January 2018

Parting A Read Sea Of Images: An Exploration Of Field Dependent-Independent Responses To Minimalist, Pictographic And Infographic Data Displays

Debra Kaye Jenkins

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PARTING A READ SEA OF IMAGES: AN EXPLORATION OF FIELD
DEPENDENT-INDEPENDENT RESPONSES TO MINIMALIST, PICTOGRAPHIC
AND INFOGRAPHIC DATA DISPLAYS

by

Debra Kaye Jenkins
Bachelor of Science, University of North Dakota, 2007
Master of Science, University of North Dakota, 2010

A Dissertation
Submitted to the Graduate Faculty

of the

University of North Dakota

in partial fulfillment of the requirements

for the degree of

Doctor of Philosophy

Grand Forks, North Dakota

May
2018
This dissertation, submitted by Debra Kaye Jenkins in partial fulfillment of the requirements for the Doctor of Philosophy from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done and is hereby approved.

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This dissertation is being submitted by the appointed advisory committee as having met all of the requirements of the School of Graduate Studies at the University of North Dakota and is hereby approved.

Dr. Grant McGimpsey, Dean of the School of Graduate Studies

May 1, 2018

Date
PERMISSION

Title Parting a Read Sea of Images: An Exploration of FDI Responses to Minimalist, Pictographic and Infographic Data Displays

Department Teaching and Learning
Degree Doctor of Philosophy

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Debra K. Jenkins
April 25, 2018
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I dedicate my dissertation to my children and my grandchildren. I pray they all aspire to their highest callings and contribute to the well-being of states, nations and people throughout the earth. And to my Lord Jesus who brought me through darkness into light.
ABSTRACT

Western society reflects an “eikoncentric era” when contemporary instruction has become image-centered. Textbooks, journals, popular media as well as computer-based and web-based instructional media are filled by pictures that are intended to accomplish learning. Imagery is widely believed to represent an efficient, understandable method for relaying information and clarifying instruction for nearly all learners. However, those who subscribe to the adage “a picture is worth a thousand words” often fail to acknowledge individual differences in visual comprehension and cognition. The field dependent-independent (FDI) cognitive style describes individual learner differences that can thwart visual learning. Information graphics are among the frequently used types of imagery that portray data. There is little empirical evidence to guide their design, and their creation is often based on intuition or opinion. This study researched the ways FDI learners comprehend and aesthetically assess minimalist information graphics, pictograms and infographics. Those participants who represented the most extreme field-dependent or field-independent learners were invited to participate in a two-part study. An instrument named the Comparative Information Graphic Test (CIG-T) was developed for testing comprehension of and perceived aesthetic efficacy, value and preference for minimalist information graphics, pictograms and infographics by FDI learners.

Keywords: information graphics, data displays, field dependent-independent cognitive style, visual learning, visual cognition, visual instructional design, eikoncentric era, medieval learning, graphs, charts, pictograms, infographics, Gestalt
CHAPTER I
INTRODUCTION

Contemporary urban Western Europeans and Americans are immersed in a sea of images (Helfand, 1997; Martins, 2002; Schroeder, 2002; Ratwani, Trafton, & Boehm-Davis, 2004; Gitlin, 2007; Gillenwater, 2009; Gurri, Denny, & Harms, 2010; Hixon, Barczyk, Buckenmeyer, & Feldman, 2010; Przyborski, A., & Slunecko, 2012; Schroer, 2014). Schroer (2014), commenting on the pervasiveness of images in society, said, “In light of the abundance of visual material surrounding us in our daily environments, it can hardly be denied that we live in a ‘visual culture’” (p. 206). Considering this prominence of imagery, “we have, over time, come to regard sight as providing our immediate access to the external world” (Jenks, 1995, p. 1) and this is reflected by the “primacy Western culture attaches to vision” (Otto, 2005, p. 363).

Because images are so pervasive, and because they are viewed as our “immediate access” to the world, we tend to rely on them (subconsciously and consciously) as primary modes of learning about the world. It is perhaps no surprise, then, that images are often used for informational and instructional purposes. Although distinctions between “instructional” and “non-instructional” images have been made, the reality is that many types of images can be useful for diverse kinds of learning. People can learn, for example, informally or formally from paintings, posters, billboards, architecture, websites, labels or storybook pictures, graphs, diagrams, charts, photographs, cartoons or advertisements. Although artists or designers have often made a distinction between
images as “art” vs. “information,” that dividing line is blurred. Practitioners in various fields tend to qualify imagery according to their fields’ aesthetics.

Graphs and charts, for instance, are normally considered by statisticians as utilitarian informational visual aids. The importance of graphics and the blurred line between information and art is exampled by the incorporation of imagery into graphs and charts. Pictorial statistics, or in other words, statistical displays that embed imagery into graphs and charts, can be found in popular culture, media, advertising and marketing, and in a large assortment of educational venues. Created by professional graphic artists for popular audiences, these pictorialized graphs or charts may be judged by others as inadequate or cartoonish.

Fine artists, for example, may view imagery in graphs or charts as utilitarian and lacking a fine arts aesthetic. Art historian James Elkins (1995) argued that imagery can go unacknowledged as art by other practitioners, such as communications theorists. Elkins noted, “in the dry language of communication theory, images found in graphs, charts or pictographs are used solely to convey information” (p. 155).

Scientific or instructional design communities have sometimes viewed charts or graphs that incorporate artistic imagery as unnecessarily embellished. Imagery, in their frames of reference, competes with data for a viewer’s attention. However, whether embellished with imagery or not, charts and graphs as visuals tools for learning are increasingly used in both formal and informal instructional media.

When it comes to educational materials that incorporate graphic elements, the goal of an instructional designer should be to determine which images among many are
likely to benefit a learner in terms of the instructional goal. The goal is to “part a sea of read images” into those that enhance and those that may detract from learning.

**A Two-Fold Study Purpose**

This study had a two-fold purpose. The first was to create a general treatise about visual instruction and instructional design from the medieval eikoncentric through the contemporary eikoncentric eras. The approach to this study on visual instruction and cognition was intentionally holistic---considering an array of influences, beyond scientific findings, that affect the real-world design of visual instruction.

This review of literature was deemed important because some influential factors in visual instruction are seldom discussed. Scientific experiments conducted during the early cognitivist era and the breadth of research about visual perception, communication and cognition across fields may be relatively unknown. The obscurity of historical insights and empirical evidence, have potential to cause instructional designers to believe all contemporary work on visual instruction is original. This faulty premise can lead to studies that essentially “re-invent the wheel” because there is limited knowledge about prior research or field-tested practices.

Many visual instruction research designs over the past half century have been wedded to cognitivist thought. These studies often yielded findings about visual instruction based on examination of single elements. This approach to visual instruction research is limited and rarely addended with holistic consideration of historical and social factors that impact design.

Assorted guidelines for organization and design of instructional screen media or for print have often been developed and endorsed after research of single variables. Much
of the recent research that has yielded practical guidelines for design is recast from conscious or unconscious reexamination of historical beliefs. These may date anywhere from to antiquity to the early to mid-twentieth century when ideas about Gestalt principles emerged. However, opinion has also guided design in the absence of any clear-cut empirical evidence.

Eikoncentric Eras

The last eikoncentric (or image based) era of learning and instruction occurred during medieval times before the advent of the moveable type printing press (During an eikoncentric era text, images and numerical figures are always a part of instruction but imagery becomes a greater focal point in instruction). Chapter Two demonstrates how Western society began exiting a grammacentric (or text-based) era of learning, during the latter part of the 1800’s as new print and media technologies made pictorial material more accessible for instruction and communication of information. Text was no longer the dominant or only way to learn about a subject.

Unfortunately, when considering the use or design of informational images, practices have been driven by more arbitrary and inconsistent practices than empirical evidence. The principles used to generate instructional images are not well informed by historical, sociological, cultural, or empirical research factors. Cultural, environmental, and individual learner characteristics also mandate that the impact and processing of graphical elements during learning will vary widely, thus precluding the establishment of “tried-and-true” principles that will work for all contexts and learners. To understand the roots of this issue, and describe visual learning holistically, it was deemed necessary to delve deeper into the history of instructional image and text use in society over past eras.
Chapter II reveals key propositional statements about visual learning made in both medieval and contemporary eikoncentric eras. These propositions resembled each other despite their separation by centuries and greatly differing societal mindsets in almost every other way. Scholars in both time periods, for example, posited memory systems for images, described visual metaphor and analogy and proposed models of stage-like visual processing. Visual instructional design thought was and continues to be related to these concepts.

Today’s instruction is eikoncentric, incorporating an extensive amount of visual material into instruction. Whether on pages of text books (Evans, Watson & Willows, 1987; Bliss, 1990; Woodward, 1993; Martins, 2002; Bungum, 2008; Holsanova, Holmberg, & Holmqvist, 2009; Cook, 2012) or in formal web-based or computer-based learning media or within informal learning media (Bolter, 2000; Kress, 2003; Carifo & Perla, 2009), the visual nature of instruction becomes more established over time.

Scientific research into visual instructional design is of a very recent vintage and made this treatise practically necessary. It may be fair to say few instructional designers have a grasp of the deep roots of historical visual instruction and design. This is problematic because it leaves us with no real historical foundation for visual instruction or launching point for fruitful new research. It may also be fair to say that it is difficult to sort contemporary visual instructional design research that has been characterized as contradictory and a “fascinating, disputatious literature” (Anglin, Vaez, & Cunningham, 2004, p. 866).

Twentieth Century Research. Apart from Gestalt psychology, cognitivism, during the late 1950’s, was the first school of psychology to challenge behaviorism,
recognizing internal mental processes could be studied. This opened the door for examination of visual cognition. Cognitivism, however, for much of its earliest history, was most interested in psychology of speech and memory studies. Picture facilitation studies were among the most important visual studies undertaken in the early years of cognitivism, and of course these studies really investigated ways pictures facilitated reading. Picture superiority experiments were also conducted about the superiority of pictures for memory.

So, the agenda for visual research was often pressed into service of instructional agendas for reading achievement or cognitivist memory study agendas. This is not to undervalue such studies, but merely point out a narrow focus on visual instructional design research in the early years of cognitivism that further short-cut the timeline of contemporary visual instruction research. Research about visual instruction did broaden during the latter cognitivist era. It increased in tandem with development of computer and web-based and computer-based instruction. The nature of research into visual instruction and design, however contemporary, has made nearly all findings from studies difficult to generalize.

**Problems with visual research.** Research of visual instruction and design has always face greater complications than, for example, reading research where letters are nearly uniform except for variation in fonts. Arguably, differing visual characteristics intrinsic to unalike images create predicaments for contemporary visual instruction research. Traits of visual displays or images are not standardized. Images have distinctive stylistic differences. This makes comparisons from one study to the next thorny if a study is not exactly replicated. Photographs are not illustrations are not cartoons are not
realistic oil paintings are not sketches are not diagrams are not pie charts are not watercolors, etc. If color is eliminated in one study from a photograph are the results transferable to a study where color is eliminated from a diagram?

Chapter II questions how much headway had been made toward understanding how to design visual material for learning given our field’s extant, contemporary studies. Although there may certainly be headway, research results may not be as appreciable or applicable as we would like. As recently as 2004, Anglin, Vaez & Cunningham said, despite an accumulation of visual instruction and cognition research, it was “not clear how students use illustrations in instructional materials or that they even know how to use them” (p. 876). This statement was issued at a time when invention in computing technologies led to mass data generation and along with it, a greater need to visually portray data to find meaningful patterns or trends and make sense of data in general. These needs led to questions about how data displays should look and how they should visually transmit data meaningfully for learners.

Visual Instruction from Data Displays

Theories of graph comprehension had been developed as data displays were increasingly used in journals and popular media publications. Cleveland & McGill’s Ten Perceptual Tasks (1984), Stephen Kosslyn’s Analytic System (1989), Pinker’s Theory of Graph Comprehension (1990) are brief examples given in Chapter II as basic theories of graph comprehension. Cleveland & McGill (1984) offered a researched list of ten perceptual tasks that learners used when decoding graphical displays alongside recommendations for graphic design. Kosslyn’s (1989) syntactic, semantic and pragmatic analyses each require assessment of the component parts of a graph or chart, i.e. the
background, the framework, the specifier and the labels, as well as analysis of other organizing principles. It is doubtful that a designer would use his system with regularity for each graph or chart under development due, at the very least, to time constraints.

Pinker found that "a striking fact about human cognition is that we like to process quantitative information in graphic form" (1990, p. 73). He contended that learners begin by studying an information graphic then graph schemas and Gestalt processes are automatically triggered. Pinker's (1990) computational theory posited differences between bottom-up and top down visual processing and acknowledged that individual differences could account for significant differences in graph reading or interpretation. Instruction, he surmised, could overcome individual differences.

Today’s scholars may believe scientific proofs or theories underwrite current visual instruction or information design. It is apparent there have been numerous, earnest efforts by researchers to discover the ways visual cognition operates or how to design instructional imagery for optimal learning. However, research findings may often have a lessor influence on real-world design of visual instruction than other factors.

**Four Determinant Factors**

This author contends in this general treatise that four determinant factors have a greater influence than research on the real-world design of contemporary visual instruction. These determinant factors include: 1) marketplace forces; 2) aesthetics; 3) societal preoccupations/ worldviews based on absolute presuppositions; and 4) the visual rhetoric of communities of practice. The four determinant factors continue to operate co-extensively and powerfully, continuously shaping the landscape of visual instruction and have been at work around visual data representation.
Visual and data display designs for instructional media are not, as many assume, informed by current empirical research so much as they are based on mediation by the earlier mentioned four determinant forces. It is important to recognize the formidable roles these factors play in determining the kinds of information graphics and images that are prevalent in instructional media.

Questions about how data displays should look were publicized around scientific and academic communities during the 1990’s when the Tufte-Holmes debate emerged. Tufte was a statistician who preached use of minimal detail in information graphics and discredited data displays, such as infographics, that included pictorial detail. Holmes was a professional graphic artist who produced pictorial graphs and charts for national newspapers, magazines or journals. Elements of the four determinant forces could be seen at play at that time and are influential today.

First, hard and soft marketplace technologies that made various kinds of static and interactive data visualization possible were under development and expanding boundaries. New marketplace technologies primed marketplace demand for data displays, whether in scientific journals or textbooks or popular print or electronic media.

Second, although there was little, if any scientific evidence, to support Tufte’s contention that minimalist (the term “minimalist” is used as a synonym for “essential”) information graphics were superior to any kind of pictorial statistics for clarity, accuracy or learning. He offered a well-articulated aesthetic assessment and argument to a community of scientific and statistical experts. One of the effects was that the minimalist aesthetic was embraced by a number of professionals who found this aesthetic likeable and consonant with serious work.
Third, Tufte’s minimalist aesthetics were subsequently supported by and upheld, not only by individuals, but communally as the rhetoric of many scientific communities. He has been called a statistical “guru.” Tufte’s aesthetic formulas for correct data portrayal were adopted as correct method among communities.

Finally, Western societal preoccupations/ worldviews based on absolute presuppositions backed Tufte’s contentions. The absolute presupposition that science is serious and popular media is not (particularly given use of cartoons) underpins much of Tufte’s argument against Holmes-style infographics. Furthermore, trimming out visual detail to arrive at a quick, efficient display was in line with Western society’s value for quickness and efficiency. Tufte embraced a value for quickness and efficiency in displays—this value being concordant with an absolute presupposition that elimination of extraneous detail makes transmission of a data message efficient and usable. Underlying this absolute presupposition is the belief that “a picture is worth a thousand words”—all the time, for everybody. There was little, if any, consideration of individual differences in learners. The absolute presupposition that all visual learners are equally able to decipher a visual display, if it is not nonsensical, supported Tufte’s bid for minimalism in an information graphic

**Individual Differences**

Notably, confidence in the universal abilities of a learner to understand visual information, unless a learner suffers from some sort of blindness or sightedness difficulty, is often assumed in studies about visual cognition. Cognitive style studies since mid-1900’s, however, suggest that as many as half of all learners will have difficulty detecting

**Quantitative Research Purpose and Design**

The second purpose of this study, therefore, was to discuss, explain and research how the field dependent-independent (FDI) cognitive style (which has been corroborated by thousands of studies since 1947) affects visual learning from information graphics. FDI cognitive theory predicts that field dependent (FD) learners are less able to interpret visual displays by detecting visual clues to meaning than field independent (FI) learners.

How may FDI influence the way learners comprehend and aesthetically assess information graphics considering the Tufte-Holmes debate?

**FDI Cognitive Style: Ramifications for Visual Learning and Instruction**

Cognitive styles have been defined as “characteristic modes of perceiving, remembering, thinking, problem solving, and decision making reflective of information-processing regularities that develop in congenial ways around underlying personality trends” (Messick, 1994, p. 122). Learners were found to exhibit either a field dependent (FD) or field independent (FI) cognitive style, beginning in the later 1940’s, according to their differing abilities to visually separate simple figures from complex background fields.

Theories of visual perception and visual cognition are based on common human processes of seeing and decoding visual displays, although there can be profound individual differences in the ways learners decipher visual information. Despite commonalities in biological visual processing or ability to detect line and spatial arrangements, learners, for example, are not equally successful in visually separating
simple figures from complex grounds. This differing ability was detected by dint of perceptual research conducted during the late 1940's and became the basis for assessing and categorizing learners as field dependent (FD) or field independent (FI).

The fixity of the FDI cognitive style has been well established. The only definitive changes in learner FDI are related to human development since children and geriatric populations tend to be more field dependent as groups than those in early or middle adulthood (Goodenough, & Karp, 1967; Witkin, Goodenough, & Karp, 1977; Jonassen & Grabowski, 1993). Witkin, Goodenough, & Karp (1967) noted FDI was so durable, that it was mostly resistant to other researchers' attempts to alter learners’ cognitive style--- even through extreme interventions. Because FDI traits are enduring and not susceptible to instructional intervention, an FD learner, for example, cannot be “taught” to be field independent. This cognitive fixity makes understanding individual differences in visual cognition essential to the design of visual instruction and information.

**FDI Visual Cognition, Perception and Learning**

Differences in the ability of FD and FI learners to find simple figures in hidden figures tests also predicts differing traits in visual cognition and perception. These differences determine the ways FD or FI learners attend to components of visual displays as well as strategies each uses to decipher visual instruction and to attain concepts.

An FD learner is not only unable to easily disembed a figure from a complex array but also perceives a field globally and as a relatively inseparable whole (Goodenough, 1976; Jonassen & Grabowski, 1993; Wooldridge, 1995; Tinajero, Castelo, Guisande & Páramo, 2011). He or she will find it difficult to detect the details in a visual
display that make it meaningful. An FI learner more naturally distinguishes the parts of a figure from its whole than an FD learner does by mentally separating a figure from its ground (Wooldridge, 1995), or in other words, by "disembedding" parts from wholes. Goodenough (1976), for example, explained that an FI learner uses a partist strategy that involves sifting and sorting out relevant from irrelevant cues. An FI learner can see both the forest and the trees. The FI learner can remix the essential components of a visual display, restructuring the mix to attain and ferret out conceptual information. An FI learner is then able to comprehend concepts portrayed in a display after identifying the most meaningful parts of the visual field.

Although an FI learner processes visual displays using a partist strategy, an FD learner uses a wholist strategy, perceiving all visual cues as equally relevant (Goodenough, 1976). An FD learner views visual displays without any deep analysis. For this reason, some researchers have also classified the FD learner as a passive spectator (Tinajero, Castelo, Guisande, & Páramo, 2011). The FI learner has been, by contrast, characterized as adopting the role of a participant in visual learning due to use of an engaged, methodical approach to analysis of visual displays.

**FDI and the Challenge of Display Types**

The FDI traits previously mentioned predict that the more geometrically abstract or complex a visual display becomes, the greater difficulties an FD learner will encounter when attempting to isolate meaningful elements. Statistical data displays are examples of complex, potentially ambiguous, informational tools that may be much easier for FI learners with analytic and numeracy skills to decipher than FD learners.
Displays of technical information as instruction became more important in the late twentieth century as more data was generated. Data generation was due to a faster pace in technical innovation, new scientific discovery and new sociological trends. Although statistical information had been represented visually since at least the mid-1800’s, by the end of the twentieth century data displays were prominently in “technical reports, research articles, and annual reports as well as less formal documents such as fact sheets, brochures, newsletters, and even monthly power bills” (Kostelnick, 2007, p. 280). Data displays were also featured in newspapers, magazines, journals as well as in textbooks or as a part of multimedia presentations. The pervasiveness of data displays in both informal and formal instruction made FDI learners’ ability to analyze data patterns more essential than ever.

It is known that FD learners have a particularly challenging time sorting through a disorganized visual display (Tinajero, Castelo, Guisande & Páramo, 2011). It is possible that all types of information graphics are readily interpreted by FI learners with their analytic orientation and superiority in disembedding visual elements in a display. Their ability to re-combine disparate geometrical elements from a data display into a meaningful whole undoubtedly assists their interpretation of an information graphic. FD learners, on the other hand, may require cues beyond geometric lines, grids or shapes.

Pictorial elements in infographics that represent context and topic may help them more successfully interpret a display. It is just as possible, however, that these pictorial elements may act as seductive detail for FD learners who tend to pay attention to the most interesting or intriguing features in a visual display while disregarding meaningful components. Pictorial content may also be viewed as clutter by FD learners who find it
difficult to hone in on salient graphical elements. For example, which data display about baseball players with more than 3000 career hits will best help an FD or FI learner understand its meaning? One with illustrations that offers context through a picture of a baseball player hitting a ball with a bar chart embedded into the ball? Or is that detail too confusing? Could an FD learner ignore the detail and find the data in the display or would a simpler more textual display explain the data better? Would an FI learner prefer an uncluttered display that is minimalist or enjoy the complexity of a pictorial data display? (Figure 1. Top heavy hitters as a pictorial data display (top) versus top heavy hitters as a minimalist display without any pictorial detail (bottom).)

Although the FDI cognitive style has been well studied for decades, it is rarely considered in visual instruction theory or research. Instructional designers and visual instruction researchers, as a collective, tend to propose a general learner who comprehends and benefits from visual instruction and information in precisely the same ways after factoring out outstanding demographic differences. Despite recent research and development of theory about visual learning, contemporary scholars mine veins like those mined by philosophers and instructors during the last eikoncentric era a thousand years ago.

This pilot study will help fill a gap in recommendations about data display design by examining and recognizing potential differences in FDI values and aesthetic preferences for, as well as, learner comprehension of data displays. Are there differences between FD and FI learner interaction and engagement with data depending on the type and amount of pictorial content embedded in a display? How does the presence or
absence of pictorial detail influence comprehension by FDI learners? The debate characterized as the Tufte-Holmes debate has not yet been satisfactorily settled.

Figure 1. Top heavy hitters as a pictorial data display (top) versus top heavy hitters as a minimalist display without any pictorial detail (bottom).

This study was also meant to add data to studies that have researched effects of minimalism or pictorial embellishment on comprehension, preference and perceived
efficacy for information graphics by learners. In this case, the study recognized that FDI learners faced different challenges when deciphering visual displays.

**Statement of the Problem**

Although the FDI cognitive style has been studied for decades, it is rarely studied as a critical factor related to visual cognition in instruction or practical instructional design that makes use of graphical elements. While instructional designers are well-versed in considering individual differences such as prior experience, reading level, first language, and other demographic characteristics, they tend to assume that all learners comprehend and benefit from visual instruction and information in precisely the same way. Nevertheless, FD learners are predicted to have greater difficulty comprehending visual information than FI learners (Goodenough, 1976; Witkin & Goodenough, 1981; Wooldridge, 1995; Tinajero, Castelo, Guisande & Páramo, 2011),

FDI differences in visual perception and cognition matter because imagery in contemporary textbook instruction and E-learning has become pervasive. Instructional designers can hardly be blamed for this, however; this is the prevailing understanding of the field. The practices advocated and adopted by instructional design scholars are in this case driven by historical precedent rather than empirical research, but most assume that the former is the result of the latter.

