimensional model with four archetypical buying behavior types can be identified: (a) Extensive buying behavior , (b) effort-minimizing buying behavior, (c) self-indulgent buying behavior, and (d) conspicuous buying behavior (see fig. 2 on the left).

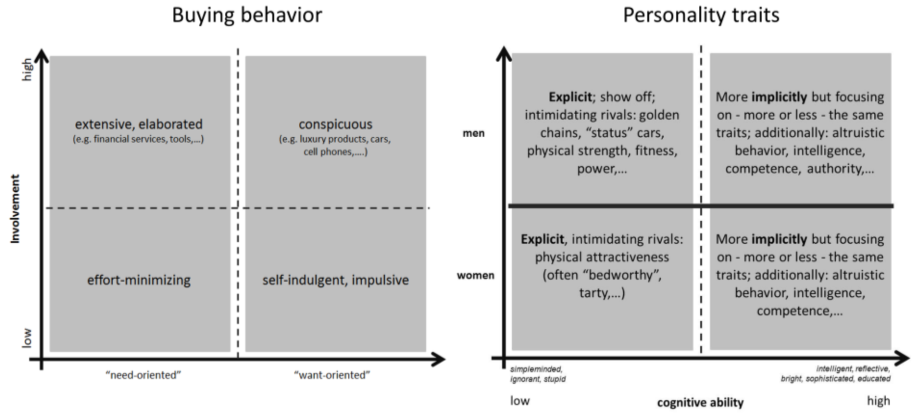

Fig. 2 Archetypical buying behavior types and personality traits

(1) *Extensive buying* is characterized by high involvement, often due to high prices. Since such goods are vital for life they cannot be renounced easily. Extensive buying requires comparably high cognitive control and as much information as possible regarding product alternatives in order to be able to choose from existing alternatives and, as a result, buy the product that appears to be best in terms of price/performance ratio. Thus, online channels will only be chosen if they are perceived as highly trustworthy and credible.

(2) *Effort-minimizing buying* takes place on a daily basis with products needed regularly. During this buying process consumers are normally minimally involved. To minimize cognitive effort customers often fall back on known products, socialized scripts or blueprints [35,36]. This buying behavior does not favor any products or brands since the consumer does not decide for a certain product out of conviction but rather through mental laziness which results in buying a substitute without hesitation in the event of the routine product being unavailable. Here online shops are an increasing alternative to bricks-and-mortar stores because of their obvious advantage in convenience.

(3) *Self-indulgent buying* is also associated with low involvement, however, here positive emotions become apparent. Such buying is fun, often a pastime and contributes to well-being. In such a case, a brick-and-mortar store is able to gain a vital competitive advantage to online shops (e. g. atmospheric variables, extended entertainment).

(4) *Conspicuous buying* is mainly a result of the urge to be perceived as an appropriate reproductive partner. Therefore products are bought that make somebody particularly potent, rich or altruistic and so forth [37–41]. Such products which are particularly suited to underline the individually indented self-expression are associated with higher involvement. Here, too, brick-and-mortar shops can differentiate to online shops with respect to the above mentioned traits like atmospheric variables and so on.

Now the crucial question is which *archetypal target groups* buy which *products* (e.g. clothing, electronic equipment, tools) following which *archetypal buying processes*? As aforementioned and referring to empirical studies the *gender [42–44]* and the and *cognitive ability [40]* differentiates the product-oriented buying process best (see fig. 1 on the right). With the above mentioned coherences in mind, the following implications can be drawn:

- Concerning the competition between the two buying channel types (web shop (WS) vs. brick-and-mortar stores (B&M); the added value of WS compared to B&M is increased convenience and a better price/performance-ratio of the indented products.
- One added value of B&M is increased buying pleasure because of atmospheric variables, and entertainment opportunities (e.g. visual and audial input).
- Another possible advantage of B&M could be a perceived reduction on environmental impact (e.g. reduced carbon footprint, strengthening local industry).
- Personal resources and their attainability (e.g. physical strength, financial status, cognitive abilities) influences which self-expression traits are relevant.

- Women more often choose products or behaviors which contribute to be perceived as more attractive.
- Men more often choose products or behaviors which contribute to be perceived as more powerful and/or affluent.
- The cognitive ability differentiates between people who choose more implicit or more explicit signals and those that do not.

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Choice of a NeuroIS Tool: An AHP-based Approach

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Abstract. The primary focus of NeuroIS research from a methodological perspective is set on methods and research design, data collection, and data analysis. In this paper, we address a practical problem, related to the data collection phase, namely the choice of a data collection instrument, or a NeuroIS tool. Before making a tool decision, researchers have to carefully study the features of each device, based on specified requirements, in order to select the most suitable tool. Thus, the tool choice becomes a multi-criteria decision making problem. In this paper, we propose an Analytic Hierarchy Process (AHP)-based approach for the selection of a NeuroIS tool. We introduce a framework based on a step-by-step procedure of decision hierarchy creation, followed by the construction of a list of potential measurement tools, and the execution of the AHP decision making process.

Keywords: NeuroIS·brain·AHP·tool selection·decision making·methodology

1 Introduction

Neuro-Information-Systems (NeuroIS) as a research field had its genesis in 2007, and has already gained considerable attention among scholars and practitioners [1–3]. NeuroIS has two major objectives: to develop new theories to accurately predict IT-related behaviors, and to design new (neuro-adaptive) IT artifacts [2,4]. Despite the fact that a number of papers have already been published in the field, NeuroIS is still in a nascent stage and more research, including papers contributing to the systematic development of a NeuroIS research methodology, is needed [1].

A recent framework for conducting empirical NeuroIS research describes eight phases [1], and the primary focus from a methodological perspective is set on methods and research design, data collection, and data analysis. In this paper, we address a practical problem in NeuroIS research, one that is predominantly related to the data collection phase, namely the choice of a data collection instrument, or, in other words, of a NeuroIS tool. This step is of high importance as it affects multiple factors related to NeuroIS measurement, namely reliability, validity, sensitivity, diagnosticity, objectivity, and intrusiveness (for definitions and details about these six factors, please refer to [1]).

Many information system (IS) constructs cannot only be measured based on traditional instruments (e.g., survey or observation) alone. Rather, their measurement can also be based on neuroscience instruments. Generally, a researcher has a choice between brain imaging tools and psychophysiological tools [2–7]. While the first group of measurement tools provides a possibility to directly track physiological activity in the brain of an individual (e.g., fMRI, PET, EEG), the second group of tools predominantly allows for measurement of autonomic nervous system (ANS) activity (e.g., skin conductance, pupil dilation, heart rate). Because tools of the second group are generally less invasive than tools of the first group, NeuroIS research in real-life environments often applies tools of the second group [2,5,7].

However, even if the type of the measurement instrument for a study, or a research program, has already been defined, a decision still has to be made on which specific tool a researcher wants to apply. For instance, today numerous heart rate monitors, or skin conductance measurement devices, are available on the market. Thus, before making a decision the NeuroIS researcher has to carefully study the features of each device, such as measurement precision, electrode placement recommendations, or price, in order to select the most suitable one. Moreover, it is clear that a researcher must have, at least to some degree, an idea about the specific requirements that a tool must meet. Generally, the choice of a NeuroIS tool is a multi-criteria decision making problem. In this paper, we propose an Analytic Hierarchy Process (AHP)-based approach for the selection of a NeuroIS tool.

AHP provides a comprehensive framework for solving decision making problems under conflicting criteria, and also presents a process model describing how the decision making process should be organized [8]. The AHP method is based on three basic principles: (1) decomposition of the decision problem into a hierarchy of interrelated elements, (2) comparative judgments by pairwise comparison of decision hierarchy elements, and (3) synthesis of priorities to derive the relative weights of decision elements [9,10]. In the past AHP was successfully applied in various decision areas, ranging from project portfolio selection and manufacturing systems optimization to conflict resolution and solving problems in health, education, and politics [10]. Importantly, the AHP method has been described as an appropriate approach for IS decision making and evaluation [11,12], and it has also been applied in various IS contexts, including the selection of enterprise resource planning (ERP) systems [13], executive information systems (EIC) systems [14], IT outsourcing providers [15], and application service providers (ASP) [16]. Moreover, the AHP approach was integrated with the Delphi method in the 1990s to study the development of research methods and the theory core in the German-speaking IS community (i.e., business informatics) [17].

The first step in the AHP process, namely the development of the hierarchical structure of elements, is the most crucial and challenging one. Hence, particular attention should be paid to identifying the relevant elements. To this end, in this paper we introduce a framework which consists of a step-by-step procedure of decision hierarchy creation, followed by the construction of a list of potential measurement tools for a particular NeuroIS study, and the execution of the AHP decision making process.

The paper is structured as follows. In Chapter 2 we introduce the framework for the NeuroIS tool selection. Afterwards, in Chapter 3, we describe the resulting AHP hierarchy. The paper concludes with a brief discussion and an outline of future research.

2 A Framework for Selecting a NeuroIS Tool

In this section, we present a framework for the selection of a NeuroIS measurement tool. The framework consists of six steps: (1) research team formation, (2) research goal definition, (3) detailed description of study setup, (4) tool attributes definition, (5) list of potential candidates' creation, and (6) tool evaluation using the AHP method. Fig. 1 shows a graphical representation of the framework. The detailed description of each step is presented below.

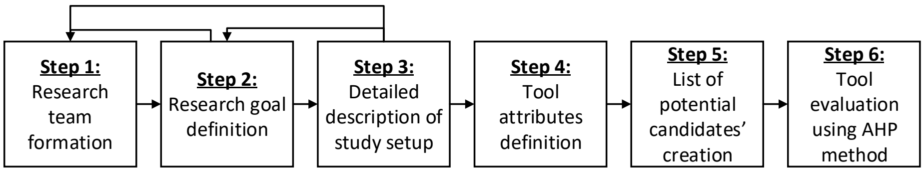

Fig. 1. A framework for the selection of a NeuroIS tool

The first step in the decision making process is to form a research team. In the best case the team should be multi-disciplinary, and hence should include specialists from both the IS and neuroscience fields. In case that the formation of a multidisciplinary team is not possible, the tool choice process is restricted, predominantly because the background of the team members influences the variable "level of knowledge necessary to apply a specific tool". Importantly, not only do complex measurements tools, such as magnetic resonance imaging (MRI) scanners, require a high level of proficiency with respect to data collection and subsequent analysis, but also does the usage of less complex tools such as eye-tracking, or skin conductance and heart rate measurement devices, imply a solid knowledge base, at least if these tools are to be applied correctly.

