THESIS

THE POWER OF ART FOR COMMUNICATING COMPLEX HEALTH TECHNOLOGIES

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ABSTRACT

THE INFLUENCE OF ART FOR COMMUNICATING HEALTH AND SCIENCE

This project examines whether art can influence audience perceptions of complex health technologies, specifically, brain-computer interface (BCI) technologies. This study used an experiment to test hypotheses about differences between those who see text about the technology, text and a scientific illustration of the technology, and text with an artistic representation of the technology (compared to a control), to determine whether an artistic representation of a new health technology can serve as an effective tool for increasing trust, comprehension, and interest of *N*=86 students from Colorado State University. This project used text and visual representations of brain-computer interface technologies to assess whether artistic representations of BCI influence trust, interest, and comprehension of the technology. Hypotheses 3 was supported, finding that that there were some significant effects for artistic visual and textual information on participants' levels of understanding.

The findings of this study help us to better understand the role of visuals in communicating science and technology in health, especially in order to improve trust in complex new technologies. It also contributes to our understanding of the role of more abstract forms of representation, such as artistic works, in perceptions of technology. Additionally, this research can help practitioners improve and broaden their communication efforts in cultivating more positive perceptions among various publics of new health technologies. Future work could focus on exploratory efforts designed to gain greater insight and further understanding towards the

impact that art and images within medical spaces and communities generates. This work provides a step towards better understanding art and its persuasive goals within communicating complex information and moves research efforts closer towards recognizing how artistic content may change perceptions.

Visual representations in media have the ability to transport a viewer through an abstract narrative, and considerable research has shown that visual information contributes powerfully to people's understanding of facts, ideas, and stories. However, that research almost always examines realistic or highly representative imagery such as diagrams, photographs, or sketches. In contrast, little is known about the role that more artistic and abstract visual messages might play in people's perceptions of health and health-related technologies. This study measures the impact of viewing art related to a new health technology, brain-computer interface (BCI) systems. It asks, can abstract art representations of a complex health technology increase trust in and improve individuals' understanding of that technology?

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CHAPTER 1. INTRODUCTION

"Our highest dignity lies in the meaning of works of art - for it is only as an aesthetic phenomenon that existence and the world are eternally justified."

- Friedrich Nietzsche, *The Birth of Tragedy* (Nietzsche, 1993)

Efforts to improve healthcare in recent years have increased their focus on preventive health, including seeking ways to communicate good practices, the available treatments, and their effects. A recent approach integrates art and design into such communication, and healthcare leaders are exploring new ways that the integration of art into healthcare can improve trust in medical procedures and technologies, decrease patients' perception of suffering, help reduce anxiety and stress, and improve patient-practitioner relationships (Sadler & Ridenour, 1998; Sonke et al., 2018). As practitioners continue to explore ways to incorporate the arts into public health promotion, scholars urge more research to be conducted within this field (National Organization for Arts in Health, 2017). This project seeks to support these efforts with a study that evaluates whether abstract art representations of a complex health technology can improve trust, understanding, interest, and comfort with the technology.

This study uses art created by the researcher to test people's perceptions of a newly emerging medical technology, Brain-Computer Interface (BCI). The art piece, "Identity through Movement" is a 5' x 5' acrylic on canvas painting created by the researcher using BCI technology (see Figure 1), and it offers observers a way to visually understand new brain biological technologies through abstract representations of the technology and its output. The goal of the painting is to generate conversation and increase patient and caregiver trust in the technology. Ultimately, the project aims to contribute to collaborative efforts exploring the impact of arts in healthcare environments.

Figure 1. Images of the art piece "Identity through Movement"

The project is based on notions of visual communication and its power to not only communicate complex messages but evoke emotion and understanding. The rapid introduction and convergence of photographic technologies into mobile communication devices has reinforced our reliance on images to communicate and interpret messages in our day-to-day lives. Visual theorist Jonathan Crary argues visuals have become dominant in our society, explaining,

> The formalization and diffusion of computer-generated imagery heralds the ubiquitous implantation of fabricated visual 'spaces' radically different from the mimetic capacities of

> film, photography, and television... Obviously older and more familiar modes of "seeing" will exist and coexist alongside these new forms. But increasingly these emerging technologies of image production are becoming dominant models of visualization according to which primary social processes and institutions function. (1990, p. 1-2)

He further suggests that modernization of visual experience introduces new modes of communication and subsequent analysis that influence the way a viewer observes and consumes technology. This supports the notion that ongoing research into the capacities of visual representations for constructing knowledge and meaning is necessary for understanding if and how visual media influence our perceptions of the world around us. By assessing the ways in which visual components influence perceptions, interpretations and comprehension of complex ideas, this project explores how art can contribute to effective means of communicating complex health and science information. Especially because art is commonly used in many types of healthcare settings, questions about how it contributes to visitors' perceptions about health and technologies are important to understand.

The study uses a pseudo-experiment conducted online in which participants view representations of brain-computer interface (BCI) technology. Brain-Computer Interface (BCI) technologies have been designed to enable communication unaided by physical movement by providing a direct link between a functioning brain and the outside world. These systems operate by translating central nervous system (CNS) activity into electrical signals that can be used to control devices such as a mouse or robotic arm or computer screen cursor. Initially, these systems were developed to replace and restore functions for individuals (Brunner et al., 2015). They require considerable practice to use effectively and can be quite complex to set up and use. The current study compares a text and images intended to represent BCI technology to text only, and it asks participants to report their levels of trust in, comprehension of, interest in, and comfort with BCI.

The findings of this study will help us better understand the role of visuals in communicating science and technology in health, especially in order to improve trust in complex new technologies. It will also contribute to our understanding of the role of more abstract forms of representation, such as artistic works, in perceptions of technology. Additionally, this research can help practitioners improve and broaden their communication efforts in cultivating more positive perceptions among various publics of new health technologies.

1.1 A Neuroadaptive Technology: Brain-Computer Interfaces

The current study examines perceptions of a new health technology, Brain-Computer Interfaces (BCIs). These are technologies that enable communication unaided by physical movement by providing a direct link between a functional brain and the outside world. Research on BCI systems traditionally focuses on efforts to establish a channel of communication for paralyzed or locked-in patients who would not be able to communicate effectively without these systems. However, recent efforts to expand BCIs to other domains, including gaming, art, and commerce, have changed the focus of some of the BCI development efforts, prompting additional objectives to be applied to BCI research to improve, enhance, supplement, and allow these technologies and subsequent interactions to serve as research tools (e.g., Wolpaw et al., 2002 p. 768; Brunner et al., 2015).

Despite the intent to further explore and identify the potential BCI devices have to serve as communicative tools for users within and among target populations that stand to benefit from these technologies (e.g., patients who rely on them for communicating and maintaining external connections and motor rehabilitation purposes), there are still challenges and limitations that serve as barriers towards widespread implementation. Though studies have addressed in-home independent use for motor-impaired users (e.g., Wolpaw et al., 2002; Wolpaw & Wolpaw, 2012;

Pfurscheller et al., 2006; Kübler & Mueller-Putz, 2007; Nam et al., 2018) more efforts need to be directed towards active analysis of target populations in order to improve reliability and contribute towards long-term and translational research (Kübler et al., 2013; Kübler et al., 2015). For example, researchers have demonstrated than fewer than 10% of published studies address this group and further involve people with severe disabilities (Zickler et al., 2013). These statistics highlight the need for research that aims to bridge the translational gap between contemporary BCI research and the potential application of these systems for users within their home or healthcare environments (Kübler et al., 2015). Efforts targeted towards increasing community engagement and awareness could improve these statistics.

By translating brain signals into new kinds of multimodal outputs that can be accessed by various groups of users, BCI systems possess tremendous potential as transformative, rehabilitative and communicative tools (Huggins et al., 2011). However, public perception of this new, complex technology is not all positive, and research is needed to explore ways to help potential beneficiaries understand and trust it.

1.2 Study Overview and Rationale

Literature within the field of perceptual psychology, a sub-field of cognitive psychology, demonstrates that visual interpretation is vital to our everyday cognitive thought processes. Researchers within this field suggest that the brain can form more complete associations of an event when it is able to integrate both the intellectual (cognitive) and sensory (visual) components of an experience. This research has argued that the sense most influential on our perceptions and understandings of objects and phenomena is our sense of sight. It is out of the cognitive processes of perception formation that we are able to make decisions, which consequently, help us shape who we are and help us to better understand why we are that way.

Taking a visual approach to thinking, argue cognitive researchers, allows the mind to tie observations together with reasoning; a combination, which in turn, enables the brain to develop more universal processes of learning (Arnheim, 1993).

Research on the role of images in meaning-making similarly argues that to make sense of the world around us, we need both creative thinking and critical thought. These can come, as research on science and technology learning suggests, from combining scientific and artistic inquiry and tasks. By exploring relationships between affect and cognition, cognitive research illustrates how an individuals' attitudes and emotions can influence the way they respond to visual and verbal stimuli, which in turn affects the way process information (Sojka & Giese, 2006). Expanding on this concept, information processing research acknowledges the differences between discursive processing and imagery processing by suggesting that imagery processing engages the working memory through sensory experiences, where discursive processing relies less on internal experiences for interpreting information. These processes contribute to the larger concept of metacognition, and helps us make sense of the information we see. This research suggests that the use of imagery-elicited stimuli enhances incidental, or indirect learning, as well as demonstrated that it reduces the gap between incidental and intentional learning (MacInnis & Price, 1987; Bower, 1972; Butter, 1970; Sheehan, 1972; Sheehan & Neisser, 1969).

In specific, literature on multimedia learning has found that learning and cognition are most effective when learning materials engage both visual and textual information in a balanced way. Scholars of multimedia learning argue that visual information, when it does not overload learners' thinking, can allow people to learn more deeply because it taps into more complex mental constructs more quickly than text alone (Mayer, 2009). This idea supports the notion that traditional definitions of literacy are no longer adequate for describing user comprehension abilities across a multimodal landscape, as both visual materials and corresponding layout techniques are common components of communication mediated by digital screen-based technologies. Scholars argue that there is a need for a new form of visual literacy in a digital environment; one in which users actively negotiate with images in order to derive meaning.

Related research on inquiry-based learning or "discovery learning," suggests, similarly, that visual representations can facilitate the creation of new knowledge and interpretations as well as enhance learners' abilities to connect new ideas to existing knowledge. This is because well-crafted images can construct relationships between known and unknown concepts quickly and easily. As a result, people are more likely to remember information and concepts because they can rely on their own mental constructs and knowledge to interpret an experience or event, as literature from the psychology of education demonstrates (MacInnes & Price, 1987; Glik, 2007).

Visual tools to communicate complex information are particularly important in the communication of complex health, science, and technical information. The use of visual elements for promoting science issues has been shown to increase levels of understanding as well as promote learning among targeted populations (Mayer, 2001; Mayer, 2003). In the field of health communication, the use of visual information to demonstrate proper health behaviors has been shown to positively influence attitudes and affect changes in existing health practices when the visual used is able to elicit an emotional response from the viewer (Houts, Doak, Doak & Loscalzo, 2006). This research further suggests that using pictures for materials designed to promote health education can help to increase the effectiveness. As science and health industries move towards incorporating more complex technologies into their respected fields of research, understanding how different types of images can be employed to communicate complex technologies and concepts will become more important to message design and delivery strategies (Liu et al., 2015).

As our communication becomes increasingly visually mediated such as via online social networking and web-based media, the ability to read and interpret images becomes more central to interpreting messages. This ability, called visual literacy, involves the intersection of visual thinking, visual learning and visual communication. Developing a visual literacy, according to media literacy scholars, requires engaging cognitive skills, with the ability to critically think, construct meaning, and communicate feelings and attitudes (Avgerinou & Pettersson, 2011). Similarly, visual semiotics researchers reinforce the importance of being able to interpret visual information, by stressing that visual information itself is a social process, one from which meaning is developed between exchanges between the producer and the reader (Harrison, 2003).

The bulk of current research in education and psychology examine graphic representations or photographs in exploring the impact of visuals on learning. However, artistic representations, including abstract art, are less well-understood. Current research in this area suggests that creative visual representations of health and science topics may assist the cognitive processes involved in understanding complex concepts (Brown, 2015). Research has also demonstrated that through artistic representation, audiences may experience important gains to individual levels of understanding because they can make concepts clearer, engage people emotionally, and empower health communication by reducing hierarchies (Sonke, 2018).

Lessons from the benefits of visual learning can be applied to challenges in communicating complex technologies as well. Science communication scholars suggest that perceptions of technologies are influenced by the information, communication, and technologies that people interact with, including media (Gilbert, Reiner & Nakhleh, 2008; Fiorella & Mayer, 2017). Early research on computer anxiety demonstrated that those with less experience and knowledge of a technology felt more anxious about them, had more negative perceptions, trusted them less, and were less likely to use them (Hogan, 2009). Information designed to improve individuals' understanding can reduce this anxiety and generate more positive perceptions.

Health technology in particular may benefit from improved understanding, as research in health communications have found that people who trust and understand medical technologies, procedures, and conditions are less anxious, more willing to seek medical help when needed, and more likely to follow prescribed treatments. This understanding can also contribute to better decision-making about health issues individuals face. However, the complexities of health technologies mean that understanding them is difficult for many people, and health educators have struggled to provide clear, usable information for patients and caregivers about different technological options (Glik, 2007; Brossard, 2013; Umea University, 2016; Mullaney, 2016). Research has found the main challenges including motivating engagement with technological information as well as negative perceptions of and beliefs about the technologies. Health literacy research largely focuses on educating patients about diseases and treatments, but pays less attention to understanding of and attitudes towards the technologies used in modern health care.

1.3 Goal and Research Question

The current project draws on theories of cognitive theory of multimedia learning (Mayer, 2001), as well as research in visual communication, to examine if and how artistic visual representations can help individuals better understand complex health technologies. In specific, it examines the impact of artistic visual representations of a new type of technology, brain-computer interfaces, on individuals' perceptions of the technology and its potential benefits.

This research aims to help us better understand the role of visuals in communicating science and technology in health, especially in order to improve trust associated with specific technologies. It will also contribute to our understanding of how more abstract representations such as artistic work can influence perceptions of technology. This research can also help practitioners improve and broaden their efforts in improving perceptions of health technologies through communication. This project seeks to identify whether art exhibit pieces can encourage conceptual understanding and attitude change towards sophisticated technologies.

Research Question: Can abstract art representations of a complex health technology improve trust in and understanding of that technology?