Graphs and charts, as well as imagery in contemporary times, have been more frequently used and more conspicuously featured in formal and informal instructional publications or in E-learning. The electronic production of mass data has been an impetus for design of instructional information graphics and data displays that portray selected trends and patterns. In addition to an increased use of images or data displays in
In a visual display, information is often currently presented as stand-alone instruction without textual explanation in books or in E-Learning units.

An FD learner, when deciphering a stand-alone visual display, may search for clues to meaning in textual passages or even in pictures. When examining a fever graph, a line graph that often portrays data with lines, making steep vertical ascents and descents as a fever might in a human being), for example, an FD learner must be able to connect information presented on the x and y-axes to interpret the meaning of the data presented. Textual captions and labels may be insufficient to assist an FD learner’s comprehension of the graph. Illustrations or explanatory textual passages may be required as clues to meaning. FI learners, who are better able to disembed single elements in a visual array, may extract meaning without any additional clues.

Failure to understand the effects of FDI cognitive style on visual learning may cause a disregard for differing ways learners “see” visual information. A belief in greater inclusion of imagery and visual displays in instruction for effective learning is allied with a popular, but misguided belief that all “pictures are worth a thousand words.” This adage implies that visual instruction—regardless of its quality or context in use—can quickly and efficiently summarize the meaning of complex content. The decision to include heaps of imagery in instruction may be based on such pop psychology rather than a body of research findings.

Because our current era is scientifically oriented, instructional designers, academicians or learners themselves may assume the design of images and displays are based on research discoveries about formal or informal instruction. We find instead, that visual instructional design is largely based on 1) the influence of the marketplace, 2)
professional or personal aesthetics, 3) societal preoccupations and worldviews based on absolute presuppositions and 4) the visual rhetoric of communities of practice that leverage debates (such as the Tufte-Holmes debate) about the correct way to present visual information. The influence of these factors provoked design practices based on intuition, personal preferences or belief systems that often lack support from empirical evidence. Contemporary design practices are largely entrenched, then, in societal factors rather than research findings.

Research and theory tend to play a lesser role in real-world design of instructional imagery or displays than mediating societal factors. Graphic artists as marketplace professionals, for example, do not simply influence design of a visual display, but decide how it will look. Graphic artists, rather than instructional professionals, most often determine how visual instruction will be designed and base these designs on their own aesthetic orientations or artistic training. Many graphic artists, for example, are taught basic principles of Gestalt visual organization. They may use Gestalt principles as a plumb line to measure the quality of a visual design. Gestalt theory may therefore exert a strong influence on real-world visual instructional designs. Graphic artists are unlikely to consult alternate instructional or learning theories, even when designing visual instruction. Their prior knowledge of art theory and practice is sufficient to accomplish a design task for formal or informal learners. Research findings about visual design, particularly from other fields, do not necessarily provide a foundation for practitioners.

Study designs in visual instruction during the past fifty years have posed their own problems whether considering the specific needs of FD over FI learners or not. Studies about visual design and cognition, in the tradition of cognitive psychology, have
regularly focused on the effects of single elements in a display. This focus is problematic when considering the ways single elements may affect FD learners who have native difficulty disembedding single items from a whole visual display. When FD study participants, (estimated as half of the entire population of learners by some reckonings) are required to isolate single elements from whole displays, they may find the task difficult or impossible. The benefit or detriment to learning through single elements in a visual display, therefore may be difficult to assess for FD learners who tend to perceive visual displays as a fused whole rather than a combination of elements.

Although most visual learning and instruction research does not account for the effects of FDI cognitive style on learning, the research itself is complicated by the existence of numerous types of instructional images, charts or graphs that can be tested. They vary widely in such aspects as style (e.g. using caricature v. naturalistic representation) perceived aesthetic quality, familiarity or reason for use. When studies are not identically replicated, it is difficult to form conclusions about any single element’s effect on learning. Conversely, when studies are identically replicated, we are often presented with findings that only inform us about the effects of a specific single design element, such as a bar in a graph that has been rendered as three-dimensional. The effects of that same three-dimensional bar, if styled differently or used in a different context cannot be easily generalized. This conundrum that plagues visual instruction research, may partly explain why it is still “not clear how students use illustrations in instructional materials or that they even know how to use them” (Anglin, Vaez, & Cunningham, 2004, p. 876).
A general learner is often posited in the wake of such contemporary research problems. Instructional designers may rely on visual design tips, intuition or whatever passes as a best design practice to create visual instruction.

Furthermore, today’s practices and theory may rest on ideas that have become conventional due to their repetition over time. It is telling that current beliefs about visual instruction and design bear resemblance to many beliefs posited during the medieval period. Although centuries apart, both medievalists and contemporary scholars, for example, have argued there is a limit to visual items that can be kept in memory, that visual cognition is a stage-like form of mental processing or that mental imagery vitally supports the use of mnemonic systems. Medieval premises and instructional pedagogies have been handed down over generations and derived from field-tested practices rather than from testing by scientific method.

Finally, contemporary recommendations for design of information graphics are widely embraced despite lack of confirming research findings. Recommendations for the design of information graphics have become memes. Statistician Edward Tufte and his numerous followers embrace Tufte’s idea that any detail that does not directly portray data must be erased from visual displays. The mien of his minimalist style of design, however, may eliminate clues to meaning that might assist FDI learners, particularly when the structure of an information graphic is unconventional or unknown. We cannot reasonably state that minimalist information graphics are more or less effective in learning than pictorially embellished information graphics (often, “infographics”) because little research has been conducted on this topic. Recommendations for the design of information graphics, rather, are largely based on opinion and aesthetic preferences.
Most of these recommendations do not account for important, differing needs of visual learners according to cognitive style.

We also find that the use of either minimalist or pictorially embellished information graphics are generally tied to the rhetoric of communities of practice. Although not necessarily prescribed, certain types of information graphics fit the proprieties of one kind of community better than another kind of community. Minimalist information graphics, for example, are often featured in professional or advanced scientific publications. Contrariwise, pictorially embellished information graphics are more often featured in popular or introductory media than in scientific or other professional journals.

Despite a current vogue for use of minimalist information graphics in fields that are regarded as scientific or “serious,” pictograms have potential to establish the context of a data display through use of icons as counters. Other embellished information graphics, such as those designed by Nigel Holmes, can provide learners with an enriched visual narrative that usually surrounds a data display while rhetorically supporting a viewpoint about a trend or pattern. How do degrees of pictorial embellishment affect learning from an information graphic? We simply do not know.

**Focus of Study**

Very few studies have investigated the influence of data display styles on visual learning, although interest in the topic is rising. Investigation into differential processing by FDI learners when learning from minimalist information graphics as opposed to pictograms or infographics is very rare. We do not know which type of design best compliments the cognitive style of either the FD or the FI learner. Consequently, FDI
learners are adrift in a sea of instructional images and displays that may or may not optimize learning. Therefore, the focus of this study was on the interaction of FDI learners with three styles of minimalist, pictographic or infographic data displays

**Terms and Definitions**

**Eikoncentric**

Instruction that is centered on imagery in a given era or time. Taken from the Greek word “eikōn” meaning a “likeness, image, figure” (Dictionary.com, n.d, para.16).

**Grammacentric**

Instruction that is centered on the written word in a given era or time. Taken from the Greek word “gramma” meaning a “thing written” (Green, 2008, p.74).

**Information Graphic**

The term “information graphic” is used in this paper as an umbrella term for all charts, graphs, maps or diagrams and follows Harris’s (1996) definition of information graphics as “Charts, graphs, maps, diagrams and tables whose primary function is to consolidate and display information graphically in an organized way, so a viewer can readily retrieve the information and make specific and/ or overall observations from it” (p. 198).

**Minimalist Information Graphic**

Minimalist information graphic is used to describe an information graphic that uses only the most essential detail to portray data.

**Visual Cognition**

Thinking in concert with seeing/ visually inspecting an object or illustration.
CHAPTER II

LITERATURE REVIEW

A Shift from Grammacentrism To Eikoncentrism

Grammacentrism is defined here as communication centered on *gramma* (Greek for the written word) and eikoncentrism is defined as communication centered on *eikon* (Greek for the image.) During a grammacentric era, instruction and information is primarily delivered through the written word. During an eikoncentric era, instruction and information is primarily delivered through images. There are no examples of a purely eikonocentric or grammacentric era (images and text are always present in some degree). Several shifts have been made between predominantly eikonocentric and grammacentric eras.

The Last Grammacentric Era

The last grammacentric era was ushered into Western society by mass publication of textual materials, particularly books, after commercialization of the Gutenberg moveable type printing press in 1454. “It has been estimated that there were perhaps 30,000 books in all of Europe before Gutenberg printed his Bible; less than 50 years later, there were as many as 10 to 12 million books” (Harry Ransom Center, University of Texas, n.d., para 5).
The moveable type press, however, could only produce letterforms on a page. Illustrations were rendered by hand or with wood blocks or engravings, making their inclusion in books costlier. Books were primarily textual (and the era, primarily grammacentric) until the latter part of the nineteenth century when lithographic press technology finally allowed inclusion of both text and images on the same page (Drucker & McVarish, 2008). Images were often inserted into books as plates (collections of illustrations inserted in the center of books) well into the 1800’s. A reader needed to stop reading to search through a book to locate plates that were widely separated from the textual passages. Therefore, even when imagery was included in textbooks, a reader was mostly occupied with text rather than images. However, if images were missing or at a distance from the text that described it, mental imagery was important to grammacentric authors.

**Ekphrasis and The Role of Images in The Grammacentric Era**

Prior to the advent of lithographic technologies, writers counted on the ability of readers to “conjure” images through descriptive prose; a literary technique termed “ekphrasis” (Bolter, 2009). Although ekphrasis has been defined as “a literary description of or commentary on a visual work of art” (Ekphrasis, n.d.), Bolter’s (2000) definition of ekphrasis as a technique is probably more precise. Bolter defined ekphrasis as a literary technique used when "prose tries to represent images" (p. 56). (Bolter’s definition is preferred for use in this literature review as it describes the role of text for evoking mental imagery.)

Passages of descriptive prose, according to Bolter’s definition of ekphrasis, paint pictures of scenes or characters in a reader’s mind. "Ekphrasis sets out to rival visual art
in words, to demonstrate that words can describe vivid scenes without recourse to pictures" (Bolter, 2009, p. 56). Therefore, even when images did not appear in text-based publications, mental imagery acted as substitutes for illustrations. Images were inserted as “plates” in-between pages of text with the advent of lithographic technology. A reader was, therefore, given support for picturing the subject of the prose. This print imagery lessened the need for ekphrasis. However, images were still not all that common and were always separated from the subject of the text by at least one page. This imposed additional cognitive requirements on the reader (e.g., looking back and forth between text and image to until meaning of text and its relationship to a print image could be ascertained). Mental imagery has also been an essential component for learning in an eikoncentric era. This holds true for historical eikoncentric eras and is also true today.

Arguably, the pervasiveness, increased production, and use of visual media in the last century is aligned with an overall societal shift away from grammacentrism towards eikoncentrism. It is important to recognize that this trend represents a reverse of the shift early humans made from pictographs to the written word. Writers working in different fields of study (White, 1987; Tversky, 1997; Bezemer & Kress, 2008; Clarke, 2001; Bolter, 2000) have observed the contemporary shift toward eikoncentrism in Western culture. Images, in this new eikoncentric era, are used extensively to communicate information to the public or as instruction in both formal and informal settings. Although captions that accompany images are often used, principal use of long textual passages for explanation of an image, as is common in grammacentric societies, has decreased.
The Role of Text in an Eikoncentric Era

The barrage of images in contemporary society has caused some to believe that graphics are now privileged over text for communicating information (Bicket & Packer, 2004). Text, overall, has played an increasingly minimal role in explaining images; it is absent or is merely augmentative. Images are “displacing writing and moving into the centre of communication” (Kress, 2003, p. i) while "graphics in printed publications like USA Today are being used to replace text. They seem to bubble out of the prose and appear before our eyes, transforming us from readers into viewers" (Bolter, 2000, p. 56). Text, in our image-saturated society, may therefore be relegated to minor roles as captions or labels in visual displays. Images, in these cases, are often meant to independently explain an instructional message without need for greater textual clarification. Although textual publications without any illustration continue to be printed, minimal use of explanatory text with maximum use of images for instruction or information is characteristic of instructional publications and media during this contemporary eikoncentric era.

Carifio & Perla (2009) stated that, according to sociologists, “we live in or in what is now referred to as a “presentation culture” (p.407). This presentation culture presents information primarily through visual displays as the “power of text is even fading from unconscious memory as trade books, magazines, textbooks, educated TV programs (even McDonald cash registers) [and] are purposefully increasing the amount of space/time occupied by visuals compared to text.” (Carifo & Perla, 2009, p. 407). Those who frequently substitute visual displays for textual information assume that their learners can decipher the meaning of these displays without difficulty.
Advertisers, for instance, typically design advertisements as large visual displays with minimal text. They assume an audience is receptive to images, expecting viewers will engage with and immediately understand a visual message. Educational publishers similarly believe visual displays such as illustrations, diagrams, photographs, charts or graphs will always lead to a better understanding of instructional content. However, “visual displays are considered tools for communication, thinking, and learning that require specific individual prerequisites (especially prior knowledge and cognitive skills) in order to be used effectively” (Schnotz, 2002, p. 102). Unfortunately, designers rarely take this into consideration, believing all learners have roughly equivalent skills in deciphering imagery. Instructional content writers, by contrast, acknowledge individual differences in reading abilities and research ways to accommodate struggling readers. For some reason, this concept of individual differences has often failed to be extended to visual cognition.

**Assumptions in Eikoncentric Instruction**

Imagery in displays are widely believed to represent an efficient, understandable method for relaying information and clarifying instruction for nearly all learners. Many people, particularly in this eikoncentric era, subscribe to the adage “a picture is worth a thousand words” that predicts images will be readily and quickly comprehended by all learners.

The assumption that all learners are equally able to decipher images, unless impaired by visual problems such as blindness, levels of prior knowledge or age differences, generally accompanies the idea that “a picture is worth a thousand words.” The notion of a universally able visual learner is speculative, despite an increased use of
images in both textbook instruction and E-learning that are thought to accommodate all learners.

Prominence of Images in Instruction

Although Google Scholar listed approximately 4,000,000 studies related to the query “visual learning” after .05 seconds of searching, research findings have likely had less of an effect on the composition of final instructional products than marketplace and other factors. The prominence of imagery in instruction, for example, is partly the result of new marketplace print and digital technologies that make design and reproduction of images easier and more cost effective than in past times. Publishers have also identified the attractiveness and attention-getting qualities of lavishly illustrated textbooks as boosters for company sales. “The marketing function of illustrations is to encourage [textbook] selectors to pick up, thumb through, and hopefully review and select a particular book or series” (Woodward, 1993, p. 118). (Marketplace and other factors will be discussed later in detail).

Images in Contemporary Textbooks

Although Kress (2003) insisted, “the screen has replaced the book as the dominant medium of communication” (p. i), textbooks continue to be used in classrooms as mainstays of instruction. They have become a visual medium unto themselves as images dominate the pages of textbooks more frequently and in greater quantities than in past eras (Evans, Watson & Willows, 1987; Bliss, 1990; Woodward, 1993; Martins, 2002; Bungum, 2008; Holsanova, Holmberg, & Holmqvist, 2009; Cook, 2012).

Bliss (1990) compared the quantity and frequency of images used in United States’ history textbooks during different decades of the twentieth century. She found that
in early 1900’s textbooks, more than six or seven pages of continuous text were featured, and the books were sparsely illustrated. By the end of the twentieth century, “at least one-third of all the information presented is visual, more than double the amount contained in early twentieth century textbooks” (Bliss, 1990, p.10). Evans, Watson & Willows (1987), In a review of more than 60 textbooks, found that by 1987 “every page in a book at the primary level and the majority of pages at later levels, has an illustration” (p. 107). Woodward (1993) noted, “One can hardly open a textbook and not find a four-color photograph or other illustration that immediately catches the eye” (p. 118). Martins (2002) concluded, “modern textbooks are organized around images” (p. 76). Cook (2012) recently noted, “A quick inspection of today's textbooks reveals that close to half of the printed space can be accounted for by illustrations” (p.64).

Imagery is now an essential part of history textbooks, mathematics textbooks, social science textbooks, basal readers and economic textbooks, among others. Technical images in science textbooks are *de rigueur*, including photographs, graphs, diagrams, schemata or charts (Bungum, 2008). After examining 60 years’ worth of science textbooks, Lee (2010) concluded that science “textbooks are among the most graphically populated print materials used for the communication and sharing of scientific ideas” (p. 5). The frequency of images in science textbooks is predictable because "images are, in many respects, essential to science" (Martins, 2002, p. 74). Chaplin (1994) concurred, arguing that, “the subject matter of natural science is not originally verbal” (p. 255). He described the process of arriving at scientific conclusions as a motion through “consecutive stages of scientific work [that] transform raw, messy data into a more manageable set of figures, diagrams and text” (Chaplin, 1994, p. 255).
The Relationship of Image and Text in a Post-Lithographic Eikonocentric Era

Changing techniques of print layout since the later nineteenth century also contributed, literally, to a “visible” shift from grammacentric to eikonocentric instruction. Images in textbooks became progressively more prominent as better print technologies allowed novel layout techniques. During most of the twentieth century, grammacentric layouts typically placed images beneath and / or above long passages of text (Figure 2. Images in layout styles; grammacentric era publications.)

The spatial contiguity (nearness) of images to text allowed readers to immediately associate a textual passage with its corresponding image. The role of an image was referential. Contrast this with ekphrasis and the distant insertion of images as plates in-between pages. The contiguity of image and text was radically changed with the advent of modern printing and layout technologies when more images could be included in
books to facilitate understanding of what was described in text. The physical distance of text from images was lessened by other layout techniques.

Images occasionally protruded into columns of text during the later nineteenth century, making an image both more prominent and fused together with blocks of text. This layout technique indicated an early progression toward text wrapping. In text wrapping, text is not typeset in geometric blocks. Text instead fluidly surrounds an image. (Figure 3. Example of early trend toward text wrapping.)

![Figure 3. Example of early trend toward text wrapping. Text protrudes into an image of musculature in the 1898 edition of Orthopedic Surgery by James Moore, M.D. From: http://www.laurelleaffarm.com/1890s-medical-textbook-orthopedic-surgery.htm](http://www.laurelleaffarm.com/1890s-medical-textbook-orthopedic-surgery.htm)

Text wrapping around images focuses learner attention on a graphic. This layout technique consigns text to the role of a “setting” for the image that becomes the “jewel” of instruction. This page layout style is commonly used in trade books and in lower grade to higher education textbooks. (Figure 4. Example of a page layout that uses text wrapping that makes an image prominent. From: Keck, L. 2009, November 19.)
Present-day layouts yield increasing proportions of surface page space to images in instructional publications. Therefore, images are often more prominent than text. Both “the frequency with which illustrations appear and their size” (Evans, Watson & Willows, 1987, p. 95) has contributed to the prominence of images on a page.

Some contemporary layouts devote a greater portion of page space to large images where short, side-by-side passages of text are minimal and function more as pithy captioning than lengthy content. When short textual passages are contoured around the shape of an image, text can act as captions or as pointers to the imagery. Consequently, the eye of a reader is directed first to images. Accordingly, because text points the eye to imagery, the imagery is prioritized as the first-to-be-inspected part of instruction.

**Layout and Cognitive Processing**

New styles of layout that increase the prominence of images are also changing the way learners process information on a page. “Unlike text, which is always amenable to a
straight, serial reading, graphics requires the reader to identify an appropriate inspection strategy” (Petre, 1995, p. 37). Learner inspection of a page dominated by imagery begins with a sort of “all at once” first look, followed by circuitous, random exploration of content according to learner interest or prominence of particular images (Holsanova, Holmberg, & Holmqvist, 2009).

Placement of a single visual display across two inside pages is increasingly common in textbooks. Readers view an image or images that cover both recto and verso pages. Images are surrounded by blocks of textual passages. This type layout was innovated by the fine artists *Fortune* magazine employed during the 1930’s (Eckstein, 2005). *Fortune* magazine raised the bar for artistic quality in popular media, hiring well-known fine artists to develop informational imagery. Textbook publishers adopted this layout technique from popular media (Figure 5. Two-page display features images of the Martin Ocean Transport.)

Although E-learning has been in common use for training or education only since the late twentieth century, technology-assisted visual instruction was in force and widely studied from the early 1900’s following invention and popularization of technologies like radio and film. During the first half of the twentieth century, enthusiasm for visual methods of instruction and a concentrated effort to develop theory, methods and pedagogical articles about technology-assisted visual instruction resulted in what was called the “audiovisual movement.” The roots of this movement were nurtured
Early Contemporary Visual Instruction Recommendations and Research

during the nineteenth century when improved print technologies allowed a cost-effective, and therefore, greater use of illustration in publications.

A bulletin entry of the Pantographic Society written in 1852 about visual instruction (that pre-dated the widespread use of systematic scientific method in research) for example, reflected early modern thought about visual instruction. “One of the most important principles upon which our system (of pantographic instruction) is based, is that of exhibiting to the eye that which we wish to have impressed upon the mind, and consequently fixed in the memory”(Carroll, 1954, p. 24).

Visual instruction research was prompted, primarily during the early twentieth century, by invention of new print or visual aid technologies, such as magic lanterns,
slides, popular magazines, film and even flannel boards. (Kinder, 1953; Reiser, 1987). Audiovisual instruction society members or academicians conducted most of the audiovisual movement's research. Unfortunately, small-scale studies during this period did not consistently employ scientific method and often yielded recommendations that were confined to conclusions of a single investigator. Wittich (1954) commented on audio-visual research studies undertaken prior to 1954. He noted that it would be difficult to generate, “a list of efficiently planned and accomplished professional research studies in the field of audio-visual education” (p. 334) when compared to a list of studies done in other academic content areas. Research conclusions from that time period would appear to be ‘very sketchy’” (p. 334).

Early contemporary era recommendations for the use of visual instruction were often matters of opinion. Principles of visual instruction were often stated as recommendations or “tips” without associated references to any formal studies. Hoban, Hoban, & Zisman, (1937) for example, determined, without reference to their own or others’ scientific research, that four basic principles should be followed to craft effective visual instruction. These included 1) use of realistic graphic media; 2) recognition of learner prior knowledge; 3) alignment of visuals pertinent to an associated learning objective and; 4) assessment of the intellectual capabilities or maturity of learners to determine whether a concrete or abstract graphic should be used in instruction.

Studies (Travers,1967) about the instructional use of film, filmstrips, slides, television or microcomputers were conducted as modern technologies were invented. Although many of these studies are now merely of historical value, they formed a backdrop of ideas and a bank of research questions alongside suggested field-tested
practices to inspire today’s visual instruction researchers. The large body of research on technology-assisted visual instruction accrued later during the twentieth and early twenty-first centuries were often reexaminations of earlier thought about visual instruction. Earlier philosophies or theories about visual cognition and learning not only contributed to current understandings but suggested research questions within the instructional design community about the use of images for E-learning.

**Prominence of Images in E-learning and Posits About Their Use**

Visual instruction through all forms of E-learning including computer-based instruction (CBI) or Web-based instruction (WBI), grew rapidly with the advent of personal computing (Gold, 2001; Rossett, & Marshall, 2010; Clark & Mayer, 2011). Today, the proportion of static imagery on instructional CBI or WBI screens often exceeds that of text, underscoring the eikoncentric shift in instruction.

This image prominence is, in part, the result of the presence of graphics necessary to a graphic user interface (GUI). GUI on-screen graphics such as navigational buttons or visual feedback devices or progress bars contribute to the visual nature of a screen.

