

Design Factors That Influence Emotional Responses to Engage in Instructional Visual  
Display Designs

By

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## **Abstract**

The purpose of this research was to understand the emotions emitted by college students in response to viewing online digital representations of evidenced-based visual display design principles. The study focused on identifying an approach to the design of visual displays that reflects human information processing design principles applicable to online instruction and that contributes to the enhancement of students' emotional engagement with online instruction. The study focused on investigating technological approaches to measuring the indicators of each participant's responses in two different emotional dimensions: emotional arousal (high/low) as detected by the Q sensor, and emotional valence (positive/negative) as detected by the CERT.

This study included a large amount of data: 12,896 electrodermal activities to generalize people's emotional arousal changes over 124 representations and 104 subjects. Also, 851,701 facial expressions were collected to generalize the effects of people's positive emotion valence. A two-way ANOVA found a difference of emotional arousal in simple-text representations. The highest emotional arousal was on good color images ( $M=0.827$ ) and the lowest emotional arousal was on poor texture images ( $M=0.632$ ). A one-way analysis of variance found the highest mean score ( $M=0.743$ ) was at the format of one paragraph with the 1.0 line spacing. The lowest mean score ( $M=0.505$ ) was the format of 3 columns. On the other hand, the fixed-mixed regression model predicted the increment of emotional valence and showed that visual variables had significantly different effects of facial expressions. The good digital visual display representations in color increased 0.023 of joy facial expressions. The good digital visual display

representations in shape increased 0.063 of joy facial expression. When the format of 3 columns was shown on the screen, the participant's joy raised 0.104. Compared to other three formats, this was the highest increment.

The findings of this research lead us to believe that to enhance student's emotional engagement in online instruction, a clear need exists to design digital visual displays that emitted their positive emotions. These positive emotions, in turn, may improve their affective experiences. In the reflections of the findings, they offer the statements and applications of representations are offered for online instructional designers and developers.

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## Chapter 1: Introduction

### **Background**

Institutions of higher education (IHEs) were quick to explore the Internet as an innovative instructional tool and an effective approach to increasing access to higher education. Since the emergence of the Internet as a viable system for the delivery of instruction in the late 1990s online instruction has grown at a rapid rate. The Babson Survey Research Group (2013) estimated that among students enrolled in an IHE during 2013, 7.1M had enrolled in at least one online higher education course. This growth has not diminished, as illustrated by the expansion of for-profit universities (Bell & Federman, 2013). Traditional public and private IHEs responded to the impact of for-profit institutions by offering their own undergraduate and graduate degrees online, which also resulted in dramatic increases in enrollments (Deming, Goldin, & Katz, 2013). According to a report from the Babson Survey Research Group (2014), enrollments in for-profit postsecondary institutions offering online courses and fully online programs increased 24 percent in 2012 (Allen & Seaman, 2013). More recently innovative initiatives such as massive open online courses (MOOCs) have greatly expanded access to learning via online technology (Allen & Seaman, 2013; President's Council of Advisors on Science and Technology, 2013).

The recent focus on online instruction at the post-secondary level represents a dramatic shift from the pedagogical traditions of face-to-face instruction. Although IHE faculty was experienced in the design and development of instructional resources and sensitive to conditions that enhance teaching and learning, many were unprepared for the

expectations that accompanied this technology driven innovation. The shift occurred quickly because of technological advancements, the perceived instructional efficiencies of the model by policy makers, and the responsiveness of students to the central features of online instruction. Included in these features were increased access to higher education and the flexibility to study online where and when conditions were best for students. These features were combined with the advantage of being able to review course content, knowing that it represented the original instructional information. Although the features were not new, they focused on such teaching principles as self-paced instruction, increased attention to prior knowledge, immediate feedback to the learner, and opportunities for learners to demonstrate what they were learning (Meyen, Lian & Tangen, 1997). These features at the heart of structuring online instruction soon became prerequisites for teaching and developing online instruction. In contrast to simply integrating these principles into face-to-face instruction during the process of teaching, instructors now needed to make them explicit as they developed online courses. The features had to be integrated into the learning experience in a manner that fit the real-time delivery mode of the Internet. This requirement added a significant level of instructional accountability as the content and instructional features were not only intended for independent study by students, but were open to public examination, if necessary.

Much of the research during the early history of online instruction focused on such topics as learner outcomes, achievement, retention, and the involvement of learners in online learning environments (Anderson & Bushman, 2001). The field paid particular



attention to the development of online teaching standards and instructional resources. Examples of standards included International Society for Technology in Education (ISTE) standards in 2004, Sharable Content Object Reference Model (SCORM) in 2004, National Educational Technology Standards (NETS) in 1998, and ADDIE model in 1975. The intent in framing standards was to maximize the quality of online instruction and to ensure instructional effectiveness. For the most part the standards addressed instructional design and focused more on the structuring and delivery of content. These standards did not address design from the perspective of visual display theory and principles developed prior to the Internet. Little was understood about the impact of the cognitive processes of learning via this mode of instruction in the context of relying on visual display (e.g., the monitor for delivering instruction). The learning consequences of moving to digital visual display designs was not emphasized in early research related to online instruction. Rather, what tended to occur was generalization of instructional design principles that were effective in face-to-face instruction to the online instructional environment.

As online instruction expanded at the post-secondary level, course developers gained experience instructional designs improved. The instructional design improvements were largely driven by feedback from students on their learning experiences, advancements in technologies, usability options and involvement of accreditation associations more than by an evidence-based design perspective. In the late 1990s the capacity of technology for supporting online instruction far exceeded the instructional design and pedagogical features applied in online instructional environments. This disparity continues today as the technology capacity for innovative

instruction exceeds the expectations of those developing online courses (Bell & Federman, 2013; Freidman & Deek, 2003). The early emphasis of higher education in online instruction was on developing asynchronous courses, but quickly moved to also developing synchronous courses. Instructional designs were largely influenced by continuing education models of the past and those teaching practices that had been successful in traditional college teaching, which, therefore, were presumed to generalize to online teaching. While Greenfield (1994) noted that employing multimedia resources in teaching improved college students' concentration, aided in developing needed study skills and enhanced intelligence, it was not until much later that multimedia found its way into online instruction as a common practice. Most e-learning environments established goals to improve student's learning (Clark & Mayer, 2011). As educational technology advanced, new possibilities emerged for engaging students in active learning, student-centered classrooms, and routine use of visual materials (Gilbert, 2005). Course designs soon emerged offering a wide array of instructional features that were later translated into blended, hybrid and/or flipped courses. Although these designs utilize visual displays in the delivery of instruction, they are totally dependent on a monitor for the delivery of instruction. Hybrid and blended approaches had yet to appear on the scene, nor was the concept of flipped courses on the horizon. The educational possibilities multiplied when integrated with the Internet communication technology to facilitate simultaneous independent and collaborative learning models (Garrison & Kanuka, 2004). However, these approaches to the integration of online instruction with face-to-face instruction still depend on visual display delivered via a monitor for the presentation of much of the

instructional experience. Consequently, the need for evidence based visual display designs remains central to quality assurance.

Today the Internet delivers and/or supplements educational experiences for learners of all ages. The National Education Policy Center (2013) reported that virtual schools now constitute the primary source of educational growth in the U.S. Numerous local school districts have established virtual schools, as have over 27 states and the District of Columbia. K-20 online instruction is now a significant component of education in the U.S. (Watson, Murin, Vashaw, Gemin, & Rapp, 2013). As early as 2003 the Observatory on Borderless Higher Education (2003) reported that paralleling the growth of online instruction was an e-learning industry with estimated revenues of \$56.2 billion. The U.S. Department of Education (2012) reported a growing number of college students were completing academic degrees without participation in traditional on-campus learning environments. Despite this growth, research has fallen short of measuring the effectiveness of what began as an innovation in education but quickly became institutionalized. Although during the early years of online instruction researchers studied pedagogy, assessing learner outcomes, retention and the integration of technology across the curriculum, there was a paucity of systematic research on those critical elements central to Internet delivered instruction (Boud, Keogh, & Walker, 1985; Dondlinger & Jones, 2008). For example, the digital visual display capacity of the monitor as the primary source of online instructional delivery, interaction, and learner engagement received little attention by researchers. The visual display has remained a constant across all online instruction. This fact raised questions about research needed to

ensure that the visual display was maximally effective in enhancing the quality of online instruction. As a critical component in online instruction, one might assume that a major investment of resources would be made in researching multimedia theory for purposes of determining how best to strengthen visual display designs representing the core of online instruction (Garrison & Kanuka, 2004). What appears to have happened was that human and fiscal resources were primarily invested in developing online instruction from a history of instructional design employed in face-to-face instruction rather than research on such areas as visual display design principles. The result is that the development of online courses currently proceeds without much of a research base on the processes of learning via visual display technology. Understandably, this growth occurred within a very short time period (Moore & Kearsley, 2011), and the drivers of this growth seemed to be due to a mixture of technical capacity, student need for access to higher education, and revenue generating opportunities. However, the need remains for better understanding of visual display design principles.

E-learning not only opened up new modes of learning and teaching but also a new way of thinking and organizing content for learning. Collaboration among different stakeholders focused on emerging standards for the design of knowledge-based learning experienced via the Internet. The traditional paradigm for designing instruction shifted during the emergence of online instruction to an object-oriented notion of digital in “learning objects.” Defined by the Learning Technology Standards Committee (2002) of the Institute of Electrical and Electronics Engineering (IEEE) as any entity—digital or non-digital—that can be used, reused or referenced during technology-supported

learning. Such learning objects are also self-contained, interactive, reusable, and tagged with metadata. The use of learning objects enhanced the development of learning experiences wherein a person could learn just enough, just in time, and just for himself/herself (Askar & Halici, 2004). The reusable objects provided the potential for more efficiency in enhancing the development and revision of curricula and instructional resources.

### **Statement of Problem**

The transformation of learning environments as a consequence of unprecedented growth in online instruction at all levels of education occurred without the benefit of broadly based programmatic research. Instead the research agenda focused on how to create of online courses and, ultimately, degrees, as a source of expansion in higher education. Early research in online instruction largely focused on (a) the structuring of content, (b) strategies for the validation of instructional design elements to enhance instruction through pedagogical features explicit in designing online instruction, and (c) an approach to instructional accountability. A body of literature, however, raised questions about the quality of online instruction, retention, student performance, and lack of engagement; as well as issues related to the need for research (Carr, 2000; Diza, 2002; Kemp, 2002; Morris, Finnegan & Wu, 2005). A more recent interdisciplinary line of research on online instruction resulted in the creation and validation of Universal Designs for Learning (UDL) (Hall, Strangman, & Meyer, 2011; Rose & Meyer, 2000; ). This research bridges education, cognitive neuroscience, and technology. Given the decency

of online instruction designed as a mode of teaching and learning, this early evolving pattern of research was important.

Only a limited amount of early research addressed visual display designs that maximize the impact of text and visual presentations in engaging and motivating online learners. The primary limitation hindering previous research on motivation and engagement could have been the lack of technologies to identify and measure engagement and motivation of learners in online instructional environments in real time. Research studies to date have not sufficiently addressed the instructional value and effectiveness of visual display designs in the teaching-learning process. Because policy makers have high expectations of technology for supporting learning, educational researchers have a growing interest in the need to research visual display design principles applicable to the online learning process. The work of such researchers as Ross (2000), Kosslyn (1985, 1989, 1994), Palmer (1992), Kosslyn and Koenig (1992), Stevens (1975), Bertin (1983) and Coe (1996) has served to inform present research about the visual variables that need further research. Contributing factors to previous omission of these variables in other studies could be attributed to the rapidity with which online instruction gained in popularity, the influence of the technology industry, the commitment of policy makers to the potential of the Internet in instruction, and the need for more time for the field of e-learning design to become more interdisciplinary.

The digital visual display design is inherently a part of online instruction, and with a good design can improve a learner's affective status (Norman, 2002). The affective experiences of online learners have received less attention than their cognitive

developments during online instruction. The affective learning experience can enhance learning experiences of online learners. When students' learning experiences were pleasurable, they demonstrated higher engagement and the affective learning experience had a significant relationship with the emotional engagement (Grafsgaar, Wiggins, Boyer, Wiebe, & Leser, 2013; Harley, Bouchet, Hussain, Azevedo, & Calvo, 2014; Picard, 2000; Picard, Bender, Blumberg et al., 2004). This fact is largely due to the focus of instruction, in all modes of teaching, being on content and learner outcomes aligned with instructional objectives. Therefore, no studies have proven strategies for achieving better affective outcomes solely through on online instructional design and pedagogy.

The lack of significant research in the measurement of emotional responses in online instruction has resulted in instructional designers and developers making assumptions about the engagement of learners in online instruction. These circumstances are changing due to increases in concern for the motivation and engagement of online learners. For example, an emphasis on analytics as an approach to measuring evidence of involvement and attentiveness has gained in popularity (Allen & Daly, 2007; Fredricks, McColskey, Meli et al., 2011; Freeman, Kuhs, Porter et al., 1983; Popham, 1999). Further, current researchers may take advantage of advancements in technology for measuring affective outcomes aligned with online instructional experiences. Technologies now exist to measure physiological responses to emotions and to calibrate them with online instructional stimuli evoking the response (Johnson, Aragon, & Shaik, 2000; McNaught, 2001; Sun, Tsai, Finger, Chen, & Yeh, 2008).

## **Statement of Purpose**

The purpose of this study was to understand the emotions emitted by college students in response to viewing online digital representations of evidenced-based visual display design principles. This study focused on identifying an approach to the design of visual displays for online instruction that contributes to the identification of visual display design principles that enhance positive emotions and engagement of students when studying with online instruction. Two technologies for measuring emotional responses of online learners were employed in this research. The first technology was the Q Sensor technology, to measure and record the physiological responses of learners to verify electrodermal activity (EDA) based on emotional arousal of learners. The second technology was the Computer Expression Recognition Toolbox (CERT), to measure the emotional valence of facial expressions in response to stimuli. This research entailed the identification and validation of text-related visual display design principles, visual variables, and information grouping layout designs from the literature.

The present research necessitated the framing of a conceptual research model for the design and development of visual images and their sequences as representations of visual design principles for use as an experimental intervention. The representations included validated examples of accurate displays of each principle and examples with varying degrees of inaccuracies. The representations were created based on design theories of human cognition: perceptual, attention memory, and mental models (Johnson, 2010; Kosslyn, 2006; Mayer, 1996; Norman, 2003; Weinschenk, 2011; Wickens, 1973), and were presented via a monitor in a controlled research environment. The six visual



variables by Bertin (1983) (e.g., visual variables, position, size, color, shape, value, color, orientation and texture) were also examined within each design principle.

### **Research Questions**

The present research posed five research questions to contribute to the evidence base about visual display design principles for engaging online instruction. The first four questions varied with regard to the design principles and the measured learner responses; the fifth question related their answers to instructional design principles.

1. How does students' emotional arousal change when representations of evidence-based visual design principles ranging from explicitly good to explicitly poor examples are visually displayed to them in digital format?
2. How does students' emotional arousal change when representations of evidence-based visual design principles with different information grouping layout design examples are visually displayed to them in digital format?
3. How does students' emotional valence change when representations of evidence-based visual design principles ranging from explicitly good to explicitly poor examples are visually displayed to them in digital format?
4. How does students' emotional valence change when representations of evidence-based visual design principles with different information grouping layout design examples are visually displayed to them in digital format?

5. What do changes in emotional arousal and valence elicited in response to change in visual information display imply for the design of online instructional resources?

### **Hypotheses**

The researcher formed the following hypotheses to test significance of the variables represented in the first four research questions. In general, the hypotheses predict that variation of design principles displayed will not result in significantly different learner responses.

1. Students show no significant difference in the emotional arousal change to viewing representations of evidence-based visual designs that range from explicit representations of design principles to poor representation in a digital format as measured.
2. Students show no significant difference in the emotional arousal change of participants to viewing representations of evidence-based visual designs that range from different information grouping layout styles in a digital format.
3. Students show no significant difference in the effect of positive emotional valence of participants to viewing representations of evidence based visual designs that range from explicit representations of design principles to poor representations in a digital format.
4. Students show no significant difference in the effect of positive emotional valence of participants to viewing representations of evidence based visual

designs that range from different information grouping layout styles in a digital format.

### **Theoretical Research Framework**

The development of a framework for this study was complicated by the lack of research reported in the literature on evidenced-based visual display designs applicable to online instruction. This issue was particularly evident in the context of visual display designs in digital formats. The paucity of reported research was related, in part, to the newness of online instruction and the dynamics that online instruction adds to the complexity of measuring physiological responses to emotions emitted by online learners in real time. Also, the challenge extended to identifying e-learning research with focus on visual information processing. Therefore, the development of digital representations of visual display design principles for purposes of this research necessitated an understanding of human visual information processing applicable to establishing a research framework and the implications of emotion. The approach adopted relative to human visual information processing was divided into three phases: sensory memory, working memory, and long-term memory. Each of these phases had properties that place constraints on design (Gillani, 2003). Humans actively organize and interpret what they see. Further, the human sensory and memory systems have limitations, and these must be respected in the creation of visual displays if the displays are to be interpreted correctly (Bertin, 1983; Coe, 1996; Kosslyn, 1985, 1989, 1994; Loening, 1992; Palmer, 1992; Steven 1975).

The body of literature on the study of emotion experienced by humans has a long history (Damasio, 1994; Plutchik, 2001). Study of emotions dates back at least to research conducted by Charles Darwin in the 1870s, if not long before. In a psychophysiological view, the idea was launched by William James (1884). A neurological view of emotions emerged from the work of Walter Cannon (1927). Attention to cognitive and non-cognitive perspectives of emotions began emerging in the 1950s. These studies generally found that humans have emotional expressions in both cognitive and non-cognitive factors. Cognitive factors are such human experiences as perceptions and memories. Non-cognitive factors are such as human experiences as motivation, grit, self-regulation, and social skills. Studies found the non-cognitive and cognitive emotions occurred when people interacted with situations in their individual lives (Tomasello, 2009).

Online learning has been described as less emotional, more impersonal and lacking in richness of emotions in contrast to face-to-face learning (Vrasidas & Zembylas, 2003). One of the challenges in researching the impact of emotions in online instruction is that some emotions are not easily visible and, therefore, difficult to observe and measure. Recent research has discovered how negative emotions (e.g., frustration, confusion) and positive emotions (e.g., engagement, pleasure) occur in online instruction during the learning process (MacFadden, 2005; O'Regan, 2003). Because emotions are multi-faceted, no single measurement technique is sufficient. This study measured two dimensions of emotions, which were emotional arousal and emotional valence. This

study measured emotional arousal by the data of electrodermal activity (EDA) and emotional valence by the data of facial expressions.

Electrodermal activity (EDA) analysis is useful in measuring human physiological reflections and emotional arousal reactions (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000). Through the EDA detector technology, the emotional arousal of humans can be observed. Picard (2004) used Q Sensor technology to conduct research on EDA responses and found that this device was effective in conducting, measuring, and recording minor electrical changes on the skin evoked by emotional responses. Physiological responses can be measured automatically as they occur. This device was designed to support researchers in more accurately measuring physiological and emotional reactions (Sharma & Gedeon, 2012). The use of EDA analysis requires a highly controlled research environment; for example, temperature control is essential during EDA measurement. Researchers at the Massachusetts Institute of Technology (MIT) developed the primary technology of the Q Sensor and conducted research on collecting EDA data (Picard, 2004). The Q Sensor became generally available from Affectiva in 2010. The Q sensor was used by project “Engagement Pedometer” to identify classroom moments that excite and interest students. Simon (2012) reported that this project, funded by the Bill and Melinda Gates Foundation, gathered two-years of data and analyzed those data to predict which teachers and teaching styles are more effective. The Q Sensor device is designed much like a bracelet. The wrist band measures subtle changes in the skin and the sympathetic nervous system responses to stimuli. However, measures of EDA only illustrate the emotional peak and cannot define the type of

emotional expressions. This functionality limits the tool's effectiveness in measuring the type of emotions being expressed. Alternatively, facial recognition systems (FRS) are used widely to identify the type of responses emitted, or emotional valence. FRS can be used to interpret facial expressions by combining EDA data with FRS data to analyze emotional states and filter the positive emotions for guidance on designing online instruction (Dashevsky, 2011).

Researchers at MIT Media Lab also developed a facial expression recognition system to measure and understand the meaning of facial expression in different contexts (McDuff, Kaliouby, Kassam, & Picard, 2011). The Acume was a simple expressive/non-expressive identification, while Affdex was more advanced and able to recognize emotional states. In 2011, as a MIT-spinoff company, Affectiva produced Affdex, which was a more sophisticated facial expression recognition tool. Affdex was designed to measure such emotional states as surprise, dislike and attention from facial expressions via a webcam. The tool employed advanced computer vision and machine learning techniques to recognize and automate the analysis of tacit expressions, and applied scientific methods to quickly interpret viewers' emotional responses and at scale (McDuff, Kaliouby, Kassam, & Picard, 2012).

Another FRS tool available at the time of this research was the Computer Expression Recognition Toolbox (CERT). CERT was developed at the University of California, San Diego. This tool was a fully automatic, real-time system available for use in academic research. The software tool estimated six universal emotions of facial expressions: happiness, sadness, surprise, fear, disgust, and anger (Black & Yacoob,

1997). CERT provides data on facial expression in real time (Littlewort, Whitehill, Wu et al., 2011) and functions similar to Afdex. A CERT research license was obtained for this research study.

### **Limitations of Study**

The present study acknowledges three limitations to generalizing the findings. First, the participants in the research were limited to college students, which may restrict generalization to populations at other developmental stages. Second, the representations of visual display design principles used in this research were focused on the works of selected human information processes theories (Bertin, 1981; Easterby, 1984, 1967; Gibson, 1953; Johnson, 2010; Kosslyn, 1975, 1976, 1978, 2007; Krippendorff, 2006; Nadin, 1988; Norman, 2003; Rouse, 1975; Simon, 2001; Tiritoglu & Branham, 1996, 1997; Vera & Simon, 1993; Visser, 2006; Weinschenk, 2011; Wickens, 1973); other theories may suggest alternative conclusions. Third, the representations reflecting examples of visual display principles were limited to simple-text, images and the short paragraph. Studies using other forms of visual display may produce different outcomes for those presented here.

### **Definition of Terms**

*MOOC*: Massive Online Open Courses are online courses that often emphasize open access features for students, professors or teaching assistants.

*Online learning environment*: The learning happens in a specific web-based area and through networks.

*Self-paced instruction:* An instructional design is self-paced when it allows learners to progress at their own rates based on their responses to the presentation of content, activities and assessments.

*ISTE:* International Society for Technology in Education is a not-for-profit organization dedicated to supporting the use of information technology to aid in learning, and teaching of K-12 students and teachers.

*SCORM:* Sharable Content Object Reference Model is a set of technical standards for the design and development of e-learning materials.

*NETS:* National Educational Technology Standards are a comprehensive set of standards for effective learning, teaching and leading in the digital age.

*ADDIE:* The ADDIE model is a systematic instructional design model that includes five phases: analysis, design, development, implementation and evaluation.

*Hybrid:* A hybrid course combines face-to-face classroom learning with online learning.

*Blended approaches:* A blended approach combines Internet and digital media with established classroom forms that require the physical co-presence of teacher and students.

*Flipped courses:* Courses are flipped when students gain first exposure to new material outside of class, usually via reading or lecture videos, and then use class time to do the work of assimilating that knowledge, perhaps through problem-solving, discussion, or debates.



*Digital visual display:* Visual display in the context of this study refers to the presentation of complex ideas and information communicated via such technology as computer monitors and hand held devices.

*Learning objects:* Learning objects are web-based interactive chunks of e-learning designed to explain a stand-alone learning objective and a digitized entity that can be used, reused or referenced during technology supported learning. The learning objects must have an external structure of information to facilitate their identification, storage and retrieval: the metadata.

*Reusable feature:* A digital self-contained and reusable entity has a clear educational purpose and at least three internal and editable components: content, learning activities, and elements of context.

*Instructional design:* Instructional design is the practice of creating instructional experiences intended to make the acquisition of knowledge and skill more efficient, effective, and appealing via technologies.

*Emotions:* Emotion may be described as discrete and consistent responses to internal or external events that have a particular significance for the organism.

*Facial expressions:* Facial expressions are a form of nonverbal communication in which the muscles beneath the skin of the face cause movements. They convey the emotional state. Ekman's six universal facial expressions (1970) are happiness, sadness, surprise, fear, disgust and anger.

*Sensory memory:* The shortest-term element of memory is sensory, which is often considered part of the perception process. Sensory memory acts as a kind of

buffer for stimuli received through the five senses of sight, hearing, smell, taste and touch, which are retained accurately, but very short and quick.

*Working memory:* Working memory is also called short-term memory, and represents structures and processes used for temporarily storing and manipulating information.

*Long-term memory:* Long-term memory is anything a person remembers that happened more than a few minutes ago. Long-term memories can last for just a few days or for many years.

*Real time:* Real time relates to computer systems that update information at the same rate they receive information.

*Visual display design:* The visual display design is meant to develop the visualization with the viewer's perception and cognition of the underlying human information processing.

*Evidence-based design principles:* Evidence-based design principles have a strong theoretical justification, are based on accurate information, and are supported by empirical research. They are also referred to as research-based design principles.

*Electrodermal Activity (EDA):* EDA is a relatively non-invasive psychophysiological measure that describes changes in the skin's ability to conduct electricity, and which can be used to study many issues including cognition, affect, and individual differences.

*Emotional Arousal:* The arousal of strong emotions and emotional behavior involves states of arousal that can be positive and negative. These states include fear,

anger, curiosity and love, which are felt with an overpowering intensity and that drives us to act, often in an unthinking way.

*Emotional Valence:* Emotional valence is a description of the psychological perspective of emotions. Emotional can reflect positive valence or negative valence of an event, object, or situation. Positive emotional valence is relative to joy. Negative emotional valence is relative to anger, sadness and so on.

### **Summary**

The focus of this study was on the identification of visual display design principles and design patterns having implications for the development and delivery of online instruction. Representations of visual display design principles, specific to text and graphics, were created in digital form and configured as the research intervention. The responses of college students to their perceptions of the representations were measured in the dimensions of EDA and FRS. The measurement technologies used were the Q Sensor for EDA and the CERT for FRS responses. The results were intended to enhance the effectiveness of designers and developers of online instruction to create visual displays that better meet the needs of the targeted students.

Johnson and Henderson (2002), in discussing the importance of a conceptual model as a framework for researching designs such as visual display designs, posited that emphasis should be on what the product, service or system is to the users not on how it looks. In this study users were students who depended on visual displays presented via the monitor to convey information to them about what they saw and were to learn from online instruction.