To examine this question, this project conducted an online survey with three treatment conditions and a control condition. Using cognitive, visual literacy, meaning-making and health communication theories, this project seeks to contribute to existing research outlining the significance of visuals for the comprehension of complex health and science information. This study tests the following hypotheses:

- **Hypothesis 1:** People's **trust** in BCI technology will be higher when they see artistic visual information with text than when they do not.
- **Hypothesis 2:** People's **interest** in BCI technology will be higher when they see artistic visual information with text than when they do not.
- **Hypothesis 3:** People's **comprehension** in BCI technology will be higher when they see artistic visual information with text than when they do not.

1.4 Organization of Thesis

In this thesis, Chapter 1 describes the role of visuals in communicating science and technology in health, especially in order to increase trust, interest and comprehension associated with specific technologies. It explains how cognitive processes and perception formation influence an individual's ability to process information and learn, as well and generate meaningful associations with content and through experience. Chapter 2 details how the ability to interpret visual information plays a key in determining how we comprehend and interact within our environments. Chapter 3 presents the methods to be used in conducting the study, and Chapter 4 provides the results and statistical analyses. Chapter 5 discusses the implications of the results, and Chapter 6 discusses overall conclusions of the study.

CHAPTER 2. ART FOR COMMUNICATING HEALTH TECHNOLOGIES

Perceptions of emerging technologies are influenced by information, communication, and technologies that people interact with, including media. As technological innovations become increasingly integrated within our everyday lives, the more likely these advancements are to significantly impact the current ways in which we engage socially, as well as the means through which we perform tasks within our society, from doing our taxes to going to the doctor. Although rapid technological progression posits the potential to generate large shifts within contemporary cultural practices, the reception and adoption of new technologies largely depends on how participatory behaviors and functional assessments evolve through public discourse (Nisbet & Scheufele, 2009). New innovations and evaluation promote the idea of change; however, prior to users being able to realize the full potential that novel inventions can afford users, a better understanding of the technological information that surrounds them needs to be established. Generating an awareness and communicating the ways in which the integration and introduction of these systems might change our ways of operating with existing technologies will be key towards developing the right public perceptions and levels of understanding needed to adopt transformative new health communication technologies.

2.1 Complications and Complexities of New Technologies

New technologies, specifically health technologies, can seem complex and confusing to the public. Scholars argue that a lack of understanding of what biotechnologies are and how they work can introduce potential barriers towards use (Gunter, Kinderlerer & Beyleveld, 1999; Frewer, Shepherd & Sparks, 1994; Satterfield, Conti, Harthorn, Pidegeon & Pitts, 2013). Evolving technologies often influence the way newer tools are received and integrated within social environments. Research within the field of technology acceptance demonstrates that the introduction of new technologies is often met with resistance, suggesting that main challenges of adopting new technologies include motivating engagement with technological information as well as the publics negative perceptions of and beliefs about the technologies. Scholars further suggest that the acceptance and intent to use a new technology depends on whether it is perceived as useful, and whether it is recognized as easy to use (Ziefle & Wilkowska, 2010). Generating positive attitudes among users has been shown to increase the acceptance of these new technologies into everyday practices, however, research on public opinion towards biotechnologies has demonstrated that various applications of new technologies has been shown to generate anxiety among users who lack a proper understanding of what they are, and have found the perceptions of risk surrounding these developments to be prevalent among various publics (Gunter, Kinderlerer & Beyleveld, 1999; Anderson, Brossard, Scheufele, Xenos & Ladwig, 2014; Glik, 2007; Satterfield et al., 2013).

Scholars argue that the public needs a better understanding of emerging technologies, arguing that a lack of information or misinformation can induce anxiety and act as a barrier towards implementation and use (Durant, 1992). They demonstrate that a lack of information can be a critical component of attitude formation towards these technologies, as individuals, they explain, rely on mental short cuts or heuristic devices that invoke preexisting values and knowledge about science towards their understanding of it (Glik, 2007; Anderson et al., 2014). In their examination of public response to nanotechnologies, for example, Anderson and colleagues (2014) posit that a key factor is understanding the cognitive processes that surround unfamiliar information among general audiences, as well as how these judgements affect the reception and perception formation surrounding the "risk" associated with emerging technologies. As such, a key component of technological development relies on being able to effectively demonstrate how emerging innovation may function within the situational context of a technologically dependent society (Webster, 2002; Scott et al., 2019). Health communication scholars describe the dynamic relationship between new and existing technologies as one that is translational, in that the future influence of a technology is principally established by its seeming use value, as well as how it is recognized by both professional, as well as universal communities.

2.1.1 Technological Anxieties and Risk

A common outcome of unfamiliarity with new technologies is a sense of anxiety (Kjerulff et al., 1992) and lack of trust, especially due to perceived risk. The concept of "risk" is rooted in cultural, sociological and psychological perspectives, and is broadly defined as the possibility of experiencing harm due to some threat (Trumbo, 2013). Risk communication scholars posit risk as a longstanding element in societal progression that affects "differentiation in social class and human health," (p. 96) arguing that the way risk has been communicated in certain situations has been shown to impact individual perception formation. When confronted with information, social psychologists argue that an individual employs two separate mechanisms for managing the task, which are known as cognitive and affective processes. These heuristic processes rely on existing mental constructs, and draw on previous experiences and relevant knowledge to form perceptions towards a message. Access to educational experience, scholars argue, can significantly affect how individuals process information, especially to technical information; if information is not understood, it is often less trusted (Trumbo, 2013).

Resistance to integrating technological integration into existing practices is often based on anxiety (Kjerulff et al., 1992). For example, in a study aimed towards examining responses to new medical technologies within a healthcare setting, researchers found anxiety to be a mediating factor towards nurses adopting new technologies, citing that those with less experience and knowledge of a technology felt more anxious about them, had more negative perceptions, and were less likely to use them (Kjerulff et al., 1992). This study also found that nurses' fear and attitudes towards technology may influence their adoption and use of new technologies, as well as their willingness to learn computer systems (Kjerulff et al., 1992; Hansen, 2006).

Research has also shown that misinformation and general lack of information about these changes can generate negative perceptions surrounding the complexity of a new technology, increasing the likelihood of avoidance (Hogan, 2009). Literature within these fields suggests that a well-developed awareness and understanding of the promises and uncertainties new innovations can potentially bring can help structure perceptions and attitudes of towards these developments. Technology acceptance research has demonstrated that failure to fully understand how to apply a new medical technology into existing treatment procedures, can not only reduce the potential gains a patient stands to benefit from, but can also increase the negative impacts a patient may be subject to (Lui et al., 2015). In a study conducted on new medical technology use, researchers found that nurses who were anxious about new technologies were more likely to have negative perceptions towards computers, experience lower levels of job satisfaction, less positive towards workplace interactions, as well as less likely to follow current care guidelines for nurses (Kjerulff et al., 1992). A separate study demonstrated that intensive care nurses who experienced anxiety towards technologies were more likely to be subject to errors which could potentially be life threatening to patients. This research suggests that a fear of working with emerging technologies could limit the quality of care administered (Hansen, 2006).

Although research has found that interactions with new medical technologies can directly elicit increased levels of anxiety and fear in patients who lack sufficient preparatory information about the treatment technologies, it also shows that information designed to improve individuals' understanding can reduce the level of anxiety patients experience, improve patient well-being, and generate more positive perceptions towards these technologies (Mullaney, 2016; Umea University, 2016). Additionally, these studies suggest that workplace adoption rates could increase if health professionals are provided with educational training for using new health technologies. As new technologies continue to mediate existing ones, professionals will have to place an emphasis on developing ways of articulating technological information in a way that promotes comprehension and understanding. The adoption of new technologies will rely on a transactional communication process; one that requires a multidirectional and planned approach that involves understanding (Corcoran, 2013; Milne & Kaitin, 2009).

2.1.2 Communicating Health, Science and Technology Information

The complexity that oftentimes surrounds communicating technical information suggests that a successful informational message would need to target several different audiences in several different ways. Latour (2005) and Callon (1986) argue that different populations may be linked with knowledge via the sociological processes of translation, which begins with the idea that as individuals learn about their environment, they develop heuristic devices that help them to organize information, also known as "knowledge networks" or "mental maps" (Glik, 2007). Knowledge networks can be interlinked with one another through socio-historical influences, and they are able to adapt and change (Bourie, 2014). By exploring how communal and individual processes of knowledge translation affect "technoscience" development within various populations, Bourie (2014) argues that individuals must be both willing to accept the knowledge and also to replicate the social and cultural structures created by these knowledge networks.

When considering different ways to communicate information about health technologies, then, the context is important. For example, providing scientific material in an entertainment context such as a television show may not be as effective as within a doctor's office. More specifically, health experts have identified that messages aimed towards positively influencing behaviors by way of combining images and text (National Library of Medicine, 2003), as well as through the integration of different channels of communication for message distribution, provide effective "presentational platforms" for the promotion of a health care message (Glik, 2007).

2.2 Communication Frameworks

To improve communication efforts, this project assumes a transdisciplinary approach towards finding solutions to this inquiry. Through combining new technologies with visual educational strategies, along with the integration of knowledge from other disciplines, more innovative strategies towards communicating complex information about new and complex health communication technologies can be developed and implemented. Nisbet & Scheufele (2009) suggest that science communication should be based on the interpersonal and social contexts, including their preferred media sources and communication channels, most relevant to individuals. By having health information occupy visually interactive and experiential spaces, the communication of new technological information may be more likely to generate awareness and positively influence attitudes towards new health and science innovations.

In recognizing media ecology as it pertains to user environments, it is important to discuss the role of visual materials in cultural process and message design, acknowledging that these meanings can arise from both formal information such as that gained in education or scientific writing or by artistic and entertainment products, such as television shows or abstract art (in this case, the creation of art). Prioritizing visual content creation may allow viewers to gain understanding through observation of, and interaction with, visual representations of biological and technical information.

2.2.1 Visuals for Interpretation

Visual interpretation is vital for understanding our everyday cognitive thought processes. (Arheim, 1993). Perceptual psychology literature argues that cognition is a process that is physically embodied and culturally embedded, suggesting that both the physical process of visual perception as well as the cultural context within which visuals are interpreted contribute to the impact of visual messages (Giere, 2008). Developing visual interpretation requires engaging cognitive skills, the ability to critically think, construct meaning, and communicate feelings and attitudes.

In human development, visual understanding precedes verbal understanding (Stokes, 2001). Visual theorist Berger (1972) explains, that for children, “seeing comes before words” (p.7). Scholars argue that the ability to read and interpret images is more central to interpreting messages than verbal skills because visual interpretation is more complex than verbal interpretation and therefore requires more analysis. They suggest that visual and verbal communication differ in their interpretive logic, meaning that most languages are focused on induction and deduction platforms for reasoning. Visual communication on the other hand, requires abduction (Moriarty, 1994). A model that represents the learning process through direct experiences, known as the Dale cone of experience model (Dale, 1970), is founded on the idea that learning develops upwards from the concrete to the abstract:

> Visual symbols are nonverbal representations that precede verbal symbols. Action activities provide the concrete base for the abstract use of symbols in defining and

> explaining the action activities. These activities of action progress to activities of observation which then are followed by abstract representations, a process that facilitates reconceptualization and understanding of the experience before describing it verbally. Because pictures or illustrations are analogs of experience and are only one step removed from actual events, these visual representations may be able to capture and communicate the concrete experience in various ways (Stokes, 2001, p. 234).

Visuals, then, are epistemic creations that enable thinking, theorizing and creating by providing an alternative system of language and representation audiences use to process information (Giere, 2008). This system is linked to not only seeing the information, but also to the development of associations among different concepts.

2.2.2 Cognitive Processes and Perception Formation

Perceptual psychologists reason that visuals matter because the brain is able to form more complete associations of an event when it can integrate both intellectual (cognitive) and sensory (visual) information. Further suggesting that sight is the most influential sense towards perceiving and understanding a phenomenon (Keller & Tergen, 2005; Arnheim, 1993). Research in this field demonstrates that our cognitive networks work to recognize and complete patterns based on the environment. As humans, we naturally recognize patterns and are influenced by prior experiences; this process is assisted by the creation and manipulation of external representations. (Keller & Tergen, 2005; Giere, 2008) External representations, or visualizations, can help to speed up the processing abilities of the human visual system, which allows individuals to more easily substitute perceptual judgments with more logical ones (Keller & Tergan, 2005).

Visual representations can serve as powerful tools for cognition (Keller & Tergan, 2005). Images traverse science and nonscientific domains alike-information presented visually, scholars argue, has the power to familiarize and de-familiarize our perception and understanding of events (Stokes, 2001; Giere, 2008). Visual tools aid the decision-making process and used as a foundation for initial understanding of events and then to persuade the others of their reality (Burri & Dumit, 2008). Interpreting visual information is an active process that unfolds through experience and development (Burri & Dumit, 2008). Thinking visually enables observations to be tied together with reasoning, allowing the brain to develop more universal processes of learning (Arheim, 1993).

Visual representations can facilitate the creation of new knowledge and interpretations by enhancing learners' abilities to connect new ideas to existing knowledge. Researchers suggest that well-crafted images can construct relationships between known and unknown concepts quickly and easily, which in turn means that people are more likely to remember information and concepts because they can rely on their own mental constructs and knowledge to interpret an experience or event. Visualizing abstract relationships between elements, allows us to tie observations together with reasoning, and may provide a foundation for externalized cognition (Scaife & Rogers, 1996; Cox, 1999; Glik, 2007).

Cognitive labor can be divided into categories of discovering new ideas but also for storing information. Visualizations pertaining to structures of knowledge and information are thought to assist individuals experiencing difficulty in processing complex topics and subjects that are not clearly defined (Holley & Dansereau, 1984; Jonassen, Reeves, Hong, Harvey & Peters, 1997; Keller & Tergan, 2005). Scholars argue that "they may help students to elicit, co-construct, structure and restructure, elaborate, evaluate, locate and access, communicate and use ideas, thoughts and knowledge about relevant content and resources." (Jonassen, Beissner & Yacci, 1993). The concept of "distributed cognition" or the idea that "cognition is computational," meaning that it is multidisciplinary and that visual models help transport knowledge models from one person to another even across disciplines can be helpful to consider within this context. (Giere, 2008; Burri & Dumit, 2008) Research within this field explores the relationship between visual models and mental models, and demonstrates that visual models can help processing by developing analogies and constructing new models of knowledge (Reiner, 2008).