Use of a visual background that corresponds to instructional content, commonly called a “visual metaphor,” for an instructional interface is conventional. A pictorial background is frequently used, in which case a screen inherits additional imagery from its background. Combinations of pictorial, functional or navigational images along with the addition of instructional graphics such as photographs or illustrations cause a WBI or CBI screen to be primarily visual. (Figure 6. Interactive Drink Training as an example of contemporary E-learning screens.)
Whereas textual passages alone were historically sufficient for content explanation in grammacentric textbook instruction, imagery has been more strongly emphasized in contemporary E-learning. The prominence of imagery over text in CBI or WBI is guided by contemporary E-learning theory. Well-respected instructional design researchers, for example, have recommended screen compositions that feature less text than images or spoken words with images, rather than text alone on CBI or WBI screens (Clark & Mayer, 2011).

Clark & Mayer (2011) emphasized imagery as a necessary ingredient in E-learning according to the “multimedia principle.” Their multimedia principle posited that word and image combinations on instructional screens promote deeper learning than either words or images alone. Because words and images are cognitively processed as different, distinct sign systems, instruction that included both would be doubly coded or
processed. They stated that “the rationale to present words as onscreen text in multimedia presentations conflicts with the way the human mind works” (Clark & Mayer, 2011, p. 89). This statement was meant to discourage instructional designers from filling screens solely with words and some empirical research findings support this principle. Although this principle helps designers avoid over-using text in our eikoncentric era, it does not provide adequate guidance for how text and images can or should be used.

Similarly, the “modality principle,” as stated by Clark & Mayer (2011), posits learner attention is better maintained and deeper learning is accomplished when words do not appear alongside animations, videos, or series of still frames on screens. Imagery alone, however, is also less effective than imagery that is accompanied by verbal explanation. When the modality principle is applied to instructional screen design, verbal commentary is substituted for textual passages in E-learning. Clark & Mayer (2011) implied that attention is preserved, and cognitive processing facilitated if learners do not have to scrutinize both words and images. “When the eyes are engaged with onscreen text, they cannot simultaneously be looking at the graphics” (Clark & Mayer, 2011, p.89-90) because “text is initially processed in the visual subsystem of working memory, it competes with the graphic for visual attention” (Cook, 2006, p. 1080). When the modality principle is adhered to in design, images become the visual centerpiece of instruction since text does not appear on-screen. However, neither the multimedia principle nor the modality principle act as coveralls for all instructional situations.
Instruction During Different Eikoncentric Eras: A Short Comparative History

Assumptions about visual instruction stated in prominent theories, philosophies or pedagogical practices during another historical eikoncentric era have been remarkably similar to those of today --- despite significant separation by time. We may assume, during our contemporary eikoncentric era, that scientific research acts as a guidance system for visual instruction.

While many instructional designers are aware of recent multimedia research, few understand the rich history of visual instruction and its theoretical/philosophical foundations. It is important to become familiar with the history of basic theories and philosophies for visual instruction during the late medieval eikoncentric era (defined for the purposes of this review, as the period from approximately 1200-1500 AD), the grammacentric era (defined for the purposes of this review as the period from approximately 1453 – 1850) and visual instruction during the contemporary eikoncentric era (beginning approximately in 1850 AD and continuing to the present-day).

Although eikoncentric and grammacentric eras are divided in this way, it must be acknowledged that transitions between eras represent lengthy periods of time. Movement toward or away from grammacentric or eikoncentric orientations have not been abrupt. Learners, centuries after the eikoncentric medieval era, may have benefitted more from visual instruction than from text due to low levels of literacy. Likewise, books in this contemporary eikoncentric era, for example, are still published that are completely textual, representing a grammacentric orientation.
Everything Old Is New Again

Contemporary foci on aspects of visual cognition or instruction are strikingly similar in many respects to those that were important during the medieval era. Why do parallels in medieval and contemporary thought about visual learning or pedagogies exist? Kemp (1996) argues “the similarity of human minds ensures that we posit much the same kinds of universals, even though they may not exist in reality” (p.118) or alternately, that contemporary ideas about visual learning “might arise because our society has inherited these from the past” (p.119). Our similarities may also be due, in part, to our mutual immersion in images that focuses our attention on the use of images for instruction. The ways people think about visual cognition and instruction, however, are most likely based on similar human experiences or traits. The common ground between medieval and contemporary learners is that we are human.

Our societies are different of course, as witnessed by conflicting historical pedagogies and theories of visual instruction. Instruction based on theology during medieval times was challenged by instruction based on the scientific method from at least from the mid- nineteenth century onward. Early contemporary era investigations into visual learning ---from the mid- nineteenth to early twentieth century, at the dawn of the contemporary eikoncentric era--- pre-dated scientific research but also presaged topics that would later be experimentally researched. Although some scholars may believe scientific findings and theory have acted as the guidance system for contemporary visual instruction, evidence points away from that conclusion. Observation, intuition and inference, have instead been essential processes to theory formation in contemporary
days, just as they were during the medieval era. Many modern theorems, in fact, have often been unconscious reexaminations or verifications of medieval axioms.

**Guiding Orientations in the Medieval Eikoncentric Society**

Medieval visual instructional pedagogies were rooted in a belief that all visible things, ---whether natural or manmade ---were intended by God as instructive signifiers of deeper, invisible, sacred realities. Medieval society was strongly oriented to the learning and discovery of principles of Christian faith through apprehension of these divine visual signs in nature (Kemp, 1990).

**Res Significans and The Power of Vision**

Visual learning was privileged in Western medieval society. Everything that could be seen, “whether bird, beast or plant, star, stone, or metal, is a res significans: It has meaning---not one which we ascribe to it metaphorically, but one which objectively is in it because God put it there ”(Vicari, 1993, p.158). The role of seeing was thought to be so central to cognition in medieval times that images “were often explicitly concerned with the power of vision, such as representations of saints and angels offering instruction in the art of seeing” (Griffiths, 2010, p. 166). “Medieval seeing was thought of as a form of feeling, providing the beholder with the sense of touching the object of vision” (Giles, 2007, p. 107). Therefore, an illiterate standing before a sacred visual representation could not only be touched spiritually but could intuitively learn from sophisticated, uncaptioned iconographies for arriving at conclusions about the nature of the world. (Clark, 2007).

Although subjects such as astronomy (that would later be classified as science) were taught in medieval schools using illustrations depicting planetary motion and the cosmology, “the primary justification for its inclusion in the arts curriculum was…[its]…
connection to the divine"(Crowthers & Barker, p. 441). Because the art of seeing connected learners to supernatural instruction, it was important to meditate on imagery. Prolonged, thoughtful examination of images and cogitation were thought to result in both spiritual and cognitive illumination.

**Guiding Orientations in the Contemporary Eikoncentric Society**

Our contemporary society, unlike Western late medieval society, is generally oriented to science or scientific reasoning rather than to philosophy or theology. However, contemporary society values "seeing" in much the same way as medieval eikoncentric society did. "The senses have, through modernity, become inflated indicators of the real, but none more so than vision” (Jenks, 1995, p. 12). We reiterate our belief in vision as primary with common everyday phrases like "Keep an eye on it… Just use your eyes!...It’s staring you in the face… Beauty is in the eye of the beholder…Look and learn’” (Jenks, 1995, p. 12). These are phrases that underscore society's value for the visual.

**Images as Fact**

Images in our contemporary society are used in instruction as objective, incontrovertible evidence of a fact, whether in journalism, business, social science, humanities or science fields. Some publishers, who have produced exclusively textual academic journals, are beginning to revise their practices as readers and authors advocate for a greater use of imagery. This demand for more images is due at least in part to the belief that images can establish “fact” more readily than written argumentation. The potential use of imagery in legal publications, for example, has recently become a matter
of debate in American law circles (Porter, 2014), because it breaks a long tradition of argumentation presented exclusively in text.

The types of images that appear in scientific articles or science instruction are meant, like images during the medieval era, to visually reveal the facts of otherwise invisible realities (Cook, 2006). Contemporary invisible realities that are revealed are technical rather than spiritual. Images are used to establish scientific fact as they “highlight theoretically vital features, arrange streams of data so that they can be categorized and taken in at a glance, help communicate how an experimental apparatus works, and illustrate complex relationships” (Gross, Harmon, & Reidy, 2002, p. 200).

Statistical data displays are used to portray or verify the reality of trends or relationships that have been stated in written material.

Gross, Harmon & Reidy (2002), in their historical survey of imagery in scientific journals, indicated the significance contemporary scientists assign to images as objective, factual, scientific proofs. The number of images presented in twentieth century scientific articles was greater than in any other century. “Only 12% of the articles in the [twentieth century] sample were without figures or tables, as compared with 52% in the 19th century” (Gross, Harmon & Reidy, 2002, p. 200).

**Value of Imagery: Quickness and Efficiency**

Imagery in contemporary society is valued for its quickness and efficiency in explaining something. This value expressed by the old saw “a picture is worth a thousand words.” The value is opposite of the medieval value for an image as a meditative object.

The goodness of quickness and efficiency is a value that emerged alongside the invention of machinery, which made mass production of goods economically viable
during the Industrial Age. “Modernist aesthetics privileges precision, economy, and objectivity-machine-age values that underpin not only art and architecture but information design as well.” (Kostelnick, 1990, p.7). Values for efficiency persist in contemporary times as computer and other digital technologies are perceived to save time and labor costs in production of information. These values are vestiges of values established in the earlier Industrial Age.

Quick and efficient design guidelines. If quickness and efficiency are prevalent contemporary values that crosscut fields concerned with visual presentation, these values help explain why instructional designers or graphic artists may seek to quicken learner comprehension through streamlined visual displays. Pettersson (1989), for example, recommended, “A visual should contain [only] the details that are essential in communicating the intended message. Too many details and too much complexity give rise to distracting ‘interference’” (p. 226). Malamed (2011), among others, recommended if a designer wants a learner to process a visual display efficiently, realism should be reduced through elimination of details. “Minimalism makes every phase of the human information-processing system more efficient” (Malamed, 2011, p.104).

These recommendations may be sage advice, in a general sense, because extraneous or “seductive” detail in instructional visual presentations has sometimes been shown to thwart learning. Seductive detail has been described as “interesting but irrelevant information” (Mayer, 2003, p. 133) that seduces learners away from an intended instructional message by causing them to pay more attention to extraneous detail in an image rather than to salient visual details meant to clarify an intended instructional
message. When distracted this way, a learner may never attend to or process an instructional message at all.

Seductive detail can make it arduous for learners to discern differences between necessary and interesting components in a visual message. Images, such as cartoons, that may contribute to understanding but are not essential to the instructional message, are often considered representative of visual seductive detail. This is a controversial standpoint, however, since other research has demonstrated that cartoons can maintain attention and enhance positive attitudes about an instructional topic (Hosler & Boomer, 2011). Research does not always demonstrate harmful effects of seductive details in learning (Lenzner, Schnitz & Müller, 2013). Some studies have found that visual detail, even when not directly related to instructional content, is beneficial. Other studies have demonstrated that details, salient or decorative, may better capture learner attention and can promote recall or transfer performance (Towler, Kraiger, Sitzmann, Van Overberghe, Cruz, Ronen, & Stewart, 2008).

**Relationship of attention to quickness and efficiency.** Today, many people buy into the idea that a “picture is worth a thousand words” ---and with it an associated idea is that an image is both instantly perceived and comprehended. This notion is derived from folk psychology. The phrase itself--- “a picture is worth a thousand words” -- is thought to have been quoted from an automobile ad in the early 1900’s. Our belief in this folk adage and our value for quickness and efficiency can result in imprecise ideas about the lengthy inspection and cognitive effort it may take to interpret an image:

Although perception of an image is a very quick process, eye tracking research has demonstrated that learners repeatedly scan images to extract meaning. Extraneous
imagery or poor visual organization can prolong scanning. Charts, graphs and all other images are subject to an inspection process that takes time and multiple rounds of visual examination (Holsanova, Holmberg & Holmqvist, 2008; Goldberg & Helfman, 2010), Figure 7. Example of the serial graphic with prototypical scanpath of one reader.)

Figure 7. Example of the serial graphic with prototypical scanpath of one reader.

The scanpath example is from a study by Holsanova, Holmberg & Holmqvist (2008) who investigated the effects different spatial layouts had on reader scanning and attention in a naturalistic newspaper reading task. From: Holsanova, Holmberg & Holmqvist, 2008, p.1221.

Hegarty (1991) argued that pictures are *not* processed quickly and easily:

Our data argue against any blanket application of the view that diagrams, even iconic diagrams, are ‘immediately apprehended.’ If the information in diagrams were immediately apprehended, then readers would have to inspect a diagram only once in order to extract the relevant information (Hegarty, 1991, p. 65).

Therefore, shallow processing may occur if learners do not deliberately attend to images. Expending time and effort to effectively inspect and scan images in instruction is necessary to deep processing.
When considering how much detail to incorporate into instructional visual displays, it is important to strike a balance between adding too much detail, which can make isolating relevant information difficult or create extraneous cognitive load or seductive detail (e.g., Meyer, 2003; Malamed, 2011), or skimping on detail, which can result in an unclear instructional message (extraneous cognitive load). Guidelines are contradictory about providing optimal detail for focusing and maintaining learner attention.

**Contemporary Studies on Learner Attention**

Oddly, discussions about how much detail will capture learner attention may be irrelevant outside a laboratory setting, because in practice, a visual display may not capture learner attention at all. Research has shown that learners may simply ignore images in instruction, particularly if their beliefs in a picture as a quick and efficient cognitive tool preclude adequate time inspection and engagement. Dwyer (1978), for example, reviewed over one hundred studies that investigated the use of supplemental pictures to facilitate learning from expository text. He concluded that pictures with realistic details facilitated learning when *sufficient processing time was provided* for images. Richly detailed images required learners to search for visual features related to learning material. If insufficient time for picture exploration was allowed, students might choose to ignore an image. When lessons were externally paced by researchers and not under learner control, the most effective images contained relatively small amounts of visual detail because learners could only use allocated time to study an image.

Learners may barely scan images in instruction if they think pictures will not convey information that is necessary for learning. Weidenmann, (1989) has called this
cursory inspection of an image “undervaluation” meaning that learners lack confidence in images to present valuable information. Due to a grammacentric emphasis on reading text to gain information, images have often been considered auxiliary to textual instruction, (Weidenmann, 1989). Learners may believe that the quickest and most efficient way to wade through instruction is simply to read text.

In an experiment, “some students admitted they appreciated all the graphics in their new text because they could ‘skip’ over them and make the reading go much faster " (McTigue & Croix, 2010). Quickly scanning images represents, to an extent, simple filtering of information--- a process that is important to locating the most relevant information in instruction. However, the problem with premature dismissal of textbook images or visual displays is that they may, and increasingly do, portray information that is not otherwise covered in text.

Ironically, the same publishers who believe in lavishly illustrating text publications, may be culpable for learner undervaluation of images in instruction. It has become more common in textbooks, for example, to replace accurate, interesting, historical black and white historical photographs or prints that display period information with vibrant color photographs or illustrations that do not effectively extend instructional content (Woodward, 1993). This practice has resulted in use of images that are more decorative than accurate. In one such case of replacement “a black-and-white print showing a grim slave auction was replaced with a color print of an auction where women slaves were dressed in nicely starched white aprons and gingham gowns” (Woodward, 1993, p. 119). Therefore, a quick glance at this type of contemporary image may not only cause a learner to prematurely move onto information that seems more detailed and
engaging but can create a false perception of history. The realistic print of slaves being sold, in the slave auction example above, offered detailed photographic evidence of the sale of impoverished human beings whereas the color print reinforced an inaccurate impression of the old South as a colorful, happy place.

**Medieval Models of Visual Processing and Cognition**

The requirement of adequate time to process an image to a is complimentary to the idea that images are processed in stages. This has been a central visual learning premise in both medieval and contemporary times. Medieval visual instructional pedagogies were based on beliefs in variations of stage-like, imaginal cognitive processing that reflected St. Augustine’s of Hippo’s (354 - 430 AD) hierarchical “tripartite scheme” of vision (Crowther & Barker, 2013, p. 436). Medieval theories of visual processing were not far distanced from ancient ideas, remaining closely aligned with those of Galen, the first century Greek physician (c.130 - c.210 AD) and Aristotle ((384–322 BC) (Carruthers, 2008).

**Medieval Stages of Visual Processing**

St. Augustine stated that a learner first physically perceived an image. Next “spiritual vision took place in the mind and included dreams and fantasies. Spiritual vision was entirely internal, but it was largely based on images seen with the external, corporeal eyes and stored in the memory” (Crowther & Barker, 2013, p. 436). St. Augustine’s final and highest stage of seeing was “intellectual,” when a learner grasped and was engaged with divine knowledge (Crowther & Barker, 2013). Carruthers (2008) explained that during stages of visual information processing the brain was thought to receive sense impressions "from the various senses in the sensus communis or fantasia,
located in the forward part of the brain" (p.4) with the eyes representing all senses. The sense impressions constituted raw sensory data that was "gathered together" (colligere) by the actions of both fantasia (phantasy) and vis formalis (the power of making forms) into images having formal properties that are perceptible and useful to human thought" (Carruthers, 2008, p.4). The resulting mental images were fuzzy rather than eidetic, and were colored, distorted or shaped under the influence of prior exposure and experience.

Avicenna (980 - 1037) was an Arab medieval physician who was widely read in Western Europe. He proposed a stage-like model of visual processing, related to Aristotle's three-part model. Avicenna identified inner senses that included the "common sense, image store, and fantasy [that] process images... [and] estimation and memory [that] process evaluations.... two of the powers, the image store and memory, are retentive but do not actually discern anything, while the others apprehend qualities in their own right" (Kemp, 1996, p. 58). The inner senses, in Avicenna’s model, were under control of the intellect as a central executive that “also receives a flow of information from them. The intellect obtains universal knowledge and checks hypotheses regarding universals with the aid of the information about individual objects and events present in the inner senses” (Kemp, 1996, p. 59).

**Contemporary Models of Visual Processing and Cognition**

Visual cognition models and theories are of a relatively recent vintage. Research was not regularly conducted, nor theories generated about visual processing until the mid-twentieth eikoncentric century. Paivio (1979) attributed a persisting lack of attention by experimental psychologists to imagery, at that time, to the dual, detracting influences of behaviorist psychology and the “rote learning tradition established by Ebbinghaus in
Both traditions dismissed notions of imaginal and introspective processes, but the behaviorist orientation in psychology was perhaps most instrumental in dismissing visual research agendas. “Imagery was so far beyond the behaviorist pale that one article that re-introduced the topic was subtitled, ‘The return of the ostracized’” (Winn, 2004, p. 84).

Studies that were undertaken about image perception in the behaviorist era were “related to lower-level learning processes (such as reading, and remembering information presented through text with or without accompanying pictures)” (Samaras, Giouvanakis, Bousiou, & Tarabanis, 2006, p. 10). Consequently, the bulk of research during that era were picture facilitation studies. A dearth of studies about image or visual display comprehension is still evident, while picture facilitation studies continue to be predominant in experimental research. (Norman, 2010; Jin & Boling, 2010).

Cognitivism began to shape research agendas and designs beginning in the late 1950’s when the “cognitive revolution” in psychology challenged behaviorism. The use of images for learning was only, and consistently, found to be beneficial after the 1970’s when cognitivism replaced behaviorism as a ruling paradigm. Rieber (1990) said that most picture research before 1970, in fact, “indicated pictures generally did not aid, and occasionally distracted, learners from processing printed text” (p.78). This phenomenon was ascribed to the “least-effort principle,” defined as “the heuristic that, given various possibilities for action, an organism will select the one requiring the least expenditure of effort” (Least-Effort principle, 2009, para 1). Therefore, it was believed that people were essentially lazy. They chose to expend less cognitive effort by looking at pictures than to expend the greater cognitive effort in reading through textual passages.
Contemporary Stages of Visual Processing

Medieval philosophies about visual cognition are closely related to theories generated under the auspices of cognitivist psychology because they both represent information processing models (Kemp, 1996). Theories in both eras commonly described discrete stages in image processing that begin with visual perception and most proceed to a second stage when the image is permanently stored in memory.

Memory was considered among the most important human faculties for learning during medieval times. Memory has been recognized as a central part of cognition in the contemporary eikoncentric era as well. Contemporary theories of visual learning (and learning in general), are often essentially theories of memory. These theories chart the cognitive passage of visual information. Processing an image begins with visual perception, then sequentially passes through several types of memory stores. "According to most learning theories, the goal of learning is to have knowledge progress from sensory memory to short-term memory to long-term memory" (Leonard, 2002, p. 125).

Theories about visual learning, generated under a cognitivist perspective, generally subscribe to the idea that images are initially perceived and held less than a second in iconic memory (Ware, 2012, p.21). The visual image is then shunted into short-term memory. Short term memory, alternately termed “working memory,” is described as memory that is conscious, limited and interacts with information in long-term memory (Leonard, 2002). Long-term memory is a store of prior learning that includes procedural, conceptual and declarative knowledge (Leonard, 2002). The interaction of working and long-term memory is not a part of medieval philosophy, particularly in comparison to Avicenna’s model of memory where memory is retentive rather than interactive.
However, if the central executive, as described by Cornoldi & Vecchi, (2003), is considered the same as Avicenna’s “intellect,” then contemporary cognitive theory about visual memory is roughly equivalent to medieval thought, differing only in terminology.

Influential components-of-memory theories that posited various kinds of memory stores were guided by research findings but have also been conceptual and inferred, much as they were in medieval times. “We cannot open up the top of someone's head to peer into their memory storage to see if it contains one chamber, as it were, for words, another for images, another for music, and another for speech” (White, 1987, p. 43).

Medieval theories of visual cognition stated that memory of images was stored in specific regions in the brain. Similarly, Hitch & Baddely (1974), for example, proposed a contemporary dual channel model of working memory, positing that verbal material was stored in a phonological loop while images were temporarily and separately stored on an inner visual sketchpad. The "central executive [was] devoted to the supervision of working memory operations" (Cornoldi & Vecchi, 2003, p. 6). This may seem to suggest they believed there were regional anatomic receptacles for memories. However, at that time, it was relatively impossible to identify specific parts of a brain that house memories of images or words (White 1987). Despite a contemporary understanding of brain anatomy that is much more accurate than medieval brain anatomy, models such as those of Hitch & Baddely were nearly as speculative as those of medieval scholars.

Models, like those of Hitch & Baddely, are foundational to today’s cognitivist learning theory that generally recognizes separate, functional memory stores. Hitch’s & Baddely’s "original account has undergone significant modification in the intervening years" (Richardson et al., 1996, p. vi), however, the basic concept of dual memory
channels persists in current times. "The exact characterization of these components has fluctuated over the years, but they are currently described as a 'central executive,' a 'phonological loop,' and a 'visuospatial scratch-pad'" (Richardson et al., 1996, p. 24).

**Memory Capacity, Mnemonics and Mental Imagery in Medieval Times**

**Memory Capacity**

Recall of instruction has been indispensable to learning in all eras. Memorization, however, was essential in the medieval era because learners were often without so much as paper and pencil for writing notes, sketching diagrams or creating memorable illustrations. Learners had to rely on their own ability to commit instruction to memory.

The limited capacity of memory was acknowledged during medieval times. Consequently, visual mnemonic techniques were used to enhance memory of instruction and information. The mnemonic methods that were devised were based on belief in a: *conspexit*, or "look," of the mental eye as measuring the length of one material division stored for recollection. So, there are Seven Wonders in the ancient world, Seven Virtues, Seven Capital Sins, six wings of the seraph diagram, each with five feathers. In memorizing a long text, one was taught to divide it into segments short enough to be easily recalled in one mental *conspexit*, and then to lay each segment away together with its address in the order of the whole text. (Carruthers, 2010, p. 20)

**Picture Superiority and Vividness**

The superiority of pictures over text for memorability was taken for granted by medieval teachers. Because "memories were thought to be carried in intense images (intentio +simulacrum)" (Carruthers, & Ziolkowski, 2004, p. 11), depictions in plays or
other illustrations portraying mutilation, beatings or other types of torture could summon up intense emotion and provocative mental images thought to be particularly effective for memory development (Lee, 2012). These intense, emotion-driven mental images could be carried in memory for prolonged periods of time.