At the second step, the goal of the research study should be defined. The experiment team should briefly sketch the research idea, research model, and the study design (e.g., the experimental design in case that the study is a laboratory experiment). At this step, following the research methodology by Riedl, Davis, and Hevner [1], the following aspects should be defined: (1) real-world phenomenon to be investigated, (2) theoretical construct(s) which represent the phenomenon, and (3) possible measurements (metrics) and measurement instruments to be applied.

Of course, the study design might demand additional experts to be involved in the experiment execution process. This is reflected in Fig. 1 by the arrow back to the first process step.

As soon as the basic idea of the study is clear, the team can proceed with the detailed description of the study setup. At this stage, in case of experimental research, the detailed description of the experiment procedure, scenario, tasks, timeline, as well as measurements to be collected should be developed. Also, at this step changes to the experiment team or experiment goal can be made, which is also reflected in Fig. 1.

Based on the detailed experiment description a number of restrictions related to the measurement tool can be derived. One important example is a tool's intrusiveness (for details, see [1]). If the participant should be able to move during the experiment, all the measurement tools which require the participant to stay (relatively) motionless have to be excluded from the consideration set. Also, spatial and temporal resolution, cost, accessibility, and knowledge how to apply an instrument should be considered [18]. Additional attributes for consideration, among others, are functional specifications such as battery life and memory capacity of the device, standard delivery package (e.g., is the software for data analysis provided together with the hardware, how many electrodes are provided and how often do they have to be replaced), availability of technical support from the vendor, and the possibility to test the device before buying it. Values of all these attributes, potentially constituting restrictions, should be identified and documented.

Creation of a list of potential candidates might be a challenging task, especially for a novice researcher. Companies, which specialize on professional neurophysiological measurement devices, often do not widely advertise their products. Thus, it might be a good idea to ask colleagues with more experience in the neuroscience field for advice, and also ask them for references. Another possibility to identify candidates is to attend large conferences where tool vendors often have stands.

Also, it should be taken into account that the vendors of measurement devices often do not provide detailed device characteristics and price information on their websites. One usually has to get into direct contact with the company representatives. This can be a time consuming task, and hence should be planned beforehand in the study timeline.

As soon as the list of potential candidates is created, some of the devices can be already filtered out based on decisive factors such as price, accessibility, or intrusiveness. The remaining candidates will be evaluated in the next step, using the AHP method.

The AHP method consists of three main stages, as outlined in the Introduction of this paper. At the first step, the AHP hierarchy should be developed based on the results of the fourth step in Fig. 1 ("Tool attributes definition"). The decision elements should be shaped in a hierarchy form in order to represent the breakdown (i.e., top-down approach) of the tool selection problem. Next, attributes' importance must be assessed by pairwise comparison (this comparison process can be done by each member of the experiment team alone, or in a group setting; in case that the latter approach is selected, individual results must be aggregated). At the last step, the relative weights of decision elements are calculated, and subsequently aggregated over the hierarchy. Based on this procedure, which is described in detail in the publications by Thomas L. Saaty (see References), the most appropriate NeuroIS tools in a specific research situation can be identified.

3 An AHP Hierarchy for NeuroIS Tool Selection

The proposed framework was applied to select a NeuroIS tool for the investigation of differences in emotional perception of business process modeling languages. An initial AHP hierarchy was constructed, as presented in Fig. 2. The first level of the hierarchy corresponds to the overall objective of the selection process, the choice of the best suitable measurement tool for a particular NeuroIS experiment. The second level of the hierarchy represents the sub-goals, which have to be defined when making a decision. The next level of the hierarchy represents particular tool characteristics, which have to be taken into account during the selection process. Finally, the lowest level of the hierarchy represents the decision alternatives (in this example specific NeuroIS tools).

In the beginning, a research team was formed consisting of three persons, one of which has considerable experience in conducting NeuroIS research, and two individuals are experts in the business process modeling domain.

The main goal of the experiment was to get a better understanding if particular aspects of business process modeling notations impact modelers' emotions and, if so, how this would affect important outcome variables of process modeling activity (e.g., formal quality of the model or understandability of the model). Specifically, heart rate (HR) and skin conductance level (SCL) were chosen as measures of arousal (for a description of the physiology of arousal and stress, see [19]; for exemplary applications of these measures in IS research, see [20–22]). Moreover, the team identified facial recognition software as an innovative and reliable way to analyze the valence of emotions (because valence cannot be established easily based on HR, and according to most scholars SCL cannot be used at all to establish valence). The goal of the tool selection process was to select a suitable monitoring device, which would allow for collection of both HR and SCL data, as well as respiration data, which is important as a control variable in HR measurement.

At the next step, the experiment setup was defined. About 100 participants (both male and female) should participate in the experiment. The participants are given a textual description of a business process. Based on this description a corresponding process model has to be created using a particular business process modeling language, implemented in the form of a software tool. Such an experiment setup presupposes that the participants should keep their natural position and should be able to move freely during the experiment (see Fig. 9 in publication [1]). In essence, the measurement instrument must not be too intrusive.

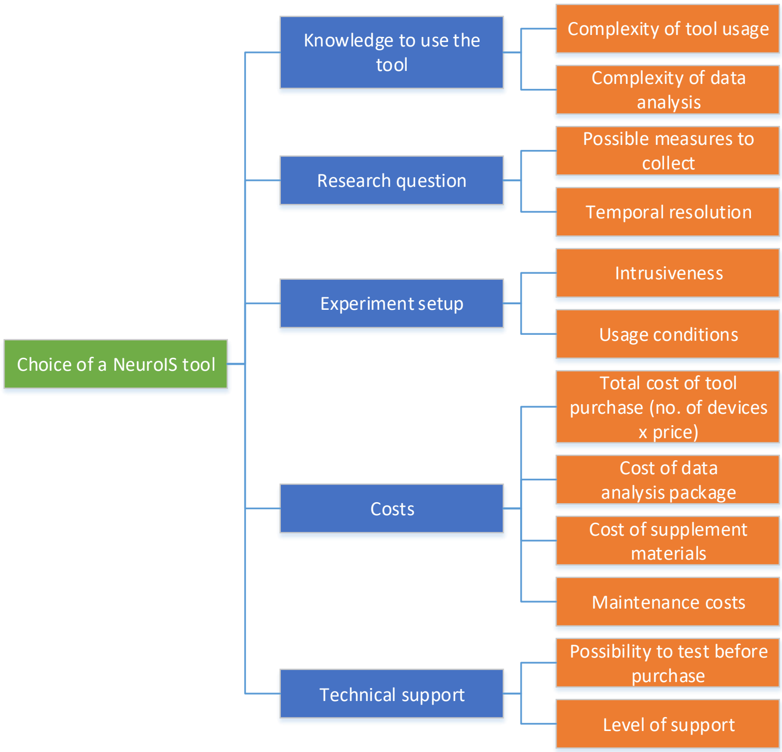

Fig. 2. Example AHP hierarchy for NeuroIS tool selection

Another important decision criterion is total costs. Total costs typically include tool acquisition costs, data analysis software costs, costs for supplement materials, and maintenance costs (e.g., electrodes). Also, availability and level of technical support have to be considered, including the possibility to test both the measurement instrument and data analysis package before actually purchasing it.

4 Conclusion

Selection of a NeuroIS tool is a multi-criteria decision problem, which depends on such aspects as intrusiveness, knowledge to apply a tool, or costs. Especially for novice researchers it is difficult to choose a suitable measurement instrument in a specific research scenario. Drawing upon an AHP-based approach, in this paper we presented an exemplary framework for selecting a NeuroIS tool. It is hoped that this framework provides help, particularly for novice NeuroIS researchers who are faced with the decision problem of selecting a NeuroIS tool. Finally, despite the fact that we consider this framework as relatively generic in nature, researchers are advised to adapt this framework to their own research purposes and scenarios. Specifically, this implies that more and/or different decision criteria (see Fig. 2) have to be used.

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Foreign Live Biofeedback: Using others' neurophysiological data

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Abstract. Advances in sensor technology and real-time analysis of neurophysiological data have enabled the use of live biofeedback in information systems and the development of neuro-adaptive information systems. In this article, we transfer this notion to the use of foreign neurophysiological data. We sketch out an experimental approach and research model for investigating the impact of such foreign data in a trust scenario. We argue that foreign live biofeedback may be a powerful means to establish social presence and thus trust among the parties. Moreover, we discuss controversies such technology is likely to raise and sketch out potential strategies for IS service providers in this regard.

Keywords: NeuroIS · Live Biofeedback · Decision Support · Trust Game

1 Introduction

Recent advances in NeuroIS research have enabled monitoring and utilizing neurophysiological data in form of additional user information in real time, namely live biofeedback (LBF). While personal LBF was in the focus of recent NeuroIS studies [1,2] the utilization of some *other* person's neurophysiological data for own decision-making processes or purposes has only gained little attention so far.

Within the scope of this article, we discuss the potential of foreign live biofeedback (FLBF) as a possible technological development in the area of neuro-adaptive information systems [3], and discuss its implications on research and possible impacts on everyday life. We define FLBF as a one-to-one provision of neurophysiological data from one person to another in real time. Specifically, we address how employing FLBF influences trusting behavior between two persons (modeled in a trust game based on [4]). Pointedly, we ask:

RQ: *How does the provision of foreign live biofeedback impact the behavior of players in a trust game situation?*

Recent advantages in information technology made it possible to measure and interpret neurophysiological data [5]. FLBF is based on the idea of measuring, processing, and interpreting others' physiological data, such as heart rate or pupil diameter in the user's immediate environment in real-time. Examples for personal measuring devices are the rationalizer developed by ABN AMRO and Philips [6], or the wireless multi sensor bracelet [7]. Given ubiquitous, seamlessly usable, and increasingly powerful devices like smartphones, smartwatches, and camera-equipped glasses, such data can be collected even without being noticed by the subject under investigation. As of today, high resolution cameras are capable of detecting even smallest differences in skin brightness and color, enabling an observer to algorithmically determine heart rate [8].[1] Clearly, from an ethical point of view, this is alarming and will most likely raise controversies or even restrictive legal measures in the future. For instance, it was recently argued that "information gathered on a person's physiology should be considered to be owned by that person" [9], and that measuring such data should be regulated to protect privacy. However, the question arises if, once available, the use of FLBF technology will be evitable at all as policies to protect privacy of neurophysiological data might turn out to be difficult or even impossible to enforce.

2 Theoretical Background and Research Model

Our approach to capture the effect of FLBF on behavior is based on the concept of perceived social presence. We acknowledge that other factors may be at play too. As FLBF represents a novel approach, we deliberately limit complexity and strive to trace back its effect to a well-established concept. In terms of implementation, we apply a standard trust game as proposed by [4] and also used by [10] in the context of NeuroIS research.