## Chapter 2: Literature Review

### **Introduction**

During the past several decades, psychology, neuroscience, and machine learning theories and research have produced principles of human learning that influence instructional design. Recently, research on human emotions and machine learning environments call for changes in educational theory and instructional designs of online learning environments (Meltzoff & Kuhle, 2009). Educational technology is increasingly embodying the principles of social interaction in intelligent tutoring systems to enhance student learning (Koedinger & Alevan, 2007). In the early 2000, Damasio focused on brain research, and now suggests that the aspects of cognition that students practice most heavily in schools, namely learning, attention, memory, decision making, and social functioning, are profoundly affected by and subsumed within the processes of emotions. Today, an important learning research topic is “engagement” and how it relates to learner affect, which becomes emotional expression (Pintrich & Groot, 1990).

The characteristics of emotions are dynamic, individualized, and subjective, consequently theoretical researchers may have different definitions of emotions. Psychologists make a distinction between emotions and feelings where feelings are responses to emotions and related to the experience of a particular situation. Further, emotions include interpretation of the situation or experience. The dictionary defines emotions as (a) the affective aspect of consciousness, (b) a state of feeling, (c) a conscious mental reaction (such as anger or fear) subjectively experienced as a strong

feeling usually directed toward a specific object and typically accompanied by physiological and behavioral changes in the body (Damasio, 2000).

The theories on which this study rests connect emotions, learning development and visual display designs. The study highlights the important role of emotional responses in online instructional design and seeks to understand the relationships among emotion changes and online instructional design elements. Through assessment of emotions during the learning process, the potential exists to expand and validate factors associated with learner engagement through design elements. If these factors are examined together, not only will measurement of emotional responses be improved, the results could inspire online learning system designs that make powerful connections with learners and teachers to create a positive online learning experience.

The theoretical framework for this study relies on (a) a cognitive psychology perspective of instructional design, (b) a human-computer interaction design, (c) a visual display design, and (d) a human learning development. The theoretical model for the emotional response measurement consists of three methods for measuring human emotions: (a) self-report [e.g., questionnaires and interviews], (b) physiological responses, and (c) facial expressions. The theoretical framework explains an approach to understanding the connections between visual design variables and emotional responses via the screen. An extension of this approach is the design of “affective online learning environments” for students. Beyond this theoretical framework, this research created the conceptual model, which had three research stages for achieving this approach.

## **Theoretical Influences**

### **E-learning**

The research literature contains several early descriptions of e-learning using varied terms. In 1997, Elitto Massie described the use of technology to design, deliver, select, administer and extend learning as online learning. Jay Corss (1998) wrote that e-learning is learning on the Internet, the convergence of learning and networks without time and place limitations, and a vision of what corporate training could become. Likewise, Cisco (1999) announced e-learning as Internet-enabled learning. These early concepts of e-learning generally still used traditional training methods with technology as the delivery mechanism.

Today, the components of e-learning may include content delivery in multiple formats, management of the learning experience, and a networked community of learners, content developers and experts. E-learning design is a broad and basically derived from such disciplines as educational psychology, computer science, information science, management, communications, and more. The breadth of subjects and objectives of e-learning among different fields of e-learning researchers have defined the meaning of e-learning and the design processes of e-learning.

E-learning can be either the lone instructional delivery tool or a supplement to face-to-face instruction. As Kenneth Brown, Steven Charlier, and Abigail Pierotti (2012) explained, the possibilities are endless as more combinations and variants of technologies create different e-learning applications with very different capabilities in the future. E-learning will always have new terms to accompany the introduction of new technologies

or applications with learning. William Bowen et al. (2012) suggested online learning is difficult to define because people have different preferences, and so the practice will come in a variety of “flavors.” Brown defines e-learning as a widely applied set of processes, which share a common feature: they rely on some type of computer technology to improve learning.

The big challenge to researchers in this field is the inconsistency of applied e-learning. Gates’ view is that it matters less what specific label or term analysts use for a particular e-learning program than that they provide clear and detailed information about the technological and instructional features embedded in it (Karrer, 2006). That is, it is important for investigators to describe the defining features of the e-learning programs they examine so findings can be appropriately aggregated and compared across studies. Although many researchers define and report details about the learning technologies and learner experiences, all these studies classified under one umbrella term, “e-learning,” which refers to all forms of electronically supported instruction.

Postsecondary e-learning commonly relies on the Internet. Studies of e-learning with this population use the term e-learning, online learning or web-based instruction on their articles, and the concept usually refers to instruction delivered through network technology. Gates (2000) commented that the term of e-learning can be used in general conditions at the college level because when students take online courses, the technology is embedded in the network. In a Google search, he found about 94 million results for “e-learning” compared with 33 million for “distance learning” and 20 million for “online learning.” The data also show the term e-learning came up in the early years of the

concept, and distance learning and online learning came later. E-learning is a key term for all learning via different computer technologies. However, when researchers examine the learning experience or outcomes, they are usually careful to note what specific type of technology for the instruction and yield particular findings.

### **Multimedia Learning**

Greenfield (1994) noted that employing multimedia resources in teaching improved college students' concentration, aided in developing needed study skills and enhanced intelligence. Researchers now report that multimedia has become a common practice in online instruction. Most e-learning environments establish goals to improve students' learning (Clark & Mayer, 2011). As educational technology has advanced, the approach has opened new possibilities for engaging students in active learning, student-centered classrooms, and routine use of visual materials (Gilbert, 2005).

The cognitive theory of multimedia learning (CTML) has been widely used in e-learning. CTML is based on the human information processing system, which includes dual channels for visual and auditory processing, but each channel has limited capacity for processing. When humans learn, active learning involves a coordinated set of cognitive process (Mayer, 1999). CTML, a widely used the theory that applies to the instructional content design, focuses on how people learn from four elements: (a) dual-coding theory, (b) limited capacity-working memory, (c) active processing, and (d) information transfer.

Most popular principles of multimedia instruction design are: multiple representation principle, individual differences principle, coherence principle, signaling



principle, split-attention (redundancy) principle, and contiguity principle. These design principles are more important for low-knowledge than high-knowledge learners, and for high-spatial rather than low-spatial learners. In general, the approach of the multimedia design principles suggests presenting an explanation in words and pictures is better than solely in words. More specifically the principles suggest that when giving a multimedia explanation, it is better to use few rather than many extraneous words and pictures. Also, when the important words are highlighted, learners learn better; when the content present words as auditory narration rather than as visual on-screen text, learners receive more information; and when presenting corresponding words and pictures contiguously rather than separately, multimedia design is better for learners (Mayer, 2001; Clark & Mayer, 2007).

### **Affective Learning**

A growing number of studies on emotion hold that to understand the concept of human emotions and interpret its role in life it is useful for dealing with human learning and development (Damasio, 1994; Plutchik, 2001). Indeed, several scientists and psychophysicists have studied with the topic of emotions over the years. Darwin (1865) explained that emotions as an evolutionary concept, and man and animals both have emotional expressions. He analyzed the muscle movements in each expression and argued that human expressions are sometimes homologous with those of primates, despite differing superficial appearances, because the underlying muscle contractions are the same. He noted that the physiology of emotions was simply a manifestation of personal feelings. After his study, other researchers began identifying emotions. James

(1884) mentioned that emotional experience is largely due to the experience of bodily changes, and a conscious emotional feeling is the from changes in the autonomic nervous system. This is the begging of the psychophysiological prospective.

Later, the cognitive or neurological view of emotions was started by Walter Cannon in the 1950's. Benjamin Bloom (1956) identified three educational activities or learning domains: (a) cognitive, (b) affective, and (c) psychomotor. Learners express their feelings, values, appreciation, enthusiasms, motivations and attitudes when they experience educational activities and materials (Krathwohl, Bloom, & Masia, 1973). The research supports the concept that human emotional expressions have their origins in both cognitive factors and non-cognitive factors (e.g., situations in a person's life).

A leading neuroscientist, Damasio has studied brain and emotions for several decades. Yang and Damasio (2007) highlighted important connections between emotions, social functioning, and decision making. They believe that better understanding of the neurobiological relationships between the constructs of elements in human emotions will provide a new basis for the design of learning environments. Griffiths (1998) wrote that Damasio (1994) found that "emotions are the perception in the neocortex of bodily responses to stimuli mediated through lower brain centers." These studies of emotions explain that human emotions interact with different situations, design elements in learning environments also have significant influences.

In more recent years, the literature has reported on affect, which refers to the interaction of emotion, motivation, attention, reward, and more. However, this body of

research still has the challenge of refining the language used with respect to affect and learning (Picard et al., 2004), and still needs more research on affective states in learning.

## **Human Performance (Human-Computer Interaction) Theory**

### **Human Information Processes**

The theory of an applied psychology of human-computer interaction is based on the theory of information processing psychology. However, studies on human-computer interaction psychology have more emphasis on mental mechanism. The use of models in which man is viewed as a processor of information provides alternative frameworks for human information processes. These models usually describe the integrated relationships among memory, problem solving, perception, and behavior. A system designer does his work not only in system design but also in information processing terms, so the emphasis is doubly appropriate in the context of instructional design. One reason for the lack of a common framework is the difficulty of melding important principles or theories, such as the use of Skinnerian contingent reinforcement. The principles or theories are not useful in general, and cannot be applied to solve the problems of the human-computer interface (Card, Moran, & Newell, 1983).

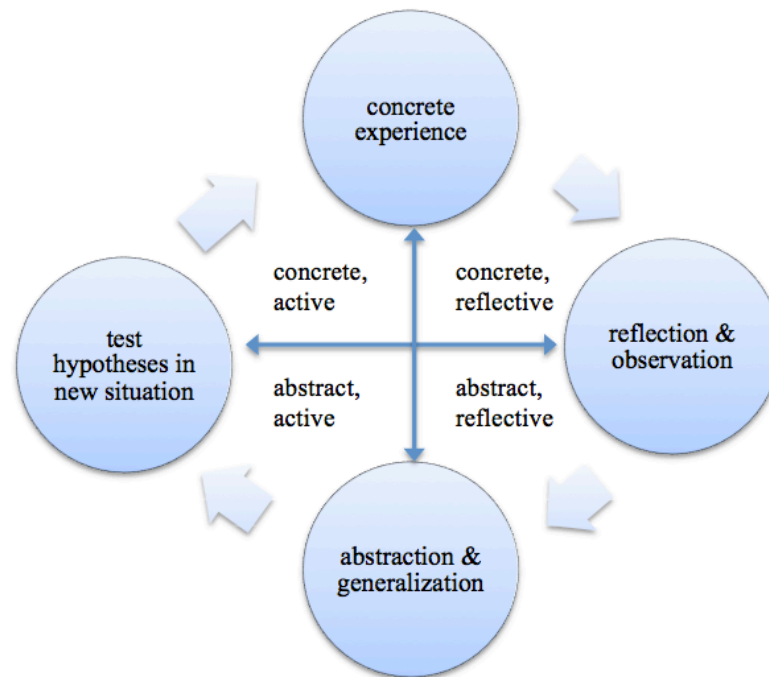
Human-computer interaction happens when a user engages in communication with a computer engage for the purpose of accomplishing a specific task. A model of the human processor can be divided into three interacting subsystems: (a) the perceptual system, (b) the motor system, and (c) the cognitive system. Each system has its own memories and processors. The perceptual system consists of sensors and associated buffer memories, the most important buffer memories being a visual image store and an

auditory image store to hold the output of the sensory system while it is being symbolically coded. The cognitive system receives symbolically coded information from the sensory image stores in its working memory and uses previously stored information in long-term memory to make decisions about how to respond. The motor system carries out the response (Card, Moran, & Newell, 1983). The human-computer interaction always embraces the theory of human information processing because the computer design should imitate the way of human information processing.

### **Affective Design**

When people deal with the activities of daily life, the design of the objects and systems has an influence on their emotions. The field of human-computer interaction design began discussing emotions in terms of human affect. Kolb (1984) proposed two dimensions for how people deal with new information. The first dimension was abstract versus concrete reasoning; the other dimension consisted of reflective versus active processing. If these two continua are placed at right angles, the quadrants represent the combinations of strength in these two dimensions (see Figure 1) that represent their learning style. Although everyone goes through the cycle as they learn new material, people are most comfortable with and extract the most information from the phases that correspond to their preferred learning style. Kolb's Experiential Learning Theory has the best experimental support for improved learning outcomes when a student's learning style is matched by the appropriate teaching methods. He suggested that learning involves a cycle of four discrete steps: (a) a concrete experience that leads to (Do) (b) reflective observation on that experience (Observe), (c) the development of theory

through abstract conceptualization (Think), and (d) test of the theory by active experimentation that generates new experiences (Plan).



*Figure 1.* Kolb's experiential learning cycle

Norman's (1988; 2002; 2007) research on affective design noted that emotions relate to experience theory. Good design will receive a user's positive feedback. User's emotions have three levels: (a) visceral level (appearance); (b) behavior level, the pleasure and effectiveness of use; and (c) self-image, personal satisfaction and memories. If the affective design study overcomes culture influences, four components of good behavioral design are function, understandability, usability and physical feel. These components process memories, and memories reflect our life experience. Cognition understands the world and emotions as interaction with the world. Norman further

explained that design objects for fun and pleasure include four dimensions, which consist of physio-pleasure, soci-pleasure, psycho-pleasure and ideo-pleasure.

### **Affective Computing**

The specific terminology for developing systems in relation to human affect is “affective computing” (Picard, 1997). In the early stage of psychology, most studies held the view that cognition confronts emotions and affective states, events, and experiences. The main theories of cognition, however, did not take into account emotions (Anderson 1983, 1993; Newell, 1990). Later, many researchers found emotional affects cognition in a variety of ways.

Some studies on affect noted cognitive and information processing aspects, such as affect can be encoded into machine-based rules and studied in a learning interaction (Picard, 2003). Other studies have identified the tendency for a pleasurable state of flow to accompany problem solving that is neither too easy nor too challenging (Hausman & Siekpe, 2009). Other scattered attempts to address emotions involved in learning are also found in the literature (Csikszentmihályi, 1990; Lepper and Chabay, 1988; Mandler, 1884; Kort et al, 2001). However, the field still has very little understanding as to *which* emotions are most important in learning and *how* they influence learning. To date no comprehensive, empirically validated theory of emotions addresses learning.

Motivation is influenced by how pleasurable past learning experiences have been, and how emotions contribute to whether a learner cares about an issue or considers it important. More research is needed to define the role of past learning experience on learning because we know that such intrinsic and extrinsic load influence emotions and

new learning experiences. Such concepts as self-efficacy and satisfaction also play critical roles in learning; and learners' beliefs about their efficacy also affect their emotions. Many researchers have connected affect and cognition and merged the results into motivation theories (Ames & Archer, 1987; Maehr, 1983; Dweck, 1986; Dweck & Leggett, 1988; Elliott & Dweck, 1988). Many efforts have provided vast insight into human affect, but the field still has very little evidence of the theories at a level suitable for implementation in an interactive machine model.

Picard (1994) explained that affective computing is human-computer interaction in which a device has the ability to detect and appropriately respond to its user's emotions and other stimuli. A computing device with this capacity could gather cues to user emotions from a variety of sources. Affective computing could offer benefits in an almost limitless range of applications. For example, in e-learning situations, the computer could detect from available cues when the user was having difficulty and offer expanded explanations or additional information. Other applications include e-therapy: psychological health services, such as counseling, delivered online. Internet-based therapy, although increasingly common, does not give a therapist as many cues to the client's emotional state as are available in a real-world session. Picard (2004) investigated that the interaction of emotions, cognition, and learning in the "Learning Companion" project in the affective computing group at MIT's media lab. This project intends to develop an "affective companion" prototype that will provide emotional support to students in the learning process by helping to ease frustration. This series of studies on emotions and learning has more relevance to online learning.

## **Mapping Design Theory to Instruction Design**

### **Models and Standards Concerned with Instructional Design Processes**

Instructional designs at the post-secondary level still need to be improved. In the late 1990s, the capacity of technology for supporting online instruction far exceeded the instructional design and pedagogical features applied in online instructional environments. Not a lot of improvements were driven by research. Most improvements to date were driven largely by experience, technology improvement and involvement of accreditations association. This phenomenon still appears in 2014 (Friedman & Deek, 2003; Bell & Federman, 2013). The early emphasis of higher education in online instruction was on developing asynchronous courses but moved quickly to also developing synchronous courses. Hybrid and blended approaches were yet to appear on the scene nor was the concept of flipped courses on the horizon. Instructional designs were largely influenced by continuing education models of the past, and by teaching practices that had been successful in traditional college teaching and found to be generalizable to online teaching. Most researchers pay attention to development of standards or models to guide online teaching and the development of resources for use in instruction delivered via the Internet based on cognitive processes of learning (Anderson & Bushman, 2001).

In 1975, the Center for Educational Technology department at Florida State University designed ADDIE Model for the U.S. Army. Today, the ADDIE model has extended to other instruction design (ID) models. The ADDIE model has had a significant influence on the field. The ADDIE instructional design model is the design



process used by instructional designers and training developers. It is based on the instructional systems design.

The ADDIE model consists five cyclical phases: Analysis, Design, Development, Implementation, and Evaluation. The analysis phase usually addresses the purpose or goal of this system. The design phase plans all tools and media for achieving the goal. The development phase starts producing the system and testing. The implementation phase is a procedure stage. Teachers and students use the system and provide feedback during this stage. Finally, the system is evaluated and modified. These processes represent a dynamic and multi-dimensions guideline for developing effective training and performance support tools.

One of the best known models for designing instructional systems is the Dick and Carey design model. Dick and Carey (1996) describe all phases of an iterative process that starts by identifying instructional goals and ends with summative evaluation. This model is applicable across a range of context areas and users. It is a student-centered model. This system model implies that it is more involved with instructional development than design. One of the limitations of this model is that behavior is not considered. Some critics feel that the systems approach is too focused on specific objectives to be successfully applied to the development of instruction that supports higher level thinking and the active construction of knowledge by learners. However, advocates of the systems approach dispute this claim, and believe the systems approach can be effectively employed to set appropriate goals and construct learning environments that facilitate the attainment of those goals (Merrill, Li, & Jones, 1990). Furthermore, the

1996 version of the model (the original model was introduced in 1968) included many important changes. For instance, Dick and Carey (add citation) considered the impact of performance technology on the derivation of instructional goals, as well as increased focus on the context of learning. The front-end analysis has a focus on instructional and learner analysis, which is very appealing, although this model is very linear (Qureshi, 2004).

Today, the shareable content object reference model (SCORM) plays an important role and widely emerging e-learning standard. The goal is ensuring ubiquitous access to the highest quality education and training, tailored to individual needs. The standards also guarantee the e-learning delivers is cost effective anywhere in the world at anytime. The U.S. Department of Defense (DOD) developed the SCORM model. The advanced Distributed learning (ADL) Initiative field-tested this model and published. The SCORM standard is focused on enabling the plug-and-play interoperability, accessibility, and reusability of web-based learning content. Accepted technology standards included XML and JavaScript, SCORM became the deface to e-learning technology standard widely embraced and supported today by world-leading corporations, universities, system providers, and content vendors (e.g., Digital Think).

International Society for Technology in Education (ISTE) and National Educational Technology Standards (NETS) developed the ISTE standards for learning, teaching, administration, coaching and computer science education in the digital age. The ISTE standards are widely adopted among educational systems. The guidelines of the standards include design student-centered, project-based and online learning

environments; improve thinking skills; prepare students for their future; guide schools to create a digital place for learning; and inspire the digital age professions (2012).

The Center for Applied Special Technology (CAST) defined the Universal Design for Learning (UDL) framework in 1990s. UDL is a set of principles that provides teachers with a structure to develop instruction to meet the diverse needs of all learners in digital age. UDL suggests that each student learns in a unique manner because a one-size-fits-all approach is not as effective. UDL guides design of instructional presentation, students' idea expressions, students engagement in learning, customized instruction and individual student need. Especially, educators can use the UDL framework to the Common Core Standards-aligned tasks for supporting students and students with disabilities to engage in learning.

The intent in framing design standards was to maximize the quality of online instruction and to ensure instructional effectiveness. For the most part the standards addressed instructional design and not design from the perspective of digital visual display images or models for the display of information via the monitor. It is important to focus more on the structuring and delivery of content. Then, visual display design principles could enhance engagement, motivation or the processing of information.

### **Cognitive Perspective**

Cognitive development theory is one important theory of human learning development. This theory refers to the mental process by which knowledge is acquired, stored, and retrieved to solve problems. Cognitive development study had an impact on the constructivism movement in education. Piaget (1952) pointed out that “the process of

intellectual and cognitive development is mental adaptation to environmental demands. To have a better appreciation of this process, it is essential to understand the following concepts: schema, assimilation, accommodation, and equilibrium (p.50).”

Piaget proposed the word *schema* to describe a mental process that adapts to environmental common patterns. O’Keefe and Nadel (1978) noted that schema is unlimited. When people grow, they gain new patterns of different environments. Papert coined the term “Piagetian learning” to mean simply learning without instruction. He gives the example of how a baby learns to speak. The baby learns to speak without direct instruction or a curriculum. The baby learns to speak because this means of communication is intricately embedded into the social and emotional life of the child. So, a child can learn to be computer literate by being immersed in computer culture. Papert supported the development of a new theory for learning with technology and illustrates this need by covering six main ideas: (a) the effect of happiness on learning, (b) the modest pencil-an analogy, (c) accessibility impacts results, (d) schools are designed for certain personalities, (e) Piagetian learning, (f) computers: teacher replacements or enhancements? Papert described learning environments in which children collaborate around meaningful projects and powerful ideas. He explained his logic behind the belief that “the computer is going to be a catalyst of very deep and radical change in the education system.” (Papert, 1984, p. 422).

### **Cognitive Artifacts of Design**

Simon’s framework (1996) has been used for design and became the main manifest influence (Visser, 2006). He proposed that “everyone design who devises

courses of action aimed at changing existing situations into preferred ones” (p.111).

Winograd (1986), on the other hand, defined design as conscious, a conversation with materials, creative communication, a social activity, having social consequences, and keeping human concerns in the center.

Symbolic information processing (SIP) and situativity (SIT) have been discussed in the different design fields (Visser, 2006). The SIP approached a sensible use of the term “situated action” referring to action that occurs “in the face of severe real-time requirements” and that is “based on rather meager representations of the situation” (Vera & Simon, 1993, p53.). Vera and Simon also noted the symbolic systems appropriate to tasks calling for situated action (SA), however, have special characteristics that are interesting in their own right. The term situated action can best serve as a name for those symbolic systems that are specifically designated to operate adaptively in real time, complex environments. The symbols are patterns and can be numerical, verbal, visual or auditory (Simon, 1990). SIP researchers pay more attention to people’s use of knowledge and representations in problem solving than to the construction of representations, and they do not analyze activities as they occur in interaction with other people and the broader environment. However, situativity-oriented researchers argued that the conditions of “sense giving” merit more attention and more study than the possibly underlying activities whether they are symbol-based or not. They focus on the social and interactional aspects of these conditions (Anderson et al., 2000). SIT researchers focus on the consequences of people’s interaction and the influence of the

environment, the social and cultural setting, and the situations in which people find themselves, but they usually neglect the underlying cognitive structures and activities.

The definitions of design vary among such fields of study as information systems, architectures, or environments. Different terms are used in these design fields to denote the activity of creating a product. A broad view of design includes alternative socio-technical and cognitive-based perspectives on shaping social, physical, semiotic and technological environments. The design has been across of technology, people, organizations and markets. To promote positive social, organizational and personal prosperity and suggests theory of design with social integration for generating value as well as promoting human life. While discussing a design theory applicable to social integration, one must start with “human factors” (Vissor, 2006). To design at a cognitive level, the specification activity consists of constructing representations of the artifact until they are so precise, concrete, and detailed, resulting in a representation of the artifact product (Goel, 1995; Vissor, 2006).

Display designs have widely used psychological principles. Easterby’s model of task, processes and display design included two parts: (a) user characteristics, and (b) display characteristics. When humans perform tasks, their sensation and perception, learning, memory, problem solving, and motor activities influence their performance. Designers need to understand the characteristic psychological processes and transform these into the display. In display design, designers may consider the legibility, conspicuity, readability and meaningfulness of a display. Although they are not psychological processes, designers can manipulate these attributes of the display

(Easterby, 1984, 1967; Rouse, 1988). Kosslyn (1975, 1996, and 1980) proposed psychological principles for designing visual displays designs. He claimed that these psychological principles can effectively deliver information via displays. The principle of capacity limitations deals with human's memory limits. The principles of perceptual organization are linked to human perception and sensation systems. The principle of compatibility and informative changes can help human learning. By following Kosslyn's (2007) principles of design, the visual displays can communicate with people without large differences in information at a time and nor unclear information. These principles achieved the purpose of connection with the audience, attention hold, and understand and memory promotion.

### **Designer Core Competencies**

Conely (2004) defined core competencies for designers based on concepts from George Miller's recognition of human memory capacity. Miller (1956) recognized that the human's short-time memory only can remember amount of information. The seven core competencies designers need to have are the ability to: (a) understand the context or circumstances of a design problem and frame them in an insightful way, (b) work at a level of abstraction appropriate to the situation at hand, (c) model and visualize solutions even with imperfect information, (d) solve problem that involve the simultaneous creation and evaluation of multiple alternatives, (e) add or maintain value as pieces that are integrated into a whole, (f) establish purposeful relationships among elements of a solution and between the solution and its context, (g) use form to embody ideas and to communicate their value. The core competencies of design facilitate specific and

tangible ways of engaging with problems. Designers need to foster the broad application of designs into new values on works. Thinking as a designer is a discipline with a set of competencies that can be understood in objective terms and applied broadly across different functions (Shneiderman, 1996).

### **The Role of Design Elements**

Representations are goal-oriented tools, that is, “constructions, which for some purposes, under certain conditions, used by certain people, in certain situations, may be found useful, not true or false” (Bannon, 1995, p.67). Zhang and Norman (1994) defined two different types of representations that differentially activate perceptual and cognitive processes. The external representations activate perceptual processes, whereas internal representations usually activate cognitive processes. A particular type of internal representations is “percepts,” that is, the mental representation that result from perception. Percepts clearly play an important role in design, especially in design of physical artifacts (Tiritoglu & Branham, 1997, 1998). How does the designer create representations that adapt to the human information processing system? Design elements have an important influence on the human visual information-processing system. Basically, designers need to understand the design methods of visual elements. These visual elements have an important role in human perception and sensation that echoes cognitive development theory. Several well-known scholars considered whether how well such visual elements as graphs, images, and texts are represented are important for delivering information efficiently (Bertin, 1981; Gibson, 1953; Krippendorff, 2006; Nadin, 1988; Tiritoglu & Branham, 1996, 1997). Kosslyn (2007 & 2012) explained



usage of the effective charts and graphs design is related to the nature of the human information-processing system. The visual elements of the displays also include pictures, text, color, texture, animation, and sound. Tufte (1983 & 1990) described the purpose of an information designer does not focus on beauty, but must communicate between readers and documents. The information designer should use the intersection of image, word, numbers or other elements to help readers scan the screen for information.