**Mental Imagery in the Medieval Era**

Images in medieval times were so closely associated with rumination and the “ability to imagine” (Carruthers, 2010, p. 19) that “all thoughts must therefore be understood in terms of images” (Carruthers, 2010, p. 19). The medieval centrality of mental imagery in rumination and cognition, its profound role in retrieval and retention of information and the fact of its existence went unquestioned, in fact, until at least the 1700’s (Carruthers, 1992). Mental imagery was thought to be an essential part of introspection that was, in turn, essential to cognition. “Introspection suggested that imagery is important in memory, problem solving, creativity, emotion, and language comprehension” (Kosslyn, Thompson, & Ganis, 2006, p. 4).

Mental imagery was not only important in conscious thought but in unconscious cognition. Kemp (1996) noted that in Avicenna’s theory, inner senses operated not only on objects viewed in the environment, but as a learner dreamt. Although external visual information was not being actively perceived, processing continued “in the inner senses on the evaluations stored in the memory, the forms stored in imagination, or, on occasion, impressions derived from the movement of the planets” (p.58).

Training in the formation and manipulation of mental imagery was a given for students in universities of the time. Medieval learners were also instructed in methods of rotating or animating mental imagery for learning. Astronomy students during the last
decades of the middle ages, for example, learned to mentally rotate images from textbooks so they could successfully visualize motions in the universe (Crowther & Barker, 2013).

A 1498 edition of *De sphaera* (the most popular introductory astronomy textbook of the time), included a diagram of a sphere as described earlier by Euclid. A student was instructed to “manipulate this [topmost] figure mentally by rotating the semicircle about its diameter and understanding that the resultant three-dimensional shape is a sphere. In the second and third figures, the reader is supposed to imagine a sphere in three dimensions” (Crowther & Barker, 2013, p.443). (Figure 8. Instructions for mental rotation of a semi-circle and imagination of dimensional spheres.)

Medieval times were extensions of ancient treatises by such philosophers as Aristotle or St. Augustine. Those who chose to master the craft became "living libraries" of information and were hallowed for their genius (Carruthers, 1992).

Medieval mnemonic devices were based on complex memory architectures based on a loci method, known to exist from ancient times (Yates, 1966). A learner using the loci method for recall of information, first established mental images of *loci*, described as “spots or locations from a well-known path” (Massen, Vaterrodt-Plünnecke, Krings & Hilbig, 2009, p.724). “In a second step the user then pictorially combines these loci with
novel, to-be-learned information” (Massen et al., 2009, p. 724). A learner would mentally stroll in an ordered progression “through mental imagery of a scene or building or other location to recall bits of information attached to the loci, which have become mnemonic anchors for the information” (Massen et al., 2009, p. 724). Loci was represented by concrete mental images (Kemp, 1990; Small, 1997). Concrete images or concrete mental images are depictions of objects in the environment that are quickly recognized as resemblances. A sketch of a tree, for instance, is a concrete image.

The method of loci allowed a learner to visualize a "simple, clearly arranged composition site, containing many useful compartments with a straightforward route among them"(Carruthers, 2010, p.22) acting as a "foundational map to use in arranging one's subjects and materials, gathering them into the location of a new composition from the networks of one's knowledge" (Carruthers, 2010, p.22). Construction of complex mental imagery allowed learners to visualize pictorial combinations for recall of salient...
details of whole concepts (Carruthers, 1998). A learner could stash slivers of information within complex mental images of architecture, gardens or according to Biblically described geographical locations. The role of prior knowledge and familiarity played an important part in selection of loci. Carruthers (2010) said "We now would never think to organize an encyclopedia of knowledge on the plan of Noah's Ark, but for a clerical audience to whom this text was as familiar as the order of the alphabet is to us—why not?"(p.22).

Although development of memory through mnemonics was a useful tool for recall, it was not used exclusively for rote memorization of facts or figures. Rationale for rote memorization differed significantly from rationale for training the memory (Carruthers, 1992). In a commentary on Aristotle by Albertus Magnus (1193-1280), Magnus said that rote repetition, or iterata scientia, was not considered to be a memoria or trained memory (Carruthers, 1992). The ultimate goal of memorization was not so much to preserve information but rather to archive information that could be shuffled and recombined for invention of original thought. This ability to connect particles of knowledge to other particles of knowledge not only represented creative, but intelligent thought. Therefore, ars memoria was a "basic feature of education at this time, not only because of the need to store material in memory, but more importantly because of the imperative to train and enhance the computational and inventive powers of the mind" (Carruthers, 2008, p.4).
Memory Capacity, Mnemonics and Mental Imagery in Contemporary Times

Memory Capacity

One of the most important focuses on memory from the mid-twentieth century onward has been on the capacity of different memory stores. George Miller’s (1956) contention that “immediate memory” (working memory) could capably deal with seven plus or minus “units or chunks” of information--- although hailed as groundbreaking theory in the 1950’s--- was a restatement of medieval ideas about the conspectus. Carruthers (2010) said that in medieval thought "The length of a particular memorized section (was) set by the requirements of human working memory, which seems to be able to manage seven plus or minus two items at any one time” (p. 20).

Miller's research was used to recommend information be broken into chunks for better incorporation into long term memory. Miller (1956) concluded “By organizing the stimulus input simultaneously into several dimensions and successively into a sequence of chunks, we manage to break (or at least stretch) this informational bottleneck” (p.95). Chunks of information, from Miller’s standpoint, were consolidations of information bits. An example of consolidation is a single word, which is a consolidation of letters. The word “consolidation” for example, includes thirteen letters, but is a single word and therefore could be considered one chunk of information. Similarly, an image, like a portrait of an individual, such as actor Jimmy Stewart, includes many facial features. However, all his facial features are consolidated into a single chunk of visual information---represented as “Jimmy Stewart.”
Contemporary Research: Picture Superiority and Memory

Medieval belief in the superiority of pictures over words for recall of information, was not initially supported by research during the contemporary era. Duchastel (1980) found that visual instructional research prior to 1980 had overall, failed to demonstrate that pictures were superior for learning despite contradictory examples. He said, however that “a long tradition of textbook design based on creative intuition and tacit knowledge strongly supports the value of illustrations in teaching materials” (Duchastel, 1980, p.3).

He recommended, because research results were so counterintuitive, that an instructional designer should “disregard the research and continue to rely on his creative instincts when it comes to the practical art, for that is what it is, of textbook illustration” (Duchastel, 1980, p.3).

Lionel Standing was an early image researcher who, in landmark studies, demonstrated the phenomenal memorability of pictures. He demonstrated that “picture memory, which represents one form of concrete learning, is a strikingly efficient process” (Standing, 1973, p. 207). Standing, Conezio, & Haber (1970) demonstrated that study participants could, with ninety per cent accuracy, identify, days later, up to 2000 images they had seen for a matter of seconds. The researchers concluded “It is certain that the bounds of picture memory, if any do exist, must be very high indeed” (Standing, Conezio, & Haber, 1970, p. 74). Standing’s research in 1973 suggested that there was practically no ceiling effect for picture memory. He found “the capacity of recognition memory for pictures is almost limitless when measured under appropriate conditions” (Standing, 1973, p. 207). In his 1973 article, “Learning 10,000 pictures,” Standing reported that study participants could recall more than ninety percent of 10,000 pictures.
viewed days earlier and that his study also indicated memory for pictures was superior to memory for verbal material.

This phenomenon is frequently called the “pictorial superiority effect” and more recently the “picture superiority effect.” Standing (1973) observed that Alan Paivio had, by 1969:

already shown that the best predictor of verbal learning performance is the imagery producing property of the verbal stimuli employed; if we look on imagery as a type of internal picture, it seems that some type of pictorial coding is likely to be of more fundamental importance in learning than verbal coding (p. 220).

Alan Pavio’s dual coding theory (DCT), posited in 1971 (Pavio, 1991), was quickly noticed “as it was the first systematic objective approach to the study of imagery” (Pavio, 1991, p. 256). Paivio (1979) said “The model is not intended to be a complete theory of memory but is concerned instead with the functional roles of imaginal and verbal processes as memory codes” (p. 178). Simply put, DCT proposed there are “verbal and non-verbal systems assumed to be functionally independent” (Pavio, 1991, p. 259) but are also interconnected, and can therefore operate in concert. "Information recognition and recall is by contrast weakened if only one channel is used. If both verbal and image stimulation is provided to the learner, recognition and recall is enhanced" (Leonard, 2002, p. 232) The word “dog.” for example sponsors a mental image of a canine for a learner just as the image of a dog can be associated with the word “dog.” The earlier mentioned Hitch & Baddely model of working memory, which proposed separate language and visual stores, reinforced Paivio’s posit that verbal and
visual inputs were processed in distinctive ways. Ultimately, Paivio (1979) bolstered the concept of picture superiority in his DCT, noting that, "Objects and pictures are better remembered than concrete nouns, which in turn are superior to abstract nouns" (p.178).

**Picture Superiority and Vivid Images**

The types of pictures that have been thought to be most superior, or memorable, have also been characterized as the most vivid images. This posit supports earlier medieval notions that vivid, emotion provoking images were most memorable.

*Vivid information* takes the form of concrete and imagistic language, personal narratives, pictures, or first-hand experience. Vividness is a matter of degree, of course, but the most vivid type of information would be an actual experience (being attacked, being involved in an accident, etc.), and the least vivid type of information would be information that one is exposed to by reading or listening to abstract, impersonal language and statistics (Hill, 2004, p. 31).

Hill (2004) described images located on a continuum from most to least vivid images. The most vivid image type he cited on his continuum was moving images with sound. The next most vivid image was a photograph then a realistic painting then a line drawing. In each case image vividness was reduced by elimination of realistic detail. Hill's least vivid information was cited as "statistics" which might also be visual. In this case, the least vivid visual information could be represented by a statistical data display. Some researchers have found that vivid information not only elicits greater emotional reactions than plainer, abstract information but that vivid imagery is also more persuasive (Hill, 2004).
Visual Mnemonics in the Contemporary Eikoncentric Era

Higbee, in 1976, observed that “virtually all of the experimental research on mnemonics has been conducted since 1960” (p. 2). Because earlier behaviorist researchers believed “mental processes were not a very legitimate area for research” (Higbee, 1976, p. 3) and because mnemonics methods had become the province of “memory-training books and commercial courses, used by mnemonists to perform amazing memory feats… [mnemonics were consequently] ignored by most psychologists” (Higbee, 1976, p. 3). Imagery research after the 1960’s investigated imagery used in mnemonics and the ways that the vividness of an image affected recall. (Brandimonte & Gerbino, 1996).

Mnemonics methods nearly became extinct when the grammacentric era flowered. Books acted as prosthetic memories for recall (Foer, 2011) rather than mnemonics techniques. Although mnemonists continue to dazzle audiences with their nearly magical ability to recall information at events like the World Memory Championship (Hisco, 2014, April 5), mnemonic systems during the contemporary era were likely to be less pictorial and more often based on words. One reason that mnemonics are seldom used in contemporary learning is that a mnemonic system should be taught, then thoroughly learned before a learner can use it. It is not an easy task to learn and afterwards consistently operate a mnemonic system. Learners must be highly motivated. "The use of a mnemonic device…reflects an intent to remember; it is a deliberate strategy, often requiring a great deal of effort to master" (Dixon & Hertzog, 1988, p. 305).
A second reason for limited use of mnemonic systems by contemporary learners is that they have often been taught a variety of study techniques and are not limited to use of visual mnemonics. “Survey studies have shown that students ranging from 8th grade to college typically know about mnemonic techniques, but prefer to use other study strategies (Putnam, A. L., 2015, p. 132).

Third, most learners have access to paper, pens, pencils and publications unlike medieval learners. Using external memory tools “including lists, calendars, memos, and clocks--is easy to learn (or train) and their use involves comparatively little cognitive effort” (Dixon & Hertzog, 1988, p. 306).

**Contemporary Ideas About Mental Imagery**

Despite mental imagery’s prominent place "in both philosophy (until the nineteenth century) and early scientific psychology" (Kosslyn, Thompson, & Ganis, 2006, p. 4) leftover disagreements exist from what has been characterized as the contemporary “imagery debate.” Although there have been many disagreements among psychologists throughout the contemporary eikoncentric era about the absence or presence of mental imagery during cognition, the most recent incarnation of the imagery debate began during the 1970’s. Given the broad scope of this protracted, complex debate, it is only possible to briefly summarize basic aspects of the arguments represented by the debate’s propositional and the analog camps. The psychologists who are most closely associated with the imagery debate are Zenon Pylyshyn and Stephen Kosslyn.

**Pylyshyn and propositional thought.** Psychologists, such as Zenon Pylyshyn, argued that thought occurred through a propositional, languagelike mental code rather than through mental imagery (Pylyshyn, & Dupoux, 2001). Stephen Kosslyn, was and
continues to be among the most prominent opponents of Pylyshyn’s propositional theory (Roeckelein, 2004; Thomas, 2014). Kosslyn (1981), argued that mental “images are not languagelike ‘symbolic’ representations [that] bear a nonarbitrary correspondence to the thing being represented” (p. 46) but are rather quasi-pictorial.

Pylyshyn, from the standpoint of the propositional camp, not only argued that current mental imagery theories were insufficiently developed to explain thinking (Pylyshyn, 1981) but said “neither language nor pictures are sufficient to represent the content of thought” (Pylyshyn, 2003, p. 113). Pylyshyn (1973) posited that thinking occurred through “abstract mental structures to which we do not have conscious access, and which are essentially conceptual and propositional, rather than sensory or pictorial” (p. 1). The format of these abstract mental structures could be compared to language with its own grammar and language-like structure.

Kosslyn and mental imagery. Contemporary theorists who reject Pylyshyn’s propositional framework, including Kosslyn, have generally supported the idea that “visual mental imagery has inherently spatial properties, and represents in an ‘analog’ fashion that is quite different to the way that language and other symbolic systems represent” (Thomas, 2014, 4.3). Kosslyn (2007) defined a mental image as "a short-term memory representation that depicts information" (p. 94) that is constructed from memory stores. Kosslyn (1995) said “Logically there are only two ways a mental image can be formed. One can retain perceptual input online or one can activate information from long-term memory” (p. 270).

Kosslyn’s (2005) theory of mental imagery specified components that “each accepts input and transforms it in specific ways to produce output. Each component is
also assumed to store information” (p. 335). When a learner begins to form a mental image a “visual buffer,” which is an “ensemble of retinotopically organized visual areas in the occipital lobe” (Kosslyn, 2007, p.97), organizes input for creation of a mental image (Kosslyn, 2005). The visual buffer unpacks properties of an object from memory stores to form this mental image. These properties can include, among others, shape or color, edges and spatial relationships among features. The visual buffer also separates “figure vs. ground” (Kosslyn, 2007, p. 99). Gestalt theory describes figure as an object that is meant to be attended to and ground as a background that helps project the figure.

Processing in the visual buffer includes three primary activities “that ‘generate,’ ‘inspect,’ and ‘transform’ the images” (Tye, 1991, p. 42). The visual buffer “acts on information stored in long-term memory about the appearances of objects and their’ spatial structure, and, from this, it” (Tye, 1991, p. 42) generates a mental image. Different processes are activated in the visual buffer to inspect an image. Through inspection in the visual buffer, patterns are specified. Learners, through inspection:

- recognize shapes, spatial configurations, and other characteristics of the imaged objects. For example, if I form an image of a racehorse, it is the inspection process that allows me to decide whether the tip of its tail extends below its rear knees (Tye, 1991, p. 42).

- Transformation in the visual buffer allows a learner to mentally rotate an image, zoom into select features or detect placement or spatial relationships of features in an image.

This concise, simplified explanation of Kosslyn’s theory betrays the large body of research that he and his colleagues compiled over the past forty years. Kosslyn’s detailed
Individual differences: formation and accuracy of mental images. Theories and models of mental imagery tend to assume a general learner with relatively uncompromised abilities to form, inspect and transform mental images, unless there is brain damage. However, Kosslyn (2007) contended that there are distinct individual differences in mental imagery formation skills. He said that studies by Kozhevnikov, Hegarty, and Mayer in 2002 and by Kozhevnikov, Kosslyn, & Shephard in 2005: found that some perfectly normal people, with intact brains, are especially good at object imagery—constructing vivid and detailed images of the shapes and surface characteristics of objects—whereas others are good at spatial imagery—representing spatial relationships between objects and imagining spatial
transformations (such as imagining rotating an object). They also found that the two types of imagery ability rarely go together. In fact, people who are good at one type tend to be relatively poor at the other (Kosslyn, 2007, p. 105).

An important implication of these findings is that different learners will differently recall or comprehend visual instruction based on their differing abilities to create referential mental imagery.

**Gestalt Theory and Mental Imagery**

Gestalt theory, a theory of perception and learning, also posited individual difference in mental image formation. Gestalt theorists found that individual learners formed mental images and recreated images differently, presumably because of the influence of their individualized banks of prior knowledge. Although an image of an object, such as a table lamp, might have novel features, some learners tended to form canonical, or in other words, typical “table lamp” imagery. “Reproductions from memory were characterized not only by loss of detail, but also by substitution of new detail, and object assimilation—a tendency of reproductions to shift toward the typical form of familiar objects” (Koriat, & Goldsmith, 2000, p.488) in individual learners.

Gestalt theorists also found a universal tendency in learners to revise characteristics of mental imagery through a leveling and sharpening processes. Leveling occurred when ambiguous or less important properties of an image are mentally erased. Sharpening takes place when parts of an image that are most important to a viewer are exaggerated in memory (Koriat, & Goldsmith, 2000). Leveling and sharpening cause a remembered image to assume “a good shape.” This conformation occurs according to the
Gestalt law of Prägnanz. The Gestalt law Prägnanz posits that images are recalled as “regular, symmetrical, and simple memory forms” (Koriat, & Goldsmith, 2000, p.488).

The Presentation of Visual Instruction: Medieval Methods

The objective of the literate ecclesiastical intelligentsia and academicians in medieval European society was to develop spiritual awareness and indoctrinate the general populace through Biblical instruction. This instruction was not only transmitted orally by pulpit clerics, but visually, through images embedded in architectural elements, public sculptures, stained glass church windows or via illustrations on church walls. (Jones, 2008). Kemp (1990) explained that because medieval mnemonic “techniques suggested that memory and learning can be aided by imagery and hence by visual decoration… From this derived, in turn, a justification for the extensive use of didactic painting, sculpture, and architecture in the Middle Ages” (p. 71).

Images embedded in permanent architectural elements of churches, in fact, operated as the primary method for transmission of instruction to the masses. Instruction was delivered through these images with minimal captioning. Clergy knew most of their congregants were unable to read Latin, much less vernacular texts. This type eikoncentric instruction was not only useful because of widespread illiteracy, but in a larger sense, it was effective because it was in harmony with prevailing societal mores. Camille (1985) described 12th and 13th century society as one that valued oral and visual expressions but mistrusted the written word (perhaps because of widespread illiteracy). He explained this mistrust caused a wariness of diverse types of documents. Legal agreements required a record of witness on a document and were only finalized after seeing a seal as evidence.
Camille (1985) explained the medieval population could be divided into three categories including those who were fully literate, those who" must rely on the literacy of another for access to written transmission" (p.32) or those illiterates "without means or needs of such reliance" (p.32). Those who had to rely upon the literacies of others for explanation viewed instructive images communally, learning from each other through discourse. "This group before the mosaic, wall painting or stained glass would have perceived these works of art, not in terms of individual response, but as a choric or mass one" (Camille, 1985, p.32).

The most well- educated clergy and academicians were in possession of privileged information by virtue of their ability to read, and were, therefore, authoritative interpreters of public instructional images ---whenever they had the opportunity. Despite the entwinement of church and state in medieval society, the general populace infrequently attended church and "the quality of religious education was uneven in a world where even the priest was not necessarily well informed as to the nature of Christian doctrine."(Cigman, 1999, p. 13).

**The Use of Symbols in Medieval Instruction**

The rudimentary characteristics of symbols are the same in all eras. Schnotz (2002) describing the work of Charles Pierce (1906), said “symbols have an arbitrary structure and are associated with the designated object by a convention” (p. 102).

Symbols are different than icons which are designed to depict or resemble a real object. Therefore, unlike symbols, icons are not arbitrary but “are associated with the designated object by similarity” (Schnotz, 2002, p. 103). Symbols are abstract images in the sense that they are arbitrary abstractions that represent another reality.
Donald Lee (1982) explained a symbol is effective according to its degree of transparency, because "transparency is a matter of seeing 'through' the symbol to something else. In doing this, one is simultaneously 'seeing' the something and the symbol"(p.126). A symbol’s transparency can be obscured for several reasons, but prior knowledge of symbol conventions is perhaps most important to allowing a learner to see through the symbol to the thing it represents.

Given lower levels of literacy and limited education among the medieval citizenry, it could be assumed that the only imagery used in medieval instruction would have been concrete or iconic, as illustrations of things that resemble other things. If symbol interpretation requires intellectual sophistication and higher levels of education, it might be expected that symbols were rarely featured in medieval instruction for illiterate learners.

However, the opposite is true. Symbols were pervasive in medieval instruction. Their use was based on the belief that everything that could be seen in the real world was a complement to the supernatural world. The:

Western Middle Ages conceptualized a universe of symbols in which, with the sole exception of God, everything could signify something else. Thus man, the microcosm, was a symbol of the universe, the macrocosm, and individual personalities could symbolize entire movements of the mind. Above all, material things signified spiritual things or even God himself (Ladner, 1979, p.226).

Prior knowledge of illustration conventions was still essential to interpretation of symbols. Medieval learners had to rely upon their own learned recognition of visual emblems and symbols for interpretation of a sacred visual text. Symbols such as halos to
suggest holiness or conventions in medieval Old Testaments where "the 'voice' of the Lord is often represented... as a pointing hand emerging from the clouds" (Camille, 1985, p.28) were meaningful depictions for most viewers. Medieval iconography changed very gradually over time, so the constancy of symbols was important to learners of the era who could count on their recurrent meaning. For example, “Saint Peter, to use an obvious and well-known example, is almost always pictured holding keys, a kind of shorthand referring to the text of Matthew's Gospel (Matt. 16: 18) in which Christ gives Peter the keys of His Kingdom” (Cook & Herzman, 2004, p. xvi).

**Medieval Narrative Through Images**

A combination of visual elements was used to produce a story in books of the time. Numerous types of symbols including numerals, decorative elements, animals, pictures of human beings could, in combination, tell a whole Biblical story or life of a saint--- whether portrayed in architecture or books. When human beings were portrayed, their gestures were important for depicting the qualities of the story (Jones, 2008). Because static human gestures implied motion, viewing may nearly have been a cinematic experience.

Visual stories or narratives were central in illustrated codices that might only include short bits of text. The expense of handmade books prior to invention of the Gutenberg moveable type printing press naturally restricted ownership to a relatively well-to-do clientele. Despite their places in the upper segments of society, most book owners were likely to be illiterate or had limited skills in reading text. Although some commoners owned or accessed written, hand illustrated medieval Bibles and books that
were dominated by text, many period books were conceived of and designed as picture books.

Cigman (1999) described a medieval French Picard version of the Old Testament as an example of a Bible that emphasized the importance of visuals over text. Cigman (1999) said it was "apparent in the fact that, unusually though not uniquely, the drawings were done first, and the text added later, crowded into areas that are often too small, sometimes spilling into the margins and even into spaces within pictures" (p.23).

**Medieval Era Illustration Techniques: Marginalia, Illuminators and Layout**

Contemporary layout techniques, as earlier mentioned, can de-emphasize text and cause learners to attend to images before reading textual passages. Medieval layout techniques, prior to invention of the moveable type printing press, were literally in the hands of scribes and illuminators. Although there were conventional uses of imagery, such as illumination of the first letter of a phrase, conventions were sometimes ignored---most notably by the insertion of marginal illustrations.

