Journal of
Information
Systems
Education

Volume 33
Issue 2
Spring 2022

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Recommended Citation: Randolph, A. B., & Raven, A. J. (2022). Engaged Brains: A Course on Neuro-Information Systems. *Journal of Information Systems Education*, 33(2), 159-168.

Article Link: https://jise.org/Volume33/n2/JISE2022v33n2pp159-168.html

Initial Submission: 10 December 2020
Accepted: 10 June 2021
Published: 15 June 2022

ISSN: 2574-3872 (Online) 1055-3096 (Print)

Engaged Brains: A Course on Neuro-Information Systems

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ABSTRACT

Neuro-marketing, neuro-economics, and now the field of neuro-information systems (neuro-IS) is growing, and our students want to know more about it all. This paper presents the examination of the learning-needs of new entrants to the field of neuro-IS. The resulting elective course is targeted at IS undergraduate majors interested in learning about the use of neurophysiological tools in organizational settings. The course is focused on the design aspects of brain-based computer interfaces for people with disabilities and the general use of neurophysiological tools to understand human mental states better. Students read seminal papers to gain a background in the latest brain-based technology and its application to various organizations. The course material focuses on the design and usability of systems, the psychological and cognitive states of users, and the evaluation of novel technology. Students demonstrate their understanding of key concepts by designing and conducting a related research study, analyzing a case in the field, or designing their own brain-based interface. This course was taught to forty-one undergraduate students in a face-to-face format and thirty-seven in an online class using active learning principles, and the course was met with highly positive reviews. Delivering a version of the class online did not have a noticeable impact on either student performance or course evaluations.

Keywords: Neuro-IS, Brain-computer interface, Neurophysiological tools, Instructional pedagogy, Course development, Introductory course

1. INTRODUCTION

There has been an explosion in the use of neurophysiological tools in business with such burgeoning fields as neuro-marketing and neuro-economics and now the field of neuro-information systems (neuro-IS). Neuro-marketing combines neuroscience and marketing to understand the true effects of advertising and sales approaches on consumer behavior (Fugate, 2007; Lee et al., 2007). Neuro-economics uses brain-imaging techniques to understand human decision-making processes (Sanfey et al., 2006). Similarly, neuro-IS uses neuroscience and brain-imaging techniques to understand the processes and effects relating to information technology (IT), such as cognitive load, technology acceptance, and design considerations (Dimoka et al., 2012; Dimoka et al., 2011; Fischer et al., 2019; Riedl et al., 2010a). These underlying processes may not be entirely revealed through more traditional means of inquiry such as surveys and observations but instead, be uncovered by examining unconscious thoughts.

Our students have kept up with these new trends in business methods and are interested in learning more: undergraduate students wish to debunk myths and learn what is fact or fiction from what they have seen in movies or online readings; and graduate students wish to explore barriers to entry to the field of neuro-IS and how they may ramp up their knowledge and begin rigorous explorations through research. Further, students recognize that learning about novel methods being used in their various fields of business and technology may give them an advantage in the marketplace, both industrial and academic.

Some researchers in the field of neuro-IS have anecdotally described attempts to provide related learning experiences for students at their home institutions; these researchers have requested training from colleagues in psychology and cognitive neuroscience, attended workshops such as those offered at the NeuroIS Retreat (http://www.neurois.org/) (Riedl et al., 2010a), and sponsored student apprenticeships with peers with active research labs using neurophysiological tools. What these actions have highlighted is a need for training that can be disseminated to parties interested in joining the field of neuro-IS. Seeing this growing interest, the lead author sought to develop an introductory course upon examination of the learning needs for new entrants to the field.

With almost two decades of experience working with neurophysiological tools within the context of human-computer interaction (HCI) and IS, along with directorship of a related research lab, the first author was well-positioned to create and offer a specialized course on the topic. Those instructors who may not have such deep first-hand knowledge or equipment may consider partnering with others actively utilizing similar technologies in Psychology or Cognitive Neuroscience programs on campus. The course is designed to take students on a journey from understanding to application. First, students learn about the non-traditional end-users of brain-based technologies, people who are completely paralyzed and unable to speak but cognitively intact, termed *locked-in* (Neumann & Kübler, 2003). Next, they are presented with core concepts of cognitive neuroscience and learn what neurophysiological recording technology is available and its constraints. These concepts are extrapolated for application by organizations that desire to learn more about what consumers are thinking. Lastly, students are challenged to apply their knowledge of IS and HCI in this novel arena.