Concept maps and graphs are important for learning because individuals use strategies of building mental maps for understanding spatial relationships (Fiorella & Mayer, 2017) Visuals are suggested to help people develop coherent representations of new information (Holley & Dansereau, 1984), and visualization helps make sense of complex data that was once intangible (Keller & Tergan, 2005). Such visualizations are commonly used in educational settings to help people process, organize, and use information and complex ideas (Keller & Tergan, 2005). Visualizations can foster the development of effective cognitive processing (Holley & Dansereau, 1984; Keller & Tergan, 2005), especially for people who prefer visual over verbal information presentation (Keller & Tergan, 2005). Researchers have found that when visual organizational tools (diagrams, etc.) incorporate illustrations that are specifically designed to represent concepts and ideas, that these types of visual strategies can provide a framework for organizing material in ways that promote critical thought and learning (Tarquin & Walker, 1997; Stokes, 2001).

Visualizations for knowledge structures have been shown to make knowledge more accessible by helping to transport information across different disciplines. The treatment of how data is processed into a visual allows for the production of new and co-shared scientific knowledge (Burri & Dumit, 2008). According to Paivio's (1986, 2007) dual coding theory, individuals experience positive cognitive gains during the process of learning when they are able to connect related associations between images and words (Leopold & Mayer, 2015).

Mayer (2009)'s cognitive theory of multimedia learning is similar; in that it recognizes the processes of formulating relationships between corresponding verbal and pictorial representations as foundational to constructing meaningful learning practices (Leopold & Mayer, 2015). In a study designed to examine whether students can learn how the respiratory system works more effectively through engaging mental imagery of scientific texts, students took part in two experiments. Students assigned to the control group read a computer-based text on the human respiratory system, a second group was instructed to form a mental image while reading a scientific paragraph, while students in a third group were shown a picture on screen prior to being asked to use mental imagery while reading scientific text, and a fourth group was shown a picture on screen after they had been instructed to use mental imagery while reading scientific text. Researchers found that mental imagery encouraged transfer and retention performance for both immediate (*transfer* d = 1.30, *retention* d = 0.74) and delayed tests (*transfer* d = .86, *retention* d = 0.98). Results also demonstrated that use of additional drawings/pictures did not have a significant impact on transfer or retention rates. The overall findings validate the imagination principle, which posits that individuals are able to learn more deeply when encouraged to form visualizations of information they are reading (Leopold & Mayer, 2015).

2.2.3 Visuals and Complex Concepts: Overarching Theoretical Framework

To unite the broader concepts of perception, cognitive processing, and interpretation, and demonstrate how they all have a role within the larger framework of how visual learning functions, this thesis draws on cognitive theory of multimedia learning theory (CTML). This theory suggests that visual information can improve learning and comprehension of complex ideas when combined with text, and has been tested extensively with scientific information. The theory posits that a viewer/learner who receives information presented through words and images (multimedia) processes these messages through two separate channels, a visual and a linguistic channel. The viewer then actively selects pictures or words from sensory memory and organizes information into working memory. From this stage, the information is processed as bits of pictorial or verbal models that become integrated with prior knowledge within the long-term memory. This theory, according to Mayer, combines the cognitive processes of how people learn from instruction with how people present instructions to understand effective learning strategies, as shown in Figure 2 (Mayer, 2001; 2003; 2009).

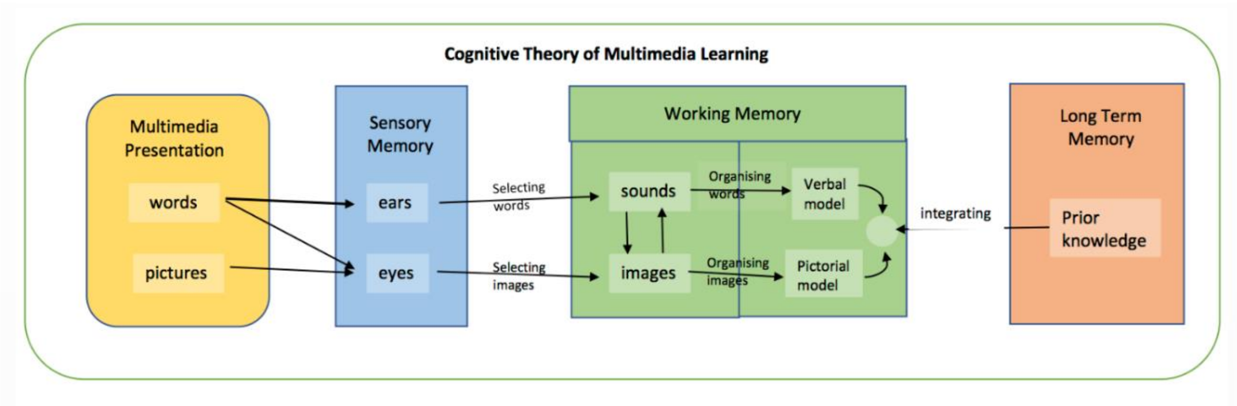


Figure 2. Mayer's Cognitive Theory of Multimedia Learning

Mayer's theory focuses on four significant elements from which people learn, which he calls the *multimedia principle*; they are the following: dual-coding theory, limited capacity working memory, active processing and information transfer. This principle posits that individuals learn better from pictures and words, rather than words alone. This principle further illustrates that the use of visuals and text when processing information in a multimedia environment helps the cognitive management of information and allows individuals to build stronger connections between their pictorial and verbal mental constructs (Mayer, 2001, 2003, 2009; Rosen et al., 2021). For the present study, this theory guides the prediction that visual information, even when technical details are limited, can enhance understanding of the complex BCI technology.

2.3 Visual Information to Communicate Health and Technology

In field of health communication, professionals have found that even individuals with high levels of literacy have demonstrated the need for assistance when processing complicated health information. Researchers argue that health professionals can improve communication about new technologies by incorporating visual materials in their message designs (National Library of Medicine, 2003; Sappol Interview, 2008; Unite for Site; 2015). Research has shown that by incorporating visuals into the characteristics of a complicated health message, patients respond more favorably to the information due to increased levels of comprehension. As Mayer's multimedia principle suggests, using visuals, rather than just text alone, can more effectively persuade a reader, and can help stimulate an emotional response within the viewer, triggering memory systems within the brain to rapidly respond (Houts, Doak, Doak & Loscalzo, 2006). For example, health education research demonstrates that visual information helps aid comprehension by providing a context for a reader to organize the information presented by accompanying text.

In addition to increased levels of comprehension, research has found that adding picture elements to written and spoken language can improve individual levels of attention and recall of health information (Houts, Doak, Doak & Loscalzo, 2006). Increasing understanding through employing visual communication strategies can help reduce individual levels of anxiety and increase feelings of self-efficacy towards the information or technologies being presented. This type of information can more effectively demonstrate to the viewer that they have the power and the choice of how to use new technologies, which in turn, encourages further understanding adoption of new health technologies into everyday health practices and behaviors (Harrison, 2003). Visual information, when used effectively, can generate more confident perceptions and positively influence attitudes and affect changes in behavior (Glik, 2007). In the present study, therefore, visual information is predicted to reduce insecurity about a health technology and increase levels of trust.

2.3.1 Art in Health Communication

Although considerable research has demonstrated the informational benefits of visual depictions of health and technological information, less is known about the role of artistic renderings of such concepts. On the other hand, art has long been used to document and analyze natural and health-related information. The relationship between art and medicine has had a long-documented history. Dating back as far as the 16th century, artists such as Leonardo da Vinci used knowledge of human anatomy to depict the human form more accurately. Although the practice of integrating visual elements with health and science concepts has been shown to translate across cultures, it was not until the early twentieth century that the United States began to incorporate art within hospitals, mainly through Works Progress Administration (WPA) efforts. Initial creative arts therapy practices began in the 1940's as tool for recovery for soldiers returning home from WWII, and since then, have been redefined through various cross-discipline research efforts that focus on improving and cultivating a more inclusive healthcare environment by including art within healthcare spaces (Sonke, 2016). There are numerous studies of representations within the sociology of health and illness (such as Showalter 1987; Stoeckle & White 1985; Jordanova 1987; Pryce 1989, 1996), and there is a long history of a relationship between art and medicine.

The study of visuals and the creation of art involves the role that aesthetic design plays within the mediated process between user and technological interface. Visual images, as Midalia (1999) explains, "are never innocent or neutral reflections of reality... they re-present for us: that is, they offer not a mirror of the world but an interpretation of it" (p. 131). Aesthetic design affects how we as social beings experience meaning, as our brains and bodies are continuously interacting with the environments that surround us.

Approaches such as art therapy or the integration of artistic practices into treatments in which patients create or co-create art themselves have been used extensively to engage communities, improve patient-physician communication, facilitate patient thinking, and improve clinical outcomes (Sonke, 2018). The creation of art allows for therapy patients to communicate that which might otherwise go unexplored or uninterpreted, as it provides a medium for conveyance of subconscious emotions through the use of metaphor (Angheluta & Lee, 2011). Art has also been used as part of health behavior messages such as smoking cessation (Parker & Ike, 2017). Although much of the research on health-related behavior change integrates artistic images into messages such as artistically filmed anti-drug advertisements, the impact of the art itself is rarely examined closely. Instead, such studies generally focus on the overall content and characteristics such as framing, priming, or social norms (National Library for Medicine, 2003; Glik, 2007; Rice & Akin, 2013; Health Communication Capacity Collaborative, 2014).

Research has also been conducted on the use of the arts generally to communicate health information. Largely this work has examined radio, television, and film, which allows for more nuanced and extensive narratives than visual arts such as paintings or photography. For example, Yoder, Hornik & Chirwa (1996) evaluated the impact of a radio drama in Zambia on knowledge and behavior related to AIDS and found improvements in some types of knowledge and increased willingness to discuss AIDS with spouses and children. Similar work in Papua New Guinea found that using arts-based approaches to integrate the narrative of local communities improved community dialog about HIV and willingness to change risky behaviors (Thomas et al., 2012).

In an important exception, a team of researchers examined the potential for using the arts for health communication in Uganda (Sonke et al., 2018). The researchers interviewed 10 public health leaders and 17 professional artists who work in public health to understand if and how the success of arts-based health communication campaigns was currently being implemented there. Sonke et al., (2018) emphasize ways that health communication relies on a common system of language, including visual symbols, and must connect with patients' cultures, norms, and attitudes. They argue that the arts are effective at communicating across language and other cultural divides, resulting in improved social learning. Their results demonstrate that the professionals interviewed feel that the arts empower health communication by engaging with people's emotions, attracting attention, focusing and clarifying messages, facilitating dialog, and cultivating solidarity. They also found that leaders felt that the arts improved communication with low-literacy populations and reached broader audiences.

Some research has found that art can bridge understanding of specific health conditions. For example, Potash, Ho, Chick, and Yeung (2013) asked participants to attend an art therapy exhibit created by people living with mental illnesses. They assess surveys, reflective writing and art, and discussion groups and found that audiences seeing the art they created responded with empathy and increased awareness and understanding of the artists and the metal illnesses. A similar study by Hurey, Linsley, Rowe, and Fontanella (2014) qualitatively studied the impact of art created by young people with mental illness and concluded that publicly-displayed art facilitated empathy and generated discussion and self-help behaviors for mental illness. Quinn, Shulman, Knifton, and Byrne (2010) similarly found that a national mental health arts festival increased positive attitudes toward the topic, although it did not decrease negative attitudes. Overall, research in this area suggests that using art as part of communication strategies for engaging audiences and improving attitudes can be fruitful. For the present study, although evidence is limited, these findings suggest that artistic renderings of a new and potentially intimidating or confusing health technology such as BCI may improve audience's perceptions of it.

2.3.2 Art and Emotional Engagement

The power of art in health communication may be related to its capacity for emotional engagement and stimulating critical thought. Visuals help to transform information into meaningful components of a medium. Visuals can help reconfigure our understanding of a technology, as they can serve as an extension of our experiences and understandings. Visuals involve a complex negotiation of cognitive social and technological, as well as cultural elements. Visuals can help to reconfigure scientific understandings through participation and action. Understanding and comprehension of information may expand or limit agency, and in this sense, visual engagement may serve as its own medium through which, may impact the way an individual is able to negotiate and exercise agency (Wood, 2007).

Incorporation of visuals into persuasive communication has been shown to be more persuasive and helpful for stimulating an emotional response within the viewer (Houts et al., 2006). Schweizer et al. (2009) highlight key principles for effective communication including the uniting of a message through cultural values, experiences and traditions to cause the audience to react in a more positive manner. Additionally, crafting a piece which communicates meaningful and relevant ideas can help cultivate critical social thinking about an issue.

These ideas stem from a process of art appreciation. May (1975) argues that appreciation of art is a creative action on the part of the viewer because at the moment of making sense of the art that is seen or heard "something unique is born in us" (p. 22). Not only can art bring us into the perceptions of another person, it can help us to think of new possibilities for ourselves. In describing the relationship between understanding one's self and relationships through a social collective, Potash (2010) draws on symbolic interactionism. He argues that the meaning a viewer ascribes to an object is determined by the interaction between object and viewer in a specific moment in time. Denzin (1992) remarks that this inner process "involves self-reflective individuals symbolically interacting with one another" (p. xiv). This perspective posits that individuals react as much to their interpretation of an object – word, image, person, event – as to the object itself. In the case of more artistic or abstract images as the object to be interpreted, meanings are more subjective, and can engage the viewer's emotions and thought processes more deeply than other types of visual renderings (Potash, 2010).

Potash (2010) suggests that there are three levels that make the process of art appreciation. The first, the empathic experiential level, relates to the viewer's immediate reactions based on their receptivity to the image, their cultural understanding, what they are seeing, and what they are experiencing emotionally. The second level, aesthetic attention, refers to a shift in attitude from a purely emotional one to one sustained by intellectual understanding. Viewers are encouraged to seek information related to the style, technique, or artist background that may help to prolong their interest. The final level is critical analysis at which viewers explore, discuss, and interpret the art in the context of both the viewer's and the artist's experience. Through this process, art becomes "object-as-experience," because individuals must reconcile their own assumptions and politics with the intentions of the creator. From this perspective, the meaning of an artwork emerges from the interactions among artist intention, social-cultural-political vantage point, and personal perspective.

The creative process also allows individuals to understand something about themselves that may otherwise be hidden or obscured by providing a forum for self-understanding and reflective distance (Potash, 2010). Allen (1995) reminds readers through her own creative experience that the creation of art is a way of knowing, while Potash (2010) demonstrates that engaging with imagery allows for an alternative way in which to make sense of one's own unique experiences. Critical theory and sociocultural studies examine discourse and forms of representation as key areas of inquiry and, within this, seek to demonstrate the importance of images as forms of communication which are culturally and socially situated within and mediated by a user's own ideology and subjectivity. By positioning the artistic creative process as one which is intrinsically relevant as well as socially valuable, new technologies may be perceived as valuable health tools for users.