Marginal illustrations were inserted into books according to the unction of a scribe or illuminator. Marginal illustrations were used as “a supplement that is able to glow, parody, modernize and problematize the text’s authority while never totally undermining it” (Camille, 2004, p. 9). Nevertheless, ecclesiastics objected to these attention-getting illustrations because they were often comic, grotesque and unflatteringly imitative or were unnatural depictions of human-animal hybrids (Griffiths, 2010). Marginal illustrations proliferated during the thirteenth century (Camille, 2004). They were called “babuini” which can be translated to our contemporary colloquialism,
“monkey business” (Camille, 2004; Griffiths, 2010). (Figure 10. A page from the Psalms with marginal babuini from the Luttrell Psalter. Circa 1325-1340.)

Figure 10. A page from the Psalms with marginal hybrids, from the Luttrell Psalter, England, N. (Lincolnshire), 1325-1340. A king and a bishop portrayed as a human-reptile-bird-like animal. The illuminated letter “D” begins the word “Dominus” and appears in the upper third section of the page. From:
http://britishlibrary.typepad.co.uk/digitisedmanuscripts/2015/10/hybrids-and-shape-shifters.html#sthash.EjH5Jq05.dpuf

Illuminators, as graphic artists of the time, frequently fitted marginalia into sacred texts, although they are also common in medieval textbooks. Illuminators rendered marginalia after the text was written by scribes (Stanford & Manning, 2014, July 24).

There has seemed to be little logic in the type of depictions that were inserted into margins. Marginalia in sacred books could represent something presented in text but were just as likely to picture characters from popular folk riddles. Depictions could be humorous or crude, even when placed in the margins of Bibles or prayer books. The
common and profane illustrations in margins included depictions of "everyday human life, the animal kingdom writ large (with realistic, fantastic and comical characters) and instances of the natural order turned upside down (Nishimura, 2009, p. 26). (Figure 11. Fantastic monsters with animal traits in comical battle.)

Figure 11. Fantastic monsters with animal traits in comical battle. Fantastic marginalia from the sacred Rutland Psalter, c. 1260. (British Library Royal MS 62925, f. 87v.) From: Stanford & Manning, 2014, July 24.

Therefore, illuminators were more than copyists. They became artists and mediators of informational or instructional text through creation of original imagery for books that offered alternate imagery. The illuminator’s traditional function as a mediator of instruction is still in evidence as graphic artists mediate instructional or informational publication through selection or creation of images for informal or formal learning.

Medieval imagery was also highlighted through layout techniques. Imagery could protrude into textual passages, foreshadowing contemporary layouts that use text wrapping. Although text exists on the page, the image is made the center of attention
because text surrounds it. When images were large, they covered most of a page with minimal text, further spotlighting the image. (Figure 12. Drawing in a cruciform shape of the Fruits of the Flesh and of the Spirit.)

Figure 12. Drawing in a cruciform shape of the Fruits of the Flesh and of the Spirit. From the Speculum virginum written after 1140 AD. God is seated at the top, a dragon at the bottom. Personifications of Reason, Wisdom, Goodness, and Law inside the cruciform. From: The British Library. https://www.bl.uk/catalogues/illuminatedmanuscripts/ILLUMIN.ASP?Size = mid&IllID = 6981

Use of Visual Metaphor and Analogy in Medieval Times

Medieval instruction commonly used visual analogies and metaphors both in sacred and secular instruction. During the contemporary era, visual analogy or visual metaphor (interchangeably referred to as a pictorial metaphor) has sometimes been defined in terms like those used when describing a verbal or written analogy or metaphor. The Merriam Webster dictionary online offers a broad definition of analogy as "a comparison of two things based on their being alike in some way" (Merriam Webster, n.d., para.4) or as "the act of comparing two things that are alike in some way" (Merriam
Webster, n.d., para. 5). Metaphor is described by the Merriam Webster dictionary in simple terms, as "a word or phrase for one thing that is used to refer to another thing in order to show or suggest that they are similar" (n.d., para. 4) or as "an object, activity, or idea that is used as a symbol of something else" (n.d., para. 5). A fuller definition would necessarily include description of a metaphor as a verbal or pictorial device that implies one thing is another thing. For example, Shakespeare's verbal metaphoric line "All the world's a stage" implies the "world" is a "stage."

Because metaphor was widely studied after the mid-twentieth century, definitions of this term have varied because “there is no general agreement on what exactly the term metaphor is meant to refer to or how it operates (Noppen & Hols, 1990, pp. 3-4). However, in seeking a definition for analogies, analogies can be said to “consist of parallels in relations. For example, … kittens are to cats as puppies are to dogs” (Dent-Read, Klein & Eggleston, 1994. p. 216) while visual metaphors compare sets of “objects that are not the same the same kind of thing” (Dent-Read, Klein & Eggleston, 1994. p. 216). For the purposes of this review, a visual analogy is defined as a comparison of two images that are alike in some way. A visual/pictorial metaphor is defined as an imaginal device that implies one thing is equivalent to a different thing.

**Medieval Pedagogy: Metaphor and Analogy**

The use of visual metaphor and analogy to link a learner’s prior knowledge to new concepts was a common pedagogical technique used during the medieval era (and we see the same use of visual metaphor and analogy today). Crowther and Barker (2013) explained that in astronomy instruction, "common [visual] analogies [were] used to clarify the status of celestial bodies [comparing] them to knots in a board and to nails
carried by ships or on the rim of a wheel—the latter also capturing the circularity of their motion "(p.447). Spiritual instruction also made use of metaphor in manuscripts. (Figure 13. Medieval visual metaphor: virtue is a spiritual ladder.)

Figure 13. Medieval visual metaphor: virtue is a spiritual ladder. A medieval metaphorical illustration describes the pitfalls and potentials of climbing the spiritual ladder of virtue. Metaphoric depiction from *Hortus Deliciarum: Ladder of Virtues* (folio 216r). Excerpted from a German Manuscript ca. 1170 AD. From: http://www.oberlin.edu/images/Art310/10644.JPG

**Learning transfer through analogy.** Although medieval instructors did not necessarily expound on the virtues of analytical reasoning, medieval learners would have benefitted from the learning transfer that analogy in instruction can provide. One of the conditions of learning transfer, as identified by Perkins and Salomon (1992) is reasoning through analogical thinking. Learning transfer is facilitated as "new material is studied in light of previously learned material that serves as an analogy or metaphor. Things known about the ‘old’ domain of knowledge can now be transferred to a ‘new’ domain thereby
making it better understood and learned" (Perkins & Salomon, 1992, para. 21). These conditions of transfer were demonstrated by medieval learners who studied geometry.

Knowledge of geometrical shapes constituted a common literacy in 15th century Italy, for example, as boys aspiring to merchant careers were enrolled in schools where they were taught geometry and how to calculate quantities of commercial goods through mathematical reasoning at a glance. (Crowther & Barker, 2013). Crowther & Barker said this literacy extended to interpretation and appreciation of fine arts as well because:

When painters used geometrical shapes, such as tiled floors, rows of columns, and round pavilions, to create the illusion of depth and distance in paintings constructed according to the rules of linear perspective, they were tapping into their audiences’ finely-honed skills in analyzing such shapes (p.438).

This is an historical demonstration of visual instruction that promotes far transfer or in other words, transfer of learning in one domain ---geometric calculation--- to another ---interpretation of fine art.

**The Presentation of Visual Instruction: Contemporary Methods**

There is no exact contemporary correspondence to the medieval practice of embedding learning graphics in the walls of churches or cathedrals, although these do exist in contemporary churches. Things like marketing campaigns have made learning about products through billboards or getting travel information from public road signage, alternate forms of choric learning. Signage has been a part of informal instruction since the dawn of the contemporary eikoncentric era. Formal choric learning was also accomplished in early years of the contemporary eikoncentric era through wall charts.
The wall chart movement that emerged in the mid 1800's was based upon use of large uncaptioned or sparsely captioned visual displays. These wall charts were communally viewed, discussed and mediated by an expert---often a classroom teacher (Bucchi, 2006). Guidebooks were often shipped with wall charts, so teachers or other lecturers understood what each illustration meant. Images on a wall chart were often realistic illustrations, maps or diagrams (Bucchi, 2006). Germany became the chief producer and exporter of wall charts by 1852, after reforms in German public education enlarged classroom sizes to an average of 136 students. Because a wall chart’s average size was “roughly 35 × 50 inches each “(Van der Schueren, 2011, Kindle Location 42-43), most students in a large classroom could view visual information at a distance. The development of chromolithography, which made publication of large color charts affordable, contributed to mass use of wall charts in formal or informal settings from at least 1850 - 1950. Wall charts could act as secular or sacred instruction. Biblical maps and stories were used in sacred wall chart instruction while multiple features related to a plant, animal, machine, geographical location or environment could be incorporated onto a single wall chart for secular instruction. (Figure 14. Wall chart of a red kangaroo.)

Modern technologies invented during the contemporary era have also encouraged choric learning from mostly unlabeled, static visual displays. Examples of static visual media inventions include instructional slides and filmstrips. PowerPoint style presentations are practically ubiquitous in lecture halls or at conventions or on any occasion when somebody delivers information to a group. PowerPoint style presentations reinforce visual thinking because slides tend to display limited text.
Symbols in Contemporary Instruction

Numerous types of symbols are pervasive in instructional visual displays. These symbols may be specific to multiple fields, including the sciences, social sciences, business, information science, communication studies or fine arts. Although symbols have been used in both medieval and contemporary eikoncentric instruction, a limited catalogue of symbols existed in medieval times. Symbols that were a part of medieval instruction were generally derived from a Christian belief system that permeated all of society and were therefore made familiar to learners through constant encounter.

Contemporary society, by contrast, uses symbols in multiple secular or sacred instructional genres. Data displays, for example, are increasingly used in contemporary instruction and are made up of symbols. Therefore, understanding the appropriate use of symbols and how best to design them so they are immune to misinterpretation is crucial during this contemporary eikoncentric era.

Figure 14. Wall chart of a red kangaroo. Multiple features are depicted including kangaroos in their native environment, a kangaroo’s skeletal structure and a fetal kangaroo. From: Van der Schueren, 2011, Kindle Location 263.
Symbols, incorporated into instruction, are arbitrary depictions that signify something. Symbols are integrated into instruction though “the meaning is not in the symbol, but in the complex webs of associations that the symbol triggers when it is deployed in a particular context” (Davis, Sumara, & Luce-Kapler, 2000, p. 17). Symbols “collect together an immensity of associations. As such, symbols are a powerful and necessary technology for thinking” (Davis, Sumara, & Luce-Kapler, 2000, p. 17).

Symbols used in numerous fields contribute to the quantity of symbols in circulation. Symbols however, are also qualitatively discrete species, made distinct by the conventions of a given group or academic field. Symbols are regularly a part of science instruction, for example, because “the symbolic world of science is now populated with entities such as atoms, electrons, ions, fields and fluxes, genes and chromosomes” (Driver, Asoko, Leach, Scott, Mortimer, 1994, p. 6). These elements can be visualized as symbols. Symbols are, however, structured in qualitatively distinct ways in different fields of science. In chemistry, for example, “specialized symbol systems—such as reaction equations, molecular structure diagrams, concentration graphs, and three-dimensional (3D) computer models… {are used to] … represent the molecular phenomena” (Kozma & Russell, 1997, p.950). Physics, botany, biology or astronomy instruction each uses different symbols. Symbol systems, (defined here as configured amalgamations of single symbols) that are in common use across fields include visual displays such as graphs, charts, timelines or maps.

The development of symbols used in contemporary instructional visual displays can be likened to “the development of the pictograms of ancient languages” (Mishra, 2004, p.183) because their evolutionary cycle begins with a realistic illustration of an
object that is abbreviated to a pictogram. Pictograms can, in turn, be abstracted into symbols. Mishra (2004) traced the evolution of the symbol for a Wheatstone bridge circuit showing the typical transformation of a figure from a realistic illustration to a symbol. The symbol is meaningful only to an experienced electrician. (Figure 15. Examples of illustration of a Wheatstone bridge circuits rendered in the 1890’s.)

![Wheatstone bridge circuit from 1890. b) Wheatstone bridge circuit from 1898.](image)

Figure 15. Examples of illustration of a Wheatstone bridge circuits rendered in the 1890’s. Original drawings of the Wheatstone bridge circuit were realistic. By 1890, as the example (a) above shows, the circuit was rendered as a crude cartoon or pictograph, using icons to illustrate the function of the circuit. By 1898 (b) the circuit had been transposed and abstracted as a symbol. From: Mishra (2004).

Because symbols are arbitrary representations of reality (Schnotz, 2002) that are associated with the things they represent strictly through convention (Rehkämper, 2011), formal or informal instruction about what each one represents are essential for comprehension. Instruction can include training in single symbols or symbol systems. The arbitrariness and ubiquity of symbols in educational and professional media makes instruction about symbols themselves more important than ever for both novices and experts. Novice problems with unfamiliar symbols can be expected, but difficulties with unfamiliar symbol interpretation are just as frequently found among experts.
Unfamiliarity with symbols: expert problems. Although novices predictably struggle with interpretation of unfamiliar symbols, it has also been demonstrated that experts in given professions or fields of study also misinterpret symbols. Griffin (1994) found that business graduate students were unfamiliar with some of the most commonly used symbols in business publications including the symbol for copyright and the symbol for Spain’s peseta or in other words, Spain’s basic monetary unit.

Experts in given science domains also have trouble transferring their knowledge of symbology from their own field to another science domain. Expertise has been described as "very specific and 'brittle'; that is, experts may encounter difficulties when tasks are altered or when transfer to new problems is expected" (Lewandowsky, Little, & Kalish, 2007, p. 84). Although it might be expected that experts in one field could intuitively decipher symbols in allied fields this is not always true. Symbols are not only differently used, but differently related to a field’s content knowledge. Studies have demonstrated that when graphs were encountered “by scientists in different fields, not only experience, but also knowledge of the phenomenon depicted affected graph comprehension (Friel, Curcio & Bright 2001). Mishra (2004) (referring to the previously given example of the Wheatstone bridge circuit), concluded that “symbols are meaningless to those with no understanding of, in this case, electrical theory. Symbols only have meaning for those who share perceptual hypotheses, or abstract theories” (p. 183-4).

Griffin (1994) drew three conclusions from his study that researched symbol familiarity among graduate business students. These conclusions could be extended to experts or learners in other fields. First, he concluded that symbols, even those assumed
to be part of a “common language” (p. 44) are poorly recognized. Second, symbols are
prey to superficial examination and “rapid judgment” (p. 44) about their meaning. Third,
“perception is relative to the context in which it is viewed” (pp. 44-45) because symbols
in isolation were unrecognized when individually displayed without other clues to
meaning.

**Becoming familiar with symbols: repeated exposure.** Symbols remain
unfamiliar to novice learners or professionals without training in their use. They cannot
be intuitively deciphered, but only understood with reference to known conventions of
design or use. It has been noted, that it is very difficult to transfer knowledge of a symbol
used in one field to another. So, instruction about *specific symbols* is essential to making
their meaning *transparent*. Apart from formal instruction, learners become acquainted
with symbols through repeated exposure.

Although today’s learners can draw from a bank of prior instruction, repeated
exposure to symbols in use is perhaps most essential to acquainting learners with
meanings of symbols. Experience in daily life exposes learners to symbols in the public
view. Symbols are learned informally when they are viewed time and again in public
media such as newspapers, magazines or on websites. Additionally, because commercial
corporations often brand their products with a symbol, symbols and their meanings
become familiar through signage or labels. Symbols can be legally trademarked, but also,
because of repeated exposure, become “trademarked” within a learner's mind. (Figure 16.
*McDonald’s* restaurant symbol: the golden arches.)

What makes the McDonald’s symbol so recognizable? Could it easily be mistaken
for a letter “m” except for its three-dimensional rendering, yellow and red colors and the
angle of the arches? Advertising and signage, now all over the world, gives the
McDonald’s symbol its distinction. Were it not for mass exposure and the characteristic
colors and angles, the symbol might otherwise look like just another “m.” Symbols, in all
cases, must have recognizable, outstanding features so they are not mistaken for a
different symbol.

Problems with symbols. Symbols or images, including scientific images “from
different times and places may look quite similar but have radically different
meanings"(Crowther & Barker, 2013, p. 433). And because “symbols are 'polysemic':
they are capable of conveying multiple meanings” (Toumey, 1996, p. 48). Therefore, one
symbol resembling another may be differently interpreted. One of the major problems
associated with symbols is their potential resemblance to other symbols.

A symbol that is used in one context may be designed for a different purpose
using similar visual features. For example, the use of peaked lines and valleys are
incorporated into a symbol for an electrical potentiometer. An experienced electrician,
will instantly recognize this symbol. However, the use of jagged lines in symbols is not at
all uncommon. If all labels and captions were removed, the electrical resistor symbol
might be confused as the symbol for a heartbeat reading by an inexperienced cardiac patient or as a portion of a fever chart by a statistician. (Figure 17. Three different symbols that use jagged lines to represent an electric resistor, a heartbeat reading and a fever chart.)

A) Electrical potentiometer B) A heartbeat readout C) A fever chart portion

Figure 17. Three different symbols that use jagged lines to represent an electric resistor, a heartbeat reading and a fever chart. A) US electrician’s symbol for potentiometer, a manually adjustable variable resistor with 3 terminals that could be mistaken for B) a heartbeat readout by a patient or C) a fever chart portion by a statistician. From: A) Potentiometer Resistor Guide. (n.d.); B); C) Hamlet.

The problem of symbol interpretation due to a resemblance of one symbol to another, can lead to misapplication of concepts. A chilling study by Latham, Long & Devitt (2013) found that children’s domain knowledge about pirate flags led them to believe that a bottle labeled with skull and crossbones symbolized a “pirate drink” (p. 274) rather than a toxic poison. (Figure 19. Children’s misconception of the skull and crossbones symbol signifying “poisonous.”)
Another reason for mistaken interpretation of a symbol is that a well-known symbol that signifies one thing is deliberately adapted to signify something else. Leonard Nimoy, who played the role of “Spock” in the Star Trek television series and movies, for example, adapted the hand sign made by orthodox Jewish Kohanim (priests) into a 'Vulcan salute'. During services, the Kohanim pronounce a benediction over congregants as they "raise their hands and arrange the fingers so as to form 'windows'. The idea behind this is that the blessing proceeds from G-d as if He is sending it through the apertures of the hands"(Jacobs, 1995, p. 385).

This hand sign has an entirely different meaning for fans of television and film versions of Star Trek. Nimoy, in his portrayal of the character “Spock,” raises his hand in the Vulcan salute uttering his own form of benediction, “Live long and prosper.” (Figure 19. Portrayal of the hands of the Kohanim forming the letter Shin (ש) representing El Shaddai or Almighty G-d (left) and Leonard Nimoy as “Spock” (right) making the same hand sign.)
Considering the problems associated with designing and displaying symbols, correct interpretation of a symbol’s meaning is impeded, particularly, by unfamiliarity, different uses of the same symbol or by a symbol that is presented out-of-context. Adoption or adaptation of a symbol for new applications can disorient learners and lead to misinterpretation of the concepts or information the symbol is intended to clarify.

**Use of Visual Metaphor and Analogy in Contemporary Times**

A visual metaphor or analogy can over overcome some of the problems associated with symbols in instruction. Because familiar images or visual elements are often used in pictorial metaphors and analogies, these devices can act as scaffolding for learners by bridging the gap between prior knowledge and introduction of new concepts. (The terms “pictorial metaphor” and “visual metaphor” are synonymous.) The use of visual metaphor and analogy can also contextualize and concretize abstract visual displays.

Visual metaphor has become more prominent in both formal and informal instruction. The considerable likelihood that all learners will encounter instructional visual metaphors makes understanding the ways they are processed and understood more
imperative than ever. The widespread practice of using a visual metaphor as a background in CBT or WBT has already been described. Textbook instruction has also made use of visual metaphor to describe unfamiliar phenomena. Levin and Mayer (1993), for example, described the use of pictorial metaphor in science instruction as an example of correspondence, which involves “constructing pictorial relationships between unfamiliar concepts and those with which the learner is already familiar” (p. 100). They used, as one example, Hurt’s (1987) pictorial metaphor of “muscles as bell-ringers” (Levin & Mayer, p. 100) that described the way muscles stretch or respond to stimulus. (Figure 20. A pictorial metaphor originally used by Hurt in 1987 to describe the way muscles operate in the human body.)

![Figure 20. A pictorial metaphor originally used by Hurt in 1987 to describe the way muscles operate in the human body. From: Mayer & Levin, 1993, p. 102.](image)

Although use of visual metaphor occurs in formal instruction, it is pervasive in popular media like newspapers, websites or magazines for informal learning as well as in advertising (Phillips & McQuarrie, 2004). Visual metaphor is commonly used as a mediator to explain expert conceptual knowledge to a general public. “Experts who wish to communicate their knowledge (e.g., their problem perspectives, decision rationales,
experiences, procedures etc.) to non-experts” (Eppler, 2003, p. 81) increasingly use pictorial metaphor to describe phenomena, and particularly scientific or technical phenomena.

Popular media often uses images that can sometimes be described as cartoonish in efforts to connect with general readers. Cartoons are illustrations that caricature or highlight only the most salient or recognizable visual features of the real-world image they portray. Cartoons have been used to amplify or exaggerate a message (Bounegru, & Forceville, 2011). Notably, experts have objected to the use of visual metaphor in popular media claiming that they are reductionist, cartoonish and thus betray the complexity of their described phenomena or undermine the seriousness of their claims. Visual metaphors however, serve in many cases, as effective pictorial introductions to material that would not otherwise be easily comprehended by novices.

When considering infographics, there may be an advantage to minimalizing realistic detail, in forms that caricature or cartoon an original subject- not only to help FD learners, but all learners. Wages, Grünvogel & Grützmacher (2004) referred to Scott McCloud’s principle of “amplification through simplification” in their discussion of aesthetics in computer games. Essentially, McCloud argued that by stripping down an image, such as a face, to “its essential meaning through simplifying and cartooning... allows artists to amplify the meaning of the image (e.g. the expression of a face) in a way that would not be possible with a realistic presentation” (Wages, Grünvogel & Grützmacher, 2004, p.223). Wages, Grünvogel & Grützmacher added that a virtue of simplification in contrast to that of a realistic image was its universality. In other words, through simplification a face becomes representative of all faces rather than that of an
individual that is realistically depicted. This is perhaps why cartooning is often associated with infographics.