In an ideal learning environment, students would work directly with brain-based interface end-users, or would develop software based on neuro-IS methods and tools (vom Brocke et al., 2020). However, this kind of experience cannot be scaled to a class with a large number of students. Instead, we provide an active learning environment, where the work is simulated, and the tasks are manageable. In active learning, students do not passively listen or read, but they solve problems. Bonwell and Eison (1991, p. iii) define strategies to promote active learning as "…instructional activities involving students in doing things and thinking about what they are doing…" Furthermore, "They must read, write, discuss, or be engaged in solving problems. Most important, to be actively involved, students must engage in such higher-order tasks as analysis, synthesis, and evaluation." Since the publication of their report, active learning has greatly evolved, including in the IS field (Riordan et al., 2017; Romanow et al., 2020; Woods, 2020). Prince (2004, p. 223) defines active learning as, "any instructional method that engages students in the learning process. In short, active learning requires students to do meaningful learning activities and think about what they are doing." In his study, Prince reviewed meta-studies of active learning, and found that they had seemingly conflicting results. More recently, Freeman et al. (2014) performed a meta-analysis of 225 studies in a variety of disciplines. Their results show that active learning has a strong positive impact on student performance. Throughout this course, active learning was incorporated as a guiding principle. Section 5, on course organization, describes the activities. The following sections describe the growing field of neuro-IS, relevant knowledge for practicing in the field, resulting course format and learning objectives, and exemplar assignments and experiences used within the course. The authors then present student feedback as illustration of the course's success and shares ideas for future dissemination of the course. Although seminal readings have been suggested for new entrants (Riedl et al., 2010a), there is no known coursework on neuro-IS available as a template. Thus, this paper presents one way to present materials and targets an undergraduate population. However, these same concepts may be useful for graduate students and academics also wishing to learn more about the field.

2. THE NEURO-IS FIELD

Neuro-Information Systems is a multidisciplinary new sub-field of IS that integrates cognitive neuroscience theories, techniques, and tools. It seeks to learn more about perception, adoption, and use of technology through neurophysiological recording techniques. These techniques may help uncover unconscious processes which inform behavior and provide a deeper understanding and new paradigm for human interaction with technology (Riedl et al., 2010b). As a result of integrating elements from cognitive neuroscience into IS, new directions for the field include: linking neural correlates to IS constructs, enhancing existing measurement techniques, and providing neural input to computers for feedback and control purposes (Dimoka et al., 2012; Riedl et al., 2010a).

To participate in this new direction, in addition to core knowledge of the IS theories and techniques commonly used in IS, a neuro-IS researcher must also understand how to: 1) select the neurophysiological measure that best matches with the question being asked, 2) choose a recording device, 3) operate the recording device or recruit knowledgeable technicians to do so, and finally, 4) analyze and make sense of the recorded results. Table 1 summarizes the breadth of knowledge desired for a researcher in neuro-IS. The *Knowledge Area* indicates the referent disciplines for this work, and the *Focal Points* summarize the relevant knowledge that these areas provide.

Knowledge Area	Focal Points
Cognitive Neuroscience	• Brain anatomy and general topography • Cognitive theories • Signal properties • Neurophysiological recording tools • Analytical software and techniques
Electrical Engineering/Computer Science	• Signal acquisition • Signal processing and common filters • Optimal setup for equipment

Table 1. Desired Knowledge for a Researcher in Neuro-IS

A new entrant should study within each of the Knowledge Areas to gain the confidence and expertise needed to succeed. In addition, there are a number of articles now published to help entrants better understand how to apply neurophysiological techniques to IS research (e.g., Dimoka et al., 2012; Dimoka et al., 2011; Riedl et al., 2010a; Riedl et al., 2010b). As a new entrant to the field of neuro-IS, using neurophysiological tools as the distinguishing method, it is necessary to gain working knowledge of brain anatomy, physiology, and the mechanisms by which signals are recorded. Brain anatomy and physiology will help researchers understand supporting literature about brain functions and general topography. Topographical knowledge helps a researcher appreciate where electrodes should be placed to achieve recordings of desired functions. In addition to an investment in physiological knowledge, additional knowledge is needed to gain appreciation of signal acquisition, filtering, and translation techniques. There is also a significant financial investment needed when acquiring equipment.