Science communication scholars Schweizer, Thompson, Teel, and Bruyere (2009) highlight key principles for effective communication, and among them, suggest that uniting your message through cultural values, experiences and traditions can cause your audience to react, and that by crafting meaningful and relevant ideas can help cultivate critical thinking about an issue. Art is an ideal way to pursue these goals, as it aims to be emotional, engaging, holistic, and even subconscious.

This view is supported by what we know about how the brain processes information and images. The mirror neuron system, located in the frontal hemispheres of the brain, is activated whether we perform an action or if we observe someone else performing the same action. It allows us to interpret another's observed emotional state by mirroring the brain activity that would occur if we were actively experiencing the emotion ourselves (Lacoboni, 2008). Scientists believe that this part of the brain specifically relates to empathy. The neuroscience links between brain activity and empathy have been confirmed through in-vivo testing (Marci, Ham, Moran, & Amp; Orr, 2007) and further reveal that the frontal areas of the brain correspond to empathy, with the left side focused on perspective taking and the right on emotional aspects (Eslinger, 1998). The right side of the brain is responsible for general feelings of connection to others and creativity (Taylor, 2008). These findings allow for the possibility of a deep connection between visual stimuli, the brain, and empathy. Incorporating the role of perspective taking in developing empathy, the implications for the role of the visual in empathy, and the use of art for social change suggests that viewing art can lead to understanding.

Art goes beyond acting as purely a mental event, however. Context, constituted by culture and situation needs to be appreciated as multidimensional which art can offer (Wood, 2007). Latour (2005) refers to “shifting out” and “delegation” as social process of fact production that can extend to the ways we produce the structures that produce our social space. He further argues that “resemiotization” is a set of practices a community uses to transpose and reify knowledges, techniques and technologies as well as interpersonal, social and cultural behaviors. This view suggests that art images in the communication of complex health technologies not only engage the viewer in different ways than other types of communication, but also that they contribute to how the physical and conceptual spaces are produced as people learn about and experience the technologies.

Despite the promise of art for communicating health information, it is rarely used to do so. Research on the power of visuals in health and technical communication (Meyer, 2005) has often stopped short of assessing images considered to be art rather than to be diagrams, infographics, or illustrations. Although the definition of what qualifies as art could be part of the reason for this, the approach generally used in visual communication for health information is rarely theorized as artistic. As a result, the power of the visual arts discussed in fields such as photography or art history remains largely untapped in health communication efforts. The current study seeks to remedy that lack with a first step looking at the impact of art on people's understanding of a complex health technology using an experimental approach.

2.4 Research Question(s) / Hypotheses

Visual information has been shown to significantly improve communication about complex topics, especially technologies. Visuals in scientific as well as cultural products such as television and film contribute to people's attitudes and perceptions about specific technologies, including health technologies. Existing research examines a range of visual elements, but these studies are largely highly representative or technical illustrations or scenarios. Little is known about how more artistic or abstract representations of technologies might influence viewers' perceptions. Therefore, this project asks, **Can abstract art representations of a complex health technology increase trust and interest in and improve individuals' understanding of that technology?**

According to theories of cognitive multimedia learning, meaning- making and multimodal discourse, exposure to visual information about a technology in an appropriate context are better able to understand it, leading to:

- **Hypothesis 1:** People's **trust** in BCI technology will be higher when they see artistic visual information with text than when they do not.
- **Hypothesis 2:** People's **interest** in BCI technology will be higher when they see artistic visual information with text than when they do not.
- **Hypothesis 3:** People's **comprehension** in BCI technology will be higher when they see artistic visual information with text than when they do not.

The findings of this study will help scholars better understand the role of visuals in communicating science and technology in health, especially in order to improve trust in complex new technologies. It also contributes to understanding the role of more abstract forms of representation, such as artistic works, in perceptions of technology.

CHAPTER 3. METHODS

In order to analyze whether an artistic representation of a new health technology can serve as an effective tool for increasing trust, comprehension and interest among viewers, this project uses text and visual representations of brain-computer interface (BCI) technology to determine whether or not artistic representations of BCI influence trust, interest, and comprehension of the technology.

3.1 Research Objectives

To examine these relationships, this project employs an experiment that tests hypotheses about differences between those who see text about the technology, text and a scientific illustration of the technology, and text with an artistic representation of the technology (compared to a control). This study examines trust, interest, and comprehension, to identify the best ways to communicate information about complex health technologies to potential users, clinicians, caregivers, as well as to members of the community.

3.2 Rationale of the Method

This thesis uses an experimental approach to identify differences in the communicative impact of text, visuals, and artistic representations of a complex health technology, Brain-Computer Interfaces. Experiments were selected for this study because they allow researchers to identify systematic patterns across participants in how informational content might influence perceptions about BCI technology. Such research is often needed to make broader recommendations to practitioners, and helps account for individual differences that may overtake qualitative research with smaller samples. Clark and Mayer (2016) identify evidence-based practices as an important step towards designing informational material, explaining that when the goal of a study is to identify what works, as well as how an instructional method works, experimental comparisons and observational studies are the appropriate methods to include in a study (Wimmer & Dominick, 2014). Prior research on health communication has successfully used experimental approaches because they allow for some generalizability and the establishment of best practices in work such as the current study that is intended to help both researchers and practitioners. Qualitative work has often been used to explore the impact of technology in healthcare settings (see Appel et al., 2020; Graves, Doucet, Dube & Johnson, 2018), but such studies generally are focused on broader questions that the current study. Although there are limitations to internet-based surveys such as the one being used here, including non-response and increased chances that participants will leave and return to the survey later (which can affect the data), internet approaches have a long history of successful use in this area.

3.3 Study Design

This project consists of an online quantitative experiment that uses a questionnaire administered in the online survey software Qualtrics and the classroom recruitment system SONA to conduct a convenience sample of 86 undergraduate college students. To evaluate whether art can influence how people see complex, new health technologies, it uses abstract visual representations to assess individual levels of trust in the new technology, understanding of it, and their interest in learning more about the technology. It also looks at whether artistic/ abstract representations of information improves understanding, trust, and insecurity related to the technology. It uses three conditions for the stimuli and a control condition: an artistic representation of the technology with a short text description, a technical diagram of the technology with the text description, a text-only description of the technology without images, and a control condition that provides no information about the technology.

Table 1. Study Conditions and Materials

Condition	Information Material
A: Art Image + Text	Artistic representation of BCI and textual description of the technology
B: Image + Text	Non-Artistic representation of BCI and textual description of the technology
C: Text only	textual description of the technology
D: No Information	Questionnaire only

3.4 Instruments and Variables

In order to assess the impact of artistic visual representations on participant responses to information about BCI, participants of this study took an online questionnaire that measured their levels of trust and interest towards this new technology, as well as their comprehension of BCI technology. Pre-existing knowledge, technology affinity, personal experiences, awareness, age, and gender will also be measured as moderators. The dependent variables for this research are trust in BCI, comprehension of BCI, feelings of insecurity about BCI, and interest in learning more about BCI.

3.4.1 Scales

The main scales used in this study in order to design an appropriate questionnaire are the following: the Trust in Medical Technology scale (Montague, 2010), the Technology Readiness Index (Parasuraman, 2001; Colby & Parasuraman, 2001), factors about insecurity from a technophobia scale (Sinkovics et al., 2002), and the Health Visual Preference Scale (Jones et al., 2019). Each of these instruments have been adapted to specifically address BCI technologies. Questions assessing participants' interest in the BCI technology, their level of comprehension, their level of trust towards the technology, their background knowledge, and their prior experiences with it have also been created. Table 2 summarizes the main variables used to measure participants' anxieties and beliefs surrounding BCI.

Table 2. Variables and Measurement

Variable	Data measurement instrument
Condition (IV)	Stimulus Condition
Pre-existing Knowledge (EV/CV) or M	Survey responses
Awareness (EV/CV) or M	Scale
Comprehension (DV)	Scale
Attitudes (DV)	Scale
Age (IV) or M	Survey Response
Gender (IV)\ or M	Survey Response
Trust towards the technology (DV)	Scale
Interest in learning more (DV)	Scale
Technological Affinity M	Survey Response

Key: IV- Independent Variable; DP- Dependent Variable; EV- Extraneous Variable; CV- Confounding Variable; M-Moderator

3.4.1 Dependent Variables

The dependent variables consist of six sets of items combined into scales to reflect interest, understanding, two versions of trust, and insecurity.

3.4.1.1 Trust in Medical Technology Scale

The Trust in Medical Technology scale (TMT) is a 28-item scale that assesses patients' trusting attitudes towards medical technology. The original TMT was designed in a checklist format and required experience with the specified medical technology to complete. In its original form, it used three subscales for trust in the technology, trust in the physician, and trust in the physician using the technology. The current study uses only the first of these, and has adapted the items to address trust in BCI and does not require experience by the participant. For example, original questions include, "The technology was accurate." and "The technology was trustworthy." and "The technology was safe." These were adjusted to: "I believe BCI technology is accurate." and "I believe BCI technology is trustworthy." and "I believe BCI technology is safe." The adapted version uses responses on a Likert scale from *strongly disagree* to *strongly agree* on a Likert scale (Montague, 2010).

A second set of trust items from the TMT was developed using different language and were focused on feelings. Items included "I have positive feelings about BCI technologies" and "I have confidence in BCI technologies." Although combined the two scales were close to reliable (alpha = .701), they were kept separate. Both scales used responses on a 5-point Likert scale from *strongly disagree* to *strongly agree*.

3.4.1.2 BCI Understanding Scale

In order to assess understanding of BCI technologies, six items about understanding BCI technologies were written that ask participants their perceptions of their own understanding. They were presented as statements with responses in a 5-point Likert scale from *strongly disagree* to *strongly agree*. Items included statements such as "I am confused about what BCI is" and I understand what BCI technologies are for."

3.4.1.3 BCI Interest Scale

To assess participants' interest in BCI technologies, a 5-item scale with items such as "I find BCI technologies interesting" and "I would like to learn more about BCI technologies" was developed. Responses were on a 5-point Likert scale from scale from *strongly disagree* to *strongly agree*.

3.4.1.4 Technology Insecurity Scale

The Technophobia Scale is a 13-item scale that was designed to measure different aversions and hesitancies towards using various technologies, while also addressing computer anxieties on a 5-point Likert scale from *strongly disagree* to *strongly agree*. This study used adapted sections from the "Human vs. Machine Ambiguity," portion of the scale and includes items such as, “I prefer to have people handle my health procedures than to use medical technologies,” “I don’t like the fact that medical technologies are becoming so prevalent in our daily lives,” and “I feel more confident dealing with a human medical professional than a medical technology” (Sinkovics et al., 2002).

The Technology Readiness Index (NTRI/TRI) is also used to assess insecurity towards technologies. The original scale was a 10-item scale with responses on a 5-point Likert scale from strongly disagree to strongly agree. Items include “I find new technologies to be mentally stimulating.” and “I do not consider it safe to do any kind of financial business online.” and “In general, I am among the first in my circle of friends to acquire new technology when it appears” (Colby & Parasuraman, 2001; Parasuraman, 2000). These items did not mention BCI in the statements, and were used as developed.

3.4.2 Other Measures

3.4.2.1 Health Visual Preference Scale

Research has demonstrated that patients have individual preferences for learning about health-related information. Studies have shown that some people prefer complex health topics to use visuals within the message content, as it makes the information easier to understand which may improve health outcomes and promote positive behavior changes. The Health Visual Preference scale (Health VIPS) is a 9-item scale that addresses preferences to receiving health information through either visual or written material on a 5-point Likert scale from *strongly disagree* to *strongly agree*. It addresses 5 validity measures which include the following: Preference test (visual versus written content), Self-rated health, Health confidence, Satisfaction with health care, Experience with health information. This study has adapted items from this scale for this research. Some of these items include, “I often find that health information that uses words, but no pictures, is harder to follow," "When it comes to understanding health information, I find an image is worth a thousand words," "I am the sort of person who doesn't need visual aids (e.g., pictures, diagrams) to understand health information (Jones et al, 2019)."

3.4.2.2 Additional Factors

To measure awareness, background knowledge, and prior experiences with BCI, the survey included questions about specific experiences and facts about BCI, such as "Have you ever seen BCI used by someone?" and "I am very interested in medical technologies in general" Items used 5-point Likert scales from *strongly disagree* to *strongly agree* for responses. The survey also assessed demographic information such as gender, age, major in school, and background with both art and medical technologies. Additionally, study participants were prompted to answer two open-ended questions on their overall impressions regarding BCI systems.

3.4.3 Scale Reliabilities and Descriptives

Descriptive statistics for the scales used in this study were conducted. Table 3 shows the mean, standard deviation, median, minimum, and maximum for all participants.

Table 3. Descriptive Statistics for Scales

Scale	N	Mean	Standard Deviation	Median	Minimum	Maximum
Interest in BCI	86	3.78	0.79	3.80	1.2	5
BCI Understand	86	3.23	0.92	3.33	1	5
BCI Trust 1	81	3.71	0.61	3.60	2.57	5
BCI Trust 2	86	3.49	0.56	3.33	2.33	5
Visual Health Information	86	3.79	0.72	3.75	1.75	5
Technology Insecurity	86	2.86	0.47	2.85	1.71	4.29

The results for the reliability of the scales used in this study are reported in the table below.

Table 4. Reliability for Scales

	Cronbach's Alpha	Mean	Variance	Standard Deviation	N of Items
Interest in BCI	.826	18.91	15.72	3.96	5
BCI Understand	.892	19.39	31.04	5.57	6
BCI Trust 1	.911	26.06	19.21	4.38	7
BCI Trust 2	.867	20.98	11.61	3.40	6
Visual Health Information	.720	15.17	8.38	2.89	4
Tech Insecurity	.629	20.04	11.21	3.34	7

The Interest in BCI Scale had a mean of M = 18.91, SD = 3.96, α = 0.826; which suggests that the Cronbach alpha value of 0.826 offered an acceptable reliability score. The BCI understand scale had a mean of M = 19.39, SD = 5.57, α = 0.892; which suggests that the Cronbach alpha value of 0.892 offered an acceptable reliability score. The BCI Trust scale 1 scale had a mean of M = 26.06, SD = 4.38, α = 0.911; which suggests that the Cronbach alpha value of 0.911 resulted in an acceptable reliability score. The BCI Trust scale 2 scale had a mean of M = 20.98, SD = 3.40, α = 0.867; which suggests that the Cronbach alpha value of 0.867 resulted in an acceptable reliability score. The Viz Health scale had a mean of M = 15.17, SD = 2.89, α = 0.720; which suggests that the Cronbach alpha value of 0.720 resulted in a moderate reliability score. The Tech Secure scale had a mean of M = 20.04, SD = 3.34, α = 0.629; which suggests that the Cronbach alpha value of 0.629 resulted in a moderate reliability score. These results suggest that the interest, understanding, and trust scores were acceptable, while the viz health and tech secure scores were moderately reliable.