Kemp (1997) argued that “no field is richer in metaphor than the body. I am less concerned here with the use of metaphors drawn from the body--such as 'the heart of the matter'-- than with metaphors for the body” (p. 11). Visual metaphors of the body as architecture have appeared from at least the 1600’s and into the contemporary era for the instruction of popular readers and novices. Three historical figures represent a timeline of the use of visual metaphor to describe the human body as architecture. The posted examples of “body-related “metaphoric images have been featured in popular media or in introductory instruction. (Figure 21. Visual metaphor from Ma'aseh Toviyyah, the encyclopedic work of Tobias Cohn, published in 1708; Figure 22. The Wonders Within Your Head” from Look Magazine, December 6, 1938; Figure 23. Der mensch als Industriepalast: Man as an industrial palace.)
Figure 22. Visual metaphor from *Ma'aseh Toviyyah*, the encyclopedic work of Tobias Cohn, published in 1708. Body organs are rooms in a house. From: Digital Clendening: Rare Text Images (2000).
Visual metaphor is rife in advertisements since the message of an ad is often based on pictures (Phillips & McQuarrie, 2004). Advertising researchers have studied visual metaphor, due to its frequent use in advertisements, perhaps more extensively than researchers in other fields. Their findings about the ways visual metaphors are cognitively processed have much to offer, especially to instructional designers who are designing visual instruction for novice learners or popular target audiences. Psychologists have developed general theories of metaphor that describe operation of visual and verbal metaphor, although most of these are focused on verbal metaphor.
General Theories of and Ideas About Metaphor

Metaphor has been studied at least since ancient times, beginning with Aristotle. The comparative view of metaphor, present in Aristotle's theory, assumes learners engage in metaphorical reasoning when they make analogical comparisons. "What Aristotle understood was that metaphor is not an ornament but is rather a cognitive tool" (Eco, 1986, p. 102) and "metaphor is in the highest degree instructive" (Eco, 1986, quoting Aristotle, p. 102). When interpreting a metaphor, the mastery of one domain of knowledge (prior knowledge) allows comparison of the traits of another domain. Salomon (1994) described this act of comparison of seemingly incompatible domains that result in metaphorical “possession” (comprehension) of a metaphor. He said:

Metaphorical possession entails a tension between literal possession and borrowed or transferred meaning. The tension is created, because the transfer from one domain to another (for example, from that of color to that of mood) is contraindicative. Yet, in a metaphor, the transfer makes sense -- that is, once the two domains are bridged, the relationship becomes understood as reasonable. Take, for instance, the many ways in which sexual relations have been metaphorically shown in films -- the train rushing into the tunnel, the boiling kettle, the blurred picture. There is a tension between what is literally shown and what is metaphorically meant, yet the relationship becomes apparent. (p. 41)

Verbalism in Metaphor Theory: Implications for Visual Metaphor

During the twentieth century, scholars assiduously examined occurrences of metaphor in literature or everyday spoken or written language. Foundational metaphor
theories, largely posited during or immediately following the cognitive revolution in psychology, emulated the cognitive revolution’s focus on speech.

Most theorists during the twentieth century proposed theorems about the use of verbal metaphor to the neglect of visual metaphor (Serig, 2006; Martín de la Rosa, 2009; Ortiz, 2011). Although some theories of visual metaphor have wholly adopted premises about verbal metaphor, this practice is faulty due to the significant differences in verbal or visual cognition (Phillips & McQuarrie, 2004). Differences in cognitive processing of verbal or visual metaphor are bound to exist, because each are based on separate sign systems. Paivio’s earlier mentioned dual coding theory (Pavio, 1991) or the Hitch and Baddely (Hitch & Baddely, 1974) memory model positing separate storage systems for verbal or imaginal information, are examples of psychological perspectives that support theories of differential verbal and visual processing.

Verbal language has been called “descriptive” while visual signs are considered depictive, and "are associated with the content they represent through common structural features. Depictions do not contain signs for relations; instead the relations are inferred" (Schnotz, Bannert, & Seufert, 2002, p. 390). Letterforms, like other notational systems such as numbers or musical notes, are arbitrary in the same way all symbols are arbitrary. Their meanings cannot be interpreted intuitively, but according to familiarity with their conventional use (Schnotz, Bannert, & Seufert, 2002).

Images themselves “constitute a largely analogical system of communication” (Messaris & Abraham, 2001, p. 216) because images are interpreted according to their resemblance to items they depict (Messaris & Abraham, 2001). Due to an emphasis on
verbal metaphor, theory about visual metaphor is incomplete and not yet ready to act as a guidance system for visual instruction.

**Contemporary Metaphor Theories**

Metaphor theories, primarily stated as theories of verbal metaphor, have often been categorized as substitution, interaction and comparison views. Substitution views of metaphor operate under assumptions that a metaphor is a substitution for a more literal expression. Metaphor, in this case, can be used to otherwise state what a factual, literal statement could alternately explain and is therefore linguistically ornamental (Ortony, 1980). Interaction views of metaphor explain the function of a metaphor rather than drilling into issues of its grammatical structure (Ortony, Reynolds & Arter, 1978). Interaction views “rest on the idea that the knowledge associated with the terms in the metaphor interacts to produce something new” (Ortony, 1980, p.352). The interaction between a metaphor’s first idea, described as the “tenor” and the second idea described as “vehicle” (Van Eck, 1996) promotes a synthesis of both ideas into a new concept. A learner perceives a similarity in ideas that allows this synthesis ---although similarities in these differing domains may never have been described before (Martín de la Rosa, 2009). The idea of synthesis of two ideas into one concept through metaphor is reminiscent of the Gestalt idea that “the whole was different from, or other than, the sum of its parts and, moreover, that the perception of the whole occurred prior to the parts” (Kubovy & Pomerantz, 1981, p. 449). The comparison view of metaphor asserts that “metaphor is an implicit comparison” (Ortony, 1980, p.352) of two differing terms.

The Lakoff and Johnson (1980) cognitive model of metaphor has served as a launching point for other metaphor theories. Their theory has been important because it
was not confined to verbal aspects of metaphor. Metaphor, in their cognitive model, “is primarily a matter of thought and action and only derivatively a matter of language” (p. 153). Lakoff and Johnson (1980) argued that metaphoric or analogical thinking is a central function of internal cognitive processing and reasoning, rather than linguistic expressions. Metaphors are conceptual rather than mere figures of speech. They viewed metaphoric thinking “as a pervasive and integrative component of human thought and problem solving” (Moore & Lehman, 1995, p. 455). In this respect, the Lakoff and Johnson cognitive model of metaphor explains how cognition operates in general and is broader than most metaphor theories.

They asserted “the essence of metaphor is understanding and experiencing one thing in terms of another” (Lakoff & Johnson, 1980, p.5). The experiential part of this definition is important. Metaphor, they stated, is embodied in all “the natural dimensions of our experience, including color, shape, texture, sound, etc.” (Lakoff & Johnson, 1980, p. 235). Their focus on personal experience qualifies meets criteria for classification of their model as a phenomenological model.

Lakoff and Johnson described metaphor as a composite of a source (vehicle) domain that is often concrete in nature and target (tenor) domain that is often abstract in nature (Forceville, 2006). The source domain is a conceptual domain that allows us to metaphorically understand a target domain (Kövecses, 2002). Therefore, in the Shakespearean line from *Romeo and Juliet* “Juliet is the sun,” the sun is the source domain that allows us to understand the concept of Juliet’s personal traits.

In a metaphor; there are two domains: the target domain, which is constituted by the immediate subject matter, and the source domain, in which important
metaphorical reasoning takes place and that provides the source concepts used in that reasoning. Metaphorical language has literal meaning in the source domain. In addition, a metaphoric mapping is multiple, that is, two or more elements are mapped to two or more other elements. Image-schema structure is preserved in the mapping—interiors of containers map to interiors, exteriors map to exteriors; sources of motion to sources, goals to goals, and so on (Lakoff & Johnson, 1980, p. 265).

This literature review adopts the position that visual metaphor cannot always be described according to established verbal metaphor theory, although there are definite theoretical correspondences of verbal to visual metaphor. A source and target, for example, can be identified in a visual metaphor (however, to identify these two domains we need to verbally express the nature of the domains). Additionally, the sum interaction of the target and source domain is considered, for the purposes of this review, to create a whole, synthesized understanding that is novel, and different than an understanding of its parts.

**Types of Visual Metaphor**

A visual metaphor is seldom monomodal and generally reliant on notational systems, such as words, numbers or symbols to clarify its instructional message. A monomodal metaphor is either verbal or visual. Monomodal visual metaphors are rare since they exclusively use pictures without accompanying text, numbers or other notations from notational systems. Metaphors can be and are often multimodal (Forceville, 2002). A multimodal metaphor incorporates both pictorial and notational elements (words, numbers, or symbols) into a visual presentation. Multimodal visual
metaphors can be classified as “minimally dependent” on words or other notations (in which case headlines, captions, labels, numbers or symbols are minimally used to support interpretation of a metaphor) or as “dependent” on words or other notations (in which case text may appear as passages or numbers and symbols may be used extensively.)

**Visual Metaphors: Findings from Advertising Research**

Although findings about visual metaphor by advertising researchers were meant to inform commercial enterprise, they also lend valuable information to instructional design. Advertising researchers have described trends in the use of visual metaphor that contribute to understandings about the current visual presentation milieu. A content analysis by Phillips (2003) analyzing visual metaphors in advertising from 1954 – 1999, for example, demonstrated a trend toward decreasing use of words and an increasing use of pictures. “Visual metaphor ads at the beginning of the time period tend to use verbal copy that fully explains the meanings of the metaphors, while more recent ads have much less explanatory copy or none” (Phillips, 2003, p. 305). Phillips (2003) speculated reasons for this trend may include a greater confidence by advertisers in their readers’ abilities to decipher a pictorial message. Given the eikoncentric nature of the contemporary era, his supposition seems reasonable and it is likely that the same confidence—or perhaps overconfidence—in learners’ visual abilities is also held by instructional designers.

**Processes in Interpreting Visual Metaphor**

Advertising researchers found visual metaphor in publications increased viewer "attention, elaboration and pleasure"(Phillips, 2003, p.303). Elaboration is described as “broadly speaking, the amount, complexity or range of cognitive activity occasioned”
(McQuarrie & Mick, 1999, p.39) by solving a metaphoric puzzle. Learners will work to solve a metaphoric puzzle (Phillips, 2003) although a target and source domain may initially seem incongruous. Using prior knowledge to generate "a simple inference that associates the two objects; if no simple inference can be found, consumers will entertain alternatives" (Phillips, 2003, p.303). Research findings suggest that ads featuring visual metaphors become "sticky" because learner attention is maintained through engagement in puzzle solving that triggers processes of inference and elaboration. When a puzzle is solved, learners experience pleasure in their accomplishment.

**Attention to Visual Metaphor**

The first step in cognitive processing of a visual metaphor is attending. The basis of a visual metaphor's attention-getting quality is its presentation of an intriguing puzzle. Learners attend to visual metaphors more readily than they do to pictures presented in other contexts. Advertisers discovered that visual metaphor is “more likely to be noticed by consumers under normal cluttered viewing conditions of low-involvement magazine reading” (Phillips, 2003, p. 303). It has been demonstrated that pictorial metaphors in advertisements are better at attracting attention than advertisements that simply feature product pictures (Bergkvist, Eiderbäck, & Palombo, 2012).

Attention will be maintained, and learners will make inferences and elaborate only if the metaphor itself is novel. If a metaphoric "puzzle" can be almost immediately solved--- because its' root expression has become cliché or because it is overly simplistic-- the metaphor is "dead." A dead visual metaphor lacks novelty. A verbal metaphor such "*that woman is a dog.*" for instance, has been "beaten to death" through overuse. Phillips (2003) asserted that dead visual metaphors in advertising have included
juxtaposition of a waterfall with a pitcher of water, bottled water or beer. Since these product images have been commonly paired with a waterfall to imply purity, the metaphor is no longer novel or "apt." An "apt" visual metaphor is one that compares "widely different objects" (Phillips, 2003). Aptness has also been described as a quality of metaphor that "reflects the degree to which a metaphor vehicle captures important features of a metaphor topic" (Thibodeau & Durgin, 2011, p.206).

When is a Visual Metaphor Dead?

It is difficult to determine under which conditions a metaphor is dead, however. Potentially, a novel visual presentation of an old verbal metaphor can intrigue learners, capturing and maintaining attention. We are familiar with verbal metaphorical expressions such as “food for thought.” However, when the same statement is captured in a visual presentation, it may appear to be novel, or is made new again. (Figure 24. A visual advertising metaphor pictorially restates “food for thought.”)

Complex Vs. Simple Metaphors

Researchers also found that moderately complex metaphors (when comprehended) capture and maintain attention, support greater retention of information and promote greater learner satisfaction (Van Mulken, Van Hooft, & Nederstigt, 2014) than simple metaphors. “There is a positive relation between conceptual complexity and pleasurable feelings until a tipping point is reached, when complexity outweighs comprehension” (Van Mulken, Van Hooft, & Nederstigt, 2014, p. 333). Learners who perceived novel metaphors as more complex due to more distantly related target and source domains, such as "violins are beehives,” require more time to process and map the metaphor (Thibodeau and Durgin,2011). However, learners are also more likely
Figure 24. A visual advertising metaphor pictorially restates “food for thought.” What exact metaphor is expressed? THOUGHT IS FOOD, BRAIN IS STOMACH or something else is something else? Metaphors may be difficult to identify or define. In addition, however novel the graphic is, it is difficult to determine whether the visual metaphor is dead or apt. “Food for thought” is a common expression. But a novel visual display may trigger initial puzzlement that causes a learner’s attention to be maintained. From: Phatak, 2015.

to willingly devote time and cognitive effort to solving the puzzle. This holds true for both verbal and visual metaphors.

Complex metaphors are a double-edged sword. On one hand, learners seem to derive more benefit from deciphering at least moderately complex metaphors. On the other hand, if a visual metaphor is too complex, there is a greater chance that learners may be unable to interpret its message (Van Mulken, Van Hooft, & Nederstigt, 2014).

**Story through Images: A Matter of Attitude**

The use of images to tell instructional stories for all ages is increasingly common in this eikoncentric era. Studies have demonstrated visualized stories can enrich instruction. The widespread use of images to tell stories in popular media, textbooks and E-learning however, is not so much influenced by research findings, but rather by a tacit
belief in the powerfulness of images to clarify meaning in a story. Pictures, when densely packed with particles of visual information can, in combination, can tell a whole story. Of all the factors that limit the use of picture book type images in formal instruction or in “serious” factually-based visual displays, attitudes toward these images perhaps is the most important.

Picture storybooks have traditionally been used for children’s instruction and therefore, adults or adolescents may be reluctant to read picture storybooks because they believe it may reflect poorly on their intellectual abilities. Picture books for adults were developed during the late 1900’s, for example, because of a campaign for adult literacy in Great Britain. Pictures were included in readers to cue the meaning of verbal phrases for new or struggling teen-aged and adult readers. Goldsmith (1987) noted publishers were initially reluctant to incorporate pictures into text. She suspected this was partly because “it was felt adults might be embarrassed to be seen in public with an illustrated reading book” (p. 53). This is undoubtedly because heavily illustrated storybooks have been associated with children’s early readers and no struggling learner wants to be considered “childish.” Nevertheless, publications such as graphic novels or comic books suited for adult readers prominently feature pictures as a part of visual storytelling and are now widely embraced.

The use of picture storybooks has not been confined to fiction genres or to informal instruction. Hosler and Boomer (2011) reported their use of a comic book, for example, as an instructional text in a sensory biology class for non-majors. The comic book not only improved non-major’s understanding of content (as might be expected with
use of *any* well-developed instructional material) but also improved attitudes about biology.

Pictorial narrative seems to make factual instruction more accessible to novice learners. The comic book, *Optical Allusions,* in the Hosler and Boomer (2011) study, made use of the type of story structure typical in comic books, using dialog to tell a story, panels to organize a timeline of events and pictures to clarify meaning or describe protagonists. (Figure 25. A page sample from the comic textbook *Optical Allusions* with pictorial narrative about a phylogenetic tree.)

![Figure 25. A page sample from the comic textbook “Optical Allusions” with pictorial narrative about a phylogenetic tree. From: Hosler & Boomer, 2011.](image)

Contextualizing and humanizing through story. Visual storytelling can be important to contextualizing factual visual information. Data displays such as graphs or
bar charts, for example, present a type of story through visual data. A learner could look at a graph about changing temperatures in the months of March, April, May, and June and tell himself or herself a short story, such as “temperatures rose over a period of four months from a low average temperature in March of 30 degrees Fahrenheit to a high average temperature of 65 degrees Fahrenheit in May.” This is a minimalist tale and may suffice as a basic summary story about weather data. However, in other instances, pictures can be used to contextualize, or even to humanize, data stories.

Statisticians have often alleged that the use of images in data displays is unnecessary and that in some cases, they threaten the accuracy of the data presented. Yet, data displays in popular media are often embellished with images and seem to be appreciated by a general readership. These differing attitudes suggest there is a divide between professionals and popular readers that may be difficult to reconcile, despite evidence for the value of imagery in instruction. Arguments in recent years about Charles Minard’s time series graph that charted the advance and retreat of Napoleon’s troops into Russia demonstrate some attitudes and outlooks about pictorial data stories that are in current operation.

**Minard’s graphic story.** The “‘Figurative Map of the successive losses in men of the French Army in the Russian campaign 1812-1813’ (Carte figurative des pertes successives en hommes de l’Armée Française dans la campagne de Russie 1812–1813, trans. French.) is a statistical time series map that describes Napoleon’s advance and retreat in Russian. It was designed by French engineer Charles Minard in 1869 (Wainer, 1997; Massironi, 2002; Grady, 2005; Dur, 2012). Statistician Edward Tufte has promoted Minard’s map as possibly “‘the best statistical graphic ever drawn” (Tufte, 1987, p. 40),
in part because its “multivariate complexity [is] integrated so gently that viewers are hardly aware that they are looking into a world of six dimensions” (Tufte, 1983, p. 40). Tufte’s position was subsequently reiterated by many scholars who examined Minard’s map. Because Tufte is a prominent, influential statistician, had he not drawn attention to this information graphic, Minard’s map might otherwise have remained an obscure historical data display (Yaffa, 2011).

Minard’s time series map is an implied graphic story. It introduces a series of story events by charting the advance and retreat of Napoleon’s army, beginning from its departure from the Polish-Russian border in June 1812, to its arrival at Moscow in September 1812 through its retreat in 1813 (Wainer, 1997). 422,000 soldiers began the Russian campaign, but a mere 10,000 survivors returned (Friendly, 2002). The wide pinkish shape at the top of the graph represented soldiers on their advance toward Moscow while their retreat is “depicted by the darker line below. It is linked to the temperature scale showing quantitatively the depths of the Russian winter” (Wainer, 1997, p. 63). The subscripted weather “graph of temperature [is] a function of time, with time running from right to left in the direction of the retreating army” (Massironi, 2002, p. 138). Miserably cold temperatures, beginning at the time of retreat, are below freezing. Massironi (2002) summarized the story told by Minard’s graphic by saying “The result is an impressive narrative condensed in a single view and readable with only a few glances. It is a drama produced by a small amount of abstract graphic marks” (p.138). (Figure 26. Minard’s multidimensional time series map showing the successive losses of Napoleon’s soldiers during the Russian campaign of 1812-1813.)
Figure 26. Minard’s multidimensional time series map showing the successive losses of Napoleon’s soldiers during the Russian campaign of 1812-1813. From: University of Princeton Library. (2012).

Does Minard’s time series map really tell a story with a few graphic marks as Massironi suggested? Perhaps it does for statisticians. Wainer (1997) proclaimed, "The story of the tragedy is clear. We can see the bodies frozen into the snow” (p.65). However, Minard’s time series map, although beautifully designed, is not commonly used as a template to plot similar information in current times. Although statisticians may be able to understand it, most learners will not be able to understand its configuration much less extract the details of its tragic story without instruction about how to decipher Minard’s novel time series map.

Dragga and Voss (2012) argued that Minard’s time series map could not express the tragic story of Napoleon’s army without the aid of pictorial cues. The absence of contextualizing and humanizing icons could be considered a violation of ethical rhetorical presentation. They stated that by presenting sterile, abstract marks that allowed an efficient presentation, Minard’s time series graph was:
“a cruel depiction. Nowhere in this visual display is the slightest indication that the subject being illustrated represents the slow dying of 412,000 human beings. It could as easily depict the number of rifles or bullets used in Napoleon’s futile effort to conquer Russia. We don’t see the people, and we don’t see their anguish. By omitting the human misery caused by that military campaign, the illustration could be said to constitute a distortion of the reality that escapes the statistics. The graphic isn’t so much deceptive, however, as it is plainly inhumane—insensitive or indifferent to the human condition it depicts” (Dragga & Voss, 2012, p. 266).

Dragga and Voss (2012) re-designed Minard’s time series map by including icons to contextualize the type of loss suffered. Living soldier, weapon and horse icons represent the strength of Napoleon’s forces, while crosses represent soldier deaths. The absence of weapon and horse icons suggests these were also lost along the route to and from Moscow. Their solution is far from elegant but does demonstrate how pictures can be important to storytelling, at a minimum, by establishing the subject of such a display.

Figure 27. Dragga & Voss incorporation of icons into Minard’s time series map. The designers sought to eliminate cruelty in depiction by humanizing the story of Napoleon’s Russian campaign. From: Dragga & Voss, 2012, p. 270
Similarities in Visual Cognition and Pedagogy during Two Eikoncentric Eras

We find there are more similarities than differences in visual instruction and visual cognition theory during both the medieval and contemporary eikoncentric eras. Imagery for instruction was pervasive in media of both time periods. Pictures were valued as a superior way for presenting instruction. Both medieval and contemporary scholars theorized that visual cognition is stage-like, begins with visual perception and thereafter, information committed to memory. Medieval and contemporary theories about visual cognition are alike because they can both be described as information processing theories. The work of the brain in processing visual information is acknowledged in both eras.

Medieval era scholars *philosophized* about brain anatomy because they had no ability to scientifically study the brain. Medieval beliefs about how images were perceptually or cognitively processed were speculative. Although contemporary anatomists and cognitive neuroscientists have more accurately mapped the brain, contemporary theories of visual cognition have often rested on conceptual models rather than on accurate regional anatomy. The Hitch and Baddely model of memory that identified a visuospatial sketchpad, a phonological loop and a central executive, for instance, was conceptual rather than based on regional anatomy. Theorists inferred a conceptual model of cognitive processing because neither a sketchpad nor a loop can be physically located in the brain.

A limited human memory capacity has been acknowledged in both eikoncentric eras. George Miller’s formula that stated seven minus or plus two items could be held in memory at a time is essentially a restatement of medieval beliefs about a *conspexitus*, that
were based on still more ancient ideas. Medieval development of mnemonic systems were partly solutions to overcoming limits on memory but were also used to think at higher levels through meditation on stored images.

Development and manipulation of mental imagery was an essential discipline in medieval pedagogy. Medieval learners used mental imagery not only as the basis of their personal mnemonic systems, but also to inspect images in all dimensions through rotations. During contemporary times the nature of mental imagery was questioned, but the ability of learners to visually inspect and rotate imagery was demonstrated and may be applicable to visual instruction.

Visual instruction was presented to choric masses in both eras. During the medieval era, instruction was embedded in church architecture for public view where an interpreter helped learners understand the meaning of symbols and sacred stories. PowerPoint type presentations similarly are given to audiences with interpretation by a lecturer. Readers in both eras used heavily illustrated books for a private learning experience.

Symbols in visual instruction were used in both the medieval and contemporary eras. Symbols, as arbitrary depictions, are not iconic because they lack resemblance to the objects they represent. Symbols during the medieval era were used extensively because everything that was visible was thought to have sacred significance. Because sacred instruction explained the meaning of symbols and because the existing catalog of symbols was limited, symbols could be used effectively in instruction. During the contemporary era, we are confronted by numerous symbols used in a wide variety of fields. Learners become familiar with these through repeated exposure or previous
instruction. The mutable nature of symbols can still make recognition difficult since many symbols that look alike are used for different instructional purposes and identical symbols can be adopted for different uses.

The use of visual metaphor and analogy to link a learner’s prior knowledge to new concepts has been a common pedagogical method during both the medieval and contemporary eras. During the mid-twentieth century, foundational metaphor theories were posited and developed, although these were primarily related to the use of verbal metaphor. Although theories have existed, there are no whole contemporary theories of visual analogy or metaphor. Much of the research about visual metaphor has been undertaken by advertising researchers who have investigated the ways learners solve metaphoric puzzles. Levels of metaphor complexity predict maintenance of learner attention as well as inferential and elaborative processing. When a puzzle is solved, learners experience a sense of accomplishment and pleasure. Metaphor in contemporary time is mostly multimodal, relying at least minimally on textual labels or captions to explain meaning.

Picture storybooks were not confined to use by children but were also important for adult instruction in medieval or contemporary eras. Pictures told stories for illiterate owners who could afford books during the medieval era. Pictures included in marginalia often told stories of their own because images were insertions that did not always correspond to content in text. Although factual stories for children or novices continued to integrate pictorial explanations into text, formal instruction for adults has also borrowed illustrative conventions from popular comic book or graphic novel genres. Despite use of graphs and charts in instruction that are meant to tell a story with data,
rhetoricians have argued for use of pictorial components to contextualize information presented as data.