3. COMMON TOOLS IN NEURO-IS

Common tools in neuro-IS include functional magnetic resonance imaging (fMRI), electroencephalography (EEG), skin conductance response (SCR), eye-tracking, and functional near-infrared (fNIR) imaging, among others (Dimoka et al., 2012; Riedl et al., 2010a). Some knowledge of electrical engineering and computer science is helpful in operationalizing these tools. The following provides an overview of each of the aforementioned tools. In general, most tools are sensitive to movement artifacts, and all have varying degrees of associated costs.

Functional magnetic resonance imaging (fMRI) – A non-invasive method for measuring oxygenated blood volume, fMRI uses a powerful, magnetized probe that can reflect activity throughout the brain (Weiskopf et al., 2004). It has a high spatial resolution, which means that researchers can tell where the brain activity is taking place. Once location is determined, we can map this placement to neuroscience literature to help determine what cognitive process is being reflected. However, a significant challenge is that mental activity does not tend to be relegated to one spot in the brain (Dimoka et al., 2012). In addition, this tool provides relatively low temporal resolution because it takes three-to-seven seconds for the hemodynamic response to register after the stimulus is presented; blood is physically flowing to certain areas of the brain, and this takes time. Because fMRI incorporates such a high-powered magnet, devices typically reside in hospitals or medical facilities and cost a few hundred dollars per participant to purchase study time because the devices themselves cost several hundred-thousand dollars.

Electroencephalography (EEG) – Electroencephalography is a bio-recording technique to measure the electrical activity of the brain collected from scalp or implanted electrodes. It has a high temporal resolution on the order of milliseconds and thus is considered real-time or imperceptibly close for most human observers (Riedl et al., 2010a). Research-grade EEG devices cost an average of $30,000. Less expensive commercial devices do exist and are most popularly from Neurosky (www.neurosky.com) and Emotiv (www.emotiv.com) for just a few hundred dollars. Most non-invasive EEG devices require that conductive gel or saline solution be used to connect the scalp to the electrodes. Dry-electrode systems are increasingly being investigated but are hugely sensitive to movement artifacts (Guger et al., 2011; Liao et al., 2012). Because brain signals travel through so many layers of fluid and tissue to reach the surface, they must be amplified for recording and analysis but may easily be overpowered by electrical signals generated from muscle movement.

Skin conductance response (SCR) – Although SCR is controlled by the Autonomic Nervous System (ANS) (Leslie & Millenson, 1996) which does not include the spinal cord and brain (Martini et al., 2001), it is a measure taken non-invasively of the electrical conductivity of the skin. Skin conductance is an indirect reflection of brain activity associated with fluctuations in the amount of sweat a person is generating and varies according to human emotional and mental states. This response is also known as galvanic skin response (GSR) (Randolph et al., 2005), and electrodermal response (EDR) (Blain et al., 2006), and a polygraph or lie-detector (Lykken, 1959). One of the least costly options, a typical configuration for a SCR device includes two electrodes placed on the index and middle fingers, areas of the skin with the most active sweat glands. Skin conductance response has a three-to-seven second delay in conjunction with the physical process to generate sweat.

Eye-tracking – The eyes truly are windows to our souls – or at least to our deepest thoughts. Systems track pupil size, eye-blinks, where someone is looking (eye-gaze), and how the person's eyes move according to various stimuli. Gaze and movement reflect interest and engagement (Rayner, 1998) whereas pupil dilation reflects arousal, stress, pain, cognitive difficulty, and deception (Wang et al., 2010). Further, visual attention is closely tied to age, gender, and hormonal states when spatial cues are not provided (Robinson & Kertzman, 1990), and the amplitude of startle eye-blinks varies with emotion, arousal, attention, and information processing (Blumenthal & Franklin, 2009). Portable eye-gaze trackers average $10,000.