Table 5. Descriptive Statistics for Moderators

	N	Mean	Standard Deviation	Median	Min	Max
I like art such as paintings and photographs	86	4.31	0.74	4.00	3	5
I am familiar with art and art history	86	2.64	0.96	3.00	1	5
I consider myself a visual artist	86	2.83	1.29	2.50	1	5
I've never really been interested in art R	86	4.10	0.88	4.00	2	5
I have a clear understanding of the difference between abstract art and representational art	86	3.27	1.25	3.00	1	5
I love going to art museums	86	3.62	1.09	4.00	1	5
I don't know much about art but often seek it out	86	3.36	1.09	4.00	1	5
In the past month how many hours did you look at art	86	2.37	0.85	2.00	1	4
I am very interested in medical technologies in general	86	3.31	1.06	3.00	1	5
I have a good idea what kinds of technologies are used by hospitals	86	3.12	1.11	3.00	1	5
Do you have experience with medical technologies as patient or family or friend of patient	86	2.80	1.22	3.00	1	5
Have you ever studied medical technologies in school	86	1.43	0.66	1.00	1	4

Of note were the responses regarding whether or not participants "like art" or whether they were "not interested in art." The mean of responses for those who claimed to "like art" was 4.31, with a standard deviation of 0.74 and a median response of 4. Those participants who responded to the reversed question of "not being interested in art" is in line with those who responded to those who answered that they "like art," with a mean of 4.10, and a standardard deviation of 0.88 and a median of 2.

Table 6. Descriptive Statistics for Condition

Condition	Frequency	Percent
Condition – Art + Text	21	24.4%
Condition – Diagram + Text	20	23.3%
Condition – Text Only	23	26.7%
Condition – No Info	22	25.6%

Table 6 reflects the descriptive statistics for each condition, demonstrating that the Text Only condition had the most participants randomly assigned to it accounting for 27% of responses.

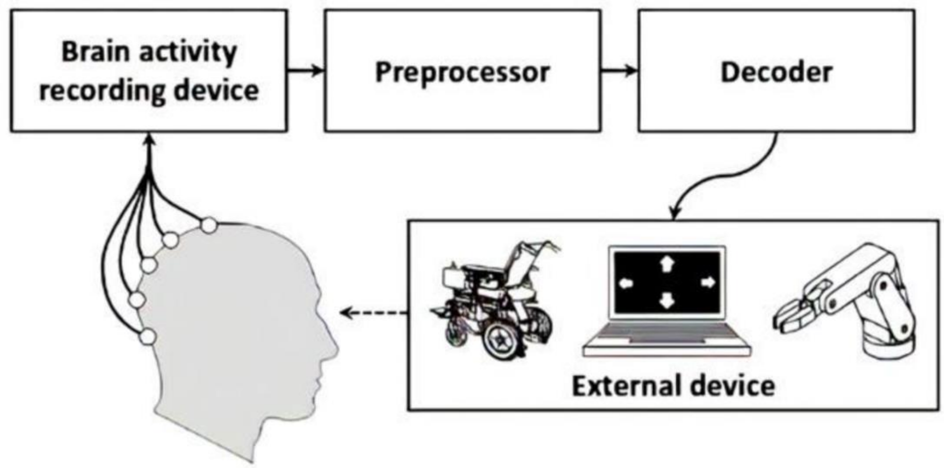
3.5 Stimulus Materials

To create the various conditions and control for the experiment in this study, high quality photographs of artistic representations of BCI technology were combined with a paint overlay and accompanied by a text description presented within the survey. The non-visual condition used the same text but without visuals. The control condition provided no visual representation or text about the technology within a digital space. Figure 3 shows an image of the visual used.

Title: Identity Through Movement

CAPTION: This piece was created using a Brain-Computer Interface system. The artist used software that aided in controlling a robot with their brain waves to control the paint distributed on the canvas. The artist used a projector mounted on the ceiling to project brainwaves of a participant testing software developed by the CSU BCIL research group as inspiration. This piece serves to express individual identity through the representation of neurological data.

Figure 3. Art image and caption for Art + Text Condition



CAPTION: BCI systems enable communication by providing a direct link between a functioning brain and the outside world. These systems operate by translating brain activity that is recorded via electrical impulses into a generated output to replace and restore function, or control an external device, such as a robot, a prosthetic limb, or a wheelchair. The data is recorded through a EEG cap that an individual places on their scalp. The information provided by an individual's brain is then precoded and decoded using Artificial Intelligence algorithms, and then translates this information into a desired actionable output.

Figure 4. Non-Artistic image and caption for Image + Text condition

All conditions except the no information condition saw text on the screen, shown in Figure 5. The text provides a clear description of BCI technology that is written at an 8^{th}-grade reading level. It describes how BCI works, what it is used for, and its benefits and drawbacks. It is intended to be easily understood by a general audience.

Brain-Computer Interface (BCI) systems allow a person to use signals from their brain to control a computer device, such as a cursor on a computer screen, a prosthetic limb, or a wheelchair. BCI allows users to control the object directly with their brain activity - by simply thinking, a person can send commands to a computer. This is done by attaching a cap with sensors (electrodes) to a user's head that sends electric activity to a computer. The computer then uses artificial intelligence algorithms to analyze the information acquired from the user's brain signals and perform external actions. Those actions can be, for example, moving a cursor to select letters on a screen, selecting tools and colors to draw images, or even controlling other devices such as a wheelchair.

Because BCI does not require the use of vocal cords or hands, it can allow people who cannot speak or use their hands to communicate, draw, or control other devices. BCI can enable a person suffering from paralysis to write a book or control a motorized wheelchair or prosthetic limb by thought alone.

Current BCI devices require different techniques for control, such as imagining moving your left or right arm, or visual focusing strategies, and considerable training to work properly. Some future applications, such as controlling a prosthetic leg, have the potential to work become more natural as the body learns the system.

Figure 5. Image of text for all conditions except no information condition

3.5.1 Artistic Representation Development

For this project, the researcher created a large art piece that represents BCI technology output. It was acrylic on a 5’ x 5’ canvas, professionally mounted and hung on a wall for the photographs used in the study. To create the art used in this study, previously recorded brainwaves gathered by Colorado State University’s Brain-Computer Interface Laboratory was used to create an abstract visual. Patient interactions with these devices were represented by neurofeedback in the form of electroencephalogram (EEG) brainwaves that were generated through an in-home session previously conducted (see Forney et al., 2013a, b, 2015, 2018; Forney & Anderson, 2015).

The brainwaves represented in this work reflects interactions between a noninvasive brain-computer interface system and individuals who all currently experience various neurological conditions and/or impairments. Recordings were done with the permission of the lab and the individuals recorded. Communication from the individual to the device is established through imagined movement techniques, and those thoughts responses then generate electrical activity that can be detected through electrodes that have been placed on the scalp.

The brain activity that is recorded through different regions of activity via electrical impulses provides the BCI system with data that is then filtered by algorithm and signal processing methods. Depending on how the data is treated, as well as what software is being used, the recorded brain activity is then used to produce various forms of output via the computer. The participant data being represented in this project was collected using a special software created by the CSU BCIL team and is known as Colorado Electroencephalography and Brain-Computer Interfaces Laboratory (CEBL). The program using in conjunction with the software is known as the P300 Speller (see Forney et al., 2013a, b, 2015, 2018; Forney & Anderson, 2015).

The researcher created an original art installation which visually depicts individual brainwave interactions that were observed while a research participant was actively engaged in communication efforts with a brain-computer interface technology (also known as direct neural interface machines). The biofeedback information was gathered through noninvasive and passive EEG recordings by the CSU Brain Computer Interface Laboratory research team, and has been provided by individuals with neurological impairments who are seeking to contribute to existing research and towards the future development of these communication systems (see Figure 6; see Figure 1 in Chapter 1 for images of the development process and an exhibit of the art in a campus gallery).

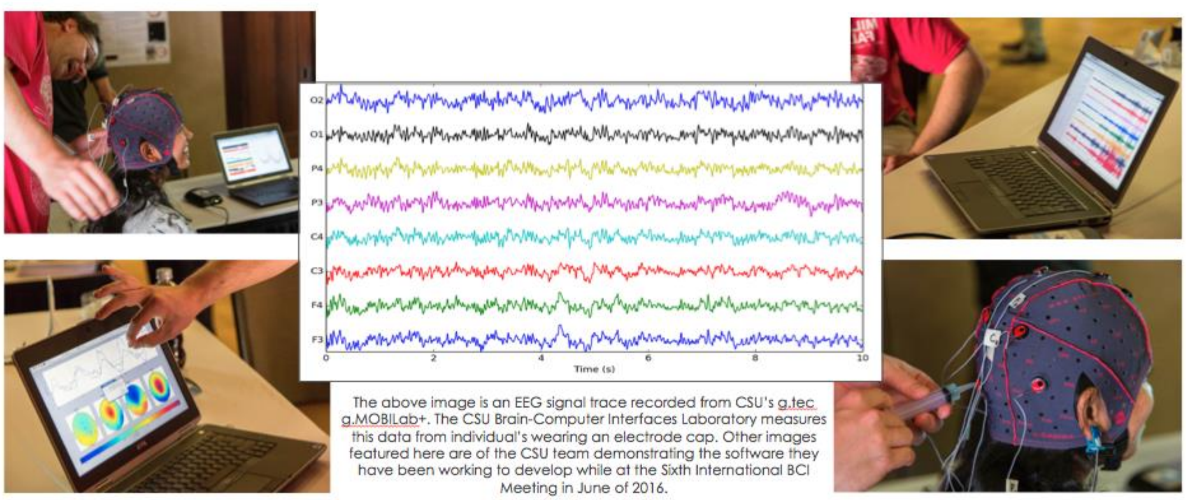


Figure 6. How EEG signals are recorded using BCI technology

The style used for the art in the art condition was representative of neurological data as a means for expressing identity. This form of visual approach exposed participants/observers to artistic representations of the technology and used a survey to assess trust, interest, and overall comprehension towards the technology. The artistic visual representation was constructed through time segments of EEG brainwaves while a participant interacted with these technologies and then recorded and photographed. The image was then projected onto to a large canvas where the researcher then used their own BCI device and P300 software to use their own brainwaves to control a Bluetooth robot that distributed the paint on the canvas in order to create a large scale abstract visual piece.

3.6 Data Collection

The study used an experiment and provided in-class extra credit as compensation through the recruitment system SONA, with a short alternative assignment for those wishing to opt-out. Participants took a 15-20 minute online survey using the survey software Qualtrics where they read a short text passage about BCI and either saw an artistic image related to BCI, a diagram of BCI, or no image at all based on random assignment to condition. Afterwards, they answered questions about opinions, trust, and understanding of BCI technology. Pre-existing knowledge of BCI, technology affinity, personal experiences, awareness, age and gender were also measured as moderators. Names and other personally identifying information were only tracked for use in compensation and were not collected by the researchers. Participants were allowed to opt-out of the study at any time.

This study included only participants over 18 years old. The rationale for this is because medical technologies and medical decisions are most relevant to adults. Minors generally do not make medical decisions independently. This population also processes information differently than younger individuals, and the study is interested in adult decision-making, perceptions, and understandings.

3.6.1 Sample and Recruitment

Participants (N= 86) were students from Colorado State University recruited to take part in this study using SONA. To be eligible, students had to provide consent and be over the age of 18. The data was cleaned for duplicate and incomplete responses, which resulted in final sample of N=86. The age range of participants ranged from 18-34 with 91% of the participants reporting being between the ages of 18-24. Although inclusive options were available for selection, participants identified as either white or non-white, with 21% identifying as non-white and 79% identifying as white. As with the various demographic options that were offered, multiple gender choices were offered however, most participants either identified as female or male. Females represented 62% of participation in this research, while male participation was reported as 38%. Most of the sample identified themselves as being undergraduate freshman (31%), with the remainder reporting they were a sophomore (13%), junior (30%), senior (23%), and graduate student (2%). It is of note that 94% of the sample declared to be pursuing an artistic degree. Table 3 shows additional descriptive statistics for the participants.

Table 7. Demographics Descriptive Statistics

Measure	N	%
Age		
18-24	78	90.7%
25-34	7	5.9%
Gender		
Female	53	61.6%
Male	33	38.4%
Race		
White	68	79.1%
Non-White	18	20.9%
Grade		
Freshman	27	31.4%
Sophomore	11	12.8%
Junior	26	30.2%
Senior	20	23.3%
Grad Student	2	2.3%
Major		
Artistic Major	81	94.2%
Non-Artistic Major	5	5.8%

3.6.2 Data Collection Procedures

For this study the researcher used the JMC SONA system and Qualtrics. Various instructors announced the project in selected JTC classes and explained how to sign up. Interested students received an email with a link to the online survey, administered in the survey software Qualtrics, as well as SONA. Participants were randomly assigned by the software to one of the four conditions and further instructed to complete the survey. The survey took about 20 minutes to complete for most participants. The results of the survey were downloaded into SPSS for analysis.

3.6.3 Pilot Study

To test the procedures and measures to be used in the study, a pilot study of approximately 20 people similar to the main study population (CSU students) was conducted. Although this sample size was not large enough to determine validity and reliability of the measures, it helped to identify any major problems with the instruments and procedures. This step also helped to identify any questions or concerns that existed, and an open-ended question was included to address any design issues regarding length and engagement, language coherency, as well as identify any additional issues that were able to be corrected prior to administering. The pilot sample was conducted two weeks before the planned start among volunteers willing to provide feedback on the survey items and administration process. No substantial changes to the study were made after the pilot was conducted.

3.7 Validity and Reliability of the Proposed Study

The question of validity refers to whether the instruments selected for a study measure what they were intended to measure. Reliability, on the other hand, refers to whether the scales used for a study can reproduce the same results administered on different occasions (Nunnally, 1978; Thatcher & Lubar, 2009; Robertson, 2017). For a study to be reliable it needs to be valid, and the proposed study aimed to address validity and reliability considerations in a number of ways. First, by using identical surveys for this study (for both the three conditions and the control condition) that were administered within identical interfaces through the same medium, i.e. the computer, this effort sought to ensure that all participants were measured under as similar of parameters as possible. Additionally, the questions for the survey for this project were tested in a pilot study using reliable scales supported by the literature and specifically tailored to address BCI technologies.