FLBF touches a very private aspect of other persons' character, as it directly provides insights into his or her emotional state. We hence suggest that FLBF is capable of conveying social presence. With respect to a communication medium, social presence can be defined as the extent to which "the medium permits users to experience others as being psychologically present" [11], which is of particular interest for online applications. Socially rich design elements can be used to create a positive user experience. In the context of online shopping, higher levels of social presence were found to positively impact perceived usefulness, trust, and enjoyment [12,13]. Also [14] confirmed social presence as a necessary precondition for trust. Better understanding how to create social presence in online contexts is thus key for researchers and practitioners. Examples include images of human faces or personalized text [12], [15]. Psychologists associate the effect of social presence with an inherent human tendency to strive for the presence of other humans and a feeling of human warmth and sociability. We propose to also investigate the role of another person's neurophysiological data in the process of creation and perception of social presence.

[1] Michael Rubinstein: "See invisible motion, hear silent sounds" at TED presentation, November, 2014 (http://goo.gl/KqWLJz).

As stated above, social presence is capable of creating trust. The economic standard protocol for trust situations is referred to as Trust Game [4]. Here, the first player decides on how much of an endowment (e.g., [10] monetary units) to transfer to the other player. Any transfer is multiplied by a factor $\delta > 1$ (e.g., $\delta=3$) and credited to the second player, who then decides on how much to transfer back. The interaction features cooperative as well as competitive aspects, which renders the introduction of neurophysiological data particular interesting. Situations concerning trust cover a wide range of business processes, like selling procedures or team work [16].

Our research model distinguishes the situation for the two types of players (trustor and trustee) as depicted in Fig. 1. As it represents a highly personal bit of information, we suggest that providing FLBF on the respective other person increases social presence (H_1 and H_4). In particular, we argue that because FLBF shows a continuous feedback about the counterpart's physiological state, this design element should directly increase the extent to which the medium permits users to experience the other person to be psychologically present. Moreover, the literature outlined above suggests that perceived social presence increases trust and benevolent behavior, which, for the trust game, is represented by the amounts invested (H_2) and returned (H_5). Hence, our working hypothesis is that the effect of the treatment manipulation FLBF on behavior is mediated by social presence. Whether or not there remain direct effects of FLBF remain open questions for the time being (Q_3 and Q_6). Lastly, the amount invested is a necessary variable to understand the amount returned, as high investments by the trustor i) are likely to be answered by higher returns out of gratitude or reciprocity, but ii) enable the financial leeway for such higher returns in the first place (H_7).

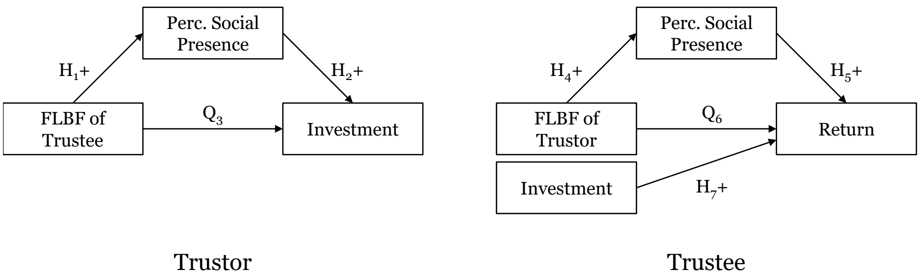

Fig. 1. Research models for trustor and trustee perspective.

3 Concluding Note

Against the background of rapid technical progress and increasing privacy concerns, questions on whether and how one's *own* neurophysiological data is used by others, will gain in importance. Based on high definition microphones, high resolution digital photography, and devices such as the Google Glass, no user can be sure to what extent other people spy on and exploit their neurophysiological data [9]. We believe that a multidisciplinary debate on this issue is due. By providing novel insights into how pirating other user's physiological data affects behavior, our research aims at contributing to this debate.

There are several conceivable practical applications for FLBF in business contexts. The most interesting appear to be negotiations and sales conversations. Being able to precisely evaluate one's counterparts' mood and temper in real time certainly represents a beneficial skill when trying to sell a product or negotiate a deal. It provides the user with an artificial form of emotional intelligence, which is "the ability to monitor one's own and others' feelings and emotions, to discriminate among them and to use this information to guide one's thinking and actions" [17] and evidently influences management capabilities [18,19], group effectiveness [20], and social interaction [21].

From the opposite perspective, being monitored by others is certainly not always desired. This thought is firmly illustrated by a series of attacks against Google Glass wearers.[2] For IS service providers, this potentially opens up a new field of business. Future video conference software, for instance, may apply filters to cancel out revealing neurophysiological signals such as variations in skin color or voice tone, and companies could advertise themselves as effective guardians of individual privacy.[3]

In summary, FLBF will most likely be a much debated topic for future IS applications and research—entailing obvious risks but also potential benefits. In this article, we have presented a first step towards investigating the role of such FLBF in IS by tracing it back to the well-established concepts of trust and social presence.

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[2] http://goo.gl/6Uez2n

[3] In a similar context, the search engine *DuckDuckGo.com* distinguishes itself from its competitors as "the search engine that doesn't track you."

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What does the skin tell us about information systems usage? A literature-based analysis of the utilization of electrodermal measurement for IS research

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Abstract. The term NeuroIS appears more frequently within the field of information system (IS). NeuroIS describes the idea of applying cognitive neuroscience theories, methods, and tools to obtain physiological responses of the user while using IS. However, before adopting these methods into IS research, a proper assessment is necessary to determine whether the methods used in other disciplines are also applicable to IS research. The present research introduces the method of measuring the electrodermal activity (EDA). Thereby, the physiology and different measurement parameters are described. By identifying the use of EDA within other disciplines, the present research reveals application areas for EDA in six different research streams in IS research and poses further research questions, which might be answer by applying EDA in these areas.

Keywords: electrodermal activity · EDA · skin conductance response · information systems

1 Introduction

The term NeuroIS is increasingly emerging in the field of information system (IS) research, which describes the idea of *"applying cognitive neuroscience theories, methods, and tools to inform IS research"* [1, p. 1]. The utilization of NeuroIS is expected to collect not only perceptive data but additional objective data, as well, which might enhance and improve IS theories and allow deeper insights on the core issues and research questions of IS research, such as IS adoption or the design of ISs [2,3]. However, before blindly adopting NeuroIS methods, a proper assessment is necessary with special consideration towards the discipline's subject matter as well as the goals of scientific inquiries. The rationale for this is that not all of the methods, which are used in other disciplines, can appropriately be transferred to IS research [3]. Riedl et al. [3] state that *"IS scholars need to become familiar with the methods, tools, and measurements that are used in Cognitive Neuroscience and in related disciplines (e.g., Psychophysiology)"* (p. ii). In the research history of psychophysiology the measurement of electrodermal activity (EDA) is one of the most widely used response systems [4]. Electrodermal measurement captures human responses by analyzing the electrical phenomena in the skin [4,5]. Among NeuroIS measurements, EDA is one of the most price effective measurements [6,7] and its utilization spectrum ranges from clinical research to behavior and attention research to information processing investigations [4]. In IS research only few studies use EDA measurement for examining IS related research questions [8–12]. Particularly because of its advantages in price and its enormous application range in other disciplines, the present paper aims to assess application areas for electrodermal measurements in IS research and thereby intends to answer the following research question:

What are the application areas of electrodermal measurement for IS research?

To respond to this question, we first explain the physiology of the psychophysiological phenomenon EDA. Second, we summarize how EDA has been used in IS research. Third, we briefly explain our methodology. Lastly, we point out limitations and acknowledge future research streams.

2 Electrodermal activity

Electrodermal activity is the general term for all electrical phenomena in skin, including all active and passive electrical properties, which can be traced back to the skin and its appendages [5]. To understand the physiological explanation behind these psychophysiological responses we next describe the physiology of the electrodermal system. Subsequently, we demonstrate different electrodermal recordings.

2.1 Physiology of the electrodermal system

There are three different pathways from the central nervous system to the sweat glands [4,5]. Theses pathways are taken by encountering stimuli, which lead to an activation of the eccrine sweat glands causing a sweat secretion. Humans have two different kinds of sweat glands which differ in location and function [4]. Apocrine sweat glands are more likely influenced by hormones rather than by neurons and take the function of sweat glands, whereas eccrine sweat glands are more interesting from a psychophysiological perspective, because they are located in the palms of the hand and soles of the feet and are influenced more by emotional stimuli than thermoregulation [4]. These changes in the skin can be captured by using electrodermal measurements, which are described next.

2.2 Methods of electrodermal measurement

For recording electrodermal activity, two small electrodes are placed at the surface of the skin, across which a low electrical current flows. These two electrodes allow to measure a change of the skin in response to different stimuli [4,5]. Two major methods of EDA recording exist: the **endosomatic method** which does not use an external current for measuring and recording the potential of the skin (SP) and the **exosomatic method** which uses an external, low electric current flowing across the skin. The latter is able to capture skin resistance (SR) and skin conductance (SC). These two measures are based on Ohm's law, *"which states that the skin resistance (R) is equal to the voltage (V) applied between two electrodes placed on the skin surface divided* *by the current (I) being passed through the skin; that is, R=V/I"* [4, p. 204]. Consequently, skin resistance can be captured by measuring the voltage between the electrodes while keeping the current constant. In contrast, skin conductance can be captured by measuring the current flow while keeping the voltage constant [4]. EDA is divided into a tonic und a phasic level. The **tonic electrodermal measurement** is *"the absolute level of resistance or conductance at a given moment in the absence of a measurable phasic response"* [4, p. 201]. In other words, tonic values represent EDA over a longer period of time and are referred to as skin resistance level (SRL) or skin conductance level (SCL). The **phasic electrodermal measurement** takes the increases in resistance or conductance into consideration, which occurs in the tonic phase mostly triggered by different stimuli. Increases in resistance are called skin resistance responses (SRR) and increases in conductance are labeled as skin conductance responses (SCR). The ideal phasic electrodermal response (EDR), shown in **Fig. 1**, encompasses other parameters, which are described in **Table 1.**

Table 1. Electrodermal measures

Abbreviation	Definition
SCR freq.	skin conductance frequency means the number of EDRs in a given time window
SCR amp.	skin conductance amplitude refers to the height of a single response
SCR lat.	skin conductance latency is the time from the stimulus onset to the response onset in the case of a specific EDR
SCR ris.t.	skin conductance rise time is the time from the onset of a response to its maximum
SCR rec	indicating the time that is needed to recover
SCR rec.t/2	time that is needed to recover 50%
SCR rec.tc	time that is needed to recover 63%
NS.SCR	non-specific response

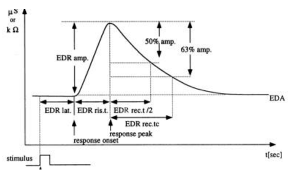

Fig. 1. An ideal EDR and all parameters of EDA (adopted from Boucsein [5, p. 154])

3 IS research and electrodermal activity

Electrodermal measurement is introduced as NeuroIS method by Dimoka et al. [7] and has been utilized in technostress, auction bidding, and decision-making contexts within IS research. In technostress context Eckhardt et al. [8] use EDA to measure the strain level of individuals under performance pressure. Results show that users under pressure to perform~~,~~ indicate a higher strain level than users not under pressure. Riedl [13] explains the human stress system and thereby states that EDA is one opportunity to capture biological stress responses. Riedl et al. [9] investigate individuals' physiological response to the malfunctioning of technology. They use EDA to measure strain reaction of men and women in cases of system breakdowns and reveal that gender differences are significant by examining technostress. In the context of auction bidding, Hariharan et al. [10] use EDA to measure arousal and its influences on bidding behavior. Minas at al. [11] apply EDA in the context of decision-making. EDA is used to measure the emotional response to information as an important component of the decision-making process. In this context, Leger et al. [12] use EDA to measure emotional responses while people make business decisions. In sum, EDA has been used to examine different phenomena and to answer various research questions. However, the dissemination of electrodermal measurement in IS research is generally low.