Philosophy and scientific theory most often consider a general learner without regarding individual differences, excepting demographic traits such as age or gender. Although we believe that scientific research has made a difference in how we design visual instruction, our practices are poorly related, in general, to research findings from the past century. Gestalt theory, however, has proven to be exceptional. Not only have today’s instructional design theorists incorporated aspects of Gestalt theory into their own theories, but aspects of Gestalt theory are applied in practice, particularly when designs are mediated by graphic designers.

**Gestalt Theory: Alternate Theory about Visual Cognition and Perception**

Information processing theories remain central to modern-day posits about visual cognition, however, Gestalt theory has, perhaps, exerted the most influence on contemporary design of visual instruction. Information processing theories worked to identify “the processing stages that occur before experience [of perception] that explain the phenomenal organization” (Robertson, 1986, p. 182). Gestalt psychologists, by contrast, assumed some pre-conscious processing, but found it less important to their theory than how a whole image was perceived.

Gestalt theory was developed in tandem with, but in opposition to behaviorist theory and was opposed to behaviorism’s “search for a bogus objectivity in psychology” (Gordon, 2001, p.12) as well as its exclusive study of objective behavior (Gordon, 2001). Gestalt theorists were at great odds with behaviorism "as a science of behavior and were instead interested in the structure of knowledge and the processes of thinking"(Weinert,
1996, p. 34). Also, in contrast to behaviorists, “Gestalt psychologists' main concern was always with perceptual phenomena” (Olson & Hergenhahn, 2009, p. 257) and their work was to uncover principles of visual organization. Perceptions in Gestalt theory were thought of as “the outcomes of organizational processes in the brain that are activated by sensory stimulation” (Postman, 1985, p. 115).

Although Gestalt theory was first posited by Max Wertheimer in 1912 (Rock & Palmer, 1990), it was developed by Wertheimer, Kurt Koffka, and Wolfgang Köhler – known as the founding figures of the Berlin School of Gestalt psychology. They “adhered to a non-mechanistic theory of causation and did not analyze the processes into stages” (Wagemans, Elder, Kubovy, Palmer, Peterson, Singh & von der Heydt, 2012, p. 1175).

Aspects of perception were most studied and emphasized in Gestalt psychology, but the theory’s scope was greater. Gestalt theorists believed the same types of perceptual laws they had uncovered could “apply to any other cognitive system; that is, representations of objects, events, or problems were organized such that they followed a certain set of rules. These rules, laws, or principles were thought to be relevant to everything from brains to social systems” (Robertson, 1986, p. 161).

Learning, according to Gestalt theory, occurs as insight or revelation when a learner ponders and eventually arrives at an independent understanding of a whole problem. (This is similar to the medieval view that learning occurred through an epiphany.) Learning, in the view of Gestalt theorists "was a derivative of innate perceptual and problem-solving processes. Incoming data from the world would be filtered by these processes and then organized into a structure" (Elshout, 1996, p. 410). Gestalt theory has also been called a learning theory, because it assumes images are
processed as wholes as are learning events. "Gestalt theory suggests that there is no clear dividing line between perceptual and cognitive functions, because cognitive functions are similar in principle to perceptual functions and differ from them only in degree of complexity rather than by their nature" (Lehar, 2003, p. 109).

**Gestalt Theory: Wholes and Parts**

The German word “Gestalt” has been translated as “something that is made of many parts and yet is somehow more than or different from the combination of its parts; broadly, the general quality or character of something” (Gestalt, n.d., para. 4). The primary claim of Gestaltists was that when viewing an object or illustration “the whole was different from, or other than, the sum of its parts and, moreover, that the perception of the whole occurred prior to the parts” (Kubovy & Pomerantz, 1981, p. 449).

Accordingly, “our perception and understanding of objects and events in the world depend upon the appearance and actions of whole objects not of their individual parts” (Winn, 2004, p. 82). Because “the whole (image) is different than sum of its parts” (Robertson, 1986; Gordon, 2004; Olson& Hergenhahn, 2009), learners perceive an image “all at once,” as a whole image. Perception of that whole image does not occur in stages beginning with methodical inspection of its constituent lines, shapes or units that then allows a learner to knit the parts together into a whole.

**Gestalt Research Methods and Reports**

One reason Behaviorists strenuously objected to the findings of Gestalt psychologists was due to their research methods. Behaviorists explored learning through analysis of "molecular behavior that could be broken apart" whereas Gestalt researchers "focused on subjective, molar behavior that could not be separated from an individual's
shaping influence of human behavior" (Leonard, 2002, p.79). Gestalt methods were labeled phenomenological because they relied on self-reports of an individual’s private experience for their results. “Gestalt methods were quite simply to ask subjects to report experiences such as what they saw when viewing stimuli or what they were thinking while solving problems” (Robertson, 1986, p. 180).

Gestalt theorists were at great odds with behaviorism "as a science of behavior and were instead interested in the structure of knowledge and the processes of thinking." (Weinert, 1996, p. 34). Gestalt theorists emphasized perception related to everyday experience over data gathered in laboratory settings, although they did work in laboratories. "Through carefully designed laboratory experiments (e.g., the solution of problems in which there was no prior experience to draw on), [they] were able to show that learning required an analysis of the entire situation, not just repeating a specific learned response" (Elshout, 1996, p. 410). Phenomena, in the view of Gestalt theorists, should not be studied in isolation but rather as a whole.

Although Gestaltists conducted laboratory research, most of Gestalt theory laws, i.e. principles, were defended and reported through demonstration. “The term ‘demonstration’ in psychology typically means the presentation of concrete illustrations of facts generally to teach or to persuade scientifically, the reference to conclusive observational proof derived from theoretical arguments and opposition to the definition of experiment” (Sinico, 2008, p. 853). The phenomenological research report presents readers with “not a table of experimental results, but a compelling illustration. The emphasis is upon experience rather than data. The reader is to be convinced, not by the results of some experiment, but by what he or she actually sees” (Gordon, 2004, p. 15).
Gestalt Laws/ Principles of Perception

Hundreds of Gestalt laws or principles of perception have been studied and proposed since the theory was first posited more than a century ago (Olson & Hergenhahn, 2009; Wagemans et al., 2012). A law central to the theory was the law of Prägnanz—"defined as the brain’s tendency of being attracted towards states corresponding to the simplest possible[visual] organization” (Wagemans et al., 2012, p. 1218). This basic law indicated that “perception tended, wherever possible, towards simplicity, symmetry, and wholeness” (Gordon, 2004, p. 17). The law of Prägnanz is exemplified by visual displays that have been given a good form through reduction of detail and/or by causing relevant detail to become more outstanding (Gordon, 2004). When a learner views an ambiguous image, he or she will perceive it, according to the law of Prägnanz, in its simplest shape or form (Rock & Palmer, 1990).

Gestalt laws are based on the ways people cognitively group components of a visual display (Rock & Palmer, 1990) “together in specific, predictable ways” (Kosslyn & Chabris, 1993, p. 36). “Grouping principles pervade virtually all perceptual experiences because they determine the objects and parts we perceive in the environment” (Wagemans et al., 2012, p. 1176). Grouping, as visual pattern-finding, occurs through discrimination of visual display features such as colors, sizes, shapes or spatial relationships (Tversky, 2006).

The law of Common Fate, for example, describes grouping of objects that seem to move in the same direction. Movement is imagined along a smooth path or line. (Figure 28. Demonstration of the Gestalt law of Common Fate.)
The Gestalt Law of Closure has demonstrated pattern finding. Per this law, when a learner views a partial pattern or image, that learner automatically and unconsciously fills in missing visual information. As in other Gestalt laws, the Gestalt Law of Closure “presupposes that our brain, though working in abstract terms, is able to lend concrete form to something that does not in fact exist” (Maia, 2006, p. 383). In other words, a learner will process arranged visual fragments—that are meaningless in and of themselves—and subsequently visualize a whole object by perceptually closing gaps in a visual display.

The ability of learners to close gaps has been demonstrated by having them identify and interpret visual displays that only show parts of a whole. Examples include displays with separated dots that follow the shape of a letter or visual presentations that feature portions of a whole complex illustration or incomplete geometric forms. (Figure 29. Demonstration of the Gestalt Law of Closure.)

**Gestalt Theory and Memory**

Gestalt researchers found that when learners recalled an image that was viewed earlier they often reported the image as having different properties. “Reproductions from memory were characterized not only by loss of detail, but also by substitution of new,
detail, and object assimilation—a tendency of reproductions to shift toward the typical [or canonical] form of familiar objects” (Koriat, & Goldsmith, 2000, p.488). Therefore, prior knowledge and experience were considered important to the accuracy of visual memory.

Gestalt theorists also posited that image processing was revisionist because images were mentally transformed into “regular, symmetrical, and simple memory forms” (Koriat, & Goldsmith, 2000, p. 488) in accord with the Gestalt Law of Prägnanz. During image processing, memory of an image is revised through a leveling process whereby ambiguous or less important property of an image are mentally erased and through sharpening, whereby parts of an image a learner thinks are most important are exaggerated in memory (Koriat, & Goldsmith, 2000).

**Gestalt and Instructional Design**

Some contemporary instructional media design guidelines are restatements of Gestalt principles of organization. Instructional design’s contiguity or spatial contiguity principle, for example, argues that deeper learning will take place if an image and related
text are placed in close proximity (Mayer, 2003; Clark & Lyons, 2010). When image and texts are grouped together in a page layout or visual display, learners unify the textual and imaginal parts into a conceptual whole. Similarly, the Gestalt law of proximity “states that elements that are close to each other will be grouped together” (Chang & Nesbitt, 2006, p. 14). (Figure 30. Demonstration of the Gestalt Law of Proximity.)

Gestalt theory has become of greater importance to contemporary instructional design in recent years for at least two reasons. First, selected Gestalt laws of organization are now widely accepted as principles of graphic design and organization, and descriptions of these appear in numerous graphic design manuals (Graham, 2008). Graphic artists are generally responsible for the design and completion of visual displays or page layouts in instructional media. Their career training has most likely exposed them to Gestalt principles of organization, and they may to refer to these when organizing pictorial elements and spatial relationships in a visual display.
Second, aspects of Gestalt theory have been incorporated into general instructional or psychological theories as well as into visual instruction guidebooks. Some research in instructional design has supported use of the Gestalt visual organization to facilitate learning and comprehension, although “Gestalt theory is not a single small set of visual principles uniformly applied by all designers. In fact, it appears that instructional visual design literature often deals with only a small set of Gestalt laws” (Chang, Dooley & Tuovinen, 2002, p. 5). Although Gestalt theory has been resurrected in recent decades for application to visual instruction, (Leflore, 2000) comprehensive use of Gestalt laws has not been typical in visual instructional design, despite a value for or application of a few selected organizational principles.

Contemporary theories of visual instruction and learning, however, have increasingly incorporated aspects of Gestalt theory. Today’s original instructional design work may not be recognized as derivations of the Gestalt principles of visual organization regardless of their similarities. Nevertheless, principles of Gestalt theory are more often cited and consulted than in the past. Although Moore & Fitz said, in 1993, “no one has systematically applied gestalt theory to instructional design,” less than ten years later, Chang, Dooley & Tuovinen, (2002) stated that Gestalt theory was “often presented as a single basis for educational visual screen design (p. 5).

**Contemporary Visual Instruction Research: Issues of Effectiveness and Application**

Because our contemporary age is an age of science, some may assume that scientific visual research and recommendations over the past century have conclusively supported or dismantled earlier historical claims. However, understandings about visual cognition and visual instruction are still preliminary with few theories, such as Gestalt
theory, that profess to be whole theories. A series of problems in the contemporary research landscape have stymied efforts to arrive at scientifically-based conclusions. It could be said that all research is plagued by the same factors that are next described. However, understanding how visual cognition operates and the best ways to design visual instruction have not been answered due to the constellation of problems listed below.

First, because behaviorism dominated thought in psychology for more than half of the twentieth century, accompanied by its denial of introspection, investigation into cognitive processing of visual instruction has a very short history. It was not well-researched until the 1970’s when cognitivism had replaced behaviorism as the new paradigm in psychology. Therefore, the greater percentage of meaningful visual cognition research has been carried out for less than fifty years. This body of research on visual learning and cognition is far less comprehensive than research on learning from reading.

Furthermore, when research had been conducted on instructional images following the behaviorist era in psychology, most of these studies sought to understand how pictures facilitated learning from text.

Second, although numerous visual instruction studies were launched, (particularly after the advent of computer and web-based instruction and when textbooks or other print instruction featured imagery as a matter-of-fact) many results proved inconclusive or contradictory. Studies such as the comprehensive review of visual instruction research by Anglin, Vaez, & Cunningham (2004) concluded that research reports constituted a “fascinating, disputatious literature” (p. 866), Their review of picture theories and instructional design studies on the use of static or animated images, seemed to leave many unanswered questions. They found that despite numerous extant studies, it was “not
clear how students use illustrations in instructional materials or that they even know how
to use them” (Anglin, Vaez, & Cunningham, 2004, p. 876). Similar statements about problems with the applicability or veracity of findings in visual instruction research have been articulated over the past fifty years.

Third, and notably, contradictory findings from visual cognition and instruction research have sometimes been ascribed to unsound study designs but also “may reflect to some degree the difficulty and complexities of the research and theory construction problems” (Carifio & Perla, 2009, p.404). Because a wide variety of differing images are studied in context of different tasks or under unlike conditions, contradictory research findings about visual cognition or optimal visual instruction designs can stem from lack of apt comparisons (Levie, 1987; Carifo &Perla, 2009; Wright, Milroy& Lickorish,1999). Textual or reading research has its own complications, surely, but also has the advantage of use of a codified alphabet that does not vary except in font styles or spatial organization of text. However, studies about the effect of seductive detail, for example, could be undertaken using diagrams, graphs, realistic pictures or maps. Any of these studies could require participants to accomplish different cognitive tasks.

Contradictory research findings can circumvent development of broad theories. Overall, Scaife & Rogers (1996) concluded that:

past research spans a wide area from map design to technical illustration to the value of pictures for children learning science, with a mélange of methodologies, explanatory frameworks and mechanisms. Recent reviews are consistent in pointing out the lack of integration in the field. The problems here are severe for any attempt to provide an overall picture (p. 187).
Fourth, experiments often are confined by an objectivist methodology that frequently investigate changes in learner performance given a single or a few independent variables that can be quantified. Other than Gestalt research, much of contemporary research on visual perception and cognition has been framed by cognitivism. Experiments, while contributing to an overall body of research, may be too narrowly focused to answer broad questions about visual cognition or instruction. “Cognitive learning research has followed, until recently, the conventional linear approach of science, that is, studying the parts … while ignoring the complexities that emerge as a consequence of the interaction of the component parts of the overall cognitive system” (Tennyson & Breuer, 1997, p. 116). Instructional design research, likewise, has often focused on specific variables like “some process such as divided attention, short term memory, concept learning or problem-solving” (Levie, 1987, p.26). The generality of findings in studies such as these may be limited.

Visual instruction research also tends to study single aspects of a visual display. Studies of parts of visual displays on screens, for example, may focus on single elements such as typography, color, arrows or other cuing graphics, etc. This kind of research is important to understanding the power of single elements in a display to contribute or detract from learning (Lee & Boling, 1999). Single element research, however, does not lend any information on how a whole display operates, in the sense of the Gestalt whole. (Lee & Boling, 1999).

Fifth, it is difficult to verify the results of similar studies in order to arrive at sure conclusions about aspects of visual learning and instruction. Similar visual instruction studies are not always exactly replicated and may have been researched under widely
differing conditions. General visual research has been conducted in diverse, unrelated fields and may easily yield results that may not be applicable to other disciplines. Studies have been developed to satisfy questions posed by many different professionals in disparate fields that are affected using images for learning.

Problems arise, even when trying to compare research studies from the same general field. Fields that began as single fields of study, such as psychology, are now partitioned sub-fields, such as educational psychology, experimental psychology, psycholinguistics, biopsychology, cognitive psychology or occupational psychology. The boundaries between these professional sub-fields may be less permeable than in the past. Accordingly, researchers in one sub-field may be relatively naive about the theories and findings by researchers in another sub-fields, however complimentary to their own investigative goals.

Complicating matters, research findings from different fields and sub-fields tend to be almost exclusively presented to members through membership publications or at conferences. It is therefore difficult to locate and collate research reports originating in one field that may also be applicable to another field. Levie (1987) made a statement about research in visual instructional design that could be apply equally to visual research overall. He stated that “An ariel view of the picture research literature would look like a group of small topical islands with only a few connecting bridges in between” (Levie 1987, p.26).

Research in visual cognition and visual instruction has been contradictory and fragmented (Scaife & Rogers, 1996; Carifio& Perla, 2009). Our thinking about and
focuses on aspects of visual cognition and instruction is much the same as it was in the medieval eikoncentric era.

General theories, in addition, only sporadically account for individual differences in visual cognition despite research that indicates learners process visual displays differently. Much of the theoretical and experimental work on visual information processing begins with the premise that all people “see” in roughly the same ways, excepting for idiosyncratic anomalies. A learner’s cognitive style, however, can have a decided impact on perception and interpretation of a visual display. Numerous studies have, for example, described the ways that the field dependent-field independent style affects visual cognition or perception.

The influence of cognitive style on learner reception and comprehension of visual information will be later discussed. It has been consistently demonstrated, however, that learning from images is made easier or more difficult according to differing visual-spatial skills or a learner’s cognitive style. It is almost certain that the more abstract a visual display becomes-- particularly when symbols rather than realistic illustrations make up most of a design-- the more difficulty someone with visual-spatial skill problems have comprehending material. Abstract visual displays, such as data displays, may present great challenges to learners depending on their cognitive styles.

Data Production in an Eikoncentric Era: More Data, More Data Images

Society became glutted with data at roughly the same time it became glutted with images. Our contemporary eikoncentric era has also been referred to as the “Information Age” or the “Digital Age” because unprecedented, massive amounts of data were produced as the result of computation (Keim, 2002; Cavoukian & Jonas, 2012; Hilbert,
Hilbert (2012) said, “2002 marked the start of the digital age. That was the year that humankind first stored more information in digital than in analogue form” (p.9).

Since then, the speed of data production has only increased. Cavoukian & Jonas said in 2012, “Ninety per cent of the data in the world today was created in the last two years” (p. 2). Wurman (2012) characterized the continuing flood of data into society as “a tsunami of data that is crashing onto the beaches of the civilized world.” (p. 39). The greatest consequent challenges among statisticians and information designers has been finding optimal ways to visually represent data so it is meaningful and comprehensible for all learners.

The most profound barrier to visually interpreting today’s mass data has been data disorderliness. Raw data, without organization is” filled with flotsam and jetsam…. none of it is easily related; none of it comes with any organizational methodology” (Wurman, 2012 p. 39).

**Visual Displays and Problems of Overload**

The solution for organizing and presenting data has been to select data to show outstanding patterns or trends in a visual display. In the absence of this type organizational methodology it is difficult to discriminate between genuinely useful information and informational noise. Raw mass data is unsorted, and therefore without selection and interpretation, all information appears to be the same. There is simply too much data to consider reasonably.

Visual displays that clearly and cogently present data are essential. Raw data that has not been interpreted or visually organized can result in “information overload.” Discussions about the effects of information overload have become a frequent
contemporary topic in instructional design. Overload is a problem also addressed by many interdisciplinary researchers (Wilson, 1996) whether they are concerned about overload for financial prediction makers (Hwang & Lin, 1999), or individual Internet users (Hemp, 2009) among many others. The term “information overload” corresponds to the instructional design term “cognitive overload,” which describes a learner’s state of cognitive distress when confronted by too much unknown or complex learning material at one time.

**Cognitive load theory.** Cognitive load theory (CLT) is rooted in a “deterministic view: images provided to learners for certain purposes are expected to result in the same responses across learners consistently” (Boling, Gray, Modell & Jung, 2014, p.31). CLT, as originally proposed by John Sweller, basically stated that “working memory is limited, and once exceeded, no learning can take place” (Leonard, 2002, p. 27) Presentation of too many pictures or words in instruction is predicted to overwhelm the processing capacity of working memory’s visual or verbal channel (Mayer, 2002). CLT is specifically tied to instructional design (Cook, 2006) and is “concerned with the design of instructional methods that efficiently use people’s limited cognitive processing capacity to apply acquired knowledge and skills to new situations” (Paas, Tuovinen, Tabbers, & Van Gerven, 2003, p. 63).

CLT identifies three distinct types of load; intrinsic load, germane load and extraneous load. A combination of each of these three types of load are often present in instruction, including visual instruction, However, control of germane and extraneous load is often stated as instructional design objectives. If the sum of these loads in
instruction exceeds a learner’s working memory capacity (Paas, Tuovinen, Tabbers, & Van Gerven, 2003) then a learner will experience cognitive overload.

Intrinsic cognitive load. Intrinsic load is dictated by the content of instruction. Levels of intrinsic load are “intrinsic” to instructional content, its complexity and the number of interacting elements. Although it is generally thought that instructional designers cannot directly alter intrinsic load (Paas, Tuovinen, Tabbers, & Van Gerven, 2003; De Jong, 2010) organization of material through simple- to –complex sequencing or by introduction of parts of instruction prior to presentation of integrated wholes are sometimes thought to mediate intrinsic load (De Jong, 2010). Instruction with high intrinsic load often presents complex concepts or requires problem solving across different domains of knowledge. Instruction with low intrinsic load generally presents simple, single concepts or bits of information (De Jong, 2010).

Germane cognitive load. Germane cognitive load “refers to the load imposed by learning processes” (De Jong, 2010, p.109) and on working memory as a result of intrinsic cognitive load (Vandewaetere & Clarebout, 2013). It “is imposed by information and activities that contribute to the process of schema construction and automation” (Cook, 2006, p. 1077). In other words, germane cognitive load is associated with learning activities as well as cognitive processes in learning new concepts and material.

Extraneous cognitive load. Extraneous cognitive load is imposed by details that appear in instruction but are unnecessary or not directly related to an instructional message. When instruction presents simple concepts or information is already well-known by learners, extraneous cognitive load does not challenge learning (Sweller, 1994). However, under conditions when learners are exposed to new or complex information, extraneous details,
such as seductive detail, can divert learner attention away from the most essential portions of instruction.

**Clutter: Dealing with Visual Noise**

Clutter in a visual display contributes to extraneous cognitive load. Elimination of extraneous detail in a data display also reduces extraneous cognitive load. Clutter is not the same as seductive detail but can rather be defined as visual noise or “the state in which excess items, or their representation or organization, lead to a degradation of performance at some task” (Rosenholtz, Li, Mansfield, & Jin, 2005, p. 761) in interpreting visual displays. Extraneous display elements can slow visual searches because a learner must examine all objects, salient or not, to identify important visual features.

Extreme sparsity in a data display can have the same effect as clutter (Rosenholtz et al., 2005) on learner interpretation of a display. Sparsity represents an inefficient use of screen or paper space by not filling spaces with sufficient visual explanation. Although there is less visual information to sift through in a sparse display, *insufficient* information can render a display useless, particularly as a stand-alone visual explanation.

Learners deal with clutter thorough schematization ---a cognitive process that is more art than science. Schematization is a process for” removing irrelevant details, exaggerating, perhaps distorting, relevant ones, even adding relevant but invisible information, {that} can facilitate information processing in a variety of ways” (Tversky, 2011, p. 525). Successful schematization reduces clutter, but also concentrates learner attention on the most essential elements in a display (Tversky, 2011).
Successful visual organization through use of appropriate space is also key to reducing clutter. Crowding elements together needs to be avoided (Rosenholtz et al., 2005). When elements are crowded together, it becomes more difficult to see a low contrast element, to detect the exact number of items in a display or even to identify an object (Rosenholtz et al., 2005).