Gestalt psychologists investigated the way human process information from a two-dimensional surface. Any mark drawn on paper stimulates an active, interpretive response from eye and brain. Applied to the concept of design, the fundamental principles are from visual perception (Arntson, 2012). Considering visual variables as the basic elements of information visualization design is very powerful. Bertin's (1983) defined seven visual variables: position, size, texture, value, orientation, shape, and color. Bertin's visual variables analyze the cartography in the creation of what it terms data graphics as part of the semiology graphics. These visual variables are broadly used in visual representations for delivering information. The basic visual variables can be created on a page. The position of visual representations can be changed in different location by x and y axis. When the visual representation changes in length, area or repetition, its size changes. An infinite number of shapes exist for representations. Their color can change usually in hue at any given value from light to dark. Their orientations can change in alignment, and their textures can vary in granularity (Carpendale, 2003). Size is the most basic and often used form of contrast in graphic design.

Most successful designs benefit greatly from size contrast in type or in image. Typography also uses value contrast. The contrast of a black, heavy type against a light one helps relieve boredom and makes the page more readable. In type design, shape refers to the contrasting characteristics of type families, Type structures can be thick / thin and serif/ sans serif. The orientation of objects generates a directional pull along the main structural lines. The brighter and more intense the color, the heavier it will be visually. Several classic sans serif typefaces were designed at the German Bauhaus. Influenced by the Bauhaus, the Swiss firm Haas worked with the German Stempel foundry in 1957 to produce Helvetica. Helvetica is still considered by many designers to be the perfect type because this font is versatile, legible, and appropriate in a wide variety of applications. Type smaller than 10 points is often difficult for older people to read, and if the final format will be a Web page, its effectiveness should be judged on the screen.

Gibson (1953) described the picture perception. The picture can have three main types o of different groups: (a) non-conventional, (b) conventional, and (c) mixed. These three types of images can be created and depend on different considerations. People explain the perception of the environment before they start speaking, and they also make a picture or an image in their minds.

### **Measurements in Students' Affective Learning**

Over the several decades researchers have recognized the significance of emotions in learning process. However, a stable, reliable and systematic analysis of emotions in the learning process of online instruction has been slow to emerge

(Boekaerts, 2007 & Zembylas, 2008). Recent studies have the topic regarding how a learner's emotions affect the learning process. Nevertheless, there is still a lack of analysis on the emotions of learning in online learning (Schutz & Pekrun, 2007).

E-learning has been described as less emotional and more impersonal, and as lacking in rich emotions compared to face-to-face learning (Vrasidas & Zembylas, 2003). In fact, people have emotional expressions in different environments. Sometimes, these emotions are too tiny to recognize. Recent research has discovered how such negative emotions as frustration and confusion and such positive emotions as engagement and pleasure occur in online learning during the learning process for learners (MacFadden, 2005; O'Regan, 2003). Wlodkowski (1999) emphasized the basic role of emotions can decrease or increase learners' motivation. In his suggestions, educators need to pay attention on the learners' expression of emotions during learning.

### **Self-Report and Questionnaires**

Many researchers conduct interviews and surveys in their research of emotions in online learning. They believe that the investigation will allow research to have an understanding of the learner's perspective and the construction of emotional knowledge within a particular social environment (Boler, 1999; Zembylas, 2008). Many studies of emotions are inspired by psychological and sociological perspectives. When researchers use interviews and surveys to understand learners' emotions, they believe that they can cover both psychological and sociological perspectives.

The nature of narrative research methodology is considered different ways: First, a narrative is a way of "ordering and presenting a view of the world through a description

of a situation involving characters, actions and settings that changes over time” (Foss, 1989, p. 229). Second, “a narrative can be critiqued by assessing its substance, form, appropriateness, aesthetic appeal, or emotional tone given the context of a particular audience” (Gross & Niemants, 2006, p. 3). This type of emotional study experiences challenges related to ahistorical conception of the subject to online learning, difficulty of analyzing the transaction between larger social forces and the internal personal psychological traits, and the fact that people who are socialized will hide their real emotions (Zembylas, 2008).

### **Physiological Responses**

Previous emotional research studies have compared facial expressions or body gestures, which people can control, to the physiological data, that is more difficult for people to control—revealing their conscious and unconscious emotions. Advancing technology is increasing the number of applications that assess emotional responses by gathering physiological data. The literature cites some common physiological signals that measure emotions (Gross, 1998; Picard, Vyzas, & Healey, 2001). Hence, several sensors can capture different physiological signals, such as electrocardiogram (ECG), electrodermal activity (EDA), and brain activity.

Emotional signals have been shown to be indicated and measured easily by EDA. Electrodermal sensors can measure the current state of the sympathetic nervous system, thus receive physiological data faster than other sensors. Even though the electrodermal responses of people are small, the sensors can still accurately measure changes in them.

Any change in a subject's focus or emotional state will potentially trigger a change in EDA.

EDA is used to describe changes in the skin's ability to conduct electricity. It is a useful, fast, inexpensive, well established (since 1880's), low-tech and relatively non-invasive psychophysiological measure, which can be used to study many issues including cognition, affect, and individual differences. The rise time for the Skin Conductance Response (SCR) tends to be between 1-2 seconds, the response peak tends to be at around 2-4 seconds and the  $\text{rect}(\pm \frac{1}{2})$  (rectangle t/2), which is the function defined to be 0, 1 or undefined, tends to take about 4-8 seconds (Lim, Rennie, Barry, Bahramali, Lazzaro, Manor & Gordon, 1997).

One recent technologies used to collect EDA data is the Affectiva Q sensor, used by the project "Engagement Pedometer" of the Bill & Melinda Gates Foundation. Biometric devices wrapped around the wrists of students identify which classroom moments excite and interest them. This bracelet can measure students' emotional responses and tell teachers in real-time which environments students are involved. These data can help educators design their instructions and hold students' interests and notices. This bracelet measures students' skin subtle changes and the sympathetic nervous system responds to stimuli. However, these devices do not distinguish between fear and interest. Researchers need to use videotaping to determine what happened at moments of response. The Engagement Pedometer project has gathered data for two years and analyzed these data to predict which teachers and teaching styles are more effective (Picard, 2011)

Biosensors can make instruments more valid and reliable for identifying teaching and learning affectivity. This technology might be a good option to collect students' emotional responses in online instruction, and test how students engage by an online lesson or online interactivities (Myszka & Rich, 2000). Physiological measures proved to be stable and insightful as cognitive measures and often correlated with newer natural symbolic measures. Emotion-based measures improve depth to our understanding of how online learning process into the moment-by-moment emotional connections.

### **Facial Expression**

Emotions have two dimensions, which are arousal and valence. Arousal measures intensity of emotions, e.g., how pleasurable the situation is, and valence measures how positive or negative the emotions are. Good approximate measures of valence can be obtained from facial expressions, and of arousal from the sympathetic nervous system. A particularly compelling nonverbal channel is facial expression, which has been intensely studied for decades (Williams, 2002).

In early studies of emotions during online learning, most researchers used facial recognition system to analyze learners' facial expressions. The Facial Action Coding System (FACS) (Ekman & Friesen, 1978) has been widely used to study detailed facial movements for decades. FACS enumerates the possible movements of the human face as facial action units. Thus, FACS is an objective measure used to identify facial configurations before interpreting displayed affect. Because a FACS quantifies facial movements present in displays of emotions, it allows researchers to identify facial components of learning-centered affect, which have been found to be different from those

in everyday emotions (Calvo & D’mello, 2010, 2011; D’mello, Craig, & Graesser, 2009; Littlewort, Bartlett, Salamanca & Reilly, 2011a; Littlewort, Whitehill, Wu, Fasel, Frank, Movellan, & Bartlett, 2011b; Zeng, Pantic, Roisman, & Huang, 2009). Identifying these action units is a time-intensive manual task, but a variety of computer vision tools are in current use, most often focusing on tracking facial feature points (Calvo & D’mello, 2010; Zeng, Pantic, Roisman, & Huang, 2009). The Computer Expression Recognition Toolbox (CERT) offers a mid-level alternative. CERT produces intensity values for a wide array of FACS facial action units, thus enabling fine-grained analyses of facial expression (Littlewort et al., 2011b). Facial recognition system highlights the intensity and frequency of facial expressions and can predict learning outcomes of the tutoring system (Grafsgaard, Wiggins, Boyer, Wiebe & Lester, 2013).

Undoubtedly, Ekman’s efforts on human’s facial expressions research have had a significant influence on the role on emotional studies. Even though technology continues to innovate new tools, human emotions are dynamic, multi-dimensional and unstable and therefore facial recognition applications usually suffer from three main problems: a reduced training set, information lying in high-dimensional subspaces, and the need to incorporate new people to recognize. Facial expressions also differ among people influenced by different cultures or values. The applications need to be adjusted for new people (Masip, Lapedriza & Vitria, 2009).

### **Summary**

Online learning includes two dimensions: learning and technology. A learner’s affective state is a significant factor of his or her learning experience. Understanding a

learner's affective states is an essential component for improving learner's engagement and motivation. This is particularly true in online instruction. The existing theories and standards related to online instruction instructional design has not had the advantage of extensive research results to effectively impact the design of online instruction that builds on evidence-based affective practices. New technologies for the measurement of emotions should contribute to research needing to be done, to improve the affective dimension of teaching and learning. This is particularly true in online learning environments, and in the application to instructional design elements that can improve learner's learning affective state and engagement in learning.



## Chapter 3: Methodology

### **Introduction**

The purpose of this research was to investigate consistency in the emotional responses of online post-secondary learners to digital representations of evidence-based visual display design principles. The intent was to determine whether participants in viewing digital representations of evidence-based visual display designs, presented via a computer monitor, would differentiate between representations that are explicitly supported by research as effective and variations that were not supported by research. The representations of principles were grouped in two categories related to the presentation of text. Group 1 was comprised of 106 representations. These representations took the form of letters, words, simple phrases and images; and this group included pairs or representations for a sample of visual display design principles with one representation of each pair reflecting a research-validated representation of a principle and the other being not research based. Group 2 was comprised of representations that were more complex and took the form of paragraphs and formats. The digital representations in Group 2 varied from a validated explicit example reflecting the respective information processes. These four representations varied in the degree to which they accurately represented the information grouping style design principle. The digital representations of each principle in Group 1 and Group 2 were presented to participants via a computer monitor in random order.

Two technologies were used to detect the emotional responses of participants to the digitally presented representations. The Q sensor was used to measure Electrodermal

Activity (EDA) responses for understating emotional arousal changes (Picard, 2011), and the Computer Expression Recognition Toolbox (CERT), a facial recognition system, was used to measure changes in patterns of facial expression in response to viewing the digital representations for understanding the effects of positive emotional valence (Littlewort, Whitehill & Wu et al., 2011)

The process in this research included six major activities:

1. identification and validation of visual display design principles that had been identified in human information process theories as applicable to online instruction
2. design and validation of digital representations reflecting varying degrees of compliance with each of the evidence-based design principles
3. transformation of representations into an experimental intervention comprised of a video structured to present the digital representations in a timed sequenced pattern
4. configuration of a data collection process to ensure synchronization of the data recorded by the Q sensor and the CERT; the responses of participants were automatically recorded via the Q sensor and the CERT
5. videotaping of each participant as they viewed the presentation of each digital representation, to add an additional source for confirming the synchronization,

6. interviewing of participants at the conclusion of their participation in the experiment to collect additional evidence supplemental to the psychophysical and demographic data.

The intended outcome of these research procedures was to collect data on the measured emotional responses of participants to representations of evidence-based visual display designs. If the pattern of responses was found to be positive to digital representations of explicit evidence-based visual display designs, this finding could have a significant impact on the design on online instruction. The results of this study could potentially contribute to maximizing the instructional effectiveness of visual display designs used in developing and presenting online instruction. The underlying goal was to enhance understanding of how different visual display designs affect the responses of online learners.

### **Research Questions**

1. How does students' emotional arousal change when representations of evidence-based visual design principles ranging from explicitly good to explicitly poor examples are visually displayed to them in digital format?
2. How does students' emotional arousal change when representations of evidence-based visual design principles with different information grouping layout design examples are visually displayed to them in digital format?

3. How does students' emotional valence change when representations of evidence-based visual design principles ranging from explicitly good to explicitly poor examples are visually displayed to them in digital format?
4. How does students' emotional valence change when representations of evidence-based visual design principles with different information grouping layout design examples are visually displayed to them in digital format?
5. What do changes in emotional arousal and valence elicited in response to change in visual information display imply for the design of online instructional resources?

### **Hypotheses**

1. Students show no significant difference in the emotional arousal change to viewing representations of evidence-based visual designs that range from explicit representations of design principles to poor representation in a digital format.
2. Students show no significant difference in the emotional arousal change of participants to viewing representations of evidence-based visual designs that range from different information grouping layout styles in a digital format.
3. Students show no significant difference in the effect of positive emotional valence of participants to viewing representations of evidence based visual

designs that range from explicit representations of design principles to poor representations in a digital format.

4. Students show no significant difference in the effect of positive emotional valence of participants to viewing representations of evidence based visual designs that range from different information grouping layout styles in a digital format.

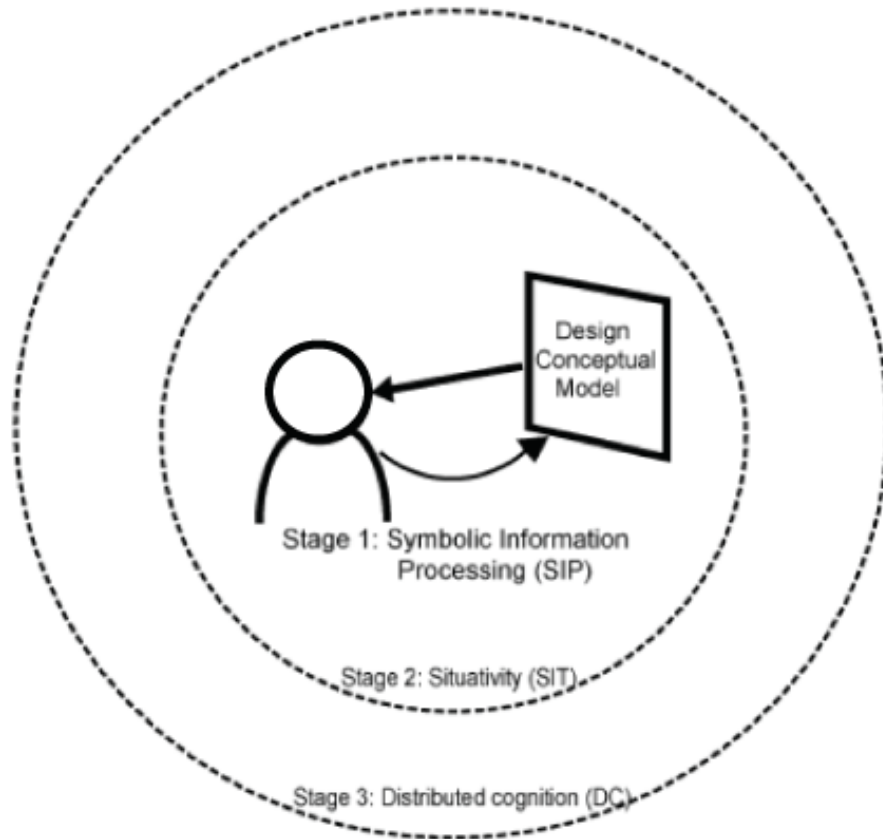
### **Research Context**

This research emerged out of a long-term interest of the researcher in emotional experiences by learners in online instructional environments. The design and structuring of online instructional environments have evolved into such varied models as hybrid and blended, and are now available such that online learners may also have interpersonal experiences with their classmates and face-to-face interactions with their instructors. Developers engaged in creating online tools are also addressing the personalization of online instruction. However, the primary delivery of online instruction remains focused on the utilization of the visual display within the capacity of the computer monitor. Through sharing this research interest with faculty and staff, a quasi-study group evolved representing expertise in visual display design from the field of art and design, human factors, instructional design, research design, and the measurement of physiological responses to stimuli. An outcome of these systematic interactions over a sustained period of time was the evolvment of a strategy for capturing the evolution of research ideas as they emerged. This process contributed to the framing of a multi-stage approach to

examining a programmatic research model that in the future would take the form of collaborative research that will build on the present study.

In reflecting on the collaborative perspective, the research group was engaged in what could be described as a core competency set for a designer, that is, a designer should have the ability to not only design a product, but also to manage and know the user (Conley, 2004). The application of dialogue mapping emerged in this research process (Conklin, 2005; Ericsson & Simon, 1993). This approach to capturing dialogue and interactions among the research group participants was viewed as being compatible with the research needing to be done in studying the responsiveness of online learners to visual display representations applicable to online instruction. It was clearly evident that an interdisciplinary set of skills such as those represented by the research group was required to design the Stage 1 research. The dialogue mapping initially employed by the group was based on a detailed literature review done by the researcher and extensive discourse on the implications of that review for the visual display research conducted in Stage 1 of the conceptual research model. Archival data in the form of notes, emails, descriptive statements by participants, work previously carried out by participants, group decisions, modifications of ideas and actions by the group came to represent the legacy work of the research group. The initial dialogue mapping approach focused on exploring visual design principles from a variety of sources and experiences of the research group. Out of this dialogue mapping experience emerged the following outcomes:

1. An extensive compilation of theory and evidence-based design principles viewed as having implications for human information process of visual display designs applicable to online instruction
2. A consensus that the initial research should address a sample of identified visual display principles identified in Stage1 due to the time inherent in developing the representations of the identified visual display principles; the initial principles to be researched in this study should to be evolutionary beginning with text only, and subsequent research can be broadened to include context designs
3. A commitment to conducting research that results in translating principles into guidelines that inform the creation of visual designs applicable to online instruction; inherent in this commitment was a consensus to focus on human-centered design principles reflected in the work of Poggenpohl (2002)
4. Consensus that the context for this research should have its roots in the representation of visual display designs as stimuli and the measurement of the voluntary and non-voluntary responses of the perceiver (the perceiver in this context is the online learner viewing visual display representations via the computer monitor)
5. An agreement on a conceptual model (see Figure 2) for the research that provided a structure for conducting Stage 1 research that was anticipated to lead to a programmatic research agenda through subsequent Stages.



*Figure 2.* The conceptual model of three research stages.

### **The Conceptual Model for the Research Stages**

The conceptual model (see Figure 2) that emerged from the research group discourse and subsequent dialogue mapping was influenced by a wide array of theorists and researchers including the work of, Poggenpohl (2002), Gibson (1986), Norman (1993), and Gibbons (2011). In the refinement of the conceptual model as a research framework particular attention was given to the works of Vygotsky (1991), Johnson (2010), Kosslyn, (2010), Gibbons (2011), Krippendorf (2006), Bertin (1983), Greeno and Moore (1993), Greeno (1998), Suchman (1987), Norman (1993), and Vera and Simon (1993b).



Central to the design of the conceptual model was the commitment of the researcher to conceptualizing a process for developing a programmatic plan of research that would build from this research. The focus of this research was on (a) the identification of human information process visual display design principles that have implications for the development and delivery of online instruction; (b) the creation of visual representations, which illustrated the respective visual display design principles; (c) the collection of data on students responses, in the context of perceivers of the representations; and (d) ultimately the impact of research findings on the integration of visual display principles embedded in instruction delivered online. This approach resulted in the development of a multi-stage program of research to be conducted over time. This study was the research conducted in Stage 1, and was designed to inform subsequent research in Stages 2 and 3. The conceptual model framed future research, which was beyond the focus of this research.

Johnson and Henderson (2002), in discussing the importance of a conceptual model as a framework for researching designs such as visual display designs, advocated for an emphasis should be on what the product, service or system is to the users. In this research, users were students participating in an intervention wherein visual displays were presented to them via the monitor and their emotional responses were measured. The results were viewed as enhancing the effectiveness of designers and developers of online instruction in creating visual displays that better meet the needs of the targeted students. In elaborating on what a conceptual model should be Johnson and Henderson, (2002) indicated that the conceptual model should be simple while providing the required

functionality. They also supported the view of Norman (1986) that conceptual models should be task-focused. In describing conceptual models from the perspective of object/actions task analysis, Johnson and Henderson (2002) stated that “Object = the names of things, declarative memory. Actions = the procedures users use to find their way around.” (p. 27)

### Research Stages in Conceptual Model

The conceptual model consisted of three research stages (see Figure 2). This research focused on the Stage 1 of the conceptual model. Researching the visual display principles resulting from the literature review was considered to be an evolutionary process. Each research stage could potentially yield results that altered the placement of a principle. Research on selected principles was conducted in Stage 1. Bertin’s visual variables: color, size, shape, texture, orientation and value also included in Stage 1 (see Table 1).

Table 1

*Bertin’s Original Visual Variables By Carpendale, 2003*

#### Size

Change in

length, area or

repetition



#### Color

Changes in hue



at a given value

**Shape**



Infinite number

of shapes

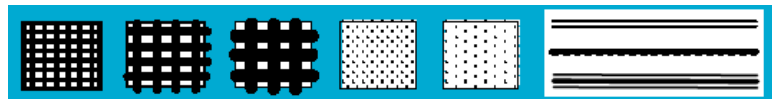
**Orientation**



Changes in

alignment

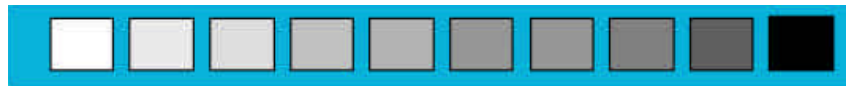
**Texture**



Variation in

'grain'

**Value**



Changes from

light to dark

The stages included the following three stages.

- Stage 1 on Symbolic Information Processing (SIP), parts 1 and 2 (see Figure 3.1 & 3.2) represented by this study and was designed to inform the representation designs for research in Stage 2.
- Stage 2 on Situativity (SIT) (see Figure 4) was designed to inform the creation of representation designs to be researched in Stage 3.

- Stage 3 on Distributed Cognition (DC) (see Figure 5) helped understand the role and function of representational media across individuals, artifacts, tools and situation in the environment.

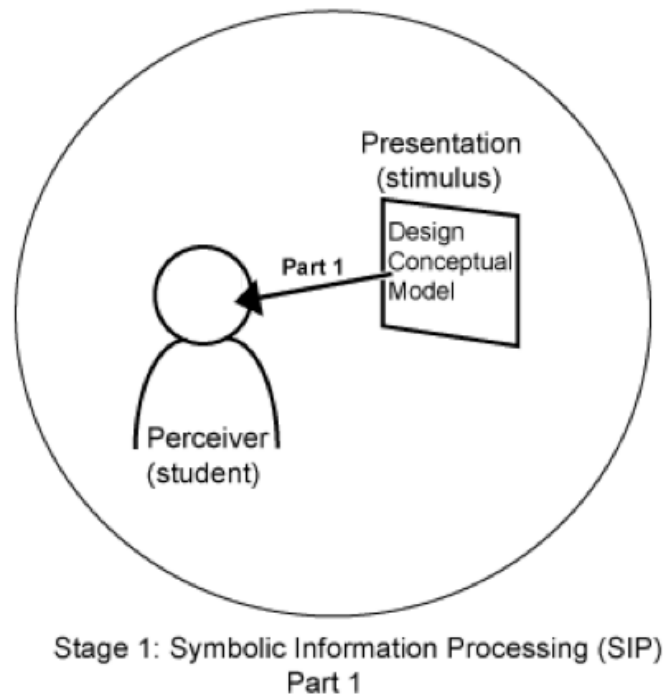
Each stage represented an essential element of the model, which was an emerging model dependent on the findings of the preceding research stage. The exception was Stage 1. The research procedures for this study, as Stage 1 only, are discussed in the Procedures section of this chapter. Stages 2 and 3 are described as currently reflected in the Conceptual Model for Research section, but are not detailed, as they were emerging stages. They will be discussed as conceived and conceptualized in the research model. The concept model of Stages 2 and 3 will be further defined in subsequent programmatic work following this research on Stage 1.

**Stage 1 in the conceptual model: Symbolic Information Processing (SIP).**

Vera and Simon (1993b) defined symbols as patterns that can be of any kind, e.g., verbal visual or auditory. Greeno and Moore (1993) defined symbols as expressions in a structure, e.g., physical or mental that is representative of something. In this study the definition offered by Vera and Simon (1993) was adhered to in that response pattern of all different forms was captured as perceived by the participants in viewing the representations presented on each visual display design principle. In Stage 1 the environment included the learner and the monitor as the source of the visual display. There were two parts in Stage 1.

***Part 1 of the Stage 1: Visual Perception & Sensation.*** (see Figure 3.1). In this environment the design principle representation was presented to the perceiver (research

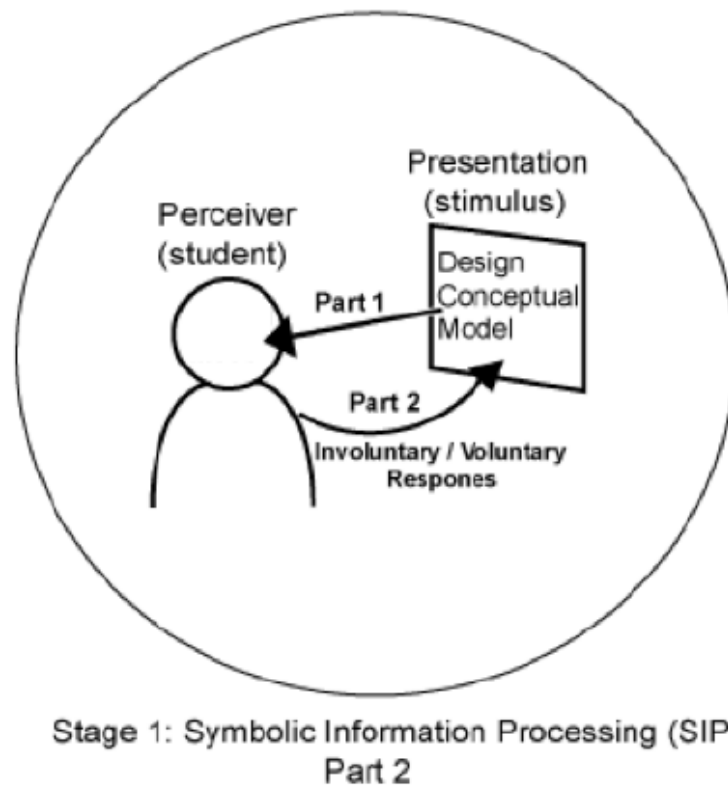
participant). The representation was in the form of text, images, or the integration of the forms. The perceiver immediately processed the information conveyed by the representation, including perceptions and sensation. In this study the representation was highly controlled to accurately and precisely represent the respective design principle. Memory and prior knowledge influenced the perceiver's perception of the representation.