To close this research gap, we next show the various applications of EDA and present areas of application for IS research.

4 Application areas of EDA in IS Research

Outside of IS research, EDA has been applied in various disciplines and hence, has been used to answer a wide variety of research questions. The spectrum of utilization of EDA ranges from clinical research to behavior and attention research to information processing investigations [4]. This section aims to show application areas of EDA for IS research and how IS research can take advantage of the electrodermal measurement. Therefore, we draw on the NeuroIS research framework [14] which structures and standardizes NeuroIS studies. Deviating from the framework, we start by choosing the NeuroIS tool EDA and try to go backwards to reveal research gaps in the IS discipline which can be closed by applying EDA. Therefore, we start by analyzing several research streams in which EDA has been applied within other disciplines based on Boucsein [5]. Subsequently, we show the relevancy of these research streams in IS research and based on that we extrapolate application areas of EDA for IS research. **Table 2** shows the research stream in the first column and its description in the second. The third column demonstrates the relevancy of the research stream in IS research and shows further research objectives within theses areas.

Table 2. Six application areas of EDA for IS research (shown in the first column)

	EDA application in other disciplines	**Application areas of EDA for IS research**
Arousal	Phasic EDA parameters such as NS.SCRs are assumed to reflect the arousal state, while the SCR amp. has been found to correspond to the inverted-U-function [5, p. 349]. In contrast to that, tonic EDA parameters show only a slight increase as a result of arousal process [5].	Emotional states such as happiness, excitement, or arousal might have an influence on IT usage [15, 16]. Hence, applying EDA in this context might enable us to obtain the following: 1. Obtain objective measurement of arousal and confirming its influence on IT usage. 2. Studying the interplay between objective emotions and cognitions.
Stress	The tonic components of EDA (e.g., SCL) increase while encountering stressful stimuli [17, 18]. Most of the examinations using EDA for measuring stress use the tonic EDA parameters, however, some investigation proposes that phasic parameters such as NS.SCR freq. also indicate stress [19, 20].	Over the last years several investigations within IS research examine the antecedents and consequences of technology-related stress named technostress [21–28]. However, besides two examinations [8, 9], most of these investigations only measure technostress perceptive rather than applying physiopychological methods such as EDA, although a current investigation reveals that physiological stress measurements and self-reported measurements measure two disjoint phenomena [29]. Hence, applying EDA in this context might enable us to obtain the following: 1. More holistic comprehension of antecedents and consequences of technostress. 2. Identification of unconscious technology-related stimuli, which can not be captured by self-report. 3. Studying the interplay between psychological, physiological and behavioral technostress.
Coping	The tonic component of EDA the SCL decreases while performing coping mechanisms [17, 18]. Most of the examination using EDA for measuring stress or coping use the tonic EDA parameters, however, some investigation proposes that phasic parameters such as NS.SCR freq. also indicate stress and the influence of coping [5].	Coping has been studied in IS research [30–33]. Several investigation examine coping mechanisms which explains individual IT users' behavior of avoiding the threat of malicious ITs [30–32]. In technostress context, coping mechanisms which counteract the effect of technology-related stimuli has been investigated [33]. Hence, applying EDA in this context might enable us to investigate the following: 1. Studying how coping mechanisms reduce physiology responses towards technology-related stimuli. 2. Analyzing which coping mechanisms are most effective [15].

Information processing	Past research indicates a relationship between EDA parameters and information processing [5, p. 314]. SCR recovery time can be interpreted as an indicator for readiness for information uptake [34]. For instance, short recovering times indicate an "open attentional gate", whereas long recovering times show a "closed attentional gate". EDA responses elicited by environmental change *"indicates a call for information processing resources"* [5, p. 319]. Furthermore, internal cognitive processes such as thoughts or expectations may themselves elicit SCRs [35]. The use of NS.SCR freq. as a tonic EDA measure may reflect the general presence of highly arousing negatively tuned cognitive activity [5, p. 320].	As part of the discipline's name, information and knowledge are at the core of the IS domain [36]. However, within the discipline the term information is not clearly defined and not fully understand [37]. Therefore, it is called to investigate human information behavior in order to design ISs [37]. Furthermore, in this context information overload has also been of interest [38, 39]. Hence, applying EDA in this context might enable us to investigate the following: 1. Analyzing open attentional gate and close attentional gate for information processing while using an IS. 2. Objective analyses of thought and expectations within the context of information overload [38].
Decision making	The somatic marker hypothesis [40] proposes that emotional processes guide behavior. Regarding EDA the parameter SCR amp. is supposed to reflect this somatic marker. Bechara et al. [41] provide a method to properly use SCR amp. to measure decision making. For example, differentiation between "good" and "bad" decisions can be analyzed by means of anticipatory SCRs [5, p. 332].	Several current examinations focusing on decision making within IS research [42–48]. EDA can be used to measure the emotional response as component of the decision-making process [11, 12]. Hence, applying EDA in this context might enable us to investigate the following: 1. Objectively analysis of good and bad decisions. 2. Studying the differences between emotional-driven decisions vs. cognitive-driven decisions. 3. Analysis of emotional processes guide decision making.
Memory storage	SCRs are also discussed as potential indicators of information storage and retrieval. Stimuli leading to a higher SCR amp. have a greater probability of being transferred to long-term memory (LTM; [49]). An elicitation of large SCR by a stimulus did not facilitate its representation in the short-term memory (STM). EDA indicates races for highly arousing stimuli in LTM. Boucsein [5] states that different SCR parameters indicating for stimulus processing in STM and LTM.	Literature in IS research shows how the various components of memory storage and retrieval play in the context of technology use [50]. Intentions are the major determinant of IT use [51–54]. This mental effort occurs mainly in short-term working memory [50]. Additionally, IS literature shows that IT usage is over time a function of habit rather than of conscious intentions [50, 54–57]. Habits activate technology use without any conscious effort, because information is stored in implicit long-term memory [50]. Hence, applying EDA in this context might enable us to investigate the following: 1. Analyzing what information is stored in LTM what in STM in order to identify differences between intentional and habitual behavior. 2. Analysis of the formation of habits within implicit LTM. *3.* Objective measurement of habitual usage.

Kommentiert [CHW1]: Included Leger et al. 2014

5 Discussion, implication and future research

The present research aims to show application areas of EDA for IS research. Therefore, we first introduce EDA by explaining the physiology of electrodermal measurements and by showing different EDA parameters. A short presentation of EDA usage in IS research shows that this method is not widespread in this field of context. In contrast, however, EDA is one of the most widely used response systems and its utilization spectrum ranges from clinical research to information processing investigations [4]. Therefore, we analyze the utilization of EDA in other disciplines. Based on that, we extrapolate application areas of EDA for IS research. Thereby, we contribute to IS research by revealing application areas of EDA for six different research streams and pose further research questions, which might be answered by applying EDA. As the present approach identifies general application areas, future research might extend these areas and furthermore specify the utilization of EDA in each identified research stream.

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A Novel, Low-cost NeuroIS Prototype for Supporting Bio Signals Experimentation Based on BITalino

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Abstract. Principles of openness and collaboration that catalyze open-source software innovation have also been successfully transferred into the world of hardware [1]. Advances in open-source hardware allow students, researchers and hobbyists to custom build devices for a wide variety of purposes. Open-source prototyping platforms like Arduino and Raspberry Pi empower people to build cheap, modular, and easy to use alternatives to expensive commercial grade scientific equipment. The authors argue that the use of open-source hardware in building neuroIS research tools will dramatically decrease the costs and complexity associated with research in university laboratories. In this work, we discuss the use of open-source hardware in neuroIS research. We present the design of a neuroIS research tool based on BITalino, a biosignal capturing and processing platform. We also present a novel prototype that is specifically tuned toward neuroIS research using the API provided by the creators of BITalino.

Keywords: NeuroIS · BITalino · Arduino · Open-source · Electrodermal Activity · Electrocardiogram · Biomedical signals

1 Introduction

Principles of openness and collaboration that catalyze open-source software innovation have also been successfully transferred into the world of hardware [1]. The proliferation in open-source hardware advancements has granted researchers the ability to custom build their own tools for various research problems. This increases the access to sophisticated research equipment which can be significantly cheaper than commercial grade hardware. For instance, the Arduino platform has made it possible for the do-it-yourself community to build complex devices from modular and easy to use components [4]. Arduino is a multi-purpose open source hardware prototyping platform targeting hobbyists, researchers and students. Such platforms enable developers to interact with the physical world through sensors and actuators. Consequently, this trend facilitated the creation of tools that can be used for research. Examples of such contributions can be seen in different fields, one of which is agriculture [2] where an Arduino based system was developed to detect crop status by monitoring soil moisture. Another example is BITalino, a biosignal acquisition system based on

Arduino [3]. It comes as a kit featuring a self-contained electronic board with sensors for Electrocardiogram (ECG), Electrodermal Activity (EDA) and Electromyogram (EMG) among other sensors. A BITalino board is ready to use out of the box, it is also supported with a wide variety of APIs that allow for accessing the board's functionality programmatically.

Motivated by this trend, it is our intention in this article to present to the neuroIS community a tool that supports some of their research activities. Particularly, our aim is to support activities relating to interfacing with a biosignal acquisition platform, in this case, BITalino. These activities include recording subject biometric data, visualizing signals, specifying recording session time, stimuli setting and display order. Additionally, features for data logging that support data analysis as well as exporting data to modular formats for post-processing and reporting will be offered in subsequent releases of the proposed prototype.