3.7.1 Internal Validity

The internal validity of a study refers to whether appropriate control over the research conditions is exercised in order to conclude that no other possible explanations can be determined by the results (Thatcher & Lubar, 2009; Wimmer & Dominick, 2014). Pilot testing has helped to increase internal validity. Measuring moderators and mediators also contributed to the internal validity of this study.

3.7.2 External Validity

External validity refers to how well the results of a study can be generalized among different populations, environments, and time (Cook & Campbell, 1979; Wimmer & Dominick, 2014). Participants for this study will be randomly assigned to be heterogeneous samples which will contribute to generalizable results. This study is also very design specific—it is operational, which will limit the ability for it to be replicated (Wimmer & Dominick, 2014). However, this study will contribute to initial and exploratory research efforts designed to gain greater insight and better understand the impact that art may have within health and science communication efforts.

3.7.3 Ecological Validity

The ecological validity of this study is limited, but it could likely be enhanced by using genuine art created by an experienced artist (the researcher) with extensive knowledge of BCI. The inclusion on two open-ended questions, as well as the fact that it is an online experiment in which the participants are in familiar surroundings, may contribute to the ecological validity of this research (Wimmer & Dominick, 2014).

CHAPTER 4. RESULTS AND ANALYSIS

In order to test the hypotheses about the relationships between information format (art, diagram, text) and participant understanding, interest, and trust, this project used correlations, t-tests, ANOVAs, and linear regression. The findings reported here are based on 86 participants that were randomly exposed to one of four conditions that included: an artistic representation of BCI technology along with textual information, graphic depiction alongside textual information of BCI technology, textual information about the BCI technology, and a condition that contained no visual or textual information. A survey to assess levels of trust, interest, and comprehension towards brain-computer interface technologies was administered during the Fall semester of 2021. The resulting observations explained here will demonstrate whether applied visuals can have an impact on a publics' attitude and perception towards this technology. Analyses of each hypothesis is discussed in the following sections.

4.1 Correlations

The first test of the relationships between conditions and the six dependent variables was a simple Pearson correlation, as shown in Table 8.

Table 8. Correlation for Conditions and Scales

Scales	Condition – Art + text	Condition – Diagram + text	Condition – Text only	Condition – No Info
Interest in BCI	0.019	-0.024	0.079	-0.076
BCI Understand	**.233***	**.254***	0.128	**-.605****
BCI Trust 1	-0.014	0.133	0.139	**-.266***
BCI Trust 2	-0.044	0.102	0.098	-0.154
Visual Health Information	-0.081	0.005	0.137	-0.063
Tech Insecurity	**.259***	0.061	-0.141	-0.171

N = 86; * = p < .05; ** = p < 0.01

The results suggested a statistically significant relationship between understanding and the BCI Understand scale, the BCI Trust 1 scale, as well as the Tech Insecurity scale. For the BCI Understand scale, the conditions of Art + Text (.23), Diagram + Text (.25) and the condition with no visual or textual information included (-.60) yielded a stronger significance among these relationships than the other 5 scales reported. Additionally, other significant results for the condition that did not include visual or textual information was introduced by the BCI Trust 1 scale with a significance level of -.26, as well as the Art + Text condition and the Tech Insecure scale at a significance level of .25.

4.2 Hypothesis Testing

To analyze the hypotheses proposed in this study one-way ANOVAS were conducted. Additionally, several individual variables were examined through correlation testing.

4.2.1 Hypothesis 1: Trust

To examine Hypotheses 1, whether or not artistic visual information influences the levels of trust people had towards a complicated communication technology, such as BCI systems, a one-way ANOVA was performed. This test evaluated whether the condition that included artistic visual information yielded higher levels of trust reported compared to the other three conditions.

Table 9. Hypothesis 1: ANOVA Trust

Measure	*df*	Mean Square	*F*	p
BCI Trust Scale 1	3	.836	2.280	.086
BCI Trust Scale 2	3	.308	.966	.413

N = 86

Table 10. Means by Condition for BCI Trust Scale 1 and BCI Trust Scale 2

Condition	N	Mean	Standard Deviation
BCI Trust Scale 1			
Art + text	20	3.701	.578
Diagram + Text	19	3.864	.694
Text Only	23	3.853	.673
No Info	19	3.421	.424
BCI Trust Scale 2			
Art + text	21	3.452	.582
Diagram + Text	20	3.600	.612
Text Only	23	3.587	.679
No Info	22	3.348	.316

The results presented in Table 9 reveal that although close to significant, message design that included artistic visuals did not have a significant effect of trust scores. The BCI Trust scale 1 reported $F(3,77) = 2.280$, $p = .086$. The BCI Trust scale 2 reported $F(3,82) = .966$, $p = .413$. Although the model was not significant, mean differences reflect the highest levels of trust in the diagram and text-only conditions for both scales, and the lowest in the no information condition, as shown in Table 10. There was no significant effect of the artistic and visually based condition on trust which suggests that hypothesis 1 was not supported.

4.2.2 Hypothesis 2: Interest

Hypothesis 2 predicted that those exposed to information about a complex health technology via the combination of artistic visual and textual components would have higher levels of interest than information that did not contain artistic representation. To evaluate whether or not artistic visual information influences the levels of interest people had towards a complicated communication technology, such as BCI systems, a one-way ANOVA was performed. This test evaluated whether the condition that included artistic visual information yielded higher levels of interest reported compared to the other three conditions.

Table 11. Hypothesis 2: ANOVA Interest

Measure	*df*	Mean Square	*F*	p
BCI Interest Scale	3	.170	.263	.852

N = 86

Table 12. Means by Condition for BCI Interest Scale

Condition	N	Mean	Standard Deviation
Art + text	21	3.809	.820
Diagram + Text	20	3.750	.898
Text Only	23	3.887	.896
No Info	22	3.681	.554

A one-way ANOVA indicated in Table 11 demonstrates that the effect of visually artistic information including text did not significantly influence levels of interest. The BCI Interest scale 1 did not differ significantly by condition $F(3,82) = .263$, $p = .852$. The means by condition show very little difference in levels of interest among the three conditions with information about BCI, but these were slightly higher than the condition that contained no information, as shown in Table 12. Hypothesis 2 was not supported.

4.2.3 Hypothesis 3: Understanding

Hypothesis 3 predicted that people's comprehension in BCI technology will be higher when they see artistic visual information with text than when they do not. To examine whether or not artistic visual information influences the levels of understanding people had towards a complicated communication technology, a one-way ANOVA was conducted. This test evaluated whether the condition that included artistic visual information yielded higher levels of understanding among participants compared to the other three conditions.

Table 13. Hypothesis 3: ANOVA Understanding

Measure	*df*	Mean Square	*F*	p
BCI Understand Scale	3	9.153	16.375	<.001

N = 86

Table 14. Means by Condition for BCI Understand Scale

Condition	N	Mean	Standard Deviation
Art + text	21	3.611	.762
Diagram + Text	20	3.658	.687
Text Only	23	3.427	.705
No Info	22	2.280	.825

This one-way ANOVA indicated in Table 13 describes that there was a significant main effect of artistic visual information with textual information on level of understanding. The BCI Understand scale reported $F(3,82) = 16.375$, $p = <.001$. Means by condition show that mean value of understanding did differ between conditions significantly with reported levels of understanding higher for the conditions that contained a diagram and text ($M = 3.66$, $SD = .687$), as well as the condition that consisted of an artistic visual and text ($M = 3.61$, $SD = .762$), as compared to the text only condition ($M = 3.42$, $SD = .705$) and the condition that did not include information ($M = 2.28$, $SD = .825$). The results indicate that there was a significant effect of the condition that contained artistic visual and textual information on levels of understanding compared to the other groups. Hypothesis 3 was supported.

As there was a significant effect for this hypothesis, post hoc analysis was conducted to determine differences among the groups. Tukey's HSD test for comparisons found that the mean value of responses for the BCI Understand Scale was not significant between the three conditions that contained text or images, but that there was a statistically significant difference between the control group and each of the three conditions. In other words, results of this post hoc analysis demonstrates that the three conditions that contained either art and text (p = [<.001], 95 % C.I. [-

1.929, -.732]), diagram and text (p = [<.001], 95 % C.I. [-1.983, -.772]), as well as text only information (p = [<.001], 95 % C.I. [-1.731, -.562]), improved levels of understanding compared to the control condition which contained no information.

Table 15. Correlation for Variables and Scales

Variable	Interest in BCI	BCI Understand	BCI Trust 1	BCI Trust 2	Tech Insecure	Visual Health Info
Had you ever heard of Brain-Computer Interface (BCI) prior to this study?	**.235***	**.290****	0.143	0.091	**.222***	-0.211
Have you ever seen or used BCI technologies in person? (y/n)	-0.093	**.238***	0.048	0.171	0.211	-0.122
Have you ever read about or seen videos about BCI technologies before? (y/n)	0.186	**.318****	0.121	0.02	0.197	0.072
Do you know anyone that has/is experiencing difficulties in communicating from a cognitive impairment?	0.197	0.161	**.250***	**.269***	0.099	-0.04
I don't know much about art, but I often seek it out.	0.034	-0.033	**.249***	**.288***	0.122	0.136
I am very interested in medical technologies in general.	0.209	**.256***	0.154	0.158	-0.055	0.054

N = 86; * = p < .05; ** = p < 0.01

Table 15 shows the significant Pearson correlations between the six dependent variables and potentially moderating variables measured in this study. No other variables measured (e.g., age, gender, major, other art background, etc.) were significantly correlated. The correlations found were relatively small (all were under .300), suggesting only weak relationships between these factors and the outcome variables. Tests for moderation using linear regression were run, but none found significant moderators. Because this project did not hypothesize moderating factors in the relationships between condition and the outcome variables, those inconclusive results are not shown here.

4.3 Summary

Analysis demonstrated that overall, hypotheses 1 and 2 were not supported, but hypothesis 3 was supported. However, examining means by condition show that the reason for this support was a difference between the no-information condition and the artistic visual and text condition and visual and text condition, rather than differences among the three informational conditions. The results of this study also demonstrate that prior knowledge, awareness, and experience of and with the technology could have acted as potential moderators on comprehension, interest, trust, and general comfort with the technology. Whether participants reported knowing someone experiencing communication difficulties significantly impacted levels of trust, as did whether participants were more likely to seek out art. General interest in medical technologies impacted levels of understanding as well.

CHAPTER 5. DISCUSSION

This study used an online quasi-experiment to assess differences in the impact of text, visuals, and artistic representations of a sophisticated health communication technology, Brain-Computer Interface systems. It measured the impact of these modalities on interest, understanding, and trust in BCI and compared them to a control group that saw no information about the technology.

The main findings of this work were that trust and interest were not significantly affected by the information presented, but levels of understanding were increased for those who saw any of the three information materials. Hypothesis 3, which predicted people's understanding of BCI technology would be higher when they see artistic visual information than when they do not, was supported, suggesting that understanding is influenced by artistic visual and textual information. However, there was no significant difference between the artistic/text condition compared to the other conditions. There was a significant main effect of message design that included artistic visuals and text on comprehension scores than those exposed to the text-based information or the control group which included no additional information. Although these findings do not fully support Mayer's cognitive multimedia theory (2001) predicting comprehension would increase when people see visual and text versus text only, it does demonstrate that participant perceptions of their own understanding is greater when they see information about a technology. Although this may seem obvious, it is important to note that this information was brief and very basic, so it is encouraging that even a small exposure such as the one in this study resulted in increased feelings of comprehension. It is also important to note that the art condition, which had the potential to be distracting and potentially reduce feelings of understanding, did not inhibit it in this study.

Contrary to the results of testing hypotheses 1 and 2, this study hypothesized higher levels of both trust and interest among participants who saw an artistic representation of the technology. No significant differences were found among any of the conditions for either. This may be because the sample size was quite small for showing small effects, reinforced by the mean differences by condition that did show higher levels of trust and interest among those who saw information about BCI. The highest levels of interest were in the diagram/text condition, followed by the art/text condition for Trust 1, and diagram/text followed by text only for Trust 2. Further research is needed to identify if and how visuals and text, including artistic text, can influence trust. A larger sample size is needed to explore further if visuals increase trust and if information about a technology can increase trust overall. It is possible, for example, that more information about a new, complex technology that has the potential to seem intimidating could actually decrease trust, although here trust was lowest in the no information condition. These results in particular need additional research and theory to explore the broader relationships between trust and knowledge about health technologies.

The levels of interest in BCI were the most similar across conditions compared to the other outcome variables tested in this study. This suggests that even with larger sample size and more robust measures, interest may not be influenced by increased understanding of a technology. The limited relationships between interest and other potential moderators such as experience or prior knowledge of BCI and with training such as classes suggests that this relationship is weak at best. The means for interest were overall higher than for trust or understanding at close to 3.8 for all conditions compared to a range of 3.2 to 3.8. The lack of significant findings could therefore alternatively be due to a ceiling effect, where interest was already somewhat high for this technology and additional information of any kind would have little effect. Indeed, because participants had choices about which study to join in the recruitment process, it is possible that those who already had some interest in BCI self-selected into this study, creating an artificially high level of interest measured on the scale used.

Overall, this study indicates that information that uses visuals, including artistic visuals that may be more difficult to link to concrete facts, improve understanding of a complex health technology. Despite the fact that hypotheses 1 and 2 were not supported, it is encouraging that the artistic expression of the technology did not *hinder* trust, understanding, or interest. The limitations of the study, discussed next, likely contributed significantly to the overall lack of findings in the study, and further research is needed to understanding the relationships between visuals of different types and perceptions of complex health technologies.

5.1 Limitations

This theory posits that people learn better when both words and images are integrated, as opposed to words alone, and although this study did not observe this, the lack of significant findings in the tests of hypotheses 1 and 2 may be due to several limitations. (Mayer, 2001; 2017, 2019). First, the sample size was small. Because there were only 86 valid cases in this study, and effect sizes seem to be quite small, it is possible that real effects were not captured at statistically significant levels in the tests but would be present with a larger sample size. Indeed, when examining the coefficients for the correlations, their direction is as hypothesized, suggesting that future research may uncover additional important relationships. As statistical power refers to the level of probability for discovering an effect if it exists, the small sample size of this study is a weakness, as a larger sample size may have made it easier to identify effects present. If, as results and analysis imply, the effects on trust, interest, and understanding of art versus the non-art conditions are small, a larger sample size would have been needed to detect them. Due to the low statistical power of this project, small effects could have gone undetected resulting in the presence of Type II errors (Wimmer & Dominick, 2014). Future research with a larger sample is needed to determine if the trends found in the present study are consistent and predicatable.