*Figure 3.1.* SIP: part 1: visual perception & sensation model.

***Part 2 of the Stage 1: Involuntary / Voluntary Responses.*** (see Figure 3.2). In this research environment perceivers responded to their perceptions of the design representation. Their immediate responses to the representation were involuntary. The perceivers automatically emitted an emotional response that was involuntary. The emotional arousal changes were detected by Q sensor, and the effects of emotional valence were measured by the facial expression analysis system, Computer Expression

Recognition Toolbox (CERT). A perceiver cannot control non-voluntary responses as illustrated through the solid line between the perceiver and the representation (stimulus). However, in online instruction there is extensive reliance on structuring conditions within the representation that created options for voluntary response(s) by the perceiver, e.g., action, activities, choices, and or performance tasks.

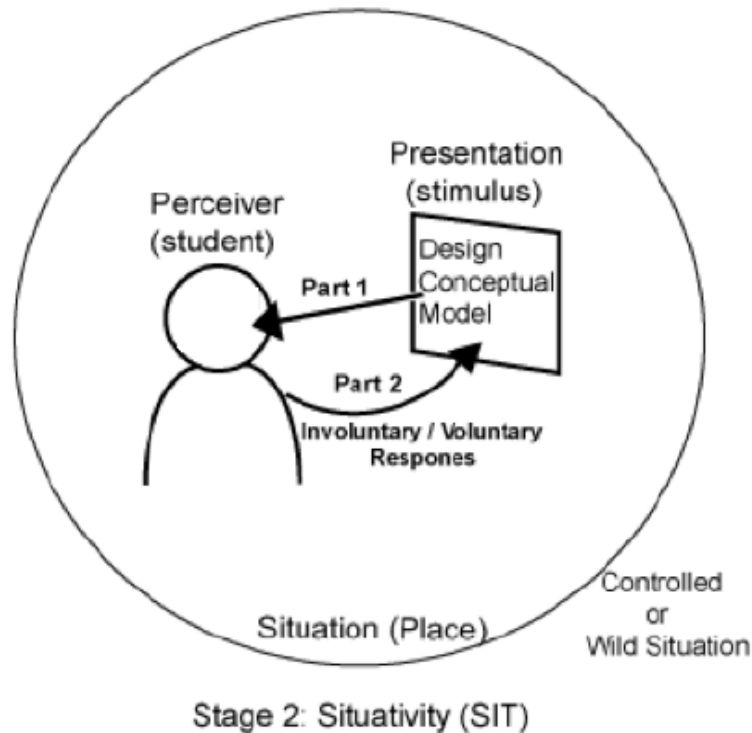


*Figure 3.2. SIP: part 2: involuntary / voluntary responses model*

**Stage 2 in the conceptual model: Situativity (SIT).** (see Figure 4) Vera and Simon (1993b) referred to this stage as Symbolic Information Processing (SIP). In the conceptual model developed for programmatic research this Stage was identified as Situation (Place). The environment included more than one learner and also included

interaction with the stimuli and among the learners. Place became important in defining the environment.

Stage 2, in the conceptual model included: (a) a reference to knowledge from the result in Stage 1 and how experience and the environment impacted students' learning responses; (b) recognition that the situativity framework was a useful tool to "diagnose" the teaching or clinical event; (c) the notion that increasing individual responsibility and participation in a community (i.e., increasing "belonging") was essential to learning; (d) understanding that the teaching and clinical environment can be complex (i.e., non-linear and multi-level); and (e) recognition that explicit attention to how participants in a group interact with each other (not only with the teacher) and how the associated learning artifacts, such as computers, can meaningfully impact learning (Durning & Artino, 2011; Greeno, 1998).



*Figure 4. Stage 2: situativity (SIT) model*

**Stage 3 in the conceptual model: Distributed Cognition (DC).** (see Figure 5).

In the conceptual model Stage 3 refers to the larger environment of application. This Stage can be viewed as the “wild situation.” In the development of online instruction it represented the environment where teaching and learning occurred and was not controlled. The process was totally wild, and the reality of applying Distributed Cognition and described human work systems in informational and computational terms. This Stage was also useful for analyzing situations that involved problem-solving. As it helped provide an understanding of the role and function of representations, this Stage had implications for the design of technology in the mediation of the activity, because system designers would have a stronger, clearer model of the work. Thus, DC was an



important theory for such fields as computer-supported collaborative learning (CSCL), computer-supported cooperative work (CSCW), human-computer interaction (HCI), instructional design, and distance learning (Hutchins, 1990; Perry, 2003). DC was adopted for the culminating stage of the conceptual model because online instruction is evolving into a variety of approaches that are far less controlled than the early versions of online instruction. New technologies were emerging that would further extend applications.

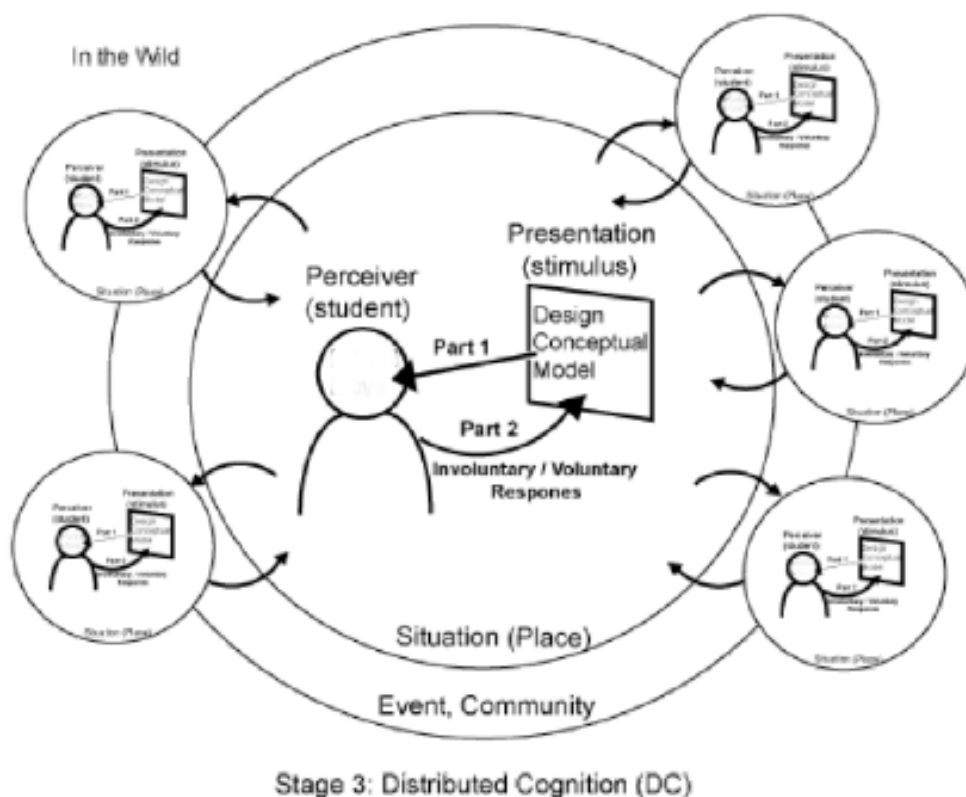


Figure 5. Stage 3: distributed cognition (DC) model

As noted in Figure 2 the programmatic research design focuses on three stages. This research study was carried out as Stage 1 with Stages 2 and 3 representing separate studies that will evolve from this work. Stages 2 and 3 are beyond the scope of this study.

Stage 1 illustrates the most controlled conditions of the conceptual model and the context for this study. Stages 2 and 3, while conceptualized, were emerging stages and subject to change based on the results of research in Stage 1. While Stage 1 research was an experimental design, the research designs employed in Stages 2 and 3 are anticipated to change due to the expanding environment, increased interactivity, and the distributed nature of situations that evolved subsequent to Stage 1 work.

### **Procedures**

The research procedures were highly integrated with the conceptual model for the research framework. This integration was due to the centrality of the design principles to the evolutionary nature of the multi-stage approach of the conceptual model. An iterative element was inherent in the formulation of the conceptual model for the research and the specifications of research procedures. For example, the review of the literature informed the process of designing the conceptual model, but the model informed the final selection of the design principles to be researched. The intent was to ensure that the research procedures were compatible with the overall goal of conducting research within Stage 1 of the conceptual model in a manner that would have a significant impact on the subsequent initiation of a programmatic research effort.

### **Visual Display Design Principle Identification Process in Stage 1**

The following criteria were applied in the selection of visual display design principles to be researched in Stage 1.

1. Text only-sequence, default no formatting, just ordering the text to fit across an appropriate amount of screens. Notes: Default included no visual variables such as color, size, etc.
2. Text only-hierarchy + emphasis, manipulated text weight (bold, thin, etc.), style (italic, all caps, lowercase, etc.), and color to call out specific information. Notes: Hierarchy-Emphasis/color-typographic
3. Text only-hierarchy + layout, manipulated space, scale (text chunking, white space) to manipulate placement of where information is on screen. Notes: Hierarchy-Orientation (Sequence)/ layout “space”
4. Text only-hierarchy + emphasis + layout, manipulated all variables for meaning (color, weight, space, scale, layout). Notes: All variables

Considerable power in creating different visual representations came from choosing which visual variable would be most appropriate to represent each aspect of the information (Carpendale, 2013.) The visual representations also followed Bertin’s visual variables: size, shape, value, color, orientation, and texture.

The literature review combined with the dialogue among team members resulted in the identification of evidence-based design principles applicable to visual displays with implications for online instruction. It was apparent in reviewing the identified display

principles that there was overlap among some principles and some were more general than others.

The first step, in organizing the principles for purposes of this research involved sorting the principles into three stages of human visual information processing which include sensory memory, short-term memory (constraints) and long-term memory. There were eight major visual design principles in these three stages of human visual information processing (see Table 2). Those visual design principles modified from Kossly, 1989, 1985 & 1994; Kosslyn and Koenig, 1992; Palmer 1992; Stevens, 1975; Bertin, 1983 and Coe, 1996; Gibson, 1979. The design principles listed under A. Sensory Memory and B. Short-term Memory in Table 2 were applied to create visual representations for the experimental intervention in this study. The primary focus on this study was the Stage 1 of the conceptual model.

The first group of visual representations was applied absolute discriminability and relative discriminability principles of the sensory memory. Also, using the Bertin's visual variables to be noted in accordance with their importance in the visual representations, such as color, size, shape, texture, orientation and value needed to be great enough to present the information. The second group of visual representations was applied to the information grouping layout design principles of short-term memory constraints stage and long-term memory processing stage. The visual representations chunk the information in one paragraph within the 1.0 line spacing, one paragraph within the 2 line spacing, two columns and 3 columns for understanding the better information grouping layout for the reader to store information in their short-term memory. The

research also used principles of representativeness and the “mark” in some important words and had an appropriate image in the second group of representations for understanding the long-term memory processing. See all visual representations in Appendix A.

Table 2

*Design Principles For Structuring A Visual Display, Based On Psychological Evidence Of Human Information Processing*

<b>Three Phases of Human visual information processing</b>	<b>A. Sensory Memory (Sensation &amp; Perception)</b>	<b>B. Short-term Memory Constraints (Limited-capacity &amp; duration) Short-term memory is a limited-capacity "working memory." One can avoid short-term memory problems by considering carefully the following.</b>	<b>C. Long-term Memory Processing (Repository of all one knows) Thus, the input must enter long-term memory before it can be recognized or interpreted (which requires matching against stored information).</b>
Design principles	<p>1.0 Adequate discriminability</p> <p>Marks must be discriminable on the display and from each other. Variations in visual variables must be great enough to be easily noted. There are two aspects of this principle:</p>	<p>1.0 Memory-capacity</p> <p>Only about four perceptual units (“chunks”) can be held in in short-term memory at once. Thus displays must not require the reader to consider more than this number of</p>	<p>1.0 Principle of representativeness</p> <p>The intended meaning of a mark should correspond to the spontaneous interpretation of it. All marks have a preferred interpretation. Thus labels should name words that are</p>

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1.a Absolute discriminability  
visual variable must have a minimal magnitude to be detected. This absolute threshold has been computed for many different types of visual variables. Neurons that detect edges inhibit each other, if a mark is not large enough; the cells that typically would detect it are inhibited from responding.

1.b Relative discriminability  
Visual variables must differ by a minimal proportion to be discriminated, e.g. Just Noticeable Difference JNF. This just noticeable difference has been determined for many types of visual variables.

perceptual units.

We can hold in memory only about four perceptual units ("chunks") at the same time. Short-term memory is a dynamic state, and information is retained because neurons are actively firing. Consider juggling: the number of balls one can keep in the air depends on how high one can throw the balls, how quickly the balls fall, and how adeptly one moves his or her hands. Neurons quickly adapt (fall) and continue to fire only if stimulated repeatedly (thrown up) — but there are limitations to how quickly they can be re-stimulated (hand movements). These limitations appear to involve the speed with which certain chemicals are

indicative of the class (including the correct connotations) and pictures should depict appropriate objects (a picture of a penguin-like bird should not be used to label birds in general).

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produced and absorbed. Displays should contain no more than four to seven perceptual groups. At the most only about seven perceptual groups can be seen at a glance, and only about four can be held in the mind at once.

## 2.0 Processing priorities

Some marks are noticed and attended to more than others; also known as 'salience.' Visual variables should be chosen to be noticed in accordance with their importance in the display.

Some colors, weights and types of line, and sizes are noticed before others. For the most part we do not have formal rules for determining which these are; instead we rely on a general principle: the visual system is a

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"difference detector." Any sharp contrast will draw attention. Some stimulus properties have been determined empirically to be "salient" (for example, all other things being equal, a yellowish-orange is recognized before a deep blue). Physical dimensions of visual variables should be used to emphasize the message; they should not distract from it -for example, the background should not be too prominent.

### 3.0 Visual properties

Variations in different kinds of marks can be used to convey information, some better than others.

The visual variables (size, value, orientation, texture, color & shape (form), suggested first by Bertin and modified and explained in more detail by others, provide a systematic

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way for converting verbal, numerical and other forms of data into visual information.

#### 4.0 Perceptual distortion

The visual system sometimes results in our having distorted impressions of visual dimensions.

Some visual dimensions are systematically distorted, notably area (size differences are underestimated), volume (size differences are very much underestimated), and intensity. On the other hand, line length (and width) is registered relatively accurately (although vertical lines appear longer than horizontal lines of the same length). These distortions are described by the exponent in the psychophysical power law (S. S.

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Stevens)

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### **Experimental Intervention Development Process**

The experimental intervention was comprised of a series of images that were representations of selected visual display design principles. The representations were presented to research participants via a computer monitor. Participant's electrodermal activity (EDA) responses were recorded by the Q sensor and their facial expressions were recorded by the Computer Expression Recognition Toolbox (CERT). The development process that contributed to finalization of the research interventions included the following steps.

1. The identification and validation of visual display design principles applicable to online instruction.
2. The selection of human information processing design principles and Bertin's visual variables most applicable to Stage 1 of the Conceptual Model.
3. The translation of the selected principles in to visual representations. Visual representations had explicitly conveyed the respective principle, and did not convey the respective principles.
4. The creation and ordering of the representations for purposes of conducting the experiment.

5. The development of instructions to guide the participants through the experiment.
6. The framing of questions for the concluding interview.
7. Repeated pilot testing to assess the reliability of the presentation of representations in the intervention, the structuring of the intervention, the sequencing of images, time exposure and rest periods related to the image presentations.
8. The synchronization of the Q sensor, CERT, and videotaping process.
9. The usability of the data collection procedures in establishing baselines and in reporting results.
10. The modification of the intervention based on the results of each pilot test.
11. Refinement of the final version of the interventions and associate procedures.

### **Experimental Conditions**

A room was dedicated as space for conducting the experiment. The room was 11' by 11' and located in an area where traffic, noise, illumination and temperature could be controlled. The room had no windows. As a further initiative to control traffic, signs were placed inside and outside the research suite indicating that an experiment was underway. The furnishings were selected to represent what might be a typical study area and included a desk, office chair, side chair, and a picture on the wall behind the desk where participants sat while engaged in the experiment. The same MacBook Pro with a 17" monitor was used to present the intervention to all participants. The initial position

of the computer on the desk was the same for all participants, but participants were allowed to adjust the placement of the computer if needed. The office of the researcher was located across the hall from the room used for the experiment. Adjoining offices were not occupied during the experiment. Participants were scheduled at one hour intervals. Detailed directions for locating the experiment room were provided in advance, and participants were met at the stairs or elevator and escorted to the research suite. The researcher met with each participant individually in her office prior to beginning the experiment. She then invited the participant to accompany her across the hall to the room where the experiment was conducted.

### **Pilot Testing**

No similar studies were identified in the literature review using the Q sensor and the CERT facial recognition system because they were relatively new technologies. For this reason, pilot testing was considered essential to finalizing the research procedures. It was assumed that the initial field test would reveal the need for more targeted pilot testing. At this point in the research, a faculty member with expertise in measuring physiological responses and prior experience in the use of similar technologies joined the research group. Although the individual had not conducted research specific to this study, his prior work in measuring physiological responses using similar technical systems was helpful and provided important insights into the research design and structuring of the pilot tests.

**Pilot #1.** The first pilot study was designed to achieve the following seven outcomes.

1. Test the synchronization of the Q sensor and the CERT. (Note: The participant(s) were videotaped while progressing through the display representations embedded in the intervention. This procedure was an added technique for checking synchronization of the Q sensor and the CERT.)
2. Ensure control of the required experimental conditions under which the experiment was conducted.
3. Confirm the application of procedures and instructions for engaging research participants in the experiment.
4. Identify the options for data output to facilitate analysis.
5. Confirm that the visual display representations were aligned with data recordings.
6. Verify the effectiveness of the time allotted for viewing the representations, time between representations and time provided research participants in responding to the pacing of the representations of the representations of visual displays and the groupings of visual displays.
7. Identify any need for modification of the experiment due to the structure of the experiment or misunderstanding of instructions by the participants.

***Pilot Test #1 process.*** Five participants were selected from volunteers to participate in the field test. Two were female and three were male. All were undergraduate students at a major Midwestern public university. The procedures and conditions tentatively planned for the final conduction of the experiment were followed

in this field test. They are detailed in the description of the first field test. The field test involved three steps described below.

*Step 1 occurred in the office of the researcher.* The researcher greeted each participant and expressed appreciation for his/her willingness to participate. She explained that their participation would take about an hour to complete. The participant completed the demographic form during the time, and also signed the consent form.

The researcher explained the purpose of the study. The researcher had notes on the instructions with her that she had practiced in mock presentations, but did not read the following explanation of the study. The instructions were as follows:

The purpose of this study is to research the effectiveness of visual design displays that will be presented to you on a computer monitor. The visual displays are much like images you might see while completing online instruction. You will review a series of displays that begin as very simple text examples. Images will be added as the series continues. The displays will become detailed and resemble the presentation of information that you might encounter in an online lesson. The intent is to identify how students respond to visual displays that are presented to them via a monitor and to determine their application to instruction offered online. The over goal is to share what is learned from this research with educators and others who are responsible for the design and/or development of online instruction.

When you view images on the monitor, two devices will record your responses. One is a Q sensor that is like a wrist watch and feels like wearing a watch. The other is a facial recognition system. It is a camera that watches you, but is not fastened to you. Both devices sense your responses while viewing the images on the computer monitor. The session will also be videotaped. You will not be asked to navigate through the process. The computer will automatically move the images on the monitor an every two seconds as you watch. The monitor will go blank for a second when the images change. The images are grouped in sets. After each set there will be a four second pause and you will hear soft music. The next series will then appear automatically. You will not need to make any commands. Your task is to watch the monitor as the images are presented.

I will help you put the Q sensor on your wrist and adjust the camera. We will go through a practice experience. The practice session involves viewing images presented via the monitor. I will return to my office after the practice session. Once you start the study you will complete the review of images in one session.

I will return at the end of the viewing session. At that time we will visit about the experience and I will ask you some questions. There will be no right or wrong answers to the questions. The experiment will last about thirty minutes.

Each participant was provided a brief written statement reviewing the purpose of the research. They were then asked to sign an informed consent form before they went to the experiment room.

*Step 2 occurred in the experiment room.* Each participant was escorted to the experiment room and was asked to be seated. They were also asked to turn off their cell phones and other electronic devices they had with them.

The researcher turned on the computer. A “Welcome” page appeared. She explained that the computer would function as a projector in that the computer automatically presents the images and that they would not personally need to enter any commands. Participants were asked to adjust the computer on the table so that it was comfortable for them see the monitor. The researcher helped the participants put on the Q sensor and asked them to adjust the wrist strap so that it was snug but comfortable. The researcher checked the Q sensor to insure it was making sufficient contact with the wrist.

The researcher explained that the facial recognition system uses the camera on the computer to detect facial reactions as they progress through the review of the images that are presented on the monitor. The participants were asked to look at the monitor and confirm that they could identify the camera used by the facial recognition system. They were asked not to look away from the monitor or to obstruct the view of their face with their hands.

The researcher also explained that a video recorder would be recording their participation in the experiment. The video does not record a participant’s face; rather it records the research scene including the computer. The researcher asked the participants



if they had any questions about the equipment or process. If they did she would respond to the questions.

As each participant was ready, the research said, "Let's do a practice session." A practice session involved watching the images presented on the monitor. The researcher depressed the "enter" key to start the practice session. The researcher did not speak during the practice session. During the viewing of the images in the experiment following the practice session, the participant was in the experimental room alone.

During the experiment the participants reviewed a series of images via the monitor. Each visual design image displayed for 2 seconds automatically followed by a one second blank screen. The researcher clicked the "enter" key and allowed a series of images to appear. The researcher then stated that the images are organized into two groups, and at the end of each group the screen would go blank for four seconds and music still be heard. The computer was set to automatically restart to progress through the next series of images in the next group. This sequence continued through the remaining series of images. The participants did not use the mouse or keyboard to interact. The system played automatically like a projector. At the end of the last series a message appeared on the monitor stating, "The End." At that time the researcher would return to the experiment room.

When the practice session was completed the program automatically returned to the "Welcome" screen. The researcher instructed the participant to push the "enter" key when they were ready to start the experiment. The researcher said to the participant at the end of the practice session, "When you have completed the review of the images in

the actual study a “The End” message comes on the screen. I will return at that time and assist you in taking off the Q sensor. I will also ask you a few questions. There will be no right or wrong responses to the questions. You can now begin by pushing the “enter” key.”

*Step 3 occurred in the experiment room.* The researcher returned once the participant completed the experiment. The researcher and the participant visited about the experience in general. A series of prepared interview questions were presented by the researcher. The participant was informed that there was no right or wrong response to the questions, which are listed in Appendix B. When the participant completed the entire experiment, the researcher assisted the participant in taking off the Q sensor and turned off the facial recognition system.

***Lessons learned from Pilot Test #1.*** The process for reviewing the results of the first pilot study was focused on the expected outcomes previously described. This process took the form of a series of debriefing sessions with the researcher and the technical staff. They developed the pilot test version of the intervention and the configuration of data resulting from the pilot test sharing detailed information based on their observations throughout the pilot test and examples of data reports. Other participants in the debriefing included members of the study group, plus two additional individuals with expertise in research design and statistical analysis. The following summary of lessons learned from the first pilot test reflects the significant changes recommended by the group for conducting Pilot Test #2.

First, when measuring galvanic responses with devices such as the Q sensor, the group was advised that it is important to keep in mind that physiological response is triggered by sweat glands. This fact meant that the temperature in the research setting must be controlled. Research has documented that the temperature throughout the experiment must be between 22 and 25 degrees centigrade (71.6-77 Fahrenheit). In the first pilot study it was noticed that the room temperature varied and might have had an effect on responses of the participants as measured by the Q sensor. The researcher noticed when placing the Q sensor on the wrists of the participants that some were cool. The decision was made to install the Q sensor on the wrists of the participants during the second field test as soon as they arrived and to allow an increased period of time for the adjustment of participants to wearing the Q sensor. Additional attention was also recommended to standardizing the temperature in the experiment room during the Pilot Test #2.

Second, in reviewing the data from Pilot Study #1 it was observed that the 2 seconds of exposure to the representation images was not sufficient. A decision was made that during the Pilot Test # 1 the time of exposure for each image representation for Group 1 representations would be tested at image viewing times of 4, 5, and 6 seconds; and that the time between the presentation of images remain at 6 second intervals. For Group 2 the exposure time for the images was recommended to be 6, 7 and 8 seconds with 6 seconds between presentations.

Next, the group recommended that the scope of the research study be limited. The study group members most knowledgeable about this type of research shared the

perspective that in doing physiological research it was important to keep the emphasis on conditions that enhance verification of what was being measured. In the intervention tested in Pilot Test #1 12 images were presented for each principle. Six images were in the form of gradations from the most explicitly good example to less good, and six images were in the form of explicitly poor to less poor. This design resulted in 324 representations in Group 1 images being presented to each participant. Additionally, there were plans to add 108 representations from Group 2 to the intervention. In examining data from the Pilot Test #1 there appeared to be some evidence of experimental fatigue on the part of the participants. A decision was made to reduce the number of representations for each principle in Group 1 from twelve to four. In the development of Group 2 representations it was decided to reduce the representation to six and the number of representations per principle to four. The total of representations was 124. In subsequent testing, Group 1 had 108 representations and 16 representations for Group 2 were developed and validated for inclusion in Pilot Test #2.

The discussion participants also recommended that a relaxation break between Group 1 and Group 2 representations be allotted for rest. It was further recommended the screen be blank or a light color and music be played during the interval between images for Groups 1 and 2. No other distractions would be structured during this period.

From a review of the data from Pilot Test #1 on physiological responses, as measured by the Q sensor, researchers had difficulty clearly determining the response pattern. For purposes of analysis it was essential to establish a baseline for each subject. That was difficult to do as there may be multiple baselines. Therefore, another

recommended adjustment in Pilot Test #2 was assessments be made at 1 second intervals over 5 second intervals.

Finally, Pilot Test #1 data led to a recommendation that the instructions for progressing through the experiment be presented via the monitor in a format that was standardized for all participants. If a participant had a question about any aspect of the instructions he or she could ask for clarification from the researcher before proceeding with the experiment. This approach would ensure that all participants received the same instructions.