2 Background

Researchers in the neuroIS community often encounter some obstacles such as access to scientific tools that are quite expensive. High grade commercial scientific equipment can be relatively expensive to many students who are interested in studying biomedical signals. For example, an fMRI session can cost a researcher up to $500 USD per hour [7], and purchasing commercial grade equipment can cost researchers thousands of dollars. Furthermore, researchers may have to locate other auxiliary software for customizing their experiments based on their needs. For instance, researchers, who are examining subjects' neurophysiological responses to stimuli may need different software to create and conduct their experiments. Software which supports experimental psychology exists, examples include Open Sesame [5] and PsychoPy [6], however, these packages lack the functionality specific to neuroIS experimentation. Thus, the proposed prototype has been derived as a response to the scarcity of a convenient, self-contained system that has the ability to build an experiment, control its flow, acquire and visualize the data, and potentially process and analyze stored signals. Having a self-contained system will reduce the complexity of conducting experiments along with reducing its costs.

3 Design

Following the principles of the design science research paradigm [9], our proposed artifact takes the form of a software instantiation. The development commenced over two cycles of 2 weeks each. Emphasis on orienting the solution towards neuroIS research has guided all the design decisions. After conducting several brainstorming sessions, a set of design guidelines and functional requirements was reached and then prioritized. First, it was essential to provide the user with a multimedia repository that allows tagging media items (text, images, audio or video) based on its content. Having such a repository in a self-contained solution allows for specifying the stimuli to display during a biomedical data acquisition session. Second, the design also features the ability to specify triggers scheduled to occur during a recording session. Whether a recording session is automated (i.e. stimuli appearance is predefined on the timeline by the researcher) or subject-triggered, guaranteeing synchronization between triggers and the signal becomes essential. Additional features allow the researcher to design an unattended recording session in addition to storing the procedure for sharing or for later use.

The high-level architecture is shown in fig. 1a. It was conceived during the first iteration and was used as a point of reference throughout the development process. Fig. 1b and 1c show the final hardware design and the BITalino board respectively.

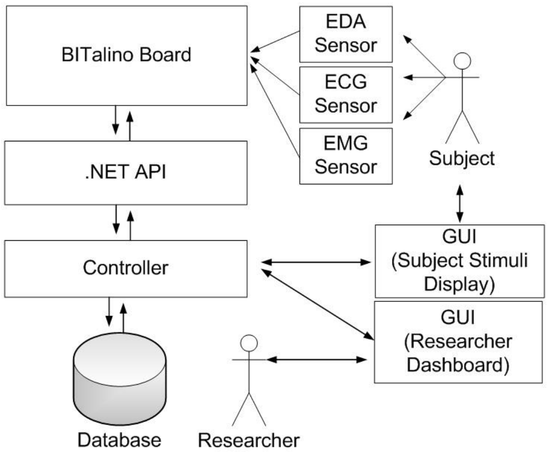

Fig. 1 a. Architecure for NeuroIS research prototype

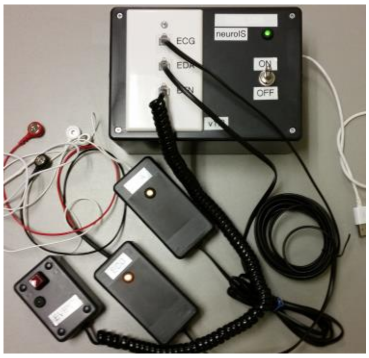

Fig. 1 b. Tool in enclosure

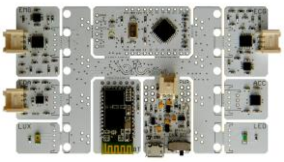

Fig. 1 c. A BITalino Board

Two separate user interfaces were designed to support the researcher as well as display stimuli for a subject simultaneously during the recording session. The researcher should be able to visualize the captured signal in real-time while also observing the progress of the session. The subject's interface will solely be used to display stimuli and log keystrokes. The researcher can mark and annotate points on the signal that correspond to the instance where a stimuli was displayed.

As for the second iteration, several enhancements on the researcher-facing GUI were implemented. Overall system performance was enhanced by separating the GUI from the logic on two separate threads. A limitation in the proposed prototype is that the researcher can only select one sampling rate: 10, 100 and 1000 Hz across all channels. This limitation can be overcome during further iterations by using an additional microcontroller running in parallel to the one used in BITalino. As a result, the researcher will be able to specify the desired sampling rate for each sensor individually.

4 Evaluation

During initial evaluation, two subjects were recruited for two short recording sessions in which ECG and EDA signals were individually obtained. ECG was captured at 1 KHz sampling frequency. Three ECG leads were connected to the subjects following the Einthoven triangle [8]. As for the EDA signal, a 100 Hz sampling rate was selected. Two electrodes were attached to subjects' non dominant hand index and ring finger's palms. Fig. 2 shows the raw signals for both subjects. Fig. 3 shows a snapshot of the researcher-facing GUI used for visualization and annotation.

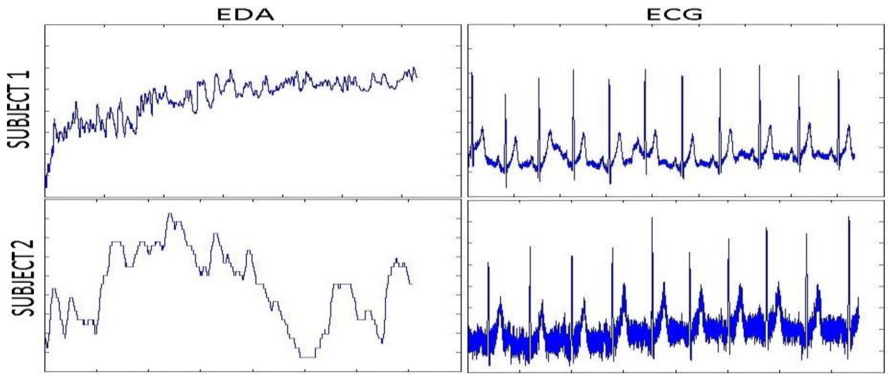

Fig. 2. Raw ECG and EDA reasings obtained from 2 subjects during alpha testing.

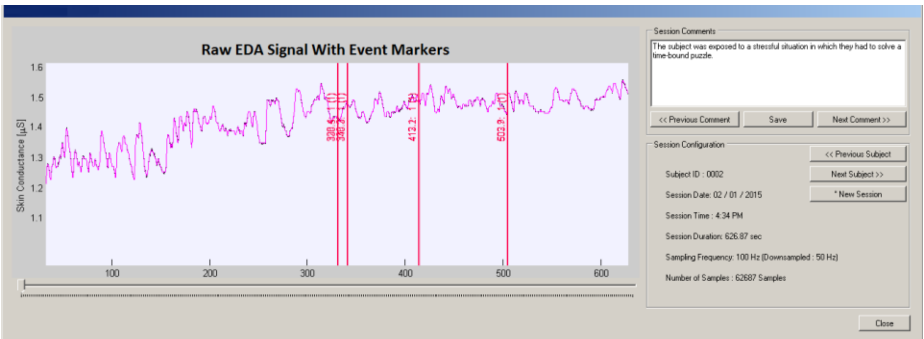

Fig. 3. Signal visualization and annotation screen from the researcher-facing GUI

During the recording session, both subjects were asked to relax for about 15 seconds after which they were asked to recall a stressful situation in order to observe changes to the obtained signal.

The planned evaluation for the proposed prototype will be performed throughout the course of the future development cycles. For the researcher and subject interfaces, multiple experiments with different types of stimuli, recording time and sampling rates will be conducted in order to gauge system performance and reliability.

Planned evaluation will further test system performance metrics relating to response time as well as ease of use. A survey to measure the overall ease of use will be distributed to all users who are interested in evaluating the beta version. Feedback from the evaluation will be utilized to derive additional design requirements during future releases.

5 Limitations

Several limitations exist in the proposed prototype. First, the microcontroller unit in the BITalino board can only sample at a unified rate across all channels. This can reduce flexibility when configuring sensor operation. Additionally, the prototype can be greatly enhanced with more feedback coming from further evaluation. The code will eventually be made available to the open-source community for additional enhancement.

6 Discussion

The proposed prototype is designed to provide researchers in the neuroIS community with a convenient and easy to use solution that is capable of designing and running experiments. Moreover, it facilitates running unattended recording sessions. The main objective of the proposed prototype is to reduce the complexity of running experiments by combining functionality within a self-contained solution. Researchers who are interested in conducting similar experiments would have to rely on multiple software packages in order to achieve their goals. As a response, this prototype aims to provide a one stop shop for students and researchers interested in biomedical signals and stimuli. Additionally, since the prototype is built around an open-source foundation, the cost associated with acquiring this prototype is significantly lower than that of acquiring commercial-grade research tool. At this point in the tool's lifecycle, the total cost is approximately $250 USD. This represents a small portion of commercial research equipment's cost.

7 Conclusion

Open-source platforms have the potential to dramatically reduce the costs of research while increasing access to sophisticated research tools. Such a trend has a great impact on the neuroIS community and on society in general. As for the neuroIS field, the proposed prototype has the potential to dramatically reduce the complexity and costs associated with research. This can, in turn, lower entry barriers to neuroIS research. Furthermore, we believe that such prototype is an exemplar solution that can be adopted and further enhanced once it is made available to the open-source community. This will aid in bringing more talent in order to refactor the prototype and increase its value to the users.

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The evaluation of different EEG sensor technologies

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Abstract. We tested seven different EEG electrode systems according user centered, operator centred and technical aspects. In the initial testing phase we focused on technical aspects and more simple experimental tasks. The results of these first tests were used to select the best three systems in an advanced testing phase. In this second phase a P300 based BCI was used to navigate through a multimedia player, selecting music and video clips. The results showed that each of the systems has its advantages and disadvantages which should be considered when planning furture NeuroIS studies using EEG.

Key words: EEG·sensor types · dry electrodes · water-based electrodes

1. Introduction

In the past years many papers have been published which used electroencephalography (EEG) to investigate brain patterns related to IS research topics like trust/distrust, technostress, neuromarketing or decision making [1,2,3,4,5]. Moreover EEG is the dominant method in contemporary NeuroIS research, e.g. 25% of all papers that appeared in the proceedings of the Gmunden Retreat on NeuroIS, constitutes investigations based on EEG. Since there are a lot of different EEG systems commercially available it is hard to find out which system fits best for one's own research. On the signal acquisition side there exist different criteria which may be used to categorize currently available electrode systems. The systems may be categorized based on amplification, the method to contact the electrode to the skin and the amplifier system.