Functional near-infrared (fNIR) – Near-infrared spectroscopy (NIRS) is a process used to measure changes in oxygenated blood volume on the surface of the brain resulting in what is called fNIR imaging. Oxygenation of blood reflects vascular activity that has a three-to-seven second delay and only indirectly reflects brain activity (Coyle et al., 2004; Kleinschmidt et al., 1996; Randolph & Moore-Jackson, 2010). These devices cost approximately $50,000.

Certainly, there are pitfalls to which a new entrant to neuro-IS may succumb. For example, a newcomer may not appreciate the differences in the temporal resolution of EEG versus the spatial resolution of fMRI and select a tool out of convenience that mismatches with the research question being posed. In addition, many newcomers have taken advantage of the availability of less-expensive, commercially available recording devices for EEG, but have found themselves challenged with setting up the systems to obtain reliable data, and they lack knowledge of how to interpret the data that has been recorded. Although fMRI-based systems require a technician with specialized knowledge for running scans and reports, the other tools are relatively accessible to researchers to learn how to use. Further, research budgets may be saved by the use of open-source analysis tools such as the EEGLAB plug-in to MATLAB (Delorme & Makeig, 2004) and BCI2000 (Schalk et al., 2004). Aside from learning these subtleties from first-hand experience, entrants may gain knowledge of how to avoid these pitfalls from conversing with existing researchers in the field and reading referent literature.

4. COURSE DESCRIPTION AND FORMAT

To aggregate key information from the Knowledge Areas in Table 1, gain a basic understanding of the common tools used in neuro-IS, and convey some pitfalls of the field, a course was devised. The inaugural neuro-IS course was listed as an upper-level, undergraduate elective targeted to IS majors. Forty-one (41) students were enrolled in this course, filling it to capacity with one override, and none withdrew. The course was held on the main campus of the university, once a week, in a block of 2 hours and 45 minutes as a face-to-face experience. This long block of time allowed ample opportunity for students to participate in off-campus field trips, rich in-class discussions, and live technology demonstrations. Although no pre-requisites were required, most students were upper-level IS majors. There was no textbook for the course, and readings were pulled from academic papers and popular media. The course was described in registration materials as follows:

> Neuro-marketing, neuro-economics, and now the field of neuro-IS is growing. This elective course focuses on design aspects of brain-based computer interfaces for people with disabilities, new uses in organizations, and better understanding of human mental states. Students read seminal book chapters and papers to gain a background in the latest brain-based technology and its application to various organizations. The course material focuses on design, usability, psychological and cognitive states of users, and evaluation. Students demonstrate their understanding of key concepts by designing and conducting a related research study, analyzing a case in the field, or designing their own brain-based interface.

5. COURSE ORGANIZATION

5.1 Course Objectives

The following were the overall objectives of the course as students explored the challenges and opportunities created in society by brain-based technologies:

- Investigate the problems and opportunities created by brain-based technologies.
- Investigate innovative applications of brain-based technology in society.
- Explore the process and resources needed to develop a sound research study.

The learning objectives of the course were laid out over twelve modules. These modules spanned a typical semester and allowed time for independent project work in teams. Table 2 summarizes the learning objectives and provides example learning experiences in which students participated. Where possible, the learning experiences were set up to facilitate the desired active learning. Where appropriate, learning goals and activities were aimed at the higher levels of Bloom's Revised Taxonomy (Anderson & Bloom, 2001).

One of the student groups designed an interface for a system that allows a locked-in patient to change settings in the environmental controls in their home. Although the system is still rudimentary, a patient's EEG can in theory control all aspects of a smart home. The learning experience the student team had can be evaluated from the perspective of Bloom's Taxonomy. In addition to the lower level skills (Remember, Apply, Understand), they also applied the higher-level skills (Analyze, Evaluate, Create). Their end product, the interface design, was a creative product that resulted from their collective ability to understand and analyze the fundamental issues in neuroscience and to evaluate their ideas to determine what would realistically work. Their learning was enhanced by the direct personal experiences of one of the team members.