**Pilot Test #2.** The lessons learned from Pilot Test #1 served as the guidelines for designing Pilot Test #2. The implementation of the recommendations resulting from Pilot Test #1 represented the parameters for the intended outcomes of the second pilot test. All modifications in the procedures, the intervention design and the conditions in the experimental room were made in advance of conducting the second pilot test. The one exception to this statement was that the recommendation to transform all instructions into an integral part of the intervention presented via the monitor was not implemented. The reason for not acting on this recommendation was that conducting the second pilot test with the instructions as presented by the researcher from the first pilot test would likely reveal additional information. That the time of exposure for each image representation for Group 1 representations be tested at image viewing times of 4, 5, and 6 seconds and that the time between the representations of images remain at 6 second intervals. For Group 2 the exposure time for the images was recommended to be at 6, 7 and 8 seconds with 6 seconds between presentations. The results determined the

sufficient time exposure of the representation images. Also, because the representation images for Group 2 had not been developed they were in need of being tested. Those representations were developed and validated prior to conducting Pilot Test #2.

A checklist, which appears in Appendix C, was also compiled for use by the researcher to follow prior to the engagement of each participant in the experiment to ensure the accurate operation of the Q sensor, CERT and video recorder, and adherence to the standard procedures specified for the experiment. The list checking process was observed by the technical staff member that provided the installation and data collection configuration of the devices.

### **Intervention Description**

The intervention design and experimental procedures were based on lessons learned from Pilot Tests #1 and #2 results. While both pilot tests contributed significantly to the final version of the intervention the second pilot test was informed by results of the first pilot test and/or insights of the study group members. Thus, the specific recommendations following Pilot Test #1 and tested in Pilot Test #2 served to confirm the observations made in examining the results of the first pilot test or answered questions generated by the first pilot test. The outcomes of Pilot Test #2 informed the final design of the intervention for the experiment.

The final experimental intervention (see Figure 6) included the following eight conditions.

1. In Group 1 the number of images was reduced to **108** images (6 sets: letter, words, sentences, simple image, completed image and detail image).

2. In Group 2 the number of images was reduced to **16** Images (4 sets).  
Increased narrative was integrated with images.
3. A standard set of instructions was included before the practice session.
4. A practice session was added. This session involved the presentation of 6 images. The practice session took 34 seconds.
5. An experimental session involved 2 groups of images. The Group 1 images were exposed for 2 seconds and had an interval time between images of 6 seconds. Between the sets of images in Group 1, there was a pause of 8 seconds. The Groups 2 images were exposed for 12 seconds and had an interval time between images of 8 seconds. Between the sets of images in Group 2, there was a pause of 8 seconds. The entire experiment session took about 20 minutes.
6. A cool down session was added before the Group 1 images and the Group 2 images shown. This was a period of time for relaxation by the participant with no experimental presentation of images. The cool down session involved the participant being exposed to a blue blank background screen with music for 1 minute and 25 seconds.
7. Images within each set were randomized and the sequence of the sets within the two groups was also randomized.
8. The entire experiment was timed to be 21 minutes 43 seconds. This includes the practice and cool down sessions.

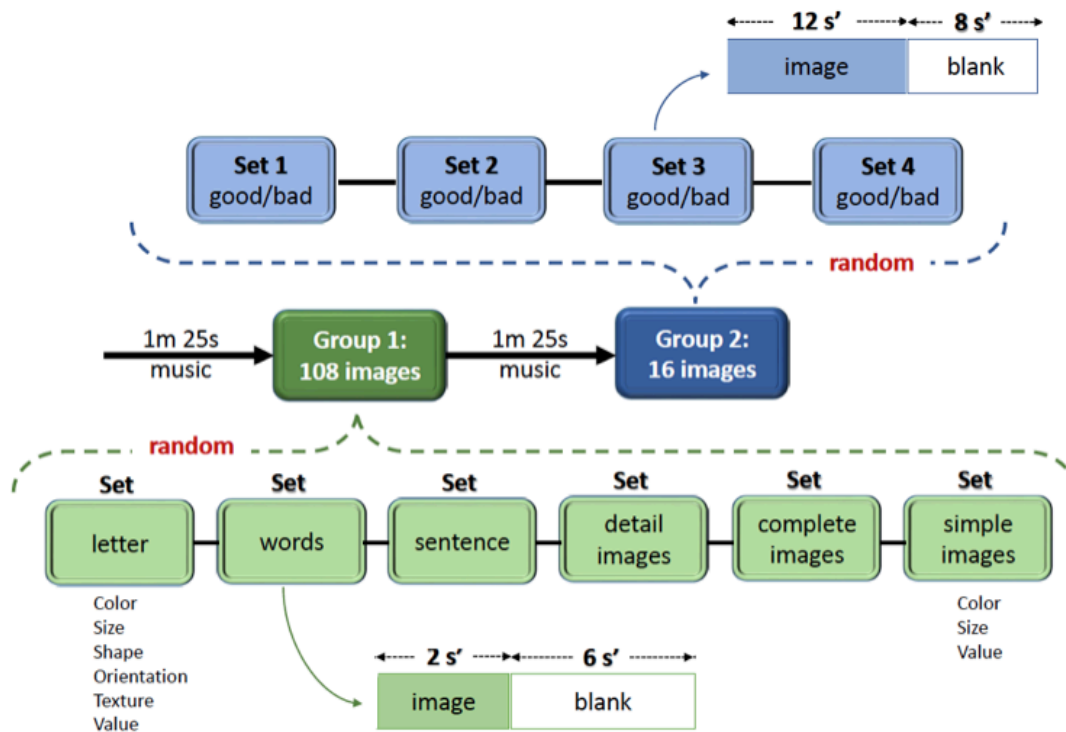


Figure 6. Procedure of the experimental intervention.

### Sample Selection

The sample was comprised of undergraduate students from a comprehensive Midwestern university. A convenience sample approach was employed involving two strategies. The first strategy was the use of a system established by a department in the university for recruiting students to serve as participants in research studies. The process involved the submission of a research proposal prepared in accordance with prescribed requirements including the approved Institutional Review Board (IRB) (Appendix D). Once approved the students enrolled in specific courses were given the opportunity to participate in the study.



The second strategy involved the identification of faculty with experience in online instruction willing to share the announcement of the research participation opportunity with their students. The same information included in the research proposal required in the first strategy was shared with the faculty in this strategy. This strategy was also aimed at eliciting assistance from faculty in the recruitment of student research participants.

### **Demographics**

Upon accepting the opportunity to serve as a participant in the research study, students were provided an information statement describing the study and what would be expected of them as a participant. This statement included information on the demographic form they would be requested to complete. The demographic form was completed when the student arrived at the scheduled time for participation in the experiment (Appendix E). The student also signed the consent form at this time.

### **Post Experiment Interview Protocol**

Ten interview questions were included in the post experiment interview. The interview was conducted by the researcher immediately following completion of the experiment. The purpose of the post experiment interview was to elicit the perceptions of participants on their experience during the experiment. The questions were open ended with no correct or incorrect responses (Appendix B).

### **Data Collection and Analysis**

The research involved the collection of data on the physiological responses of research participants to viewing representations of visual display principles presented via

a computer monitor. All participants were subjected to the same experimental conditions. Two forms of data were collected: electrodermal activity (EDA) response data as measured by the Q sensor, and facial expression response data as measured by the Computer Expression Recognition Toolbox (CERT). The analysis steps involved multilevel steps. The first step involved analyzing the two data sets independently to ensure alignment of raw data from the two measurement systems with the visual representation images to which participants responding. This stage also allowed for determining patterns of responses by participants to the images. When necessary to confirm synchronization the video of the experimental process for the respective participant and images was reviewed.

The second step focused on the Q sensor data analysis and to find the common individual baseline. The common individual baseline allowed for analyzing the individual emotional arousal changes to each representation.

The third step was the comparison of results from the Group 1 and Group 2 representations. The first comparison analysis carried out the emotional arousal difference between good and poor examples of different digital visual design principles for the group one representations. The second comparison analysis also allowed the researcher to find the emotional arousal difference across different information grouping layout designs for the group two representations.

The fourth step focused on the CERT data analysis. The step was to create the individual baseline model theory for fitting all participants' responses.

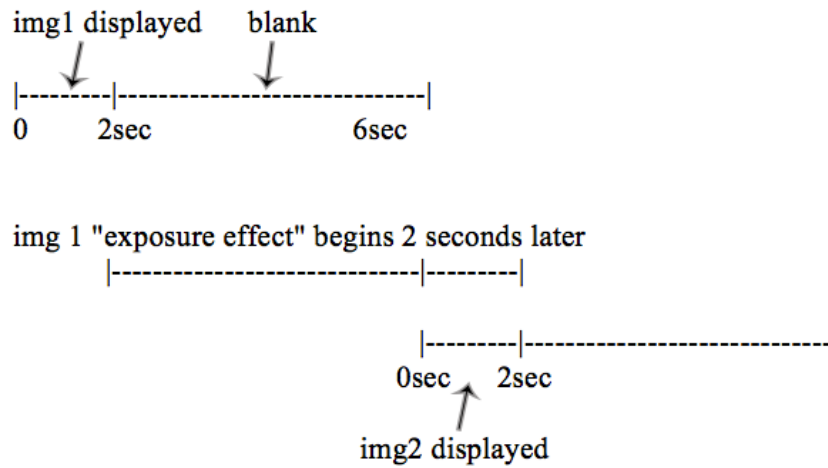
The fifth and final data analysis step compared the data for the Group 1 representations and the Group 2 representations. The first comparison analysis allowed the research to find the effect of the positive emotional valence between good and poor examples of different digital visual design principles across 104 participants for the group one representations. The second comparison analysis was designed for the researcher to find the effect of positive emotional valence of different information grouping layout designs across 104 participants for the group two representations.

### **Q Sensor Analysis Procedures**

There was no universally agreed on method for electrodermal activity data analysis found in the literature search. In this study, the EDA data were exported from the Q sensor 2.0 into CSV files, and were collected when the participant arrived. The EDA included skin conductance level (SCL) and skin conductance responses (SCRs). The data were explanation of sympathetic neuronal activity. SCL is the background tonic and SCRs were rapid phasic components (Braithwaite, Watson, & Jones, 2013). The raw varying EDA data were smoothed using a filter process proposed by in Ledalab, which was made available as a Matlab module. Benedek and Kaernbach (2010 & 2011) published approach on the decomposition of superimposed SCRs was not only based on mathematical modeling but also took into account a particular model of the electrodermal system and solved several SCL and SCR problems. The procedure provides a numeric summary of the electrodermal response for each stimulus time frame. The various mathematically based de-convolution methods offer considerable progress in the evaluation of overlapping SCRs which are very common to stimulus sequences with short

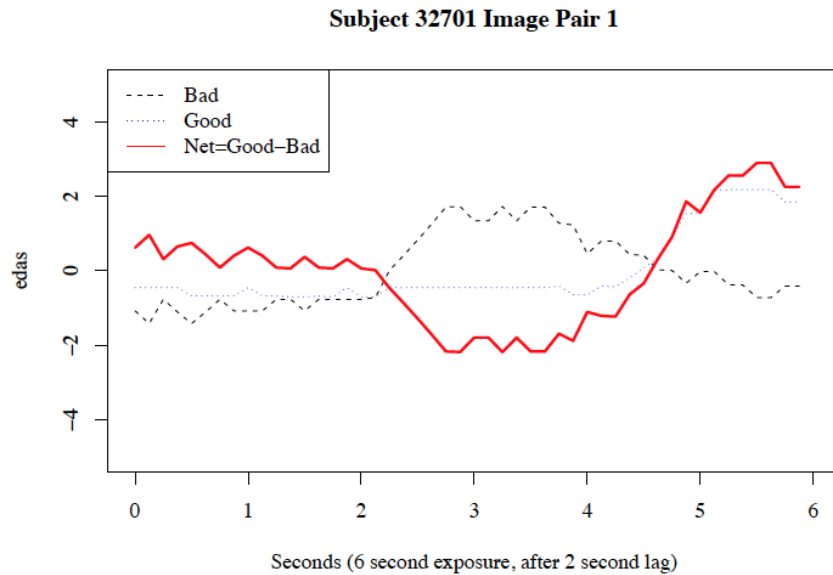
inter-stimulus intervals (ISIs) (Boucsein, 2012). Integrated skin conductance responses (ISCRs) means raw electrodermal activity data after the decomposition procedure for every image and participant were calculated in Ledalab. The average microSiemens ( $\mu\text{S}$ ) value was considered when the participant was in the cool-down section. Before every image was shown, it was preceded with 6 seconds of a blank screen. The average 6 seconds EDA data became the participants' baseline values. The changes of EDA data when every image was shown for 2 seconds versus the baseline values were considered. The sets of representations were randomized in the sequence in which they were presented to the participants. The individual representations of good and poor representations of principles were a randomized within sets. To clarify the time interval selections for the Q sensor data, 6 seconds were allowed for calculating the effect of each image. As noted in Figure 7 the intervals were "right shifted." The effect of image 1 begins at 2 seconds, which was after the image displayed and continues to 6 seconds total, gobbling up the first 2 seconds of image 2. This time interval is illustrated in Figure 7.

According to the electrodermal activity theory, each individual emotional arousal time was different. Some people were fast response and some were slow. Taking the data of the first 2 seconds of image 2 solves this problem.



*Figure 7.* The time interval selections for the Q sensor data.

Data plotting was carried out with R software. The plot example of subject 32701 for image pair 1 is shown in Figure 8. The following analysis was conducted to understand effects of visual display designs arousal and effects of the design principles. After all participants' data were analyzed by Ledalab using ISCRs data to run two ways analysis of variance (ANOVA) to determine the difference between good and poor between principles across all participants. These analysis processes were used with both Group 1 and Group 2 visual display representations.



*Figure 8.* The EDAs of subject 32701 for image pair 1.

### **Computer Expression Recognition Toolbox (CERT) Analysis Procedures**

Data collection via CERT was real-time involving fully automated coding of facial expression from the video by using a standard webcam. CERT provided estimates of facial action unit intensities for 19 Action Units (AUs), as well as probability estimated for the 6 proto-typical emotions (i.e., happiness, sadness, surprise, anger, disgust, and fear). It also exported a set of seven basic emotion detectors (i.e., anger, contempt, disgust, fear, joy, sad and surprise) plus neutral expression by feeding the final AU estimated into a multivariate logistic regression (MLR) classifier. The classifier was trained on the AU intensities, as estimated by CERT, on the Cohn-Kanade dataset and its corresponding ground-truth emotion labels (Kanade, Cohn, & Tian, 2000). MLR outputs the posterior probability of each emotion based on the AU intensities as inputs (Littlewort

et al., 2011; Wu, Butko, Ruvulo, Bartleet, & Movellan, 2009). This research used the outputs of seven basic emotion detectors.

The facial video, which recorded in the experiment, was coded by CERT system and exported to CSV files. The facial data was compositional. The raw data file was imported into R. There are several separate steps in data preparation. First, the sum of all data proportions was 1.0, which reported by the CERT process. This can be interpreted as compositional data. This research followed Aitchison's theory (1986). The values were transformed so that they were applied into the centered log ratio transformation and showed approximately normally distribution. This research used the geometric mean to center each proportion value with compositional data. The centered log ratio transformation converts the proportion value reported at each time point. The value of this transformed variable was equal to 0 if the observed value of an emotion was exactly equal to the average of all of the other emotions.

Next, aligning the observed data with a substantively relevant time scale was a problem. Each image was displayed to the participants in a randomly shuffled order because some were 6 seconds and some were 8 seconds. The difference in displayed times was due to a pause that the system allowed between image groups. This research compared the participant's response to the good and poor images over time. A baseline emotional level was calculated before each image was displayed on the screen by isolating the measurements of the emotion in the time beginning 2 seconds before the image appeared on the screen. The results included the baseline, the effect of segment 1 which was 2 seconds of image exposure and the effect of 2 seconds after image was

displayed. The data analysis measured the effect of segment 1 and segment 2 because the theory explained people have facial expressions right after they saw the stimuli.

However, the lasting effect would be occurred, too (Ekman, 1978). This data analysis procedure made the effect results more reliable.

The multilevel regression model was used because “unmeasured individual differences” needs to be taken into account. The estimated general regression equation is:  $y = X\beta + \hat{\epsilon}$ . That assumes all rows in the data are equivalent, whereas the model as additional individual and image pair effects, when the results were assumed existed, but they can't be measured directly. The estimated multilevel regression equation is:  $y = X\beta + \hat{\epsilon} + b1 + b2$ .  $b1$  is a person level effect and  $b2$  is the image pair separate for each person.  $X\beta$  shows visual variables (size, color, texture, orientation, shape and value) effects. A random effects (mixed effect) multilevel regression model was taken into account the many sources of random variation. The random effects in the model were for each participant and for each image pair. These effects were included so that these effect scores could explain the important substantive question, which was the emotional effect due to variations in image size, color, texture, orientation, shape and value. This step had emotional response data for a particular type of visual variable, but the difference didn't calculate yet. However, the same pair of images was displayed at separate times during the experiment. The emotional data for the pair of images needed to be measured the difference in the responses to good and poor examples.

In the multilevel model, the individual, image pair, and image quality effects as a set of additive estimates. The additive process was summarized in Figure 9. The model



explained how the baselines of the images were established. It assumed that there was a random effect estimated for each paired image ( $b_0$ ), and then there was a random difference between the good and poor images ( $b_1$ ) within each pair. These effects combined into the baselines, which was the 2 seconds before image exposure. Random variations across time were also occurred due to measurement error, so the actual data fluctuated across time. After the data analysis step showed whether the participant has a response on a paired image in the certain visual variable. To analyze the difference between the good and poor variants of the images in the certain visual variable grouping was the next step.

To assess whether there is an emotional difference in the response to the two paired images, the fixed effect parameter estimates for the good and poor images were used. The observed response to the poor image, for example was thought of as the sum of a baseline level for the image pair, which  $b_0$  was represented and emotional differentials represented by  $\beta_1$  and  $\beta_2$  in the first and second time segments. This research looked for the difference in the participant's response to the good and poor variants. The theory model assumed that those same responses were also present in the response to the good image, but they were supplemented by additional effects  $\beta_3$  and  $\beta_4$ . These coefficients represented the effects of the certain visual variable on joy that was separately measurable in time segments 1 and 2.

### Comparing Image Pairs: Shared Baseline Approach

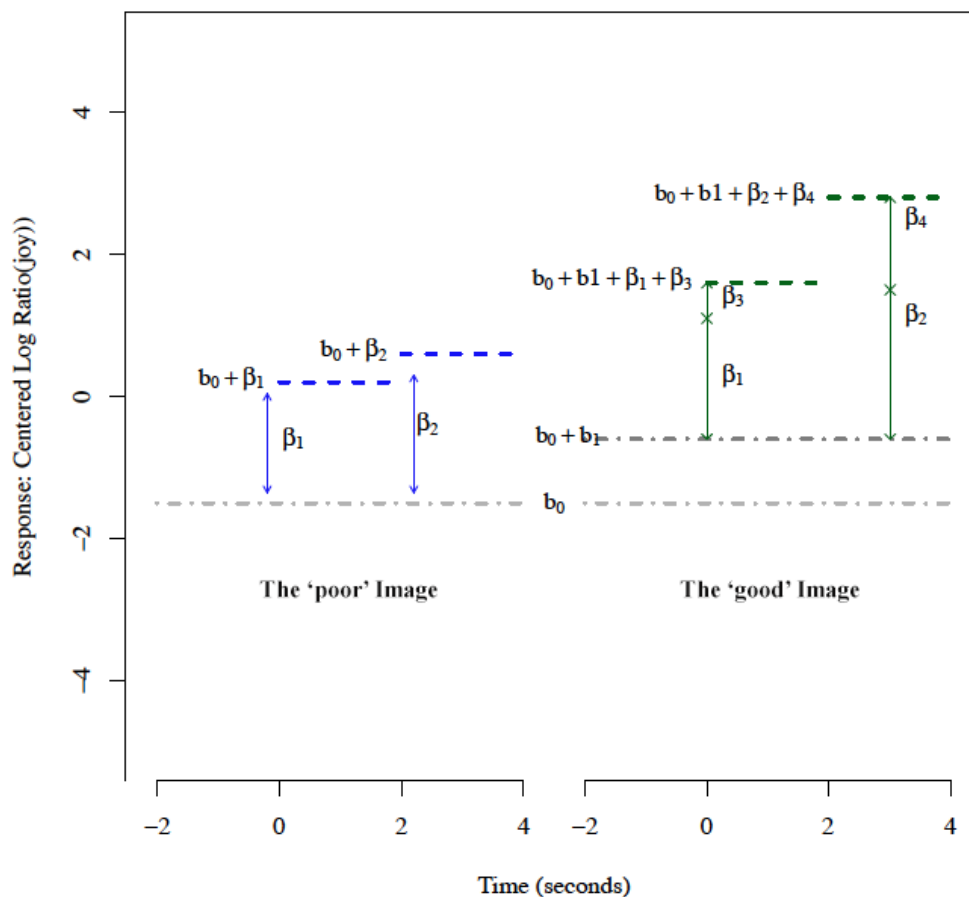


Figure 9. The theory model of individual responses for an image pair

Since the main research question in Group 1 was whether the good image's effect is different from the poor image's effect. A multi-level model estimation procedure (Bates and Pinheiro, 2000) was organized to target that difference. This research looked for the fixed effects of visual variables, but the analysis steps were aware of several sources of random variation that needed to be taken into account. First, there was a random effect at the participant level. Throughout the experiment, some respondents were measured with more joy than others and these needed to be taken that

into account. Second, to isolate the random reactions that participants have to the various images from the substantively important reactions that were keyed to image types. In other words, is there a systematic difference within the image pairs where the good/poor contrast was categorized as a variation in texture, size, color, orientation, and value?

Random fluctuations in response to the images were expected, but this research primarily explored the impact of the visual variables. In order to assess the effect of the visual variable, for example, texture, all of the images in the texture group were allowed to have randomly (and separately) determined emotional effects. Then, the result could state that there was an effect of texture, when the random effects estimation was allowed for each particular image. The random effects were coded and applied in layers because the good and poor images of each paired image were compared. To consider each image pair in isolation, there was a shared emotional response due to the similarity of the images in the pair, and there might also be a separate emotional response that affects the observations during the good image within that pair. To measure the difference in the response to good and poor image was not the main purpose of this research, so there are random effects to summarize the fluctuations in the emotion data. However, the main purpose of this research was whether the responses to the images in a collection depend systematically on visual variables. A fixed quality effect as it applies to all of the image pairs within a group of images. These models were estimated with the R (R Core Team, 2014) using the package lme4 (Bates, et al, 2014).

The analysis method changed in the research of the images in Group 2. Unlike the representations in Group 1, which the research looked for the impact of good and

poor paired images, in Group 2, the research focused on the more general comparison of four formats of information grouping designs. The coding of the effects in the models was not primarily designed to measure the difference between good and poor, but rather to estimate the average response values for each format of information grouping designs. Another difference in the Group 2 was that the images were more elaborate and they were displayed on the screen for a longer time. The baseline values were estimated in the time before the image appeared on the screen and the emotional responses were measured on segments 1 and 2 (4seconds each). (See Figure 10.)

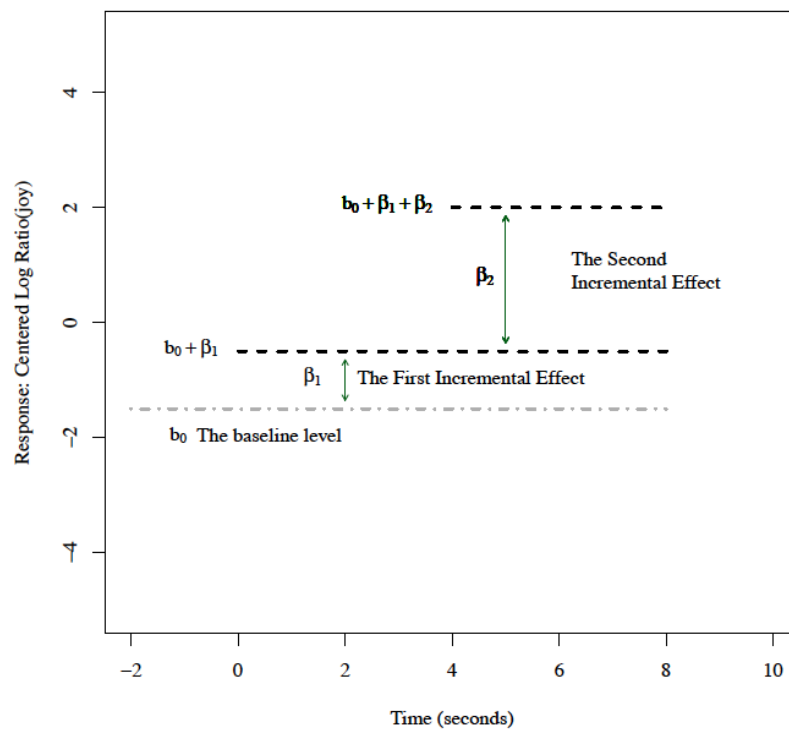


Figure 10. The theory model of individual responses.

## Chapter 4: Results

### **Introduction**

The purpose of this research was to study the measured emotional responses of participants to representations of evidence-based visual display designs. If the pattern of responses was found to be positive to the digital representations of explicit evidence-based visual display designs, then this finding could have a significant impact on designs currently employed in the development of online instruction.

### **Measurement Devices**

Two devices were used for this study. The Affectiva Q sensor was used for collecting electrodermal activity (EDA). The Affectiva Q sensor is an easy-to-wear wristband device. Q sensor is designed to measure activity of the autonomous nervous system in challenging and everyday life settings (Hedman, Wilder-Smith, Goodwin et al., 2009; Poh et al., 2010). The Q sensor was used to measure the emotional arousal of participants while viewing good and poor representations of each visual display principle.

The second device was the Computer Expression Recognition Toolbox (CERT), which tracks facial action units and predicts the basic emotions being expressed by individuals when observed by the system. The CERT was used in this study to detect the facial expressions of research participants as they viewed representations of visual display design principle. This instrument provided a measurement of the participants' emotional valences to the representations. The CERT automatically collects data derived from a camera system that instantaneously translates the data into a format for analysis. The CERT detected participants' facial expressions while viewing different visual

representations. The facial expression data allowed the participants' emotional valence to be studied and analyzed.

### **Digital Visual Representations Development**

The visual display design principles selected for development as representations were based on a review of the literature by the researcher. The digital visual representations were created by following the summary of human information processing design principles and Bertin's six visual variables. The researcher summarized the results of the literature review pertaining to principles in a format structured to facilitate the review by content experts. The brief summary statements of principles were from the psychological perspectives of human information processing. The design principles were organized in a brief statement format with research citations provided for each principle (Bertin, 1983; Coe, 1996; Gibson, 1979; Kosslyn, 1989, 1985, 1994; Kosslyn & Koenig, 1992; Palmer 1992; Stevens, 1975) Table 2 in Chapter 3 provides a list of the selected principles.