(1) *Signal amplification:* In the past years there was an evolution from passive gel-based electrodes to active gel-based electrodes. Whereas the passive electrodes require the application of abrasive, conductive gel between electrode and skin the active ones function without the necessity to abrade the skin because the signal is pre-amplified at the electrode.
(2) *Skin contact:* Normally, the EEG is recorded from the surface of the head with gel based electrodes to get low electrode-skin impedance. If passive electrodes are used, the skin must be abraded beforehand to reduce the impedance. With active electrodes, which contain an amplifier inside, the electrode gel is injected between the electrode material and the skin. This allows a faster montage of the

electrode system. One of the main advantages of gel based active electrodes is their robust behavior, but the main disadvantages are the long montage time and the need to wash the user's hair after the recording. This can be overcome by using a dry electrode system (e.g. g.SAHARA, gtec, AT) or a water based system (e.g. TMSi, Twente Medical Systems International BV, Netherlands).[6,7,8]

(3) *Connection to amplifier:* Electrodes may also be distinguished by the method how they are connected to the amplifier. In most cases long lead wires are used to connect each single electrode to the biosignal amplifier which is interconnected through a USB cable with other computers. The disadvantage of such a setup is that the subject is quite limited in its mobility. The wireless amplifier systems (e.g. g.MOBIlab or g.NAUTILUS from g.tec; eego sports from ant neuro) release this constraint by using a Bluetooth connection between the computer and the amplifier.

In this paper we report first results on the evaluation of different commercially available electrode systems (see Table 1). The selected systems have been tested regarding technical factors (e.g. high signal to noise ratio, robustness to noise), user centered and operator centered aspects (comfortable to wear, short preparation time, long-term stability and reliability). Whereas the technical factors have been tested without montage on the scalp, for the two other testing aspects simple and advanced experimental tasks were performed on five and eight healthy volunteers, respectively.

2. Test Setup

The selected systems (see Table 1) have been tested regarding technical factors, user centered and operator centered aspects.

Table 1. Overview of evaluated electrode system with system properties

Company	Product name	Type of Electrodes	activ/ passiv	wireless	Positioning of electrodes	Hairwash necessary
TMSi	Mobita	waterbased	p	No	free	no
Emotive	EPOC	waterbased	p	Yes	fix	no
Advanced Brain Monitoring	B-Alert X4	gel	p	Yes	fix	yes
g.tec	g.SAHARA	dry	p	No	free	no
g.tec	g.GAMMA	hydrogel	a	No	free	yes
g.tec	g.NAUTILUS	dry	a	Yes	fix	no
Brain Products	actiCap	hydrogel	a	No	free	yes

We performed an initial testing, where more simple tasks have been executed and an advanced testing, where participants controlled a Multimedia player with a P300 based BCI system.

1.1. Technical Tests

To be able to perform a quantitative comparison, we defined several parameters that are subject of the testing and that can be compared. All quantitative tests of the sensors were performed with CE certified, released equipment. The parameters defined for the comparative tests have been a) DC behaviour of the amplifier and electrode, in a simulated environment; (b) Noise of amplifier and electrodes in a simulation environment; (c) Frequency response analysis and (d) Sensitivity of the electrodes for light. All the tests will include the whole system that is electrodes and amplifiers.

1.2. User and operator centered Aspects

The user centered aspects will mainly address the question of comfort of the system. For example is the montage pleasant/unpleasant, do the electrodes hurt after some time, is it necessary to wash the hair afterwards, etc. These aspects will further include preparation time and usability facts too. Additionally we used the System Usability Scale (SUS), a simple, ten-item attitude Likert scale giving a global view of subjective assessments of usability. The operator centered aspects additionally assessed questions concerning easiness of use, including time for cleaning the sensors and aspects concerning system integration and user friendliness of the software.

1.3. Initial testing

A sample of 5 healthy volunteers with no history of neurological disorders took part in this initial testing phase. All participants were naive to the purpose of the study and paid for their participation. They have to perform simple motor and cognitive tasks. Since we have extensive experience with brain oscillations (ERD/ERS), especially motor related and Event-related potentials (ERPs), like the P300, we used the following experimental tasks:

1.4. P300 speller

The P300 speller is a special type of BCI (Brain Computer Interfaces). BCIs are systems enabling communication between a person and a computer without muscular intervention, that is only by thoughts. The P300 speller is based on ERPs which are cerebral waves propagated in the cortex after visual, auditory or tactile stimulation. In the P300 speller, a matrix of letters and symbols is presented to the user on a computer screen. The rows and columns of the matrix are intensified successively for some milliseconds in random order. After intensification of a row/column, the matrix is blank. At any given moment, the user focuses on the letter /symbol he/she wishes to communicate, and mentally counts the number of times the selected letter/symbol flashes. In response to the counting of this oddball stimulus, the row and column of the selected symbol elicit a P300 wave, while the other rows and columns do not. The detection of the P300 makes it possible to match the responses to one of the rows and one of the columns, and thus identify the target symbol.

1.5. Motor task

For the motor task, participants have to perform/imagine a simple foot movement, which will induce special well known brain oscillations (ERD/ERS) over the foot area. After the presentation of a black screen (for 2 s) an arrow appears in the middle indicating the execution or imagery task. That is immediately after the arrow appears participants have to start their foot execution/imagination several times as long as the arrow is visible (5 s). After it disappears they should stop and relax.

The absence or even a very small component elicited during these standard experimental paradigms could be an indication for sensor quality.

1.6. Advanced Testing

Based on the results of the initial testing phase we selected the three best systems for the following advanced testing. Additionally a new EEG prototype, namely the g.NAUTILUS (g.tec, Austria) was included. A sample of 8 healthy volunteers took part in this testing. In the advanced testing the P300 BCI was used to run a special application, namely the Multimedia Player.

1.7. Test protocol

The test protocol consisted of six parts: (1) Preparation: Montage of EEG-cap and instruction of participants. (2) Speller training: The word “BRAIN” was used for P300 training (3) First copy spelling run: The participants had to spell the words “SONNE” and “BLUME” consecutively.(4) Multimedia player run: The subject had to start a slideshow and to look at certain pictures within the multimedia player. Every command to be selected was indicated by the investigator. In the ideal case, the task could be completed with ten correct selections. To correct wrong selections, the investigator indicated a correct alternative or the way back to the last correct selection. If the goal couldn’t be reached within 15 selections the task was aborted. The matrix for this task consisted of six rows and three columns. (5) Second copy spelling run: This was equal to (3). Like in the initial testing participants completed several usability questionnaires (NASA-TLX, eQUEST2.0, VAS) after the measurement.

3. Results and Discussion

Study participants achieved mean correct selection accuracies above 70 % for the different tasks with most of the tested systems. The gel-based g.GAMMAsys provided best test results for all tasks. In both testing scenarios, initial and advanced, the dry electrode systems were very sensitive to movements. This fact might partly explain the lower performance of g.SAHARA and g.Nautilus, compared to the gel-based g.GAMMAsys. Some problems occurred during the measurement with three participants with the g.Nautilus. It was impossible to perform the calibration of the P300 BCI system. Since the same users had no problem with the g.Sahara system, which uses the same electrode type as the g.Nautilus, the source of the problem is very likely the g.Nautilus headset. We assume it may be a problem of the radio connection between the amplifier and the base station. Maybe another radio transmitting device which uses the same or a neighbour frequency channel interferes with the g.Nautilus. Similar problems occurred also with the Mobita system, which uses a fixed WLAN channel. If another WLAN device uses the same or neighbouring channels, the system sometimes performs worse or stops working without any additional notification. (Remark: These problems have already been solved by the system developers).

The VAS scores reveal a high satisfaction of the users with all the systems. Some users rated systems with lower than 5,0 which means “not satisfied”. This can be explained by the frustrating low P300 selection accuracies of those persons. The 3 most important features, evaluated by the eQUEST2.0 test, are (1) speed, (2) effectiveness, and (3) durability together with the learnability. The values for the most important feature, speed, are between 3.3 and 3.7. These values are lower compared to the values of the other eleven questions. So the participants were mainly unsatisfied with the speed. Concerning user-centered aspects the dry and water-based systems were better rated since no hair wash after the measurement was necessary and the setup was faster compared to the gel-based.

Concluding, the choice for a special EEG sensor type should consider the type of signal which will be measured (oscillations or ERPs), the sample of participants (patients or healthy) and also the type of task (e.g. motor or cognitive), to guarantee a reliable and low noisy measurement.

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Choice Architecture: Using Fixation Patterns to Analyze the Effects of Form Design on Cognitive Biases

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Abstract. User-generated online reviews are an important input into purchase decisions, but are susceptible to cognitive biases, which ultimately undermines the reviews' value. As even minor changes to the design of online environments (such as Web pages) can influence people's behavior, design modifications to online review forms could help reduce biases. We hypothesize that design modifications to online forms can help reduce three common sources of biases (availability, anchoring, and response style), and propose an experiment that employs eye tracking and recording of mousing behavior to test the hypotheses.

Keywords: Online reviews · choice architecture · biases · eye tracking

1 Introduction

User-generated online reviews of physical goods or services have become an important input into purchase decisions [1], and research has shown that purchase decisions differ based on the reviews potential buyers are exposed to [2]. Research has also shown that features such as length or depth of online reviews or the density and diversity of arguments [3] can influence whether a review is being perceived as helpful by the consumer [4]; in addition, it stands to reason that the accuracy or truthfulness of online reviews is important for consumers.

However, user-generated online reviews are per se subjective and therefore can be influenced by various biases, often resulting from heuristic thinking [5,6,7]. Yet, as biased reviews can lead customers to make suboptimal decisions [7], "the value of online rating systems depends on their unbiasedness" [7, p. 3]. Further, as biased reviews can cause a bandwagon effect, in that earlier biased reviews have the potential to influence later reviews [5], the cumulative effects of improved review quality can have wide-ranging impacts that go beyond any single review, and undermine the value of review systems [7].

Although biased reviews may also result from fraudulent behaviors, such as crowdturfing [8], opinion spam or fake product reviews [9], we investigate biases that are not caused by fraudulent behavior, but which result from reviewers' heuristic thinking. We argue that these biases are of particular importance since they happen largely subconsciously and thus affect a wide range of (if not all) online reviews. In this regard, reviews are not only based on judgments about the product or service itself, but are also influenced by cognitive biases during the *writing* of the review. For example, people may be influenced by viewing prior reviews [7]; such biases potentially influence ratings and, therefore, reduce the accuracy of reviews. Consequently, the overarching aim of this research is to improve the quality of the input into online review forms ex ante—that is, before and while the review is being written.