As another example, Figure 1 shows the result of a student's participation in a technology demonstration where he was able to spell his name completely hands-free using just his thoughts and a P300-Speller (Donchin et al., 2000). Such experiences allowed students to better grasp the concepts being taught.

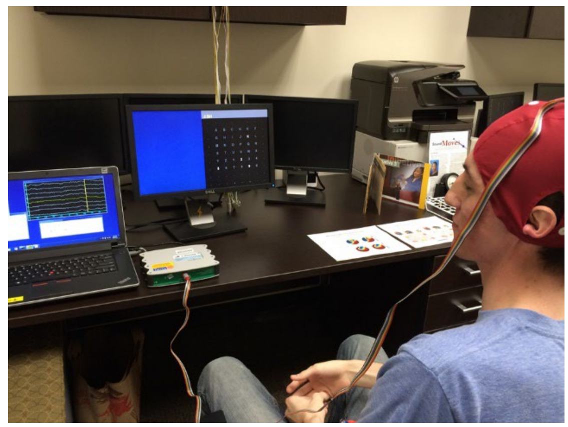

Figure 1. A Student Spells His Name Using a Neural Speller

5.2 Course Assignments

The following describes the assignments incorporated into the course that may be used as examples for others who wish to devise something similar. The authors included structured reflection and meaningful application as key ways of solidifying student learning (Lee, 2012).

Term Project (45% of final grade – main area of active learning) – Reflected the application of the neuro-IS concepts learned and was conducted by teams. This project provided students with an opportunity to explore and analyze how brain-based technology might be used in the real world and integrate the course materials. Teams conducted an experimental study using equipment in the author's research lab (or may do so through an affiliate lab), identified and analyzed a case where brain-based technology was being utilized or conceptualized to advance IS theory or design, or designed, their own brain-based interface. Students were not expected to implement their designs due to the lack of pre-requisites for the course.

Module	Topics	Objectives	Experiences
1	Overview of the Neuro-IS Course and Introduction to Brain-Computer Interfaces	Define brain-computer interfaces.	Discuss TED-style lecture on brain-based interfaces and recording tools.
2	About the User: Cognitive Neuroscience Crash Course	Identify parts of the brain utilized for cognitive processing and control.	Listen to guest lecture from a professor in cognitive neuroscience.
3	About the User: Experience Having a Disability	Recognize challenges of being a non-traditional end-user of technology.	Participate in “Dialogue in the Dark” to simulate being blind.
4	About the User: Experience Matters	Appraise needs of a non-traditional end-user of technology.	Listen to guest lecture by person with quadriplegia who uses assistive technology.
5	About the Technology: Available Neurophysiological Technologies	Identify current technologies that incorporate neural or psychophysiological recordings.	Participate in technology demonstrations in-class.
6	Applications: What Can We Do and Should We?	Criticize advancements of biotechnology and its use.	Debate the ethical boundaries of neuro-IS as sparked by watching trailers for new video games incorporating advanced biometrics.
7	Applications: Choosing the Tool	Examine the audience and goals of selected term projects.	Iteratively walk through project proposals and plans for each team.
8	About the Technology: Individual Differences	Compare different control-abilities of end-users.	Read, review, and discuss academic papers on individual differences and neural control.
9	Applications: Assessing Mental States	Discuss applications for using brain-imaging techniques to assess human mental states.	Visit local hospital to see an fMRI in action. Review article about Microsoft’s use of neurophysiological tools to assess mental states.
10	Applications: Neuromarketing	Examine marketing concepts using brain-imaging techniques.	Watch and discuss video based on “Habit” by Dr. Neale Martin (2008).
11	Applications: Term Projects	Design and demonstrate useful integration of information systems with novel input from the brain.	Conduct case analysis, design, or experiment in teams and present to the class with panel of expert visitors.
12	Applications: The Future of Neuro-IS	Evaluate the long-term viability of brain-based interfaces.	Debate the viability of the neuro-IS field.