A representation was developed for each selected principle with visual variables and embedded in an independent digitized visual display for presentation individually to participants via a computer monitor. Two groups of digital visual display representations were developed. Group 1 included 108 digital visual representations that used the statement principles of Sensory Memory (Sensation & Perception). Two visual representations of each principle were paired with the principle along with one visual variable from Bertin (1981). This process resulted in 54 digital visual representations involving a good example and 54 digital representations of a poor example of the same

the principle along with one visual variable. In other words, Group 1 contained 54 pairs of good and poor examples of the principle aligned Bertin's six visual variables. This paring was done to determine if participants would respond differently to the good and poor representation of the same visual variable. All digital visual representations in Group 1 included one of Bertin's visual variables: color, size, value, texture, orientation, and shape (see Table 3). The digital visual representations were also structured in six different sets: letter, words, sentences, simple images, detailed images, and complex images. The emotional responses were coded by good and poor digital visual representations of the principles and aligned with Bertin's six visual variables. The representations were randomly presented in the intervention. The samples of visual representations were shown in Table 3.

Table 3

*Integrate 6 Bertin's Original Visual Variables to Human Information Process Design*

*Principles in Stage 1*

Sensory Memory (Sensation & Perception)

	Design Principle	
	<b>1. Adequate discriminability</b>	
	Marks must be discriminable on the display and from each other.	
Bertin's	1.a Absolute	1.b Relative discriminability
Visual	discriminability visual	Visual variables must differ by a minimal
variables	variable must have a	proportion to be discriminated, e.g. Just
	minimal magnitude to be	Noticeable Difference JNF.

detected.

Size	Buzz	B	B
Color	Buzz	B	B
Shape	Buzz	<b>B</b>	<b>B</b>
Texture	Buzz	B	B
Orientation	Buzz	B	B
Value	Buzz	B	B

Design Principle

Bertin's

2. Processing priorities

Visual

variables

Some marks are noticed and attended to more than others; also known as 'salience.'

Size

**What's the Buzz?**

The secret life of bees are finally revealed.

Color

Shape

Texture

Orientation

Value

To survive some bees species developed new ways to live together. Some found new ways to "talk" to each other, or communicate. Others developed other new skills and new behaviors.

Scientists call these kinds of changes **adaptations**.

Over a long time, a group of bees can change so much it becomes a new species.



Bees come in different sizes. There are fat bumblebees and bees not much bigger than the tip of a pencil. There are bees of many colors, from dull black to glittering green. Some species of tropical bees are such bright reds and blues that they sparkle in the sun like little jewels.

Design Principle



Bertin's  
Visual  
variables

### 3. Visual properties

Variations in different kinds of marks can be used to convey information, some better than others.

Size



Color



Value



### Design Principle

Bertin's  
Visual  
variables

### 4. Perceptual distortion

The visual system sometimes results in our having distorted impressions of visual dimensions.

Size

Some can't sting.

Color

Some can't sting.

Shape

Some can't sting.

Texture	Some can't sting.
Orientation	Some can't sting.
Value	Some can't sting.

Principles in Group 2 included more complex representations. In contrast to the Group 1 representations that focused on letters, words, sentences, simple images, detailed images and complex images, Group 2 representations contained a narrative passage selected from the National Assessment of Education Progress (NAEP, 2009), Grade 4; the reading passage was titled *What's Buzz?* by Margery Facklum, and grouped in different layout styles. Group 2 included 16 digital visual representations. The 16 digital visual representations were structured into four sets and used the statement principles of Working (Short-term) Memory Constraints and included four different information grouping layout designs. All digital visual representations were shown in the Appendix A.

### **Participants**

A convenience sampling was utilized in the selection of participants enrolled at a large comprehensive university. A total of 104 students volunteered to participate in the research; two recruiting procedures were employed. The experiment was registered with the SONA (Sona Systems, Ltd., 1997-2014) program, which alerted students in selected courses of opportunities to participate in research. Faculty members were also recommended to the researcher as instructors of courses where students with previous

online instructional experience would likely be enrolled. One hundred and four students met the criteria for participation and were invited to participate in the research.

### **Participant demographic background information**

Participants were asked to complete a demographic data form as part of the application process. They were asked to provide information on gender, age, current level of education, current major, online course taken experience, computer usage proficiency, ethnicity, vision clarity, comments on the future of online instruction, and the predicted change in online instruction. (For a copy of the demographic form see the Appendix B.)

Participants included 104 students of whom 60.6% were female and 39.4% were male (see Table 4). Ninety-three percent of the participants were age 18 to 24 years (see Table 5). Participants represented ten majors enrolled in the same Midwestern university (see Table 6); 49% were freshman and 32.7% were sophomore (see Table 7.). In terms of ethnicity, 64.4% of the sample reported that they were White, 19.2 % Asian/Pacific Islander, 6.7% Hispanic or Latino, and 2.9% African American. Participants considered their ethnicity as Other because they had multiple ethnicity background (see Table 8).

Table 4

#### *Participant Genders*

	Frequency	Percent
Female	63	60.6%
Male	41	39.4%

Total	104	100%
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Table 5

*Participant Age Distribution*

	Frequency	Percent
18-24	97	93.3%
25-30	6	5.8%
31-36	1	1%
Total	104	100%

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Table 6

*Participant Current Level of Education*

	Frequency	Percent
Freshman	51	49%
Sophomore	34	32.7%
Junior	5	4.8%
Senior	8	7.7%
Graduate	6	5.8%
Total	104	100%

---

Table 7

*Participant Majors*

	Frequency	Percent
Liberal Arts and Science	28	26.9%
Architecture, Design & Planning	2	1.9%
Business	20	4.8%
Education	13	7.7%
Engineering	5	5.8%
Health Professions	6	19.2%
Journalism & Mass Communications	7	12.5%
Music	4	4.8%
Nursing	1	5.8%
Pharmacy	7	6.7%
Others	11	10.6%
Total	104	100%

Table 8

*Participant Ethnicity Distribution*

	Frequency	Percent
White	67	64.4%
Hispanic or Latino	7	6.7%
African American	3	2.9%

Asian/Pacific Islander	20	19.2%
Other	7	6.7%
Total	104	100%

---

**Online courses experienced.** Twenty-four students (23.1%) had not completed an online course in the past, 42 (40.4%) had taken or were currently enrolled in one online course, 20 (19.2%) had taken or were currently enrolled in two online courses, and 18 (17.3%) had taken or were currently enrolled in more than three online courses. Those students who said they did not have online courses experiences did so because they did not consider such widely used online learning as Blackboard as an online courses experience. The online courses student had experienced are shown in Table 9.

Table 9

*Participant Online Courses Experienced*

	Frequency	Percent
None	24	23.1%
1	42	40.4%
2	20	19.2%
3 or more	18	17.3%
Total	104	100%

---

**Proficiency of computer usage.** Twenty-four students (23.1%) thought they were more proficient than other student in their classes, 77 (74%) thought they were as

proficient as other students in their classes, and only 3 (2.9%) thought they were less proficient than other students in their classes. The participant levels of computer proficiency are shown in Table 10.

Table 10

*Participant Proficiency of Computer Usage*

	Frequency	Percent
More proficient than other students in my classes	24	23.1%
As proficient as other students in my classes	42	40.4%
Less proficient than other students in my classes	20	19.2%
Total	104	100%

**In response to the question on viewing images on the monitor.** Fifty-six students (53.8%) reported that their vision was excellent for viewing images and or text on the monitor, and 48 (46.2%) reported that their vision was corrected and excellent for viewing images and/or text on the monitor. None of them reported a vision problem. The clarity indications of viewing images on the monitor are shown in Table 11.

Table 11

*The Clarity Indication of The View Images On The Monitor*

	Frequency	Percent
My vision is excellent for viewing images and/or text on the monitor.	56	53.8%
My vision is corrected and excellent for viewing images and/or text on the monitor.	48	46.2%
Total	104	100%

**The prediction on how popular online instruction will be at the college level fifteen years from now.** Sixty-one students (58.7%) thought online instruction would be more popular, and 32 (30.8%) thought online instruction would be somewhat more popular. The prediction on how popular online instruction would be at the college level fifteen years from now are shown in Table 12.

Table 12

*Popularity Prediction for Online Learning*

	Frequency	Percent
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More popular than it is currently	61	58.7%
Somewhat more popular than it is currently	32	30.8%
Not likely to change in popularity	4	3.8%
Somewhat less popular than it is currently	5	4.8%
Much less popular than it is currently	2	1.9%
Total	104	100%

---

**The personal prediction on how online instruction will change at the college level fifteen years from now.** Fifty-one students (49%) thought online instruction will be customizable to the preferences of students, 43 (41.3%) thought online instruction will become much more multimedia, 3 (2.9%) thought online instruction will remain about the same, and 7 (6.7%) reported no idea. (See Table 13)

Table 13

*Prediction of Online Instruction will Change at The College Level*

	Frequency	Percent
Remain about the same	3	2.9%
Become much more multimedia	43	41.3%
Be customizable to the preferences of students	51	49%
None	7	6.7%
Total	104	100%

#### **Different Analysis of Data from the Two Devices**

Electrodermal activity data were collected relative to students' emotional arousals, and facial expressions explained students' emotional valences, i.e., their emotion states. These were two types of data collected under different response time conditions due to the nature of the devices. Consequently, the analysis process was customized to the requirement of the devices. The analysis of the data collected via the Q sensor and the CERT devices are discussed separately.

**Q sensor data analysis.** The electrodermal activity data was smoothed in Ledalab, which was a Matlab based software for the analysis of EDA. Benedek and Kaernbach (2010, 2011) published a paper on this approach to the decomposition of superimposed SCRs and took into account a particular model of the electrodermal system, which solved several SCL and SCR problems. The various mathematically based deconvolution

methods offer considerable progress in the evaluation of overlapping SCRs, which are very common to stimulus sequences with short inter-stimulus intervals (ISIs) (Boucsein, 2012). Integrated skin conductance responses (ISCRs) means raw electrodermal activity data after the decomposition procedure for every image and participant were calculated in Ledalab. After all individual participant's data were analyzed, using ISCRs data, a Two-Way Analysis of Variance for determining the affective increment between two image qualities and six visual variables across all participants for Group 1 representations. The comparison of four different layout designs was analyzed for Group 2 representations.

### **CERT data analysis.**

Facial expressions data were collected from CERT, which distributed student's emotional valences in emotion states: joy, sad, surprise, anger, etc. This part of the research focused only on selected human basic emotions. These were joy, sad, and surprise (Ekman, 1984), and neutral to analyze. This study used Aitchison's clr transformation, centered log ratio, equals 0 when emotion is exactly at the average of all other emotions. The differences were compared in the incremental effect in 3-4 seconds of Group 1 images and in 6-8 seconds of Group 2 images. Using the linear mixed-effects model, a comparison among good and poor images across all participants was performed. Also, analysis determined the differences among visual variables: shape, size, color, orientation, texture, and value. The results are reported in two sections, i.e., the data collected via the Q sensor technology and the data collected via the CERT technology.

### **Q Sensor Data Results**

#### **The Research Question of the Group 1 Representations of the Research.**

Research Question 1: How does students' emotional arousal change when representations of evidence-based visual design principles ranging from explicitly good to explicitly poor examples are visually displayed to them in digital format?

Hypothesis 1: Students showed no significant difference in the emotional arousal change to viewing representations of evidence-based visual designs that range from explicit representations of design principles to poor representation in a digital format.

**Group 1 of visual representations.** Previous analysis was completed in MATLAB for the individual emotional arousal changes and across 108 images, with individual variation. Emotional arousal scores were subjected to a two-way analysis of variance having 2 image qualities (good, poor) x 6 visual variables (color, size, orientation, shape, value, texture), and two-way analysis of variance in order to examine the affective increment between image quality and visual variables. All main effects between subjects were found to be statistically non-significant. However, there was very little difference between the marginal means for the good and poor images across the six visual variables. The marginal means of poor images over 6 visual variables were 0.763, 0.776, 0.759, 0.723, 0.632 and 0.746. The results showed a higher emotional arousal pattern for 6 visual variables in good images (0.827 vs. 0.785 vs. 0.822 vs. 0.761 vs. 0.758 vs. 0.803). The highest marginal mean score (M=0.827) was at the group of good images in color. In other words, when the color good image was displayed on the screen, participants had the highest emotional arousals. The lowest marginal mean score (M=0.632) was at the group of poor images in texture. In other words, when the texture poor image was displayed on the screen, participants had the lowest emotional arousals.

Overall, the marginal mean scores of emotional arousal in good images exposure were higher than poor images exposure (see Table 14).

Table 14

*Emotional Arousal Mean Scores Between Image Quality And Visual Variables.*

Visual Variables	Image Quality	
	Good	Poor
	<i>M</i>	<i>M</i>
color	0.827	0.736
size	0.787	0.766
orientation	0.822	0.759
shape	0.761	0.723
texture	0.758	0.632
value	0.803	0.746

### **The Research Question of the Group 2 Representations of the Research.**

Research Question 2: How does students' emotional arousal change when representations of evidence-based visual design principles with different information grouping layout design examples are visually displayed to them in digital format?

Hypothesis 2: Students show no significant difference in the emotional arousal change of participants to viewing representations of evidence-based visual designs that range from different information grouping layout styles in a digital format.

**Group 2 of visual representations.** A one-way analysis of variance was conducted to evaluate the relationship between four formats of information grouping layout designs: one paragraph with the 1.0 line spacing, one paragraph with the 2.0 line spacing, 2 columns and 3 columns digital visual representations and the emotional arousals difference while viewing different digital visual representations. The independent variable, four digital visual representations included: one paragraph with the narrow line spacing, one paragraph with the regular line spacing, 2 columns and 3 columns. The dependent variable was the difference of the emotional arousals (ISCRs) while viewing different digital visual representations. There were no statistically significant differences between four formats of information grouping layout designs as determined by one-way ANOVA,  $F(3,1660) = .898, p = .441$ . The emotional arousals changes between 4 different information grouping designs of the digital visual representations were not statistically different. However, there was still very little difference between the group means for four formats of information grouping layout designs ( $M=0.628$ ). The means of four formats of information grouping layout were different (0.743 vs. 0.672 vs. 0.591 vs. 0.505). The highest mean score ( $M=0.743$ ) was at the format of one paragraph with the 1.0 line spacing. In other words, when the images which were the format of one paragraph with the 1.0 line spacing were displayed on the screen, participants had the highest emotional arousals. The lowest mean score

( $M=0.505$ ) was at the images which were the format of 3 columns. In other words, when the images which were the format of 3 columns were displayed on the screen, participants had the lowest emotional arousals (see Table 15).

Table 15

*Means and Standard Deviations for Four Formats of Layout Designs*

Four formats of layout designs	<i>M</i>	<i>SD</i>
one paragraph with the 1.0 line spacing	0.743	2.334
one paragraph with the 2.0 line spacing	0.672	2.714
2 columns	0.591	2.246
3 columns	0.505	1.316
Total	0.628	2.213

**CERT Data Results**

**The Research Question of the Group 1 Representations of the Research.**

Research Question 3: How does students' emotional valence change when representations of evidence-based visual design principles ranging from explicitly good to explicitly poor examples are visually displayed to them in digital format?

Hypothesis 3: Students show no significant difference in the effect of positive emotional valence of participants to viewing representations of evidence based visual designs that range from explicit representations of design principles to poor representations in a digital format.

In this study, emotional valence was collected from participant's facial expressions by CERT for answering this research question. Data of Group 1 representations were collected while participants processed different visual variables designs which were size, orientation, color, value, texture, and shape. The facial responses were recorded 10 times per second, resulting in a very large data set. The total number of observations used to estimate the Group 1 models was  $N= 681,893$ . Summary tables for the models estimating the models for Joy, Sad, Surprise, and Neutral are presented in Tables 16 through 19.

These tables follow the same format. The tables were shown estimated random effects for each participant, image pair, and the good image within each pair, 4 variance components were reported in each model. It showed the large estimates of the standard deviation across participants, within image pairs, and then for the good images within pairs. At the same time, however, the fixed effects for the time segments for each of the 6 categories of image variation were also estimated. The data shown the participant and image random effects should become a good deal of the idiosyncratic variation. It was encouraging that the baseline values for the image categories were all basically the same, meaning that the emotional pre-disposition was the same for the images within each set.



For the following time segments, the affective differential was the primary purpose of this research. These were the effects represented by  $\beta_3$  and  $\beta_4$  in the Chapter 3. These coefficients were the estimates of the good/poor difference within the images of each type.

The results found the difference of facial expressions when participants reviewed the good and poor digital visual representations. The results also showed the some design principles will have significantly different effects of facial expressions.

**Visual variables predicting joy.** Color, shape, texture and value significantly predicted participants' facial expression of joy. However, only color and shape visual variables had an increment of joy. When digital visual representations which were good visual variable: color representations compared to poor visual variable: color representations, participants' facial expressions on Joy were increased 0.023. When digital visual representations which were good visual variable: shape representations compared to poor visual variable: shape representations, participants' facial expressions on Joy were increased 0.063. However, when were digital visual representations which good visual variable: texture representations compared to poor visual variable: texture representations, participants' facial expressions of joy were decreased 0.082. The same situation was also found in visual variable: value. The representations which were good visual variable: value representations decreased participant's joy by 0.054 (see Table 16 and Figure 11).

Table 16

*Joy Multilevel Model of Visual Variables*

	<b>Visual Variable</b>	<b>Estimate</b>	<b>(SE)</b>
Baseline	color	-2.492***	(0.113)
	orientation	-2.492***	(0.115)
	shape	-2.508***	(0.115)
	size	-2.463***	(0.113)
	texture	-2.516***	(0.115)
	value	-2.477***	(0.113)
Segment 1	color	-0.001	(0.005)
	orientation	-0.017*	(0.008)
	shape	-0.046***	(0.008)
	size	-0.010	(0.005)
	texture	0.027***	(0.008)
	value	-0.003	(0.005)
Segment 1	color	-0.004	(0.008)
affective difference	orientation	0.040***	(0.011)
	shape	0.027*	(0.011)
	size	-0.012	(0.008)
	texture	-0.072***	(0.011)
	value	-0.002	(0.008)
Segment 2	color	0.007	(0.005)
baseline	orientation	-0.005	(0.008)
	shape	-0.031***	(0.008)

---

	size	0.025***	(0.005)
	texture	0.070***	(0.008)
	value	0.032***	(0.005)
Segment 2	color	0.023**	(0.008)
affective difference	orientation	0.001	(0.011)
	shape	0.063***	(0.011)
	size	-0.003	(0.008)
	texture	-0.082***	(0.011)
	value	-0.054***	(0.008)

N = 681,893      RMSE = 0.613

Random Effects ( $\sigma$ )

Residual = 0.613

Image pair within participant = 0.889

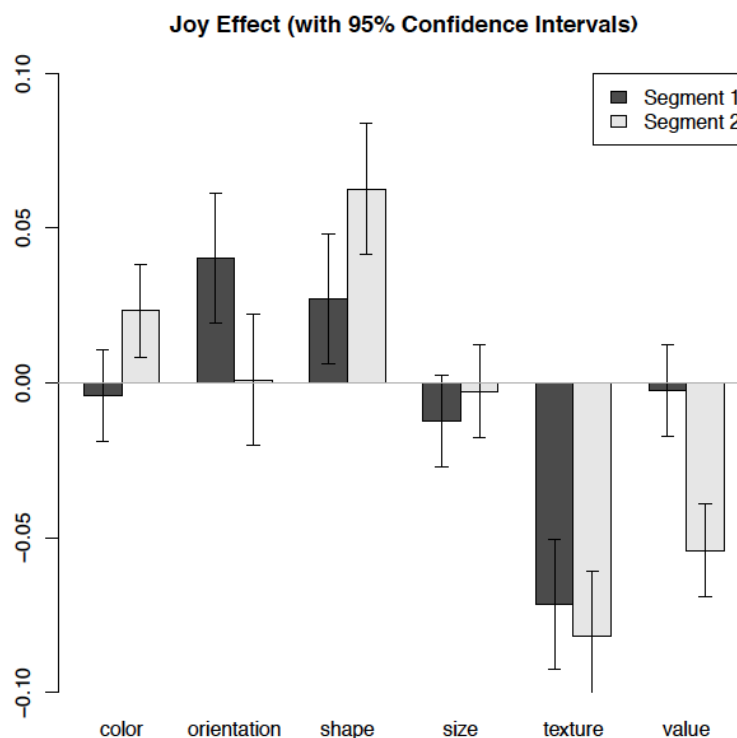
Image quality within pair within participant = 0.992

Participant = 1.136

Pseudo  $R^2$  = 0.849

\*  $p \leq .05$  \*\*  $p \leq .01$  \*\*\*  $p \leq .001$

---



*Figure 11.* The effect of joy on paired of images of 8 visual variables.

**Visual variables predicting sad.** Orientation, size, texture and value significantly predicted participant's facial expression of sad. However, only orientation visual variables designs had an increment of sad. When digital visual representations which were good visual variable: orientation representations against poor visual variable: orientation representations, participants' facial expressions of sad were increased 0.036.

On the contrary, when digital visual representations which were good visual variable: size representations against poor visual variable: size representations, participants' facial expressions of joy were decreased 0.020. When digital visual representations which were good visual variable: texture representations against poor visual variable: texture representations, participants' facial expressions on also decreased

0.049. The same situation also found in value visual variable. The digital visual representations which were good visual variable: value representations against poor visual variable: value representations decreased 1.8% participants' sad facial expressions (see Table 17 and Figure 12).

Table 17

*Sad Multilevel Model of Visual Variables*

	<b>Visual variables</b>	<b>Estimate</b>	<b>(S.E.)</b>
Baseline	color	1.372***	(0.087)
	orientation	1.396***	(0.089)
	shape	1.380***	(0.089)
	size	1.374***	(0.087)
	texture	1.415***	(0.089)
	value	1.348***	(0.087)
Segment 1	color	0.001	(0.005)
	orientation	-0.005	(0.007)
	shape	0.010	(0.007)
	size	0.000	(0.005)
	texture	-0.036***	(0.007)
	value	0.027***	(0.005)
Segment 1	color	-0.013	(0.007)
affective difference	orientation	-0.016	(0.009)
	shape	0.012	(0.009)

---

	size	-0.015*	(0.007)
	texture	0.031***	(0.009)
	value	-0.016*	(0.007)
Segment 2	color	0.004	(0.005)
baseline	orientation	-0.030***	(0.007)
	shape	0.006	(0.007)
	size	0.024***	(0.005)
	texture	-0.031***	(0.007)
	value	0.047***	(0.005)
Segment 2	color	-0.007	(0.007)
affective difference	orientation	0.036***	(0.009)
	shape	0.011	(0.009)
	size	-0.020**	(0.007)
	texture	0.049***	(0.009)
	value	-0.018**	(0.007)

N = 681,893      RMSE = 0.529

Random Effects ( $\sigma$ )

Residual = 0.529

Image pair within participant = 0.640

Image quality within pair within participant = 0.772

Participant = 0.883

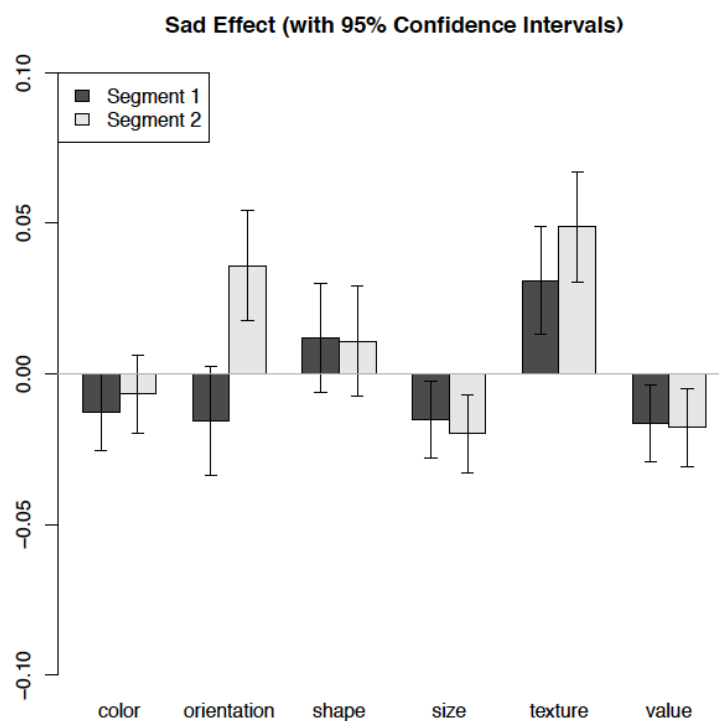
---

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Pseudo  $R^2 = 0.813$

\*  $p \leq .05$  \*\*  $p \leq .01$  \*\*\*  $p \leq .001$

---



*Figure 12.* The effect of sad on paired of images of 8 visual variables.

**Visual variable predicting surprise.** Orientation, size, texture and value significantly predicted participant's facial expression on surprise. Only shape of visual variables design had an increment of surprise. When digital visual representations which were good visual variable: shape representations against poor visual variable: shape representations, participants' facial expressions of surprise were increased 0.051.

On the contrary, when digital visual representations which were good visual variable: orientation representations against poor visual variable: orientation

representations, participants' facial expressions of surprise were decreased 0.025 (see Table 18 and Figure 13).