Drawing on literature from psychology, behavioral economics, and user experience, we reason that for online reviews, the design of the review form can have an important impact on review quality [10]. It is our aim to modify the design of online review forms to "debias" users' inputs. Thus, our research question guiding this study is: *How does the design of online review input forms influence product ratings?* To address this question, we propose hypotheses related to three common sources of bias, namely availability [11], anchoring [7], [11,12], and response styles [13], and describe a proposed experiment using eye tracking and recording of mousing behavior to test these effects in a simulated review scenario.

2 Online Reviews

Especially in business-to-consumer e-commerce, electronic word of mouth has become an important aspect of consumer decision making [14], with consumers sharing product or service evaluations on social media sites, online retailers' Web sites, or dedicated review sites (such as tripadvisor.com). As the reviewers have no stake in the product, such reviews are often considered more credible than marketing information [15]; further, the presence of reviews has been shown to influence the perceived usefulness of online shopping sites [1].

Yet, research focusing on the distribution of aggregate reviews has shown that online reviews are far from representative, with online star ratings of products or services often being biased towards the extreme positive or negative ends of the spectrum, resulting in a bimodal distribution [6]. Overall, biased reviews can have various negative consequences, for example by leading to suboptimal purchase decisions, potentially hurting a retailer's future business due to decreased trust [16].

2.1 Debiasing Online Reviews

In order to keep user-generated online reviews helpful, the overarching aim of this research is to reduce cognitive biases during the input into online review forms while the review is being written.[1] Research in the area of *choice architecture* has demonstrated that the design of environments (such as Web pages) can influence people's choices [10]. For example, in the context of organ donation Johnson and Goldstein

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[1] While some online retailers are attempting to use technological means to detect and remove fraudulent reviews (ex post), such attempts are beyond the scope of our research.

[17] have shown that simply changing defaults (opt-in or opt-out) in online forms can significantly influence whether people consent to being organ donors, suggesting that even small changes to forms can influence people's inputs.

Accordingly, such design modifications may also influence online reviews. Reviews are often influenced by biases stemming from reviewers' emotions, social influence, or even factors related to the time or device used [7], [18,19]; these biases are the result of automatic processing, or effortless, uncontrolled, subconscious and fast thinking [see, e.g., 20]. Debiasing—i.e., reducing the effects of cognitive biases by reducing automatic cognitive processing in favor of controlled processing [21]—may reduce deviations in judgment [see also 22,23] and may thus help to increase the quality of reviews. Tversky and Kahneman [11] have identified various heuristics that can bias judgment, such as availability or anchoring; in addition, responses styles may bias online reviews, leading to extreme ratings [13]. In the following paragraphs, we will hypothesize how to counter the effects of such biases using interface design.

2.2 Hypotheses

Availability. User-generated online reviews are likely to be influenced by the availability of thoughts, or "the ease with which instances [i.e., thoughts of products or services] can be brought to mind" [11, p. 1127]. We speculate that form granularity (i.e. presenting several rating dimensions instead of just one overall dimension) can reduce availability bias, as asking people to provide detailed attribute ratings is likely to divert attention away from the most easily accessible thoughts about a product or service, potentially lowering the effects of the availability heuristic. As a result, an interface encouraging attribute reviews will lead to less extreme reviews, which will be perceived as more helpful by other consumers [4].

H1: Form granularity will reduce the effects of availability

Anchoring. Another commonly occurring bias is related to anchoring and adjustment [11]. Specifically, people tend to use an initial piece of information as anchor, and adjust later decisions or judgments around that anchor. One such anchor possibly biasing reviews is the display of prior, existing reviews [7], [12], especially when provided alongside the review input form [5], as people tend to compare their own decision to the decisions of others [11]. One obvious way to reduce such effects of anchoring is to hide the ratings/reviews of others.

H2: Hiding reviews of others will reduce the effects of anchoring

Response Styles. Finally, people's response styles (i.e., the tendency to select the end points of a scale [13]) often lead to review star ratings displaying a bimodal distribution [6]; anchoring and adjustment may help to moderate the effects of such response biases and normalize the rating distribution. For example, we speculate that setting defaults (i.e., anchoring the star rating in the center) can help debias reviews, resulting in decreased review extremeness, possibly counteracting bimodal distributions.

H3: Setting defaults will reduce the effects of response styles

3 Proposed Study

To test these hypotheses, we propose conducting an experimental study. In particular, we will develop a Web site that mimics online review forms. Participants will be randomly assigned to a version of a fictitious scenario about a recent service encounter. After the participants have finished reading the scenario, they will be redirected to a distractor task lasting for about 15-20 minutes, to mimic the typical delay between a service encounter and the writing of the review and to reduce detailed memorization of the scenario. The scenarios will be created to be equivalent in length and level of detail, but differ in valence (positive/neutral/negative), allowing us to establish boundary conditions of the effects of the proposed design changes.

The participants will then be randomly assigned to different versions of the review system (see Figures 1 and 2), where they have to review the service provider, before providing demographic information and being debriefed and dismissed. Hence, the study will follow a 4x3 factorial design with 4 different Web site designs (control group, availability, social anchoring, and anchoring of star rating), and 3 levels of review valence (positive/neutral/negative).

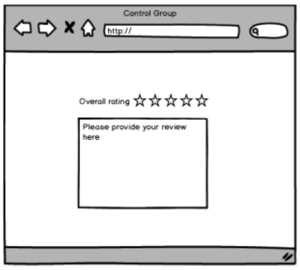

Fig. 1. Control group: Review input form with star rating and text input

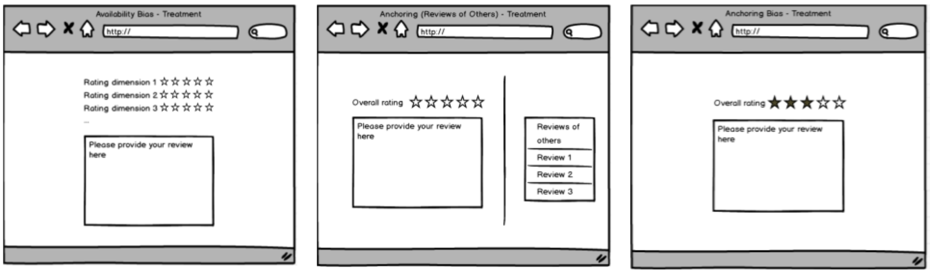

Fig. 2. Treatment groups: left: availability; center: anchoring (review of others); right: anchoring (star rating)

To examine the effects of the interface design on the dependent variables, we will 1) assess the quality of the reviews using independent coders, and 2), we will use text-mining approaches such as latent sentiment analysis (LSA) [24] to analyze the density and diversity of arguments [3]. Additionally, we will capture star ratings so as to be able to compare the distribution of ratings across different interface designs. As research has shown that star ratings often follow a bimodal distribution [6], we expect to reduce this effect when using the debiasing treatments (see Figure 2). At the same time, as neurophysiological methods can complement traditional methods by providing deeper insights, in particular when evaluating interface design [25,26], we will draw on neurophysiological methods to gain a deeper understanding of the underlying mechanisms in a low-intrusive [27] and comparably high-authentic context [28]. In particular, we will use eye tracking as this allows us to gather data on where and for how long participants focus on stimuli [29]. Against this background, we will capture and analyze the participants' gaze fixation using a Gazepoint GP3 eye-tracker. Fixation patterns can provide us with insights about the subjects' focus of attention or potential anchoring or adjustment processes during the completion of the reviews [see, e.g., 30]. Likewise, as eye movements tend to correlate with mouse data [31], participants' clickstreams and mouse movements can provide indications about changes in form inputs, which, for example may be indicative of anchoring or adjustment processes.

4 Expected Results and Conclusion

Drawing on literature in behavioral economics, psychology, and user experience, we argue that biases such as anchoring, availability, or response styles can influence online reviews, leading to suboptimal purchase decisions. Consequently, reviewers should be encouraged to use controlled processing instead of automatic processing to debias product reviews. We hypothesize that design modifications can reduce biases in user-generated online reviews, and propose a study to test these modifications. Our expected results contribute to the literature on human-computer interaction by providing design recommendations that can be easily implemented on Web sites to address the sources of subconscious biases.

Our research contributes to practice by helping to increase review quality, benefitting online retailers, review sites, and customers alike. Customers perceive reviews as being useful when shopping online [1], and online vendors are interested in quality reviews to positively influence their visitors' buying decisions.

In sum, the overarching objective of this research in progress is to reduce bias in product reviews by deriving theoretically based recommendations for the design of review input forms to increase the quality of online reviews. On a broader level, the expected results will provide a broader understanding of the influence of online form design on users' responses in general, and can be extended to a variety of other settings and contexts.

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Neurophysiological Analysis of Visual Syntax in Design

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Abstract. Creative design activities in the development of software-intensive systems involve the wide use of visual tools, such as flowcharts and UML diagrams. In this research-in-progress paper, we explore the potential of eye fixation related potential (EFRP) as a method to assess the efficacy of visual notations used to build and evaluate IT artifacts. Drawing on past work in the areas of visual syntax and semantics, we ask whether selection of visual forms is a significant predictor of design artifact quality and utility. In particular, we propose a study that combines the use of EEG and EFRP methods to analyze the neurophysiological correlates of how designers employ visual syntax in the development of IT artifacts for software-intensive systems. Implications for both research and practice are discussed.

Keywords: Visual notation · Diagrams · Design · Eye fixation related potential (EFRP) · Electroencephalography (EEG) · ArchiMate®

1 Introduction

In their exploration of the potential contributions to design-oriented research from neuroscience, vom Brocke et al. [12] highlight the persistence of conceptual modeling in the design process of IT artifacts. The notations used to represent models, constructs and instantiations that these artifacts comprise have evolved from flowcharts that first appeared in the 1940s. Moody [8] argues that the cognitive effectiveness of flowcharts and other more recent visual notations has been under-researched, particularly as regards their contribution to design.

Hevner et al. [2] propose a 2x2 model of the design process from the perspective of neuroscience (Figure 1). The x-axis distinguishes the External (Task) Environment from the Internal (Cognitive) Environment; the y-axis separates the Problem Space from the Solution Space. In this research, we focus on the iterations of observation and generation of candidate designs that advance the design build process from the internal problem space to the internal solution space, creating candidate solutions in response to the requirements in the problem space. The question to be studied concerns the forms in which the design candidates are represented, manipulated, and presented to the software system developers for implementation as use artifacts.

In this research-in-progress paper, we motivate the research in Section 2 with a concise presentation of visual notations and their syntactic and semantic implications for design. In Section 3 a research study is proposed using ERFP and EEG methods to explore how graphical symbols (syntax) impact the quality of artifact designs. Section 4 concludes with a discussion of research directions and implications.