Second, this study attempted to generate responses to art and text in an online survey that are hypothesized to occur in a real-world space such as in a clinic or hospital. It is possible that if participants saw the art, text, and diagram in full-size in a clinic that their responses would be different. This would be especially important if part of the mechanism that art triggers in such spaces is related to attention. That is, if art draws participants' attention more than just text or more than text and a diagram, the art could have a more powerful impact than these types of displays. This is in-line with theories of information processing that suggest an individuals' ability to learn is influenced by a variety of factors including the amount of attention given to information for selective processing, levels of motivation, as well as emotion responses. Similarly, theories of novel information suggest that people pay more attention to novel or unusual imagery, which would be provided by art to a greater degree than by a diagram or than by text alone (Stuckey & Nobel, 2010; MacInnes & Price, 1987). If an artistic rendering of BCI as used in the present study were more likely to seem novel or unusual to viewers, it may have a greater impact on comprehension and interest than a diagram or text-only information formats.

Items worth additional consideration are that this study sought to emphasize the perceptions of understanding rather than aspects of learning and retention. A limitation to this study may be that follow-up testing was not conducted after exposure to one of the three conditions and control. Despite results of a regression analysis failing to identify any significant moderators, findings suggest that prior knowledge, awareness, and experience of and with the technology could have acted as potential moderators on comprehension, interest, trust, and general comfort with the technology. Also, whether participants reported knowing someone experiencing communication difficulties significantly impacted levels of trust, as did whether participants were more likely to seek out art. General interest in medical technologies impacted levels of understanding as well.

5.2 Concluding Summary

Although this analysis did not result in all 3 hypotheses being supported, this work still demonstrates that art, despite not significantly improving participant levels of understanding towards this technology, did not hinder understanding. This result is somewhat surprising, as Mayer suggests that concrete, specific visual information (such as in a diagram) should improve comprehension, but illustrative or decorative information should hinder comprehension. This study did not find this to be the case. In other words, although theories about the potential for distraction that artistic information about a topic may introduce, in this study participants did not experience lower comprehension when artistically rendered information was included. Although this finding does not indicate, as hypothesized, that art improves comprehension, trust, or interest, it may be the case that art offers other benefits to individual responses to complex information in relation to health technologies.

This is especially encouraging because many health environments such as clinics and hospitals use art as décor and aim to use it to put patients at ease to counteract the stress of coming to a health provider for treatments or diagnoses. This study did not assess whether participants felt more at ease or comfortable in general – instead, it only asked about their feelings about the specific technology being studied. Future research in a more real-world setting is needed to determine if there are benefits to displaying art that is related to health technologies in healthcare settings beyond the ones tested here.

Overall, this study indicates that future research is needed to unpack what aspects of comprehension are influenced by the mere presence of information and what are influenced by information in different formats in this context. Moving forward, this study will contribute to initial and exploratory research efforts designed to gain greater insight and better understand the impact that art and images within medical spaces and communities can generate. This work provides a step towards better understanding art and its persuasive goals within communicating complex information and moves research efforts closer towards recognizing how artistic content may change perceptions.

CHAPTER 6. CONCLUSIONS

This research aims to examine whether visual information, in the form of artistic expression, can influence levels of trust, comprehension and interest towards complex health technologies. This analytical approach assumes that visuals can communicate complex messages and evoke emotion and understanding and seeks to assess how art can contribute to more effective means of communicating health and science information. Research shows visual information contributes to people's understanding of information, conceptual awareness, and external narratives. Despite this, research almost always emphasizes graphic or realistic visual representations of content such as, diagrams, photographs, or illustrations, while less is known about the role that more art and abstract visual messages might play in people's perceptions of complex communication and health-related technologies.

The findings of this study help us to better understand the role of visuals in communicating health and science information, especially in order to improve trust and understanding towards emerging and complex technologies. It contributes to theories about multimedia learning by expanding research into artistic images, which is currently limited in the literature. Although the study's sample size is limited, thus reducing generalizability, the results provide insight on how adults learn about complex health technologies for future scholars. Additionally, this research acknowledges the role of art and design in communication and seeks to construct new interpretations for technological spaces by engaging explanation and understanding through art.

6.1 Inferences

The current study contributes to multimedia and messaging theories that has been less often examined. There was a significant main effect on visual information and levels of understanding which is in line with Mayer's cognitive theory of multimedia learning. Given these statistical analyses, it could be inferred that art can be considered as a mode of visual content that could be applied within efforts to improve individual levels of understanding towards complex information. Although not all of the hypotheses were supported, this research can expand existing and limited potentials for evaluating artistic representations for individual and communal meaning making inquiries. The population was confined to university students, but if open to professionals as well as universal populations, it could offer further insight into the persuasive and informative impact of art.

6.2 Critical Analysis of Project

Using cognitive, visual literacy, meaning making and health communication theories, this project contributes to existing research outlining the significance of visuals for the comprehension of complex health and science information. This research helps us better understand the role of visuals in communicating science and technology in health, especially in order to levels of understanding associated with specific technologies. It will also contribute to knowledge pertaining to abstract representations, such as artistic work, can influence perceptions of technology. Additionally, this research can help practitioners improve and broaden their efforts in increasing individual awareness and opinion formation towards health technologies through communication. This project further explores art exhibit pieces as a tool for encouraging conceptual understanding and attitude change towards sophisticated technologies.

6.2.1 Instrument Limitations

It is possible that there may be issues with adapting scale questions, question clarity, and could be affected by bias due to the researcher being involved in designing and determining which visuals participants will be exposed to. It is also possible that more open-ended questions could have provided more insight into the hypothesized relationships. Limiting participation by requiring the survey to be taken on a desktop rather than a mobile device could present a barrier and subsequently could have contributed to a smaller sample size. Also, it is of note that this project was to include a second component of in-person surveys to assess the impact of art within a health space. This would have provided more context into the communicative impact that art may have. The pandemic required the research design to be revisited and altered.

6.2.2 Data Sampling and Analysis Limitations

Analytical issues may have impacted the results of this study. One-way ANOVAS were used in order to be able to test multiple independent variables and multiple groups, while independent t-tests were used to assess the effect of an independent variable on two samples of the population (Wimmer & Dominick, 2014). Additionally, possible issues with Qualtrics and random assignment pertaining to gender may present potential problems with the data gathering approach, sample, and analysis procedures. The survey used in this study could be affected by bias due to the researcher being involved in designing and determining which visuals participants will be exposed to. Limits to this study also include issues of testing with a smaller population size.

6.2.3 Inferences Limitations

There are some possible pitfalls to the assumptions presented by this study. This project uses inferential statistics and the data collected may have to be adjusted in order to be applied to other groups of people. This study was comprised of 126 variables with some removed for reliability concerns. Issues with reliability with translating scales may have presented problems to this research. Another issue that arose was from the Tech Secure scale as having no causal direction and serving as a variable rather than moderator. This study tested these items after exposure however, these items are not really moderators as it is unclear without exposure to a condition.

6.2.4 Exploratory Analysis of Open-Ended Responses

Of note were a few interesting individual variables that included responses to the following questions: “Have you ever taken an art history course in college or at the college level?” “Do you like visual art such as paintings and photographs?” and post survey measures evaluating trust in BCI technologies. Additionally, responses to two open-ended questions included at the end of the survey that asked, “What are your general impressions about this technology? How do you feel about future advances of BCI systems?” provided an opportunity to acknowledge participants’ perception and opinions alongside measure responses. Reactions ranged from sentiments of excitement to those expressing ethical and dystopian concerns. Overall, most responses reflected conceptual consideration on behalf of the participant and suggested optimistic and hopeful outlooks for the future of the technology, citing recognition of its potential benefits, however, mentions of risk, a sense of social responsibility and some anxieties were also noted.

6.3 Future Projects

Future research could add to the validity of these inferences. Several conceptual projects could support this work in the future. For example, artistic representations of mammograms from breast cancer survivors within a treatment center could assess levels of self-efficacy, trust and comprehension towards the health conditions patients face, as well as towards the treatments they are receiving could be examined.

This work could also be furthered through efforts that explore patient-led treatment models and patient-led care approaches for creative expression through reciprocal learning processes between a user and a BCI interface (see Jones et al., 2018, for patient-led treatment model, see National Organization for Arts in Health 2017 for patient-centered care, p. 17). Multi-step learning processes that serve not only for calibration between human/computer, but also provide therapists and loved ones with opportunities for expanded conversation pertaining to user experiences through artistic forms of mediated communication could shed light on interface navigation via artistic representation of biological data.

Ultimately, this research could offer initial support for work that highlights the importance of recognizing the potential for BCIs to act not only as an interface with which to develop a creative product, but as a communicative and social technology centered around the enablement of discussion and understanding of the art which is created. It could offer more inclusive reconsideration of not just the interface design, but the entire environment in which the user/technology interaction occurs, as well as the social interactions that take place once the creative process is complete. It is only when the user is allowed expression through a process that is specifically tailored to their individual capabilities and needs, that full therapeutic benefits of identity-formation and self-expression can be realized.

Using artistic representations to communicate information about complex and emerging communication health technologies is an important step towards cultivating mindful levels of awareness, understanding, comprehension and trust towards the intended development and holistic perception formation towards these systems, as well as consideration of the users who rely on them for maintaining external communicative ties. Given that visuals used within communication mediate our understanding of a phenomenon, and technology subsequently mediates communication, art should be considered as a tool that mediates information and emotion translated to action through perception.

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APPENDICES

Appendix A: Survey Questions

Medical Technologies Survey
Start of Block: Informed Consent

Q59 Thank you for participating in this study. This survey will take about 20 minutes.

Please note: because of the design of this study, you may only take the survey on a laptop or desktop computer. It will not work on your mobile phone.

If you are currently accessing the survey from your phone, please close this survey and try again from another device.

Q1 Consent Thank you for your interest in our impact of visual information for understanding complex health technologies research! You must be a student at Colorado State University and at least 18 years of age or older to participate in this survey.

There are no known risks to participating in this survey. Through this survey, we hope to gain more knowledge about Brain-Computer Interface Technologies. The survey is voluntary, anonymous, and should only take about 20-25 minutes of your time. If you decide to participate in the survey, you may withdraw your consent, stop the survey and exit at any time without penalty.

We will not collect your name or personal identifiers. When we report and share the data with others, we will combine the data from all participants. There are no known risks or direct benefits to you, but we hope to gain more knowledge on the communicating science and technology in health, more specifically, Brain-Computer Interface technologies (BCIs).

To indicate your consent to participate in this research, please click the consent button located below and proceed to the survey. If you do not consent to the survey or are under the age of 18, please exit now.

If you have any questions about the research, please contact Stephanie Scott at SMS.Scott@colostate.edu. If you have any questions about your rights as a volunteer in this research, contact the Colorado State University Institutional Review Board at: RICRO_IRB@mail.colostate.edu; 970-491-1553.

○ Yes, I have read the above information and consent to participate in the survey

○ No, I do not wish to participate in this study

Skip To: End of Survey If Thank you for your interest in our impact of visual information for understanding complex health... = No, I do not wish to participate in this study
End of Block: Informed Consent

Start of Block: Demographics

Q28 We would like to know more about you so that we can understand how different people think about medical technologies. Please answer the following questions.

Q29 Age Please enter your age:

____

Q30 Gender How do you describe your gender?

- ◯ Female/Woman
- ◯ Male/Man
- ◯ Other ____
- ◯ Prefer not to answer

Q31 Race How do you describe your race? Please check all that apply.

- ▢ American Indian or Alaska Native
- ▢ Asian
- ▢ Black or African American
- ▢ Hispanic or Latino or Latinx
- ▢ Native Hawaiian or Other Pacific Islander
- ▢ White
- ▢ Other ____
- ▢ Prefer not to answer

Q32 Major What is your major?

____

Q33 Grade What year student are you?

- ◯ First year/Freshman
- ◯ Second year/Sophomore
- ◯ Third year/Junior
- ◯ Senior
- ◯ Graduate student
- ◯ Not currently a student

End of Block: Demographics

Start of Block: Treatment Images

Q58 Cond-noInfo Please click the blue arrow button to move onto the next section.

Q3 Art-text
Please read the following text about a specific medical technology carefully. We will ask your thoughts about the technology later in the survey.

Brain-Computer Interface (BCI) systems allow a person to use signals from their brain to control a computer device, such as a cursor on a computer screen, a prosthetic limb, or a wheelchair. BCI allows users to control the object directly with their brain activity - by simply thinking, a person can send commands to a computer. This is done by attaching a cap with sensors (electrodes) to a user's head that sends electric activity to a computer. The computer then uses artificial intelligence algorithms to analyze the information acquired from the user's brain signals and perform external actions. Those actions can be, for example, moving a cursor to select letters on a screen, selecting tools and colors to draw images, or even controlling other devices such as a wheelchair.

Because BCI does not require the use of vocal cords or hands, it can allow people who cannot speak or use their hands to communicate, draw, or control other devices. BCI can enable a person suffering from paralysis to write a book or control a motorized wheelchair or prosthetic limb by thought alone.

Current BCI devices require different techniques for control, such as imagining moving your left or right arm, or visual focusing strategies, and considerable training to work properly. Some future applications, such as controlling a prosthetic leg, have the potential to work become more natural as the body learns the system.

Now, please look at the following image and read the caption.

Title: Identity Through Movement
CAPTION: This piece was created using a Brain-Computer Interface system. The artist used software that aided in controlling a robot with their brain waves to control the paint distributed on the canvas. The artist used a projector mounted on the ceiling to project brainwaves of a participant testing software developed by the CSU BCIL research group as inspiration. This piece serves to express individual identity through the representation of neurological data.

Q4 Diagram-text
Please read the following text about a specific medical technology carefully. We will ask your thoughts about the technology later in the survey.

Brain-Computer Interface (BCI) systems allow a person to use signals from their brain to control a computer device, such as a cursor on a computer screen, a prosthetic limb, or a wheelchair. BCI allows users to control the object directly with their brain activity - by simply thinking, a person can send commands to a computer. This is done by attaching a cap with sensors (electrodes) to a user's head that sends electric activity to a computer. The computer then uses artificial intelligence algorithms to analyze the information acquired from the user's brain signals and perform external actions. Those actions can be, for example, moving a cursor to select letters on a screen, selecting tools and colors to draw images, or even controlling other devices such as a wheelchair.

Because BCI does not require the use of vocal cords or hands, it can allow people who cannot speak or use their hands to communicate, draw, or control other devices. BCI can enable a person suffering from paralysis to write a book or control a motorized wheelchair or prosthetic limb by thought alone.