Table 2. Summary of Course Learning Objectives and Examples of Experiences

The following provides a summary of deliverables expected with suggested points/percentages. Assignment of points is offered on the basis of 450 total project points out of 1000 total points for the course, or 45% of the total.

- Proposal (20 points / 2%): Briefly describe the project idea with enough detail to help assure proper scope. Will you be conducting an experiment (is it exploratory, or do you have a hypothesis to test)? Will you analyze a case (how is IS enhanced or advanced)? Do you have an entirely new system to propose (what is the gap with existing technology)?
- Team Operating Agreement (10 points / 1%): It is important that all members participate in the creation of an agreement to fully understand their responsibilities and expectations for meetings and communications.
- Report (360 points / 36%): The main deliverable is a professional quality document. The length of the report will depend on the nature of the decided project. Include the following components:

1) Table of Contents (5 points / 0.5%) – List major section headings with associated page numbers.
2) Executive Summary (30 points / 3 %) – This is a summary of the entire project. Assume that the target audience is an executive with little time to read but has a need to understand the key messages from the report. This may be the same or similar to the project proposal written in past tense because the tasks have been completed.
3) Introduction/Project Motivation (40 points / 4%) – Choose the type of project that works best with your interests. Do you want to get hands-on and see what a particular brain-based device can do? Do you want to explore a particular topic in more detail as a case analysis? Do you have an aptitude for system design and ideas for integrating brain-based technology into

an existing framework? Describe the aims and impact of the project.

4) Background/Related Work (50 points / 5%) – Based on your project, what other work has already been done that relates to what you are doing? How did you conceive of the idea? Is there existing research or commercial devices that enhance/support your ideas?
5) Study Design/Case Analysis/Application Design (80 points / 8%) – Describe your project. What did you do? Who was involved? How did you make sense of the data or findings? What did you design?
6) Results (50 points / 5%) – What did you learn from this project?
7) Project Plan (20 points / 2%) – Describe your team's project plan. What were the main steps that you followed? Who was responsible for what?
8) Conclusion (40 points / 4%) – Summarize your major findings and motivation for the project. Is there future work that you would recommend take place?
9) References (15 points / 1.5%) – If you quote anyone or share any ideas that you did not originally create, you must cite them.

Your paper will have the nine components listed above, which include within-text citations summarized in the list of References and a Title Page listing all team members. Use headings to identify each section clearly. Submit as a Word document.

- Video Summary (60 points / 6%): Create a three-minute video summarizing your project and providing highlights that would be interesting to an online audience. This allows for sharing of project ideas for multiple learning platforms.
- Presentation (20 points / 2%): Presentations should be created to be no more than 5-7 minutes long for every team and thus between 5-10 slides where the first and second slides are the title and agenda slides. Highlight the team's achievements. Presentations will be graded on the following: content, visual support, and if the team held to the slide limit because it is a key skill to be able to distill a lot of information into a few highlights.
- Peer Evaluation (10 points / 1%): Indicate quality and quantity of all individual participation in team activities. The final report grade for individual members is adjusted according to majority peer evaluations of their work.

Completing an undergraduate research project can be very rewarding, but it is also challenging. There are many aspects to a research project, such as finding a topic, developing the research question, and designing a study (Robson, 2016). It would require at least a semester for students to review even the basics of what is involved. At the same time, a research project on brain-based technology is a great example of how active learning may be used in-depth and may result in novel artefacts. Awareness of intellectual property protection and non-disclosure agreements should be considered (Witman, 2005), in line with university guidelines.

Reviews (30% of final grade – development of cumulative knowledge) – Papers and films were assigned and discussed in class. Students were also required to provide written reviews of assigned materials. An example of a film used was "The Diving Bell and the Butterfly," an autobiographical account of a person who became locked-in after having a stroke (Schnabel, 2007). The papers were selected for their accessibility in reading by undergraduate students or the breadth of knowledge captured. The following are updated examples of the papers assigned for review:

1) "A Decade of NeuroIS Research: Progress, Challenges, and Future Directions" (Riedl et al., 2020a).
2) "Consumer-Grade EEG Instruments: Insights on the Measurement Quality Based on a Literature Review and Implications for NeuroIS Research" (Riedl et al., 2020b).
3) "Consumer Neuroscience: Applications, Challenges, and Possible Solutions" (Plassmann et al., 2015).
4) "Brain-Computer Interfaces for Communication and Control," (McFarland & Wolpaw, 2011).
5) "Assessing Fit of Nontraditional Assistive Technologies" (Randolph & Moore-Jackson, 2010).