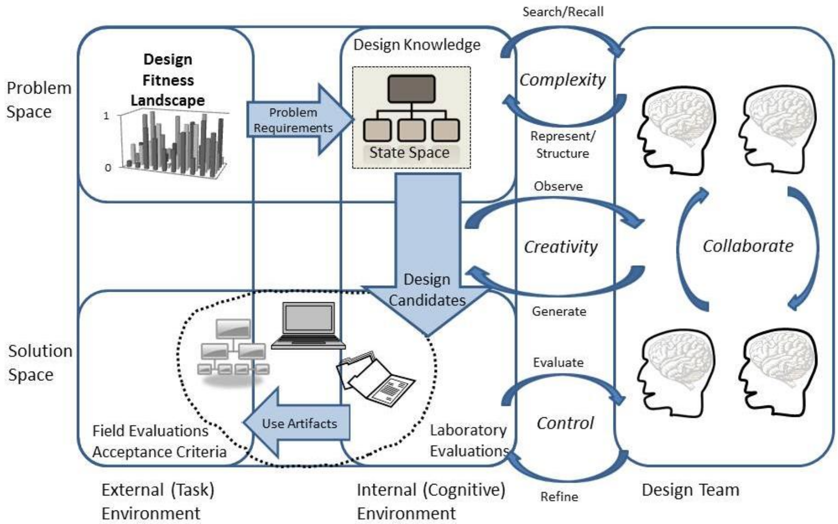

Fig. 1. NeuroDesign Model from Hevner et al. 2014 [2]

2 Visual Notations in Design

It has been observed that visual language (e.g. pictures) is perhaps the oldest form of knowledge representation, predating conventional written language by almost 25,000 years [11]. Visual notations play a critical role in communication during design activities in all creative fields. The power of graphical images stems from their capacity to 'tap' the highly parallel human visual and cognitive systems. Neuroscience studies show that almost a quarter of our brains are devoted to processing visual stimuli [5].

Visual notations used in the development of software-intensive system, such as flowcharts, UML models, Entity-Relationship Diagrams (ERDs), and ArchiMate diagrams, are uniquely oriented to human communication: their sole purpose is to facilitate the communication and problem solving activities central to design. However, their cognitive effectiveness – the speed, ease and accuracy with which they can be processed by the human mind – is largely assumed rather than having been empirically proven. Moody [8] points out that cognitive effectiveness is not an intrinsic property of visual representations. Cognitive effectiveness is something that must be designed into them [6].

A visual notation consists of a **visual syntax** composed of a symbolic vocabulary and grammar and a **visual semantics** that give meaning to each symbol and symbol relationship. Figure 2 describes the 2x2 relationships of visual syntax and semantics with usage levels of type (language) and instance (sentence) [8].

A survey of prior research shows that appreciation for and measurement of cognitive effectiveness of notational form (syntax) is particularly lacking in our understanding of how diagrams support the design process. Most research studies to date focus on the semantic content of diagrams while neglecting the effects of visual syntax on the quality of the resulting design artifacts. In fact, graphical symbols and conventions in software engineering diagrams are typically defined without any reference to theory, empirical evidence, or justification of any kind [3]. Thus, research studies of diagram effectiveness largely point to differences in content (semantics), neglecting the effects of visual syntax in the design process. The significance of this issue is compounded by the immaturity of methods for analyzing visual representations.

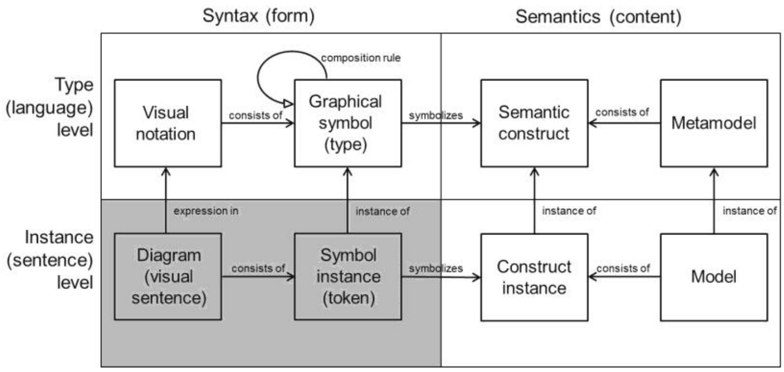

Fig. 2. Visual Notation: Semantics and Syntax from Moody 2009 [8]

In the research proposed here, we follow the call of Moody [8] for a deeper study of the cognitive correlates of how humans both encode information in diagrams as well as how humans decode information from diagrams. How do well-designed visual notations support human cognitive abilities to enable more effective encoding and decoding processes? Using the neuroscience methods of EFRP and EEG, we propose a study of fixation pauses as related to the syntactic qualities of (UML or ArchiMate) models.

3 Research Design

We propose to study how software developers read diagrams to understand existing software system artifacts and how they manipulate diagrams to design improved system solutions. Working at the level of symbol instances allows us to use EFRP to directly correlate EEG data to fixation pauses during 'interference' [12] with design artifacts. The symbolization of design constructs in UML and other diagram formats provides a unit of analysis that can be readily manipulated in our subjects' work environment. Our research design is bounded by the lower left quadrant of Figure 2.

The eye-fixation related potential (EFRP) technique uses electroencephalogram (EEG) data to measure electrical brain activity in response to eye-fixations. EFRP events are identified from EEG data by signal averaging [12]. However, in contrast to conventional event-related potential (ERP) techniques the averaged waveforms are time-locked to the onset and offset of eye-fixation rather than stimulus events. Prior studies (e.g. [7,10]) have shown EFRP to be useful in the investigation of early visual processes and for establishing a timeline of those processes during cognitive activities. Prior studies have focused on undifferentiated tasks, the majority of them using text-based reading as a common denominator to differentiate subjects' performance. Our research design builds on a study by Hungerford et al. [4] that identified anomalous (error) and non-anomalous events in the same session: this provides the equivalent of a control group and thus extends prior applications of both ERP and EFRP to the study of early visual processes.

Presenting subjects with a series of randomized tasks, some of which have been 'seeded' with syntactical anomalies, gives rise to a number of benefits. Firstly, the multi-task experimental session – about one hour – allows enough time for individual subjects to become comfortable with the equipment and the cadence of the experimental design: it also intrudes minimally in terms of both time and space in the work setting [9]. Secondly, gathering and analyzing the EEG 'live' in the subjects' work environment maintains the highest context-specificity

[12]. In turn, this allows the EFRP analysis to be interpreted through dialog with the subject: this 'talkback' component of our research design has proved effective in the articulation of characteristics pertinent to the cognitive effectiveness of other experts' work [1,4]. The experimental protocol provides a medium that enables the neurophysiological and interview data to be triangulated. To illustrate the type of study, we provide a fragment of an experimental protocol that we envision. Figure 3 shows a 'visual sentence' in ArchiMate that might serve as part of the experimental system design diagram.

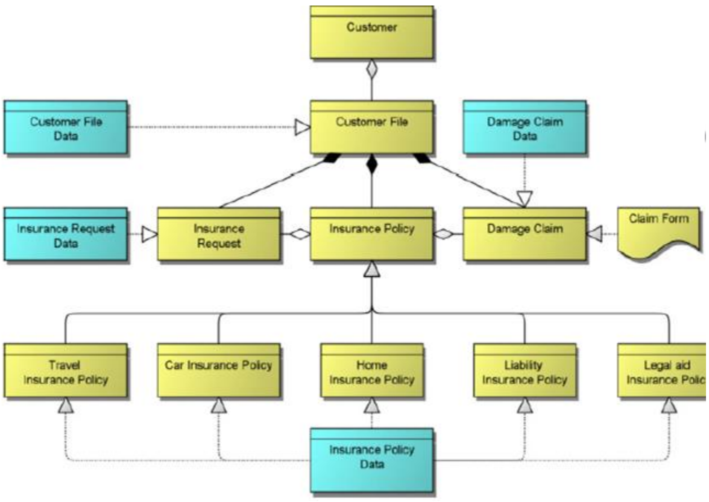

Fig. 3. A 'visual sentence' in ArchiMate®

Research Protocol

- Subject, EEG operator, and interviewer co-located at subject's workstation
- EEG consent, 'connection'
- Subject asked to assess the qualities (completeness, correctness) of a series of (ten) 'sentence level' diagrams in ArchiMate – some contain 'seeded' errors (à la [4])
- EEG operator uses EFRP to identify 'fixation pauses'
- Interviewer relates onset and offset in EFRP data to anomalies (errors) in the diagrams
- Subject articulates their analysis of the diagrams ('talkback') - verbal responses recorded

A series of experimental runs over different types of software engineering diagrams will provide us with a data set for the analyses of how these diagrams support the understanding of software design and the discovery of anomalies (e.g. defects) in the diagrams. The latter is a form of evaluation to complete the full design cycle of build and evaluate.

4 Discussion and Future Directions

From this research proposal, we anticipate three related findings:

- We expect to see few if any overlooking errors [7]. Our subject pool shares a level of competence with the design task and familiarity with the notation at the language level: it seems reasonable to expect that anomalies will not be overlooked. However, unexpected overlooking errors will be 'caught' during the talkback phase of the protocol.

- We expect to be able to correlate the fixation pauses directly with the known anomalies seeded into the design artifacts: both occurrence (a simple incidence count of a pause) and its (time) duration provide measures of the existence and significance of a limitation of the notational form for cognitive effectiveness.
- We expect to witness fixation pauses that are related to unknown anomalies. These will be identified and articulated at the talkback phase. This use of EFRP arguably produces the deepest insight into syntax. The revelation of 'false negatives' – that is to say anomalies in the notational form that had not been identified by the researchers – will articulate limitations of the ArchiMate® model that had not been anticipated.

Future experimental runs will diversify subjects into a 'multi-vertical' pool of expert designers drawn from a range of industries. Such diversification will increase the level of analytic generalizability and deepen insight into the cognitive effectiveness on design expertise and the development and retention of design competence. Further, such generalization at the 'sentence level' will allow 'language level' design anomalies such as symbol redundancy and symbol overload to emerge. Developing a typology of such emergent anomalies will provide the potential for a 'language' level diagnostic perspective, extending the scope of our neurophysiological analyses to span the top left quadrant in Figure 2. Such a diagnostic tool will enable the cognitive effectiveness of UML, ArchiMate® and other notations to be improved by proposing new visual syntax, graphical symbols and semantic constructs that overcome the limitations identified by Hungerford et al. [4] and Moody [8].

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