Current BCI devices require different techniques for control, such as imagining moving your left or right arm, or visual focusing strategies, and considerable training to work properly. Some future applications, such as controlling a prosthetic leg, have the potential to work become more natural as the body learns the system.

Now, please look at the following image and read the caption.

CAPTION: BCI systems enable communication by providing a direct link between a functioning brain and the outside world. These systems operate by translating brain activity that is recorded via electrical impulses into a generated output to replace and restore function, or control an external device, such as a robot, a prosthetic limb, or a wheelchair. The data is recorded through a EEG cap that an individual places on their scalp. The information provided by an individual's brain is then precoded and decoded using Artificial Intelligence algorithms, and then translates this information into a desired actionable output.

Q5 Narrative-only
Please read the following text about a specific medical technology carefully. We will ask your thoughts about the technology later in the survey.

Brain-Computer Interface (BCI) systems allow a person to use signals from their brain to control a computer device, such as a cursor on a computer screen, a prosthetic limb, or a wheelchair. BCI allows users to control the object directly with their brain activity - by simply thinking, a person can send commands to a computer. This is done by attaching a cap with sensors (electrodes) to a user's head that sends electric activity to a computer. The computer then uses artificial intelligence algorithms to analyze the information acquired from the user's brain signals and perform external actions. Those actions can be, for example, moving a cursor to select letters on a screen, selecting tools and colors to draw images, or even controlling other devices such as a wheelchair.

Because BCI does not require the use of vocal cords or hands, it can allow people who cannot speak or use their hands to communicate, draw, or control other devices. BCI can enable a person suffering from paralysis to write a book or control a motorized wheelchair or prosthetic limb by thought alone.

Current BCI devices require different techniques for control, such as imagining moving your left or right arm, or visual focusing strategies, and considerable training to work properly. Some future applications, such as controlling a prosthetic leg, have the potential to work become more natural as the body learns the system.

End of Block: Treatment Images

Start of Block: Post Survey Measures

Q6 We're interested in your thoughts and feelings about Brain-Computer Interface technology, also called BCI.

Please answer the following questions as honestly as possible.

Q53 *Please indicate how much you agree or disagree with the following statements about BCI, or Brain-Computer Interface technologies:*

Q52 post1-interest I find BCI technologies interesting.

- ○ Strongly disagree
- ○ Somewhat disagree

- Neither agree nor disagree
- Somewhat agree
- Strongly agree

Q51 post2-learn I would like to learn more about BCI technologies.

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

Q50 post3-read I would probably read more about BCI if I had the chance.

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

Q49 post4-convo I would be interested in having a conversation with someone who is an expert in BCI technologies.

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

Q48 post5-more-R I don’t need to know any more about BCI technologies.

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree

○ Strongly agree

Q8 BCI-Understand
These questions refer to Brain-Computer Interface (BCI) technology.

Please indicate how much you agree or disagree with the following statements:

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I feel like I understand BCI technologies better after seeing the information about them.	○	○	○	○	○
I am confused about what BCI is.	○	○	○	○	○
I understand what BCI technologies are for.	○	○	○	○	○
I understand why BCI technologies are important/useful.	○	○	○	○	○
I believe I could explain what BCI technologies are to someone else pretty easily.	○	○	○	○	○
I have a good idea of how BCI technologies work.	○	○	○	○	○

End of Block: Post Survey Measures

Start of Block: Trust in Medical Technology (TMT)

Q9 BCI-Trust1
These questions refer to Brain-Computer Interface (BCI) technologies.

Please indicate how much you agree or disagree with the following statements:

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I trust BCI technologies.	○	○	○	○	○
I have positive feelings about BCI technologies.	○	○	○	○	○
I believe BCI technologies will successfully work.	○	○	○	○	○

I believe BCI technology is well researched.	○	○	○	○	○
I have confidence in BCI technologies.	○	○	○	○	○
I believe BCI technologies are helpful.	○	○	○	○	○
I believe BCI technologies are effective.	○	○	○	○	○

Q55 BCI Trust2
Please indicate how much you agree or disagree with the following statements:

I believe BCI technologies are...

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Accurate	○	○	○	○	○
Trustworthy	○	○	○	○	○
Reliable	○	○	○	○	○
Safe	○	○	○	○	○
Precise	○	○	○	○	○
Honest	○	○	○	○	○

End of Block: Trust in Medical Technology (TMT)

Start of Block: Visual Comprehension (Adapted from Jones et al., 2019)

Q47 We are interested in your views on how health information is presented.

Please indicate how much you agree or disagree with the following statements.

Q45 Viz1-noPic I often find that health information that uses words, but no pictures, is harder to follow.

○ Strongly disagree

○ Somewhat disagree

Neither agree nor disagree

Somewhat agree

Strongly agree

Q44 Viz2-pic When it comes to understanding health information, I find an image is worth a thousand words.

Strongly disagree

Somewhat disagree

Neither agree nor disagree

Somewhat agree

Strongly agree

Q43 Viz3-noAid-R I am the sort of person who doesn't need visual aids (e.g., pictures, diagrams) to understand health information.

Strongly disagree

Somewhat disagree

Neither agree nor disagree

Somewhat agree

Strongly agree

Q42 Viz4-verb-R I prefer a straightforward verbal or written explanation of a health risk to one that includes illustrations.

Strongly disagree

Somewhat disagree

Neither agree nor disagree

Somewhat agree

Strongly agree

Q46 Viz5-written-R When I am informed about health considerations, I prefer a written document rather than one with pictures or diagrams.

Strongly disagree

Somewhat disagree

○ Neither agree nor disagree

○ Somewhat agree

○ Strongly agree

End of Block: Visual Comprehension (Adapted from Jones et al., 2019)

Start of Block: Insecurity

Q11 Now we would like you to tell us about your thoughts and feelings on technology more generally. The following questions have statements about technology and computers.

Q14 Tech-Insecure *Please indicate how much you agree or disagree with the following statements:*

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Revolutionary new technology is usually a lot safer than critics lead people to believe.	○	○	○	○	○
A machine or computer is going to be a lot more reliable in doing a task than a person.	○	○	○	○	○
It can be risky to switch to a revolutionary new technology too quickly.	○	○	○	○	○
If I purchased something from a machine using a credit card, I would usually NOT require a receipt	○	○	○	○	○
Technological innovations always seem to hurt a lot of people by making their skills obsolete.	○	○	○	○	○
I prefer to have people handle my health procedures than to use medical technologies.	○	○	○	○	○
I don’t like the fact that medical technologies are becoming so prevalent in our daily lives.	○	○	○	○	○
I feel more confident dealing with a human medical professional than a medical technology.	○	○	○	○	○

End of Block: Insecurity

Start of Block: BCI Questions

Q16 This section asks questions about your background and prior knowledge of BCI, or Brain-Computer Interface technologies.

Q17 BCI-Heard Had you ever heard of Brain-Computer Interface (BCI) technologies prior to this study?

○ No

○ Yes

○ Not sure

Q18 BCI-used Have you ever seen or used BCI technologies in person?

○ No

○ Yes

○ Not sure

Q19 BCI-seenVid Have you ever read about or seen videos about BCI technologies before participating in this study?

○ No

○ Yes

○ Not sure

Q20 Comm-diff-Self Do you experience communication difficulties at times?

○ No

○ Yes

○ Not sure

Q21 Comm-diff-Other Do you know anyone that has experienced or is experiencing difficulties in communicating from a stroke, injury or cognitive impairment?

○ No

○ Yes

○ Not sure

Q15 Mani-check Thinking back to the start of this survey, you saw some information about BCI technologies.

Please indicate whether you agree or disagree with the following statements.

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree	Don't know.
I only saw a text description of BCI in this survey.	○	○	○	○	○	○
I saw text and an image I would consider to be art or artistic at the start of this survey.	○	○	○	○	○	○
I only saw an image related to BCI but no text describing it in this survey.	○	○	○	○	○	○
I read the passage about BCI in this survey carefully.	○	○	○	○	○	○
I can clearly remember the information about BCI that I learned at the start of this survey.	○	○	○	○	○	○
I saw a video about BCI at the start of this survey.	○	○	○	○	○	○

End of Block: BCI Questions

Start of Block: Prior Knowledge and Interest

Q22 The following questions ask about your background and experience with art such as drawing, painting, photography, sculpture, or graphic design. There are no right or wrong answers. We are interested in your opinions and activities related to creating and viewing art of any type.

Q25 Do you like visual art such as paintings and photographs?

○ Definitely not

○ Mostly not

○ Somewhat yes, somewhat no.

○ Mostly yes

○ Definitely yes

Q23 Art-like *Please indicate how much you agree or disagree with the following statements:*

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I am very familiar with art and art history.	○	○	○	○	○
I consider myself a visual artist (painting, photography, sculpture, lithographs, etchings, etc.).	○	○	○	○	○
I've never really been interested in visual art.	○	○	○	○	○
I have a clear understanding of the difference between abstract art and representational art.	○	○	○	○	○
I love going to art museums.	○	○	○	○	○
I don't know much about art, but I often seek it out.	○	○	○	○	○

Q24 Have you ever taken an art history course in college or at the college level?

○ Yes

○ No

○ I'm not sure

Q26 Art-time Thinking back to the past month, about how many hours did you look at art, such as in a museum, a campus exhibit, a gallery, a café or other public display, or online?

○ None or almost none

○ Less than 1 hour

○ 1-3 hours

○ More than 3 hours

Q27 Med-interest This question is about your personal experience with complex medical technologies of any type. These are technologies used by medical professionals in clinics, doctor's offices, or hospitals. Medical technologies might include MRI or CAT scans, surgery technologies, an ultrasound scan, heart rate monitor machines, or any other complex device used for medical diagnosis or care.

As you answer, do NOT include your experiences with simple medical technology such as getting shots, taking your temperature, etc. Consider only complex medical technologies as you answer.

Please indicate how much you agree or disagree with the following statements:

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I am very interested in medical technologies in general.	○	○	○	○	○
I have a good idea what kinds of technologies are used by hospitals.	○	○	○	○	○

Q57 Do you have any experiences with medical technologies as a patient or as family or friend of a patient? Medical technologies might be having surgery, a scan, or other complex diagnostic or treatment devices used on you.

○ A great deal

○ A lot

○ A moderate amount

○ A little

○ None at all

Q56 Have you ever studied medical technologies in school?

○ None at all

○ A little

○ A moderate amount

○ A lot

○ A great deal

End of Block: Prior Knowledge and Interest

Start of Block: Open-Ended

Q60 What are your general impressions about this technology? How do you feel about future advances of BCI systems?

____

End of Block: Open-Ended

Start of Block: Debriefing

Q34 Debrief Thank you for participating in this study. The purpose of this study was to determine if and how artistic representations of a medical technology, Brain-Computer Interface, have an impact on people's perceptions of that technology or on medical technologies in general, especially trust, interest, and knowledge related to the technology. It aims to expand knowledge and scholarship about the type of images that can contribute to public understanding of complex health technologies.

The findings of this study will help scholars better understand the role of visuals in communicating science and technology in health, especially in order to improve trust in complex new technologies. It will also contribute to understanding of the role of more abstract forms of representation, such as artistic works, in perceptions of technology.

If you have any questions about the research, please contact Stephanie Scott at SMS.Scott@colostate.edu. If you have any questions about your rights as a volunteer in this research, contact the Colorado State University Institutional Review Board at: RICRO_IRB@mail.colostate.edu; 970-491-1553.

Appendix B: Recruitment Materials

Mass Email Notification SONA

Hello,

If you are receiving this message, it is because your instructor, in one or more of your classes housed in the Journalism & Media Communication Department, has registered you for the opportunity to participate in research studies to earn extra credit through SONA.

Currently, there is **XX** remaining research studies in the system that will be ending soon. By participating in one or more of these (or future) studies, you are eligible to receive extra credit in your JMC class.

Title: Impact of visual information for understanding complex health technologies

Online **SURVEY/EXPERIMENT**—[0.5] SONA credit; Open until ____

Description: This survey is interested in understanding the role of visuals in communicating science and technology in health, more specifically, Brain-Computer Interface technologies (BCIs). Participation will take approximately 15-20 minutes. This survey is completely anonymous and will not collect your name or personal identifiers.

Please remember that study participation is on a first come, first serve basis. If you are having any technical difficulties, please contact Zoey Rosen (zoey.rosen@colostate.edu)

Reminder Mass Email SONA

Hello,

If you are receiving this message, it is because your instructor, in one or more of your classes housed in the Journalism & Media Communication Department, has registered you for the opportunity to participate in research studies to earn extra credit through SONA.

Currently, there is **XX** remaining research studies in the system that will be ending soon. By participating in one or more of these (or future) studies, you are eligible to receive extra credit in your JMC class.

Title: Impact of visual information for understanding complex health technologies

Online **SURVEY/EXPERIMENT**—[0.5] SONA credit; Open until ____

Description: This survey is interested in understanding the role of visuals in communicating science and technology in health, more specifically, Brain-Computer Interface technologies (BCIs). Participation will take approximately 15-20 minutes. This survey is completely anonymous and will not collect your name or personal identifiers.

Please remember that study participation is on a first come, first serve basis. If you are having any technical difficulties, please contact Zoey Rosen (zoey.rosen@colostate.edu)

Survey Invitation Email

Dear [Student Name],

I am contacting you to ask for your help with a survey.

You have been selected to complete a short questionnaire about **impact of visual information for understanding complex health technologies**.

Participating in this survey could help inform future strategies at CSU, and your voice is valuable.

You will be given 0.5 SONA Credits, equaling typically 2.5 extra credit points, for completing the survey.

The survey should take about 15-20 minutes to complete. You will complete this survey on SONA, using this link: [LINK].

This survey is completely voluntary and confidential. You may choose to skip questions in the survey if you prefer not to answer.

If you have any questions or concerns, please contact me, Stephanie Scott, at SMS.Scott@colostate.edu.

Thank you for in advance for your help with my survey. If you are not interested in participating or believe you were contacted in error, you may opt out by replying to this email.

Stephanie Scott

SMS.Scott@colostate.edu

In-Class Recruitment Script

Hello!

My name is **Stephanie Scott** and I am a **MS** student in the department of Journalism and Media Communication.

I am currently working on a study that examines **impact of visual information for understanding complex health technologies**.

Participating in this survey could help inform future strategies at CSU, and your voice is valuable.

The survey is anonymous, voluntary, and should only take about 15-20 minutes to complete. You can

Earn ½ SONA Credit, equaling typically about 2.5 extra credit points, for participating in the survey.

I am sending the survey out tomorrow.

If you have any questions or concerns, please email me SMS.Scott@colostate.edu.

Thank you!

Appendix C: Art Process