Table 18

*Surprise Multilevel Model of Visual Variables*

	<b>Visual variables</b>	<b>Estimate</b>	<b>(S.E.)</b>
Baseline	color	-2.210***	(0.130)
	orientation	-2.262***	(0.131)
	shape	-2.185***	(0.131)
	size	-2.208***	(0.130)
	texture	-2.227***	(0.131)
	value	-2.219***	(0.130)
Segment 1	color	-0.005	(0.006)
	orientation	0.018*	(0.009)
	shape	-0.038***	(0.009)
	size	-0.020**	(0.006)
	texture	-0.004	(0.009)
	value	0.008	(0.006)
Segment 1	color	-0.016	(0.009)
affective difference	orientation	0.010	(0.012)
	shape	-0.004	(0.012)
	size	0.000	(0.009)
	texture	0.000	(0.012)



---

	value	-0.021*	(0.009)
Segment 2	color	-0.026***	(0.006)
baseline	orientation	0.050***	(0.009)
	shape	-0.076***	(0.009)
	size	-0.043***	(0.006)
	texture	-0.010	(0.009)
	value	0.005	(0.006)
Segment 2	color	-0.009	(0.009)
affective difference	orientation	-0.052***	(0.012)
	shape	0.051***	(0.012)
	size	0.012	(0.009)
	texture	0.021	(0.012)
	value	-0.012	(0.009)

N = 681,893                  RMSE = 0.693

Random Effects ( $\sigma$ )

Residual = 0.693

Image pair within participant = 0.861

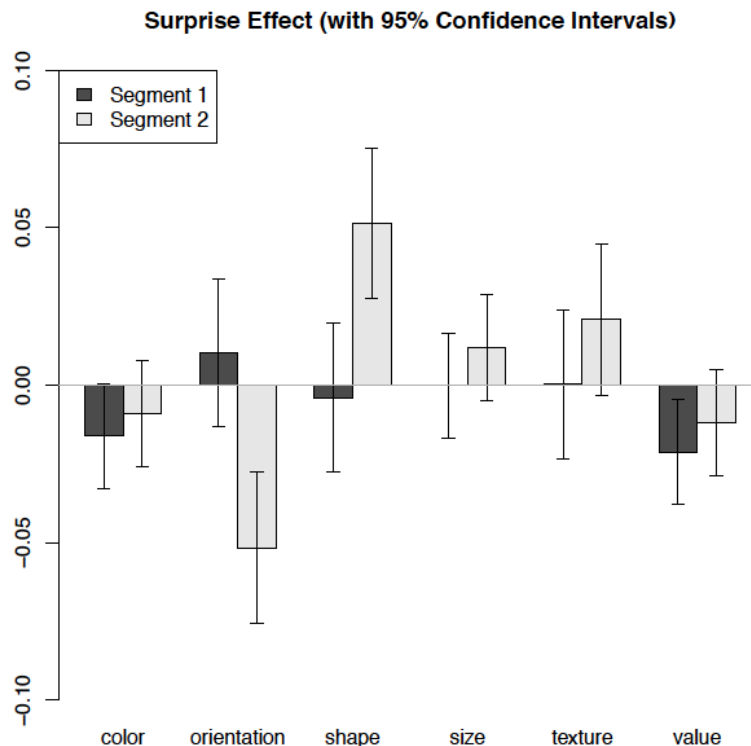
Image quality within pair within participant = 0.991

Participant = 1.313

Pseudo  $R^2 = 0.84$

\*  $p \leq .05$  \*\*  $p \leq .01$  \*\*\*  $p \leq .001$

---



*Figure 13.* The effect of surprise on paired of images of 8 visual variables.

**Visual variables predicting neutral.** Orientation and shape significantly predicted participant's facial expression of neutral. Shape, size, texture and value of visual variables design had an increment of neutral. When digital visual representations which were good visual variable: size representations against poor visual variable: size representations, participants' facial expressions of neutral were increased 0.013. When digital visual representations which were good visual variable: texture representations against poor visual variable: texture representations, participants' facial expressions of neutral were increased 0.013. When digital visual representations which were good visual variable: value representations against poor visual variable: value representations, participants' facial expressions of neutral were increased 0.036.

On the contrary, when digital visual representations which were good visual variable: shape representations against poor visual variable: shape representations, participants' facial expressions on Neutral were decreased 0.034 (see Table 19 and Figure 14)

Table 19

*Neutral Multilevel Model of Visual Variables*

	<b>Visual variable</b>	<b>Estimate</b>	<b>(S.E.)</b>
Baseline	color	3.379***	(0.086)
	orientation	3.401***	(0.087)
	shape	3.401***	(0.087)
	size	3.361***	(0.086)
	texture	3.373***	(0.087)
	value	3.370***	(0.086)
Segment 1	color	-0.002	(0.004)
	orientation	-0.010	(0.006)
	shape	0.019**	(0.006)
	size	0.004	(0.004)
Segment 1	color	0.004	(0.006)
affective difference	orientation	0.001	(0.009)
	shape	-0.010	(0.009)
	size	0.017**	(0.006)
	texture	0.026**	(0.009)

---

	value	0.002	(0.006)
Segment 2	color	-0.017***	(0.004)
baseline	orientation	-0.039***	(0.006)
	shape	0.002	(0.006)
	size	0.005	(0.004)
	texture	-0.046***	(0.006)
	value	-0.032***	(0.004)
Segment 2	color	0.010	(0.006)
affective difference	orientation	0.013	(0.009)
	shape	-0.034***	(0.009)
	size	0.013*	(0.006)
	texture	0.036***	(0.009)
	value	0.036***	(0.006)

N =681893                  RMSE=0.500

Random Effects ( $\sigma$ )

Residual=0.500

Image pair within participant=0.645

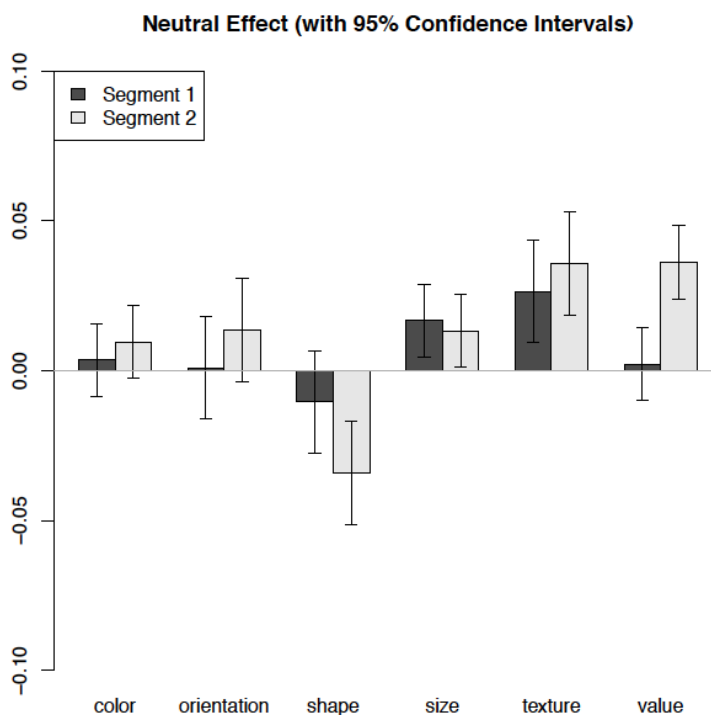
Image quality within pair within participant=0.746

Participant=0.869

Pseudo  $R^2$ =0.826

\*  $p \leq .05$  \*\*  $p \leq .01$  \*\*\*  $p \leq .001$

---



*Figure 14.* The effect of Neutral on paired of images of 8 visual variables.

Although, the effect was very small because individuals are different and the stimuli were not extremely pleasant and unpleasant images, the results still showed that different visual variables have significant different effect of joy, sad and surprised. Overall, the texture has more effects over other principles on different effect. When digital visual representations followed the color and shape visual variables, the participant's joy increased. When digital visual representations followed size, texture and value visual variable principles, they reduced participant's sad expressions.

#### **The Research Question of the Group 2 Representations of the Research.**

Research Question 4: How does students' emotional valence change when representations of evidence-based visual design principles with different information grouping layout design examples are visually displayed to them in digital format?

Hypothesis 4: Student show no significant difference in the effect of positive emotional valence of participants to viewing representations of evidence based visual designs that range from different information grouping layout styles in a digital format.

Total number ( $N = 169,808$ ) of facial expressions was collected. Data of Group 2 representations were collected while participants processed different information grouping layout designs, which were one paragraph with the narrow line spacing, one paragraph with the regular line spacing, 2 columns and 3 columns.

The layout of different designs significantly predicted participant's facial expression of joy. When the 3 columns digital visual representation was shown, the participants; joy increased 10.4%. The narrow digital visual representation was shown, participants' joy increased 2.9%. The regular visual representation was shown, the participants' joy decreased 2.5%. The 2 Column visual representation was shown, the participants' joy decreased 9.4% (see Table 20 and Figure 15).

Table 20

*Joy Multilevel Model of Format Designs*

	Design <b>layout</b> variable	Estimate	(S.E.)
Baseline	narrow	-2.523***	(0.123)
	regular	-2.404***	(0.123)
	2 columns	-2.549***	(0.123)

---

	3 columns	-2.521***	(0.123)
Segment 1	narrow	-0.012	(0.010)
affective increment	regular	-0.024*	(0.010)
	2 columns	-0.029**	(0.010)
	3 columns	-0.046***	(0.010)
Segment 2	narrow	0.029***	(0.008)
affective increment	regular	-0.025**	(0.008)
	2 columns	0.094***	(0.008)
	3 columns	0.104***	(0.008)

N = 169,808

RMSE = 0.733

Random Effects ( $\sigma$ )

Residual = 0.733

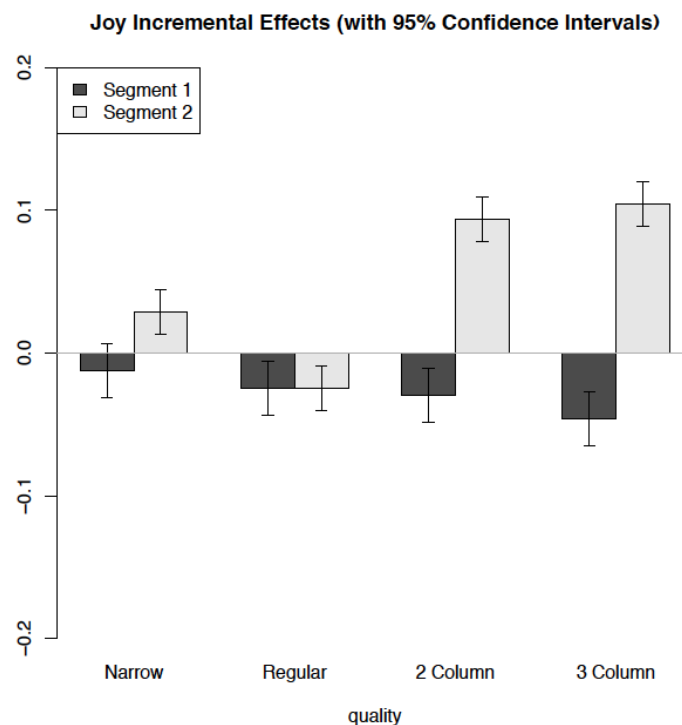
Image of format designs within participant = 0.859

Participant = 1.183

Pseudo  $R^2 = 0.801$

\*  $p \leq .05$  \*\*  $p \leq .01$  \*\*\*  $p \leq .001$

---



*Figure 15.* The incremental effect of Joy on 4 different information grouping layout design in segment 1 and segment 2.

Only narrow and 3 columns layout designs significantly predicted participant's facial expression of sad. When the narrow layout design of digital visual representation was shown, the participants' sad decreased 1.9%. When the 3 columns layout design of visual representation was shown, the participants' sad decreased 1.8% (see Table 21 and Figure 16.).

Table 21

*Sad Multilevel Model of Format Designs*

	<b>Design layout variable</b>	<b>Estimate</b>	<b>(S.E.)</b>
Baseline	Narrow	1.417***	(0.095)



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	Regular	1.362***	(0.095)
	2 Columns	1.413***	(0.095)
	3 Columns	1.380***	(0.095)
<b>Segment 1</b>	Narrow	0.011	(0.008)
<b>affective increment</b>	Regular	-0.002	(0.008)
	2 Columns	-0.032***	(0.008)
	3 Columns	0.035***	(0.008)
<b>Segment 2</b>	Narrow	-0.019**	(0.007)
<b>affective increment</b>	Regular	0.009	(0.007)
	2 Columns	-0.005	(0.007)
	3 Columns	-0.018**	(0.007)

**N = 169,808**

**RMSE = 0.599**

**Random Effects ( $\sigma$ )**

**Residual = 0.599**

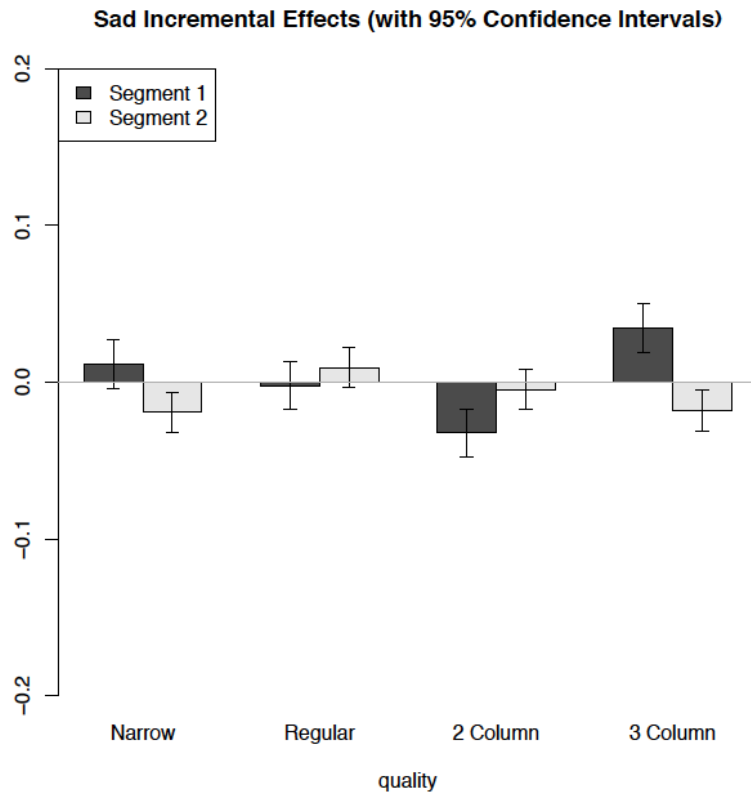
**Image of format designs within participant = 0.575**

**Participant = 0.925**

**Pseudo  $R^2 = 0.77$**

**\*  $p \leq .05$  \*\*  $p \leq .01$  \*\*\*  $p \leq .001$**

---



*Figure 16.* The incremental effect of Sad on 4 different information grouping layout design in segment 1 and segment 2.

Regular and 2 columns layout designs significantly predicted participant's facial expression of surprise. When the regular layout design of digital visual representation was shown, the participants' surprise increased 1.9%. When the 2 columns layout design of visual representation was shown, the participants' surprise increased 3.4% (see Table 22 and Figure 17).

Table 22

*Surprise Multilevel Model of Format Designs*

Design layout variable	Estimate	(S.E.)
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Baseline	Narrow	-2.236***	(0.135)
	Regular	-2.176***	(0.135)
	2 Columns	-2.251***	(0.135)
	3 Columns	-2.264***	(0.135)
Segment 1	Narrow	-0.060***	(0.010)
affective increment	Regular	-0.013	(0.010)
	2 Columns	-0.008	(0.010)
	3 Columns	0.014	(0.010)
Segment 2	Narrow	-0.006	(0.009)
affective increment	Regular	0.019*	(0.009)
	2 Columns	0.034***	(0.009)
	3 Columns	-0.020*	(0.009)

N = 169,808

RMSE = 0.796

Random Effects ( $\sigma$ )

Residual = 0.796

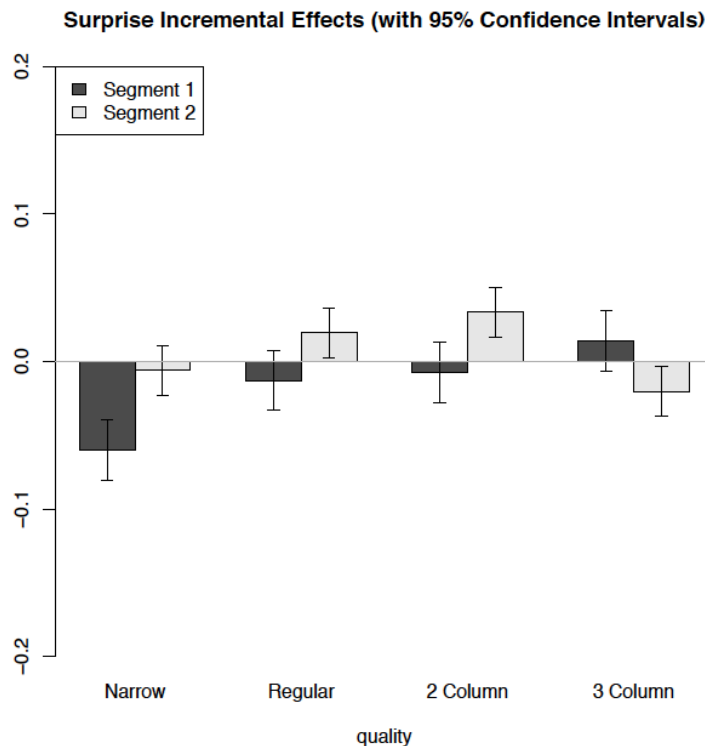
Image of format designs within participant = 0.759

Participant = 1.331

Pseudo  $R^2$  = 0.79

\*  $p \leq .05$  \*\*  $p \leq .01$  \*\*\*  $p \leq .001$

---



*Figure 17.* The incremental effect of surprise on four different information grouping layout design in segment 1 and segment 2.

Narrow, 2 columns and 3 columns information grouping layout designs significantly predicted participant's facial expression of neutral. When the narrow layout design of digital visual representation was shown, the participants' neutral decreased 0.034. The 2 columns layout design of visual representation was shown, the participants' neutral decreased 0.019. When the 3 columns layout design of visual representation was shown, the participants' neutral decreased 0.03 (see Table 23 and Figure 18).

Table 23

*Neutral Multilevel Model of Format Designs*

Design layout variable	Estimate	(S.E.)
------------------------	----------	--------

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Baseline	Narrow	3.397***	(0.093)
	Regular	3.310***	(0.093)
	2 Columns	3.320***	(0.093)
	3 Columns	3.392***	(0.093)
Segment 1	Narrow	0.001	(0.008)
affective increment	Regular	0.039***	(0.008)
	2 Columns	0.046***	(0.008)
	3 Columns	-0.012	(0.008)
Segment 2	Narrow	-0.034***	(0.006)
affective increment	Regular	0.001	(0.006)
	2 Columns	-0.019**	(0.006)
	3 Columns	-0.030***	(0.006)

N = 169,808      RMSE = 0.590

Random Effects ( $\sigma$ )

Residual = 0.590

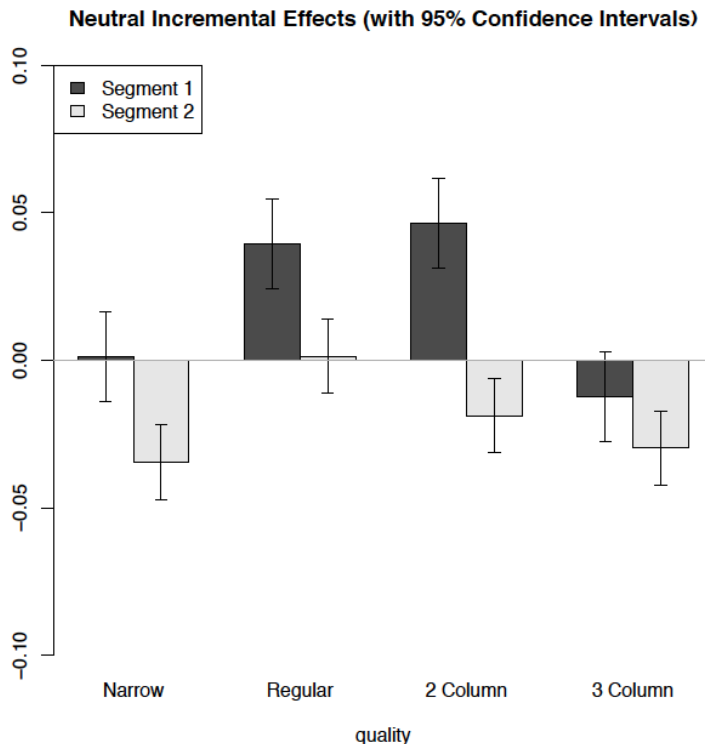
Image of format designs within participant = 0.625

Participant = 0.903

Pseudo  $R^2 = 0.778$

\*  $p \leq .05$  \*\*  $p \leq .01$  \*\*\*  $p \leq .001$

---



*Figure 18.* The incremental effect of neutral on four different information grouping layout design in segment 1 and segment 2.

Overall, results showed a difference of facial expressions when viewing narrow, regular, 2 column and 3 column. In general, facial expressions changes were found in different layout designs. Although, the same layout designs have different influences on different facial expressions, all layout designs have significant effects of joy.

This research also interviewed participant's feedback on the experiment.

### **The Feedback From Interview**

Each participant was interviewed at the conclusion of his or her participation in the experiment. The interviews were informal and intended to derive feedback on their perspective as a participant in the study. The researcher returned to the experiment room

when the experiment ended for each participant. The time required for completing the experiment was timed and the same for all participants. During the experiment participants were required to be very focused on the presentation of the intervention delivering the representations. While rest periods were provided, participation did require concentration. The researcher made an effort to allow participants to relax and respond to open ended questions. It was apparent that that while participants were responsive to the questions that they had not had time to reflect extensively on their experience.

They clearly recalled the differences between the Group 1 and Group 2 representations. They made comments about the lack of clearness of some representations in Group 1. This condition was by design in the context of the poor representations of principles, which often related to lack of clarity. Several reported that there were similarities in the representations in Group 1. This too was somewhat by design, as it was necessary to provide exposure to representations that were varied examples in the quality of the principles being responded to. There were also 108 representations in Group 1, thus it was possible that the redundancies might have caused some fatigue. However, Group 2 representations appeared last in the experiment and no similar observations were shared. There was consensus that the exposure time may have been a little long for the presentation of representations in Group 1. The time of exposure for Group 2 representations was reported as being about right.

A common view shared by participants was that they expected to see color in the images of the representations as well as levels of organization in the content where

content was included. It was apparent that they were thinking about the design of web pages once they got into the experiment, and they referenced the development of web pages and the value placed on color. Representations that were most frequently recalled were the ones including the bees. Particular mention was made to the presentation of content in columns. The term used by one participant was that the columns helped the content “stand out.” Comments were volunteered by some participants about not liking the spacing on content. In follow questioning it was clear that they were talking about the 1.0 line spacing.

The interviews went smoothly and there was no evidence of disinterest in the experiment. They understood their role. No one indicated any dissatisfaction with the participation experience.



## Chapter 5: Discussion and Suggestions for Future Research

### **Introduction**

Improvements in the design of online instruction at the post-secondary level have been driven largely by the implications of student feedback on their online learning experiences, assessments on usability, the prior experiences of instructors in developing instructional designs for traditional courses, and standards set by accreditation associations. Relatively little research has been conducted on the effectiveness of visual display design principles to guide the evolution of evidence-based visual designs applicable to online instruction. Although multimedia resources have long been employed in face-to-face instruction and valued for their contributions to improved study skills and learning achievement, only more recently have multimedia instructional features found their way into the design of online instruction. Most e-learning environments established goals to improve student learning. With advancements in educational technology, new possibilities emerged for engaging students in active learning, student-centered classrooms, and routine use of visual materials (Gilbert, 2005). A contributor to the slowness of this evolution was that instructions had to be integrated into the learning experience in a manner that fit the real-time delivery mode of the Internet. This requirement added a significant level of instructional accountability as the content and instructional features were not only intended for independent study by students, but were open to review by colleagues and others.

The early emphasis on asynchronous approaches to online instruction and its self-paced orientation may have been a factor in the lack of attention given to affective

learning. The focus tended to be on cognitive learning and the structure of content. In the transition from face-to-face instruction to visual display delivered instruction, research related to the development of activities to enhance affective learning was basically overlooked. This oversight also delayed attention to the pleasure of learning experiences that result in improved engagement in the learning environment—even though the literature widely reports that affective experiences usually enhance student learning. The design of affect-oriented experiences also adds to the design and development tasks associated with the creation of online courses.

The emotional aspects of affective learning experiences are more complicated to address in online instruction than cognitive needs. Affective instructional objectives have emotional valence and emotional arousal elements that require using multiple methods to analyze learners' emotional states. They are also aligned with definitions of emotions, which have multiple dimensions (Gross, 2010, 2013). The use of a multiple emotional measurements approach also affords researchers the opportunity to circumvent the constraints of individual learning channels and contribute to achieving greater validity and reliability of research findings (Harley, Boucheet, Hussain, Azevedo, & Calvo, 2014). Lang (1993) stated that facial expressions were effectively used to judge the affective valence when humans viewed different pictures. Skin conductance measures were associated with the measurement of arousal.

The measurement of affective experiences of online learners has also received less attention than the measurement of cognitive performance in online instruction. This lack of research is largely due to the primary focus of instruction, in all modes of

teaching, being on content and student outcomes aligned with instructional objectives. Consequently, few evidence-based strategies for achieving affective outcomes through online instructional design and pedagogy exist. The lack of significant research in the measurement of emotional responses in online instruction has resulted in instructional designers and developers making assumptions about the engagement of students in online instruction. These circumstances are changing due to increased concern for the emotional engagement of online students and increased attention being given to the use of technologies to measure the emotional responses of online learners to visual displays and activities. For example, an emphasis on analytics as an approach to measuring evidence of involvement and attentiveness has emerged as a process for measuring engagement. More importantly the use of devices for measuring skin conductance and facial recognition responses are receiving increased attention from researchers.

Much of the research during the early history of online instruction focused on such topics as student cognitive outcomes, achievement, retention, and the sustained involvement of students in online learning environments (Anderson & Bushman, 2001). Particular attention was given to the development of online teaching standards and instructional resources. Even when the research emphasized cognitive outcomes little was understood about the impact of cognitive processes of learning via this new mode of instruction in the context of relying on visual display e.g., the monitor for delivering instruction. The consequence of moving from face-to-face instruction to digital visual display was not emphasized in early research related to online instruction. What tended

to occur was researchers generalizing instructional design principles that were effective in face-to-face instruction to the online instructional environment.

Today the Internet delivers and/or supplements educational experiences for students of all ages. The drivers of this increase in online education grew because of a mixture of technical capacity, student need for access to higher education, and revenue generating opportunities for institutions of higher education (IHEs). The visual display, i.e., the monitor, remains a constant across all online instruction. This fact raised questions about the need for research to ensure that visual display designs are maximally effective in enhancing the quality of online instruction. With visual display technology being central component in online instruction, one might assume that a major investment of resources would be made in researching multimedia theory for purposes of determining how best to strengthen visual display designs representing the core of online instruction (Garrison & Kanuka, 2004). What appears to have happened was that human and fiscal resources were primarily invested in designing and developing online instruction rather than conducting research to inform the design of online research.

Only a limited amount of early research was carried out that addressed visual display designs that maximize the impact of text and visual presentations in engaging and motivating online students. The primary limitation hindering research on motivation and engagement could also be due to the lack of technologies to identify and measure in real time student engagement in online instructional environments. This situation is changing.