Class Participation (23% of final grade – active engagement) – The participation grade was based on four things: 1) preparedness and participation during class, 2) in-class and online discussions, 3) individual responses to guest lectures and field trips, and 4) submission of slides/video that introduced each student to their classmates and instructor. Example field trips included: an excursion to a local rehabilitation center, visiting the local hospital to see an fMRI in action based on instructor outreach to the radiology team for their interest in sharing knowledge coupled with a student demonstration, or participation in an experience that simulated having a disability such as being blind in "Dialogue in the Dark" (http://www.dialogue-in-the-dark.com/).

Study Participation (2% of final grade – passive engagement) – To gain hands-on experience and better empathize with users of brain-based interfaces, students were encouraged to participate in a study during the semester and provide a short summary of their involvement. Students unable to schedule participation were required to submit a written reflection of an online article about a neurally-controlled device and its potential use in business. This activity did not require significant effort by the student as reflected in the percentage allocation.

5.3 Course Feedback

Overall, course satisfaction was rated at an average of 4.625 on a scale of 1 to 5, where 5 was the highest rating (5: Strongly Agree – 1: Strongly Disagree). The response rate was 58.5% with 24 out of 41 surveys completed. The further granularity of responses and comparative data were not obtained nor retained from this earlier version of a university-wide student evaluation tool. Comments included:

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Very open free thought course. Led to many
groundbreaking discussions.

The [guest] speakers, visitors and trips
were very helpful in understanding the
magnitude to which our actions could have.
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Suggestions for improvement included "consider breaks" and omitting from the module on neuro-marketing, "[a] long video…which was ridiculous," where the video was used in lieu of a busy guest speaker physically attending who had direct, practical expertise in this area. Aggregate final grade results for the course were: Average 92.7%; Min 72.9%; and Max 100.4% with a standard deviation of 7.32. Grades could exceed 100%

for individual grade adjustments based on peer evaluations of outstanding performance on term projects.

5.4 Course Revisions

A version of this course was later created in an asynchronous online format and delivered one year after the first class to 37 students. *Class Participation* was transformed into separate *Module Discussions* and *Responses*, and *Study Participation* was omitted. Further, virtual field trips were incorporated where a local rehabilitation center offered virtual tours and online testimonials. Anticipatory comments by students enrolled in the online version included, "I love technology and I am always astounded by the power of our brains and neurological systems, so I was interested in learning more," and, "I really had no idea that brain-based computer interfaces were an actual real world application." Final comments included the following, which indicated that the course should return to a face-to-face format to increase the level of engagement by students:

> Course content was evenly distributed and made the course content interesting.
>
> The content of the course was ordered and presented in a way that was productive for learning especially for persons without a prior background in the subject matter.
>
> Great course, should be a standard course with more courses to follow.
>
> This is a great course and should be taught each semester as this is the future of IS.
>
> The content is interesting and keeps the attention of students. Although I do not think this should be an online course.
>
> This might be more of a shortfall of the class medium versus the instructor personally but it would have been nice to have more instructor interaction in some way. Unlike subjects like Math where the material is pretty dry, Neuro IS is a exploratory subject that requires more thought and interaction. The discussion board requirements are ok but I find that students post what they absolutely have to and do not openly engage in intellectual exchanges.