The purpose of this research was to understand the emotions emitted by college students in response to viewing online digital representations of evidenced-based visual display design principles. This study focused on identifying an approach to the design of visual displays that reflects research-based design principles applicable to online instruction and that contributes to the enhancement of students' emotional engagement with online instruction. The research reported focused on investigating technology approaches to measuring indicators each participant's responses in two different emotional dimensions: emotional arousal (high/low) as detected by the Q sensor, and emotional valence (positive/negative) as detected by the CERT. The two emotional measurement methods (electrodermal activity and facial expression) were analyzed separately in this investigation. This research entailed the identification and validation of text-related visual display design principles from the literature. This study also included designing and developing sequences of representations that were aligned with visual display design principles for use in an experimental intervention. The representations included validated examples of accurate visual display displays of each principle and examples with varying degrees of inaccuracies.

### **Discussion of Findings**

The importance of conceptual model as a framework for researching designs, such as visual display designs, is the premise that the researcher's emphasis should be on what the product, service or system is to the users, and not on how the product looks (Norman, 2013). In this research two categories of users were involved. They included designers and developers of online instruction who will ultimately implementing the results of this

research and students who will benefit from improved online instruction in the future. This research evaluated emotional arousal and valence in two groups of different digital visual display representations. The first group of representations included 108 images. They were simple-text representation designs, which contained six sets of different types of representations: letter, words, sentence, simple image, complex image and detailed image. Each set had a good and a poor example in six visual variables: color, size, shape, texture, orientation and value. The second group included 16 images that were more complex representations. They included four sets of information grouping layout designs: one paragraph with the 1.0 line spacing, one paragraph with the 2.0 line spacing, and information in formats of 2 columns and 3 columns.

### **Emotional Arousal Difference on Group 1 Representations by Students**

The results found difference of emotional arousal in certain simple-text representation designs. Participants demonstrated the highest emotional arousal on good color images ( $M=0.827$ ) and the lowest emotional arousal on poor texture images. In other words, when the color good image (see Figure 19.) was displayed on the monitor and screen compared to other visual variables of images, participants had the highest emotional arousal. When the poor texture images (see Figure 20.) were displayed on the screen, participants had the lowest emotional arousal over all six visual variables of images.



*Figure 19.* Good Examples of color images.



*Figure 20.* Poor examples of texture images

In summary, participants demonstrated emotional arousal changes after these five image pairs shown on the screen. The results suggested visual variables had effects on

participant's emotional arousal changes. However, two-way ANOVA model did not demonstrate a significant main effect. A possible explanation may be the fact that the similar representations have been shown several times, so participants did not have too strong of an emotional arousal change as the experiment progressed on the Group 1 representations. Other possibilities may be that the Q sensor was not sensitive enough for this experiment, and the stimuli were not strong enough to raise their emotional arousal.

### **Emotional Arousals Difference on Group 2 Representations by Students**

A one-way analysis of variance was conducted to evaluate the relationship between four criteria of information grouping layout designs: one paragraph within 1.0 line spacing, one paragraph within 2.0 line spacing, a format with 2 columns and 3 columns, and the emotional arousal difference while viewing different digital visual display representations. However, the results of ANOVA were not significant, so the emotional arousal changes between four criteria of the digital visual display representations were not statistically significant different (Figure 21, 22, 23, 24).



## What's the Buzz?

### The secret life of bees are finally revealed.

To survive some bees species developed new ways to live together. Some found new ways to "talk" to each other, or communicate. Others developed other new skills and new behaviors. Scientists call these kinds of changes adaptations. Over a long time, a group of bees can change so much it becomes a new species.



Bees come in different sizes. There are fat bumblebees and bees not much bigger than the tip of a pencil. There are bees of many colors, from dull black to glittering green. Some species of tropical bees are such bright reds and blues that they sparkle in the sun like little jewels.

*Figure 21.* A sample of one paragraph within 1.0 line spacing design.

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*Figure 22.* A sample of one paragraph within 1.5 line spacing design.

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*Figure 23. A sample of a format with 2 columns design.*

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*Figure 24. A sample of a format with 3 columns design.*

There was still very little difference between the group means for four formats of information grouping layout designs. The highest mean score ( $M=0.743$ ) was at the format of one paragraph with the 1.0 line spacing. The lowest mean score ( $M=0.505$ ) was

at the images which were the format of 3 columns. Taken together, the results suggested that when participants viewed one paragraph with the 1.0 line spacing design, they have high emotional arousal compared to other three formats. When participants viewed 3 columns designs, they have lower emotional arousal than when paired to the other three formats. However, high emotional arousal may represent excitement or anxiety. It didn't mean that participants had a positive response. But, the results showed that different formats of layout grouping designs might have contributed in the effects on participants' emotional arousal change.

### **Facial Expression Differences on Group 1 Representations by Students**

The facial expression data were analyzed using different statistics than used in analyzing the electrodermal activity data. The results of the facial expressions analyses found the difference of facial expressions when participants reviewed the good and poor digital visual display representations across all representations. The results also showed that visual variables had significantly different effects of facial expressions. To find the effects of different visual variables on the positive emotional valence, look at the increment of joy. For example, only color and shape visual variables indicated an increment of joy. When digital visual display representations followed the color visual variable design was compared against the representations, which do not follow the color visual variable design, participants' facial expressions of joy were slightly increased 0.023%. In other words, when participants viewed the good digital visual display representations in color, their joy facial expressions increased.

When digital visual display representations that followed the shape visual variable design were compared against those that did not follow the shape visual variable design, participants' facial expressions of joy increased by 0.063%. As participants viewed the good digital visual display representations in shape, their joy facial expression increased too.

However, when digital visual display representations that followed the texture visual variable design were compared against those that did not follow the texture visual variable design, participants' facial expressions of joy were decreased by 0.082%. The same situation was also found in value visual variable designs. The representations that followed the value visual variable design principle greatly decreased participant's joy by 5.4 %. When participants viewed the group of the simple-text representations, which included six different visual variables, only four visual variables— color, shape, texture, and value—had effects on participants' emotional valence. Participants' positive emotional valence, joy, increased in good color and shape examples. However, they did not increase positive emotional valence in good texture and value examples. Although the effect was very small because individuals are different and the stimuli were not extremely pleasant and unpleasant images, the results still showed different visual variables have significantly different effects of joy. When digital visual display representations followed the color and shape visual variables, the participants' joy increased. When digital visual display representations followed size, texture and value visual variables, they reduce participants' sadness. The possible explanation may due to

the fact of inconsistent facial expressions and that people have different perspectives of image designs.

### **Facial Expression Differences on Group 2 Representations by Student**

The fixed-mixed regression model predicted the increment of emotional valence in different information grouping layout designs. The model significantly predicted participants' facial expressions. The results showed that the positive emotional valence, joy, increased while participants viewed the representation in the last 2 seconds.

When digital representations of one paragraph within 1.0 line spacing were shown on the screen, the participants' joy rose by 0.029. With digital representation of one paragraph within 2.0 line spacing where on the screen, the participants' joy reduced 0.025. When digital representations of 2 columns were shown on the screen, the participants' joy rose by 0.094. When digital representation of 3 columns were shown on the screen, the participant's joy rose by 0.104.

Overall, results showed the pattern of the difference of facial expressions on viewing complex representations. In general, facial expressions changes were found in different layout designs. The same layout designs have different influences on different facial expressions, all layout designs have significant effects of joy. The 2 columns and 3 columns layout designs have a statistical significance similar to the amount of positive affective increment. Although the increments and decrements were small, they still shown the statically significant effects of the variables. The findings were encouraging because human facial expressions are usually small, and the research found different

information grouping layout designs have influence on people's positive emotional valence, joy.

This research evaluated these two emotional dimensions for different digital visual display designs. The study found the effects of digital visual display design representations on emotional arousal and emotional valence. Although the findings of this research did not show large differences of emotional arousal across all simple-text representations and all complex representations, the results still showed participants had statistically significant differences in emotional arousal related to certain good and poor visual variables designs: color, value, and orientation; and one paragraph within 1.0 line spacing and 2 columns of the complex representations. In addition, the findings showed the differences of emotional valence in both groups of digital visual display representations. When good representations of visual variables were exposed, participants had more positive emotional valence in the form of joy. On the other hand, participants all had a joy increment when 2 columns and 3 columns representations were shown. According to the results, the digital visual display designs showed the effects on participants' positive emotional valence.

### **Implications**

This research has a significant implications and applications to the field of instructional design. This research assessed two facets of emotions—emotion arousal and emotion valence—over 104 participants viewing evidence-based digital visual display design representations. This research included large data of 11,232 electrodermal activities from the group of simple text and 1,664 electrodermal activities from the group

of the complex representations to generalize people's emotional arousal changes. Also, 681,893 facial expressions data while viewing a group of simple text and data and 169,808 facial expressions data while viewing a group of the complex representations were collected to generalize the effects of people's positive emotion valence. Overall, the findings suggested that participants reflected different emotional responses to the different digital visual display design representations. Emotional arousal and valence are associated to learner's emotional engagement (Picard, 2004), and this research found that some visual variables and information grouping layout designs have significant effects on students' emotional arousal and valence (Table 24). The results were intended to enhance the effectiveness of designers and developers of online instruction in creating visual displays that better meet the needs of the targeted students.

Table 24

*Significant Emotional Arousal and Emotional Valence Over Simple-Text Representations And Complex Representations*

<b>Group of Representations</b>	<b>Emotional Arousal</b>	<b>Emotional Valence</b>
<b>Simple-text representations</b>	Significant difference in participants' emotional arousal	Significantly different effects of emotional valence in different visual variables
<b>Complex representations</b>	Significant difference in participants' emotional arousal	Significantly different increment effects of emotional valence in different information

The findings of this research believed that to enhance student's emotional engagement in online instruction, a clear need exists to design digital visual displays that enhance students' positive emotions toward the information displayed. These positive emotions, in turn, may improve their affective experiences. In the reflections of the findings, the following statements and applications of representations are offered for online instructional designers and developers.






- Online instruction design must provide visual variables and information grouping layout designs that are friendly and well design, and they must communicate high expectations for all students. Especially the visual variables of color, value and orientation need to be used carefully in online instruction. A format of information grouping styles also needs to consider in the online instruction design.
- Online instructional designers and developers should use visual variable for showing marks on the display appropriately, so those "marks" will represent the different information. When learners have affective increment and then they will more engage in the online learning. There are two aspects of this principle: Absolute discriminability and relative discriminability.
  1. **Absolute discriminability.** A visual variable must have a minimal magnitude to be detected. This absolute threshold has been computed for many different types of visual variables. Neurons that detect edges inhibit



each other; if a mark is not large enough, the cells that typically would detect it are inhibited from responding (Table 25).

Table 25

*Examples of Bertin's Visual Variables on Simple-Text Designs*

Bertin's	Simple-text representations: Absolute discriminability
visual	
variables	
color	
size	
shape	
texture	
orientati on	

value

---

Some can't sting

---

2. **Relative discriminability.** Visual variables must differ by a minimal proportion to be discriminated, e.g. Just Noticeable Difference JNF. This just noticeable difference has been determined for many types of visual variables (see Table 26).

Table 26

*Examples of Bertin's Visual Variables on the Simple-Text Designs*

---

Bertin's Simple-text representations: Relative discriminability

visual

variables

---

color

B









B

size

B

B

---

shape		
texture		
orientation		
value		

---

- Online instructional designers and developers should use visual variable as “salience” for showing the importance in the display (see Table 27). This design showed the most important information or words on the screen. Due to the findings show that visual variables design had the effect of learners’ affective increment, this design should engage learner’s emotions in the online environment.

Table 27

*Examples of Bertin's Visual Variables Shown the Importance in the Display.*

Bertin's            Complex representation: Show the importance

visual

variables

color

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size

shape

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much it becomes a new species.

texture

Some found new ways to "talk" to each other, or communicate. Others

Bees come in different sizes. There are fat bumblebees and bees not much bigger than the tip of a pencil. There

orientation

developed other new skills and new

are bees of many colors, from dull black to glittering green. Some species of

value

behaviors. Scientists call these kinds of changes

tropical bees are such bright reds and blues that they sparkle in the sun like little jewels.



*adaptations*. Over a long time, a group of bees can change so

- Online instructional designers and developers should group information in the display. According to Kosslyns (1985) and Norman (1988), only about four perceptual units ("chunks") can be held in in short-term memory at once. Thus displays must not require the reader to consider more than this number of perceptual units (see Table 28). The findings show learners have emotional changes on different formats of information grouping designs, so if online instructional designers and developers take this into account, learners will engage in the online instruction more.

Table28

*Examples of Chunked Information Designs to the Display*

---

Chunks      complex representation: show the importance  
2 columns

---

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3 columns

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**Recommendations for Future Research**

The research results showed that the digital visual representation designs have an influence on the emotions of participants in the simple text representation and the complex passage representations. Although the effect was small, the results are still statistically significant. This research also found the specific visual variables had more effects of participants' emotional changes. This research examined that participant's perceptual and sensational responses. In the following research, the participant's actions can be added in the environment. In addition, the environment and the collaborative influence will be included in the future research. The limitations of this research can be studied in the future.

To generalize the emotion responses among the same group design representations was difficult because the experiment randomized all representations across groups and sets. The random effects estimator was employed because separate image baselines needed to be calculated.

Future research needs to be done with the sets randomized but do not randomize the pairs of good and poor representation of principles. Rather retain the representation of good and poor representations as individual pairs.

The results of this study demonstrate that further research should be conducted using the representations of research-based principles in real online instructional activities. Future research needs to investigate the dynamic interaction between Group 1 visual design principles and Group 2 visual design principles when integrated and presented in an experimental online instructional lesson. In addition, to integrate audio

and video activities with the text related representations studied in this research will be needed in the future research.

Such research results could result in specific design and development guidelines for online courses for students at the post-secondary level. This study could be replicated with secondary students serving as research participants in the future.

Demographic data on the attributes of participants were not factored into this study. Subsequent research should explore the impact of selected demographic characteristics on the emotional responses of participant.

### **Conclusion**

The affective experiences of online learners have received less attention than the cognitive developments of online learners. This difference is largely due to the focus of instruction, in all modes of teaching, being on content and student outcomes aligned with instructional objectives. The field currently lacks sufficient evidence based strategies to maximize the achievement of affective outcomes through on online instructional at the post-secondary level. The lack of significant research in the measurement of emotional responses in online instruction has resulted in instructional designers and developers having to make assumptions about the engagement of students in online instruction. These circumstances are changing due to increases in concern for the emotional engagement of online students and the availability of technologies to measure learner responses to visual displays employed in online instruction.

This research analyzed how college students responded to digital representations that adhered to human information processing principles and Bertin's visual variables in

108 simple-text designs and 16 complex designs. The research found that six visual variables and information grouping produce emotional arousal changes across all participants. However, simply because some visual variables did not show statistically significant main effect in emotional arousal does not mean they did not have any effects; rather the study found that all visual variables had significantly positive impacts on emotional valence. The findings of this research could provide developers of online instruction with more information about the design of the online course environments. This could involve the selection of visual display designs the visual display designs investigated in this study. Selected visual display design principles could then be transformed into experimental online instructional activities. The influence of the visual design principles, as measured through responses of participants to the digital visual display representations, has effects on students' emotions. The possibility exists to embed designs from this study found to be good digital visual display designs that provide certain advantages towards students' emotional engagement in to experimental.

The results of this study also provide potential for creating more efficiency in enhancing the development and/or revision of online instructional designs.

Further research may apply these visual elements and a format of information for grouping designs to design an online lesson and investigate the affective influence of dynamic interaction relative to that online lesson.



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## APPENDIX A

## Visual Representations





Img no.	Image thumbnails	5	
1		6	
2		7	
3		8	




4		13	B
9	.	14	B
10		15	B
11		16	B
12		17	B











18	B	23	B
19	.	24	B
20	B	25	Some can't sting.
21	B	26	Some can't sting.
22	B	27	Some can't sting.



28	Some can't sting.	33	Some can't sting.
29	<b>Some can't sting.</b>	34	Some can't sting.
30	Some can't sting.	35	Some can't sting.
31	<small>Some can't sting.</small>	36	Some can't sting.
32	Some can't sting.	37	

38		43	Buzz
39	.	44	Buzz
40		45	BUZZ
41		46	Buzz
42		47	Buzz

48	Buzz	53	Buzz
49		54	Buzz
50	Buzz	55	
51	Buzz	56	
52	Buzz	57	

58		63	
59		64	
60		65	
61		66	
62		67	

68	B B	73	* B
69	B B	74	B B
70	B B	75	B B
71	B B	76	B B
72	B B	77	B B








78	B B	83	<p>Some can't sting.</p> <p>Some can't sting.</p>
79	<p>Some can't sting.</p> <p>Some can't sting.</p>	84	<p><b>Some can't sting.</b></p> <p>Some can't sting.</p>
80	<p>Some can't sting.</p> <p>Some can't sting.</p>	85	<p>Some can't sting.</p> <p>Some can't sting.</p>
81	<p>Some can't sting.</p> <p>Some can't sting.</p>	86	<p>Some can't sting.</p> <p>Some can't sting.</p>
82	<p>Some can't sting.</p> <p>Some can't sting.</p>	87	<p>Some can't sting.</p> <p>Some can't sting.</p>

88	Some can't sting. Some can't sting.	93	
89	Some can't sting. Some can't sting.	94	
90	Some can't sting. Some can't sting.	95	
91		96	
92		97	Buzz Buzz

98	Buzz Buzz	103	Buzz Buzz
99	Buzz Buzz	104	Buzz Buzz
100	Buzz Buzz	105	Buzz Buzz
101	Buzz Buzz	106	Buzz Buzz
102	Buzz Buzz	107	Buzz Buzz





<p>118</p>	<p><b>What's the Buzz?</b> The secret life of bees are finally revealed.</p> <p>To survive some bees species developed new ways to live together. Some found new ways to "talk" to each other, or communicate. Others developed other new skills and new behaviors. Scientists call these kinds of changes adaptations. Over a long time, a group of bees can change so much it becomes a new species.</p> <p>Bees come in different sizes. There are fat bumblebees and bees not much bigger than the tip of a pencil. There are bees of many colors, from dull black to glittering green. Some species of tropical bees are such bright reds and blues that they sparkle in the sun like little jewels.</p> 	<p>123</p>	<p><b>What's the Buzz?</b> The secret life of bees are finally revealed.</p> <p>To survive some bees species developed new ways to live together. Some found new ways to "talk" to each other, or communicate. Others developed other new skills and new behaviors. Scientists call these kinds of changes adaptations. Over a long time, a group of bees can change so much it becomes a new species.</p> 
<p>119</p>	<p><b>What's the Buzz?</b> <small>The secret life of bees are finally revealed.</small></p> <p>To survive some bees species developed new ways to live together. Some found new ways to "talk" to each other, or communicate. Others developed other new skills and new behaviors. Scientists call these kinds of changes adaptations. Over a long time, a group of bees can change so much it becomes a new species.</p> <p>Bees come in different sizes. There are fat bumblebees and bees not much bigger than the tip of a pencil. There are bees of many colors, from dull black to glittering green. Some species of tropical bees are such bright reds and blues that they sparkle in the sun like little jewels.</p> 	<p>124</p>	<p><b>What's the Buzz?</b> The secret life of bees are finally revealed.</p> <p>To survive some bees species developed new ways to live together. Some found new ways to "talk" to each other, or communicate. Others developed other new skills and new behaviors.</p> <p>Scientists call these kinds of changes adaptations. Over a long time, a group of bees can change so much it becomes a new species.</p> <p>Bees come in different sizes. There are fat bumblebees and bees not much bigger than the tip of a pencil. There are bees of many colors, from dull black to glittering green. Some species of tropical bees are such bright reds and blues that they sparkle in the sun like little jewels.</p> 
<p>120</p>	<p><b>What's the Buzz?</b> <small>The secret life of bees are finally revealed.</small></p> <p>To survive some bees species developed new ways to live together. Some found new ways to "talk" to each other, or communicate. Others developed other new skills and new behaviors.</p> <p>Scientists call these kinds of changes adaptations. Over a long time, a group of bees can change so much it becomes a new species.</p> <p>Bees come in different sizes. There are fat bumblebees and bees not much bigger than the tip of a pencil. There are bees of many colors, from dull black to glittering green. Some species of tropical bees are such bright reds and blues that they sparkle in the sun like little jewels.</p> 		
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<p>122</p>	<p><b>What's the Buzz?</b> The secret life of bees are finally revealed.</p> <p>To survive some bees species developed new ways to live together. Some found new ways to "talk" to each other, or communicate. Others developed other new skills and new behaviors. Scientists call these kinds of changes adaptations. Over a long time, a group of bees can change so much it becomes a new species.</p> <p>Bees come in different sizes. There are fat bumblebees and bees not much bigger than the tip of a pencil. There are bees of many colors, from dull black to glittering green. Some species of tropical bees are such bright reds and blues that they sparkle in the sun like little jewels.</p> 		

**APPENDIX B****Interview Questions****Name:****Date / Time:****Interview Questions:**

1. Please describe your thoughts during the process of viewing the different images.
2. In reflecting on the many images that you have viewed was there a pattern of images that stood out as being very good? Please describe. (Show the experiment images)
3. In reflecting on the many images that you have viewed was there a pattern of images that stood out as being very bad? Please describe. (Show the experiment images)
4. When you saw those visual images, do you remember any of them? Why do you remember them?
5. After the experiment, what was your thought about difference between Group 1 and Group 2 images?
6. How do you feel about the time allowed to view a specific image?
  - a. About right
  - b. Too short
  - c. Too long
7. If you have had experience in developing web pages what do you believe is most important in helping others to see and understand the images?

8. When you read material presented on a monitor what do you expect to see in terms of clarity and the presentation of images?
9. When you study lessons online what content designs do you expect to see? For example how do you expect the information to be organized?

## APPENDIX C

### The Experiment Checklist

#### **The Experiment Check list**

##### **Prior to the student entering the room**

- (1) Post a Sign in front of the elevator to guide the student to come in the lab.
- (2) **POST a QUIET SIGN** near the sink area and lock entrance from the west by Tom's office.
- (3) Turn off heater if used to warm up office to control noise
- (4) Install computer in the experiment room as the student will use it.
- (5) Position the camera and chair so that the CERT captures the face and allows some movement.
- (6) Set up video camera in the correct position

##### **When the student arrives:**

- (1) welcome the student to come in for the study
- (2) Sign the consent form. Give the student a copy.
- (3) After the student signs the consent form, fill in the demographic information

##### **When the student is in the experiment room:**

- (1) put Q sensor on the student's wrist
- (2) ask the student to adjust the chair and the distance of the monitor
- (3) if the heater turns on, the heater needs to be turned off
- (5) turn on the facial video recording
- (6) inform the student to have an orientation on the monitor
- (7) doing the practice session with the student

##### **When the student completed the practice session, the research leaves and the subject will be alone:**

- (1) ask the student "Do you have any question?"
- (2) tell the student "will return to the room after he/she completes the experiment"

##### **When the student completed the experiment, the research return to do the interview:**

- (1) be sure videotaping is still on

##### **After completing the interview:**

- (1) take off the Q sensor
- (2) turn off the videotaping

## APPENDIX D

### Approved Institutional Review Board (IRB)



#### APPROVAL OF PROTOCOL

December 5, 2013

Yu Hsu  
yupingh@ku.edu

Dear Mrs. Yu Hsu:

On 12/5/2013, the IRB reviewed the following submission:

Type of Review:	Initial Study
Title of Study:	Validating Emotional Responses to Theory Based Visual Display Images Indicative of Engagement in Online Learning
Investigator:	Yu Hsu
IRB ID:	STUDY00000398

The IRB approved the study from 12/5/2013 to 12/4/2014.

1. Before 12/4/2014 submit a Continuing Review request and required attachments to request continuing approval or closure.
2. Any significant change to the protocol requires a modification approval prior to altering the project.
3. Notify HSCL about any new investigators not named in original application. Note that new investigators must take the online tutorial at [https://rgs.drupal.ku.edu/human\\_subjects\\_compliance\\_training](https://rgs.drupal.ku.edu/human_subjects_compliance_training).
4. Any injury to a subject because of the research procedure must be reported immediately.
5. When signed consent documents are required, the primary investigator must retain the signed consent documents for at least three years past completion of the research activity.

If continuing review approval is not granted before the expiration date of 12/4/2014 approval of this protocol expires on that date.

Please note university data security and handling requirements for your project:  
<https://documents.ku.edu/policies/IT/DataClassificationandHandlingProceduresGuide.htm>

You must use the final, watermarked version of the consent form, available under the "Documents" tab in eCompliance.

Sincerely,

Stephanie Dyson Elms, MPA  
IRB Administrator, KU Lawrence Campus

**Human Subjects Committee Lawrence**  
Youngberg Hall | 2385 Irving Hill Road | Lawrence, KS 66045 | (785) 864-7429 | [HSCL@ku.edu](mailto:HSCL@ku.edu) | [research.ku.edu](http://research.ku.edu)

## APPENDIX E

### Demographic Form

#### Post-Secondary

**Please provide the following information about yourself.** No information reported will be shared. Return completed form to [yupingh@ku.edu](mailto:yupingh@ku.edu)

#### **Part 1 Background Information**

1. Are you a \_\_\_\_\_ Male \_\_\_\_\_ Female?
  
2. Please indicate your age: \_\_\_\_\_
  
3. Please indicate your **current** Level of Education:  
 Postsecondary / College:  
 (\_\_\_\_) Freshman (\_\_\_\_) Sophomore (\_\_\_\_) Junior (\_\_\_\_) Senior (\_\_\_\_) Graduate
  
4. What is (was) your undergraduate major(s) (e.g. physics, political science, undeclared, etc.) \_\_\_\_\_?
  
5. How many online courses have you experienced? (e.g. blackboard, etc.)  
 \_\_\_\_\_ None  
 \_\_\_\_\_ 1  
 \_\_\_\_\_ 2  
 \_\_\_\_\_ 3 or more
  
6. How proficient are you in using the computer?  
 \_\_\_\_\_ More proficient than other students in my classes  
 \_\_\_\_\_ As proficient as other students in my classes  
 \_\_\_\_\_ Less proficient than other students in my classes
  
7. Your ethnicity:  
 \_\_\_\_\_ White  
 \_\_\_\_\_ Hispanic or Latino  
 \_\_\_\_\_ African American  
 \_\_\_\_\_ Native American  
 \_\_\_\_\_ Asian/ Pacific Islander  
 \_\_\_\_\_ Other

8. Please indicate the clarity with which you view images on the monitor.

\_\_\_\_\_ My vision is **excellent** for viewing images and/or text on the monitor

\_\_\_\_\_ My vision is **corrected and excellent** for viewing images and/or text on the monitor

\_\_\_\_\_ My vision is **a problem** when viewing images and/or text on the monitor