Overall, course satisfaction was rated at an average of 4.53 on a scale of 1 to 5, where 5 was the highest rating (5: Strongly Agree - 1: Strongly Disagree). The response rate was 54.1% with 20 out of 37 surveys completed. Further granularity of responses showed: strongly agree (5) = 13 responses (68%), 4 = 3 responses (16%), and the rest (3 through 1) = 0 responses (0%). These are the extent of the supporting statistics provided by the student evaluation tool issued by the university. For further context, during the same semester, on the same five-point scale for the overall course satisfaction question, the instructor received an average of 4.35 with a response rate of 20 out of 36 (55.6%) for a general survey course on IS that they had taught repeatedly for five years as a mandatory course for all undergraduate business majors; the department average was 4.0 with a response rate of 845 out of 2063 (41.0%), and the college average was 4.23 with a response rate of 5711 out of 14765 (38.7%). These results indicate that the instructor performed better than average for the department and college in teaching for both the specialty and regularly offered course. Aggregate final grade results for the course were: Average 91.0%; Min 70.0%; and Max 100.1% with standard deviation of 8.86. Again, grades could exceed 100% for individual grade adjustments based on peer evaluations of outstanding performance on term projects.

Both course evaluations and student performance were comparable in the face-to-face and online versions. In general, student performance in online classes is, in many cases, not as good as in regular face-to-face classes. Past studies have found conflicting results in student performance, and Chauhan et al. (2020) have created a conceptual model that explores mediating factors that can impact the relationship between information technology and learning outcomes. For instance, their study found that the learning environment is a factor that mediates that relationship.

Alanazi et al. (2020) investigated a different set of factors that impact perceived performance. Applying the Task-Technology Fit theory, they found that one of the main determinants is the perceived usefulness of the task. In the online class, this could explain the student comment about finding the discussion board too limited. A synchronous, face-to-face discussion would likely have been found more useful by the students.

6. GUIDELINES FOR SUCCESS

This course has met with great success per student reviews and recommendations to their peers. Based on experience, we offer the following general guidelines for success:

- Focus on active learning, not memorization. This is a very applied and multi-disciplinary topic by its nature. To have a stronger grasp of the underlying concepts and encourage higher-level learning, students should be encouraged to see the technology in action by offering demonstrations or field trips and engaging with the material. Expect that many students will want to try the technology first-hand despite the stated risks for an fMRI scan or inconvenience of gel in one's hair with an EEG.
- Create a safe space for sharing candid remarks about applications of the technology or personal experiences. As a relatively new area, most people will feel inexperienced with the topics and thus may be intimidated in discussions. Encourage students by emphasizing that all experiences are relevant and contribute to this multi-disciplinary field.
- Expect that some students may feel lost when first formulating their projects and be unable to grasp how to tackle this new area. Have students do their best to create a project proposal. Review the proposals together in class and offer consulting on how to give the projects more structure by encouraging students to think about their audience and impact. Then, allow students to submit revised project proposals as their final contracts for work.
- For its interdisciplinary nature, consider waiving any particular courses as pre-requisites but instead insist that students are at a junior or senior level in their majors. Having students farther along in their college careers will increase the likelihood of including mature individuals

ready to think at a higher level who possess substantial grounding in their field of choice.

- Use the course as an opportunity for community engagement by inviting a panel of related professionals and academics to hear and review final projects. Inform students that there will be esteemed audience members in attendance for their presentations who will be able to provide them with feedback. Students should rise to the occasion with thoughtful defenses of design decisions.

7. CONCLUSIONS

Information systems and interactions are rapidly changing. A course on neuro-IS provided an opportunity to present topics from a truly emerging viewpoint: the use of neuro-based tools and techniques to inform human-computer interaction. Students were highly engaged in learning about topics in this novel arena. This level of engagement without the support of an existing textbook and structure presented a challenge to the instructor to keep pace. However, delivering a version of the class online did not have a noticeable impact on either student performance or course evaluations. The next iteration of the course is proposed as a hybrid format to recapture the dynamics of the discussions and field trips when held in person. For a new entrant to the field as a researcher, the course material may provide structure for learning but should be supplemented with seminal journal readings as suggested in section 2.

8. ACKNOWLEDGEMENTS

This work was partially supported by funding from the Kennesaw State University's Research and Development Committee.

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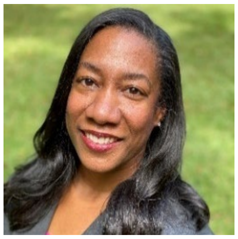

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ISSN 2574-3872