Grouping items together creates categories of objects in a visual display. Grouping reduces clutter, not only because it streamlines a learner’s visual search, but because it helps a learner identify categories of elements. “Things that are related are placed contiguously or in close proximity; things that are not related are separated in space” (Tversky, 2011, p. 119).

**Visual Organization of Data**

Due to contemporary society’s visual orientation and to rapid influxes of data streams into the public sphere, learners are increasingly called to navigate both formal and informal instruction that exhibit diverse types of information graphics. Information graphics/infographics, as visual summaries of data patterns, can organize data and overcome issues of information or cognitive overload. A major end goal of these displays is to clarify information that “has approached some kind of maximum in terms of the human brain's capacity to deal with it” (Stetka & Levitin, 2014, para. 8).

Information graphics and infographics, though varying in structure, are visual displays that selectively present portions of data that represent trends and patterns. They can also schematically describe otherwise invisible entities such as atomic particles or locations, for example, on a geographical map. Structural differences are commonly associated with definitions for information graphics or infographics. The term
“information graphic” is a coverall for any visual display that presents data. Pictorial statistical displays include pictograms, where icons are typically used as counters and infographics that feature explanatory or reinforcing images with a standard information graphic.

Infographics often embed recognizable information graphics, such as a bar graph, into an image that operates as a topical, metaphoric or analogical background. “Vampire Energy,” a Nigel Holmes infographic for instance, uses an image of Dracula to suggest “Energy is Money Sucker.” (Figure 31. Vampire energy: comparison of a generic statistical information graphic without pictorial elements and a statistical infographic.)

Figure 31. Vampire energy: comparison of a generic statistical information graphic without pictorial elements and a statistical infographic using illustration techniques associated with commercial art. L. Debra Jenkins Unpublished. R. Nigel Holmes: Published with permission.
Data in an infographic may also be contextualized by using icons or pictograms as numerical counters in a display. Infographics, as described, currently appear in popular or instructional media, for example, but rarely in academic journals.

**Historical Development of Information Graphics and Infographics**

William Playfair, a Scottish economist, was so prolific in his invention of quantitative displays during and after the 1780's, that he has been considered the principal founder or "father" of modern statistical displays (Massironi, 2002). Playfair was said to have designed his visuals with an "instinctive understanding of our psychological capabilities" (Spence, 2006, p.2426). Most of the data displays he invented are still in wide use today.

In addition to invention of the doughnut chart (Dur, 2012), Playfair invented both the bar chart and the pie chart and the time-series line graph (Spence, 2005). "He was first to advocate and popularize the use of the line graph to display time series in statistics. The pie chart was his last major graphical invention" (Spence, 2005, p. 353) and was introduced in 1801 (Dur, 2012; Symanzik, Fischetti, & Spence, 2009; Friel, Curcio, & Bright, 2001).

Playfair’s data displays appeared initially in the *Commercial and Political Atlas* (1786) and his *Statistical Breviary* in 1801 (Dur, 2012). Wainer (1997) noted the novelty of Playfair’s work saying that his *Commercial and Political Atlas* featured data displays “in which spatial dimensions were used to represent nonspatial, quantitative, idiographic, empirical data. Such a representation now seems natural, but before that time it was rarely done and was hence quite an accomplishment” (p. 5). Beniger and Robyn (1978) noted Playfair's bar chart was "the first quantitative graphic form that did not locate data
either in space (as did coordinates and tables) or time (as did Priestley's time-lines)" (p. 3.) The graphic inventions by Playfair and Priestly were deliberate efforts "designed explicitly to harness the visual learning capacities of the human mind by turning numbers back into pictures" (De Bruyn, 2004, pp.129 - 130). Although these data displays are abstract, Playfair believed they were perceptually vivid aids for learning. He esteemed data displays for their ability to communicate a story through symbols. Wainer (1990) said "Along with Playfair's desire to tell the story of history graphically was the desire to tell it dramatically" (p. 354).

Playfair was among the first data display designers to express theories of instruction associated with statistical displays. Because Playfair viewed his data displays as tools for learning, he also practiced or proposed methods of instructional design recognizable in current practice. Playfair culled information about his learners, for example, from informal learner analyses. His understanding of his intended learners/users guided both his design and method for enhancing learner cognition. Playfair identified differing abilities of novice or expert learners to decode his abstract data displays. Playfair believed his visual inventions could be intuitively decoded by a learner who had studied geometry or had some mathematical background. However, he felt it incumbent to draft verbal explanations to assist interpretation (De Bruyn, 2004) or instructions for use, since prior knowledge could not be counted upon.

The need for the explanatory notes that accompanied Playfair's data displays also pointed to the limitations of graphs and charts (De Bruyn, 2004) for inexperienced users. Du Bruyn (2004) cited the line graph as an example of these limitations. "A series of numbers plotted over time on a graph facilitates comparative judgments, but the reasons
for the differences over time that a graph displays cannot be understood without a broader, more contextualized understanding of history, economics"(p.131) and politics—contexts the notes are intended to supply.

Playfair believed statistical visual displays were superior representations of information because they maximized cognitive efficiency and were memorable. He believed the eye, at a single glance, could detect a data display's proportion, progression, and quantity (Casner, 1990) and that everything that was viewed was immediately committed to memory (De Bruyn, 2004). Playfair warned against fitting information into tables, believing tables diminished information retention in memory. He argued instead, for the superiority of abstract representation in charts and graphs to visually depict relationships saying, "Figures and letters may express with accuracy, but they never can represent either number or space. . . Information, that is imperfectly acquired, is generally as imperfectly retained "(De Bruyn, 2004, p.130 quoting Playfair). Playfair added that tables were inferior in achieving long term memory because "a man who has carefully investigated a printed table, finds, when done, that he has only a very faint and partial idea of what he has read; and that, like a figure imprinted on sand, is soon totally erased and defaced" (De Bruyn, 2004, p. 130 quoting Playfair). Spence (2006) observed that Playfair designed his data displays so they would be better lodged in memory. Playfair's designs were in harmony with cognitivist design recommendations for instructional presentations according to limitations of short term memory and keeping problems with cognitive load in mind. Spence (2006) said:

Playfair’s charts are almost always constructed so that comparisons in different domains (lines, colors, labels, etc.) do not exceed attentional and working
memory capacity. Time series in the line graphs never exceed three or four in number; no more than three or four colors are used in a chart; labels are positioned next to the lines themselves rather than in legend boxes distant from the time series; similarly, areas are labeled directly rather than being referenced in legends in some other region (p.2426).

Playfair’s charts and those of his descendants form the body of generic information graphics in use today. They use lines, shapes and other geometric figures to communicate data information, but did not include imagery as infographics do.

**The historical roots of infographics.** Novel political-economic statistical charts and graphs were invented during the late eighteenth through mid-nineteenth century. Mid-nineteenth century experts in social sciences, let alone general readers, required extensive written explanations about the structure of the new quantitative graphics to make sense of the data they visually portrayed.

An increasing use of quantitative graphics by experts during the mid-nineteenth century resulted in the founding of an “International Statistical Congress” that devoted congress sessions to setting standards for statistical displays for expert use (The International Statistical Congress, 1860; Beniger, & Robyn, 1978;). Because of standardization, certain symbols or configurations in visual data displays became recognizable, then familiar. Data displays were thereafter designed according to these new graphics conventions. Codification of statistical displays resulted in expert’s becoming familiar with newly introduced data displays but were relatively unusable for the general population.
Statistical graphs and charts began appearing in articles that were about social-political conditions or science after 1850. These became accessible to the public, as novice audiences, when they were widely circulated in popular almanacs in Europe and the United States beginning in the late 1800’s (Dalbello & Spoerri, 2006). The copiously illustrated statistical data displays in these popular almanacs were integrated with colorful and artful renderings. Michael Friendly (2008) called the era of almanacs “the golden age of statistical graphics when some of the most exquisite graphics ever produced appeared” (p.502). The images that accompanied statistical displays were a part of common culture, so a novice could immediately identify the nature of a display according to the nature of the accompanying image. An example of such an embellished statistical display appeared in 1904 to illustrate the relative military power of nations. Prototypical military men of varying heights were dressed in national uniforms. The tallest men represented the greatest military power of a given nation, while the shortest characters represented nations with the least military power. (Figure 32. An example of statistical displays in popular almanacs explaining the military power of different countries on land and sea in 1904.)

Beniger, & Robyn (1978) noted that by the beginning of the twentieth century “statistical graphics had begun to diffuse---through textbooks, college courses, and the mass media---into the popular domain. A major vehicle for this diffusion was the pictogram…” (p.6). Pictograms, as iconic illustrations of people, animals, machinery or anything else that could be seen in one’s surroundings, were more familiar to the public

than the visually spare, abstract combinations of lines and shapes that were used to create statistical displays for experts. Therefore, pictorial images or pictograms were widely incorporated into early statistical displays for the public as infographics.

Over time, statistical charts and graphs that incorporated pictorial elements became more familiar and accepted by the public, while abstract, unadorned statistical displays were gradually accepted as the province of experts. Infographic statistical displays remain popular. The familiarity of pictorial images, particularly for the public, has provided clues to meaning of novel statistical displays without requiring extensive training for interpretation.

Information Graphics in Contemporary Instruction

Information graphics in instruction “facilitate cognition” (Hegarty, 2011) by revealing patterns and relationships that could not otherwise be detected. Graphs, charts
or other diagrammatic information graphics are important to revealing invisible features of physical or natural phenomena. "Atoms, continental plates, and the evolution of species are among the abundant examples of entities that are inaccessible to everyday observations but need to be attributed the same reality as visible observable entities" (Martins, 2002, p. 74). A growing need to include imagery that visually documents invisible scientific concepts emerged during the twentieth century, due to continuous scientific discovery and invention. The use of pictorial images in information graphics was often incorporated into popular science publications, such as Popular Science Monthly, when scientists wanted to acquaint non-specialists with invisible concepts, relationships or processes. (Figure 33. An example from Popular Science Monthly of an information graphic that visualizes the invisible make-up and operation of two-way television.)

Given an increased use of information graphics over time and a large circulation for these publications with a general readership, it could be assumed the greatest number of science-based images are found in popular media. However, Dimopoulos, Koulaidis, & Sklaveniti (2003), after completing a study on scientific imagery found just the opposite, noting that by the turn of the twenty-first century, “science textbooks in comparison to the press material use[d] ten times more images” (p. 189).

Graphs and charts have been among the most frequently used information graphics in science instruction over the past century. Beniger & Robyn (1978) said “Graphs of mathematical functions began to appear in U.S. textbooks after 1902, and statistical graphs of temperature and population trends appeared about 1910; bar and pie charts were added in the period 1915-1918" (p.6). Although they are of relatively
Figure 33. An example from Popular Science Monthly of an information graphic that visualizes the invisible make-up and operation of two-way television. Pictorial images of human receivers and senders as well as mechanical schematics of machinery and transmitting cables above ground reveal invisible processes of telephony for non-specialists. From: Popular Science Monthly (1930). Two-Way Television is Demonstrated in Laboratory as an Engineering Stunt.

modern usage, statistical graphs and charts have become staples in social sciences as well as science textbooks because they can visually portray otherwise invisible trends or compare quantities. Almost all instructional content, regardless of discipline, addresses processes, relationships or structures that are invisible, conceptual or data driven. Each can be efficiently modeled through diagrams or previously learned data displays such as
bar or pie charts or line graphs, rather than through lengthy and potentially ambiguous textual descriptions.

**Common Information Graphics and Their Functions**

Although Harris’s (1996) compendium of information graphics was “illustrated with about 4,000 charts, graphs, maps, diagrams and tables, ranging from the most basic to the very specialised and covering almost every sort of illustration that one could come across” (Meng, 2000, p.1837), far fewer types typically appear in instruction. Pie charts, bar and line graphs, timelines, statistical maps or diagrams are among the most common types of information graphics in use. Instruction provided through public school education teaches learners how to interpret this familiar repertoire of information graphics.

Common information graphics serve distinct functions according to their types. A statistical information graphic such as a line or fever graph, for example, illustrates “relationships among variables, at least one of which is continuous” (Winn, 1987, p. 153.) Charts depict “relationships among categorical variables” Winn, 1987, p. 153). Pie charts belong to a proportional area group of charts and illustrate “the relative size of components to one another and to the whole” (Harris, 1996, p. 281) Diagrams describe “whole processes and structures often at levels of great complexity” Winn, 1987, p. 153) and often incorporate symbols, schematics or pictorial elements. Among the most commonly used information graphics, as earlier mentioned, are diagrams, line graphs, bar charts, pie charts, statistical maps and timelines.
Design of Common Information Graphics

Although how-to-books during the early to mid-twentieth century recommended curbing pictorial excess in data displays and offered techniques for creating accurate displays, most recommendations that were made were based on intuition rather than empirical evidence (Friel, Curcio, & Bright, 2001) and what seemed to make visual sense in a display. Willard Brinton was, for example, author of widely respected handbooks that included “Graphic Methods for Presenting Facts” published in 1914 (Friel et al., 2001) as well as “Graphic Presentations” published in 1939. Brinton (1939) stated that although a great many handbooks on statistical displays had been published since his own original 1914 version, “there has been some discussion of the effectiveness of graphic methods to convey facts and ideas, but no comprehensive analysis has thus far been made measuring results from organized materials carefully prepared and presented graphically” (pp.21-22). Brinton’s, 1939 handbook, nevertheless, devoted almost all page space to illustrations of exemplary maps, charts and graphs with few references to research on effective designs. Similar handbooks are published today (Cleveland & McGill, 1984; Kosslyn, 1994; Wong, 2010) that do not grapple extensively with research findings, although some may be enriched with statements about current thinking on graphical perception or theories. These handbooks generally recommend use of specific data displays for specific purposes, offer guidelines for their design and are heavily illustrated with examples of correct or incorrect designs.

Overall, Hegarty (2011) argued that information graphics are created, in many cases, through a designer’s intuition and/or knowledge of expert opinion but are not necessarily supported by empirical studies. Levy et al (1996) for example, sought to
confirm or disconfirm expert opinion that derided the addition of “gratuitous” depth cues to 2-dimensional (2-D) displays to create 3-dimensional (3-D) information graphics. Expert opinion that 3-D displays, filled by gratuitous detail, threatens comprehension was not proven in this study. Levy et al (1996) found that 3-D displays initially “impaired accuracy in both a magnitude estimation and a perceptual match task. However, this performance difference was small…[and]…vanished when subjects had to make their judgments from memory (perceptual match task exercising a very short-term form of working memory) (p. 49). Furthermore, users preferred 3-D over 2-D displays under different circumstances. The preference of learners for 3-D displays as well as their continued popularity in popular media suggests that they can enhance rather than obstruct interpretation.

A proliferation of software that templates graph and chart forms has made it easier for both novice and expert designers to produce their own information graphics and particularly their own data displays. Anyone can insert numerical data into blank fields, push a button and a graph or chart instantly appears on a screen. Designers can further customize the look of their displays through computer selection of colors, fonts, grids or line types. These artistic alterations may or may not support optimal design for learning. The scope of possible revisions to a computer-generated information graphic is relatively limited. Artistic personalization of information graphics, however, could only have been accomplished by hand mere decades ago. Despite software’s ability to offer some creative latitude, varieties of information graphic templates in popular software have generally been limited to a few display types that are reused repeatedly. It can
therefore be said that “technology has a paradoxical effect on data design, both ossifying and democratizing conventional genres (Kostelnick, 1998, p. 474).

Recognizable graphs, charts, diagrams, maps or timelines can all be created without much effort on the part of the designer. Most learners are acquainted with common information graphics. Familiarity with graphs and charts is essential for accurate interpretation of data. Learners can, however, encounter obstacles to comprehension when confronted by the need to interpret unconventional historical or novel contemporary information graphics.

**Problems with Uncommon Information Graphics**

Kostelnick (2015) noted a “new burst of graphical innovation [that] has been accompanied by a growing scholarly interest in the history, theory, practice and pedagogy of data design” (p. 255). A trend toward novel information graphics has become evident as designers abandon software templates and create new interactive and static displays. “As graphics technologies have become more sophisticated, graphical displays have grown more varied and more baroque” (Levy, Zacks, Tversky & Schiano, 1996, p. 42). These “baroque” information graphics are often unique and without conformation to the structures of common information graphics. This makes interpretation difficult or impossible for most learners. (Figure 34. “Winning the Lotto”: an example of a novel, and difficult to decipher information graphic.)

Information graphics that are uncommonly used have often been given laud by scholars due to their originality in design or because of their historical or societal impact. However valuable these graphics may be, they impose problems for learners who encounter them for the first time. Accurate interpretation may be limited by how
comprehensive accompanying textual instructions are in describing the use and structure of an uncommon graphic. Comprehension of uncommon information graphics may be further limited by the intuitive or visual-spatial reasoning skills of a learner.

Contemporary learners may misinterpret uncommon information graphics if they wrongly apply the same information graphic schemas they derived from common

Figure 34. “Winning the Lotto”: an example of a novel, and difficult to decipher information graphic. “Winning the Lotto’ is supposed to present the frequency of appearance of every number from one year to the next one” (Friedman, August 2, 2007, para.21). Retrieved from http://www.smashingmagazine.com/2007/08/data-visualization-modern-approaches/

graphics. Learners who encounter information graphics that are infrequently used may become confused when symbols and notations resemble those in familiar types of graphs and charts but operate differently. An example of near resemblance of one kind of information graphic to another is the polar graph to the contemporary pie chart.
Nightingale’s polar area graph: an information graphic that looks like a pie chart. Remarkable for the effect it had on Victorian medical practice, Florence Nightingale’s innovative revision of a polar area diagram during the Crimean War “left no doubt that many more soldiers died from disease and the consequences of wounds than at the hands of the enemy” (Friendly, 2006, p.15). This explains the iconic status (Magnello, 2012) Nightingale’s information graphic attained among scholars because it “revolutionized the idea that social phenomena could be subjected to mathematical analysis, and using statistics, she graphically illustrated the need for sanitary reform” (Meyers & McNicholas, 2008, p.246). The polar area diagram, while sharing traits with a pie chart, is only occasionally used to display information in instructional materials but is “used today primarily in mathematical and engineering applications” (Magnello, 2012, p.32).

Segments representing quantity in Nightingale’s pie chart variation are not contained within a typical pie chart circle, but instead extend outward (Harris, 1996). Nightingale’s polar area graph uses a circle, but:

is essentially an XY plot drawn on a circular grid, which shows trends in values on the basis of angles. The X values define the angles at which the data points will be plotted whereas the Y value defines the distance of the data points from the centre of the graph, with the centre of the graph usually starting at zero” (Magnello, 2012, p. 32).

In Nightingale’s polar area diagram soldier deaths in the Crimea are represented in two different years by wedges. The blue wedges represent deaths attributable to disease, the pink represent deaths from wounds and the gray represents death from all
other causes in two separate years. Each wedge represents a month in each year. (Figure 35. Florence Nightingale’s polar area chart uses segments to demonstrate causes of mortality for an army during the Crimean War.)

The polar area diagram is dissimilar in enough respects from pie charts that most learners would probably have difficulty intuitively comprehending Nightingale’s abstract visual explanation. The polar area diagram does not function in the exact same way as a more familiar pie chart and looks as much like a fan as it does a pie chart. Most learners would require prior training about the chart’s composition and its use of segments and graphic divisions before drawing accurate conclusions about the data portrayed.

Gelman, & Unwin (2013) critiqued Nightingale’s polar area graph noting it, “is an excellent example of “infographics”—it is attractive, grabs one’s attention, and gets you
thinking—but it is not so great as ‘statistical graphics’ in that it does not directly facilitate a deeper understanding of the data” (p.18). Accordingly, Gelman & Unwin (2013) redesigned Nightingale’s polar are graph using conventions more familiar to learners today. (Figure 36. Gelman & Unwin redesign of Nightingale’s polar area graph.)

A contemporary learner would predictably encounter multiple difficulties if having to natively decipher a polar area graph. Reliance on clues to meaning whether through written explanations, inclusion of familiar pictures or familiar symbols would be necessary for accurate interpretation. Although we may assume learners can readily interpret common graphics, this may be false. The example of the polar area graph

Figure 36. Gelman & Unwin redesign of Nightingale’s polar area graph. From: Gelman & Unwin, 2013.
introduces a discussion about the complex cognitive processes inherent in information graphic comprehension as well as historical ideas about best practices in designing information graphics.

**Notable Work in Graph Perception and Comprehension**

Theories or models to explain the ways graphs were perceived and comprehended were developed after the 1970’s (Friel et al., 2001). However, Carifio & Perla (2009) noted, as recently as 2009, that despite known differences in visual perception given a learner’s cognitive style, “few studies that have been done of graphs (or their associated theories) have controlled or accounted for such individual differences” (p. 420). Research has been conducted to inform theory on the interplay of human perceptual and cognitive processes with information graphics, faults in data displays that hamper comprehension or interpretation, problems with muddled terminology or on designs that can foster misinterpretation.

The scope of this paper limits coverage of graph theory to brief descriptions of three major, influential works in the field. Cleveland and McGill (1984, 1985) were “responsible for formulating one of the first theories of graphical perception” (Friel et al., 2001, p. 134) by identifying ten elementary perceptual tasks a learner performs to decode information presented in a graph. Stephen Kosslyn (1989) proposed an analytic system that could be used detect problems in graphs and charts. Kosslyn’s (1989) analytic system has been used as a touchstone for explaining best practices when designing charts or graphs and for defining necessary elements in a display. Experimental psychologist and cognitive linguist, Steven Pinker, was among the first psychologists to propose an overarching graph comprehension theory (Pinker, 1990). Graph comprehension has been
defined as “graph readers’ abilities to derive meaning from graphs created by others or by themselves” (Friel et al., 2001, p. 132). His theory is covered in some detail in this section because other contemporary graph theories are variations of Pinker’s 1990 theory. Pinker’s theory is also a reflection of contemporary thought since his foundational ideas drew from “existing perceptual and cognitive research” (Cleveland & McGill, 1984, p. 532).

Cleveland & McGill: Ten Essential Perceptual Tasks

Cleveland & McGill (1984, 1985) said their initial work in graph perception constituted an “identification and ordering of the perceptual tasks [that] is a theory in a less restrictive sense: It is set of plausible statements that describe a phenomenon--- the relative accuracy with which various graphical forms convey quantitative information” (Cleveland & McGill, 1985, p. 552). These statements were developed in conjunction with their own experimental research and that of others, as well as on accepted theory about visual perception and cognition at the time.

Ten tasks. Cleveland & McGill described their development of theory, or plausible statements, as a two-part process that first required identification of ten elementary graphical-perception tasks learners use when deciphering and extracting quantitative, numerical information from a data display (Cleveland & McGill, 1984). These ten tasks included judgement and perception of “angle, area, color hue, color saturation, density (amount of black), length (distance), position along a common scale, positions on identical but nonaligned scales, slope, and volume” (Cleveland & McGill, 1985, p.838). Secondly, they ordered the ten tasks according to learner accuracy in decoding information encoded in an information graph. Cleveland & McGill described
the differences between encoding and decoding in graphs. They said, “When a graph is constructed, quantitative and categorical information is encoded, chiefly through position, shape, size, symbols, and color. When a person looks at a graph, the information is visually decoded by the person's visual system” (Cleveland & McGill, 1985, p.828).

Table 1 restates their hierarchical order of elementary graphical-perception tasks (Cleveland & McGill, 1985, p.830), based on “how accurately people perform them” (Cleveland & McGill, 1984, p.531). (Table 1. Cleveland & McGill’s order of elementary graphical-perception tasks.)

Table 1.

*Table 1. Cleveland & McGill’s order of elementary graphical-perception tasks.* Position along a continuous scale, ranked 1, represents the most accurate task judgment while color hue, ranked 7 represents the least. Angle and slope are both ranked 4. Volume, density and color saturation are all ranked 6 since the differences in task judgement were considered insignificant. There is a total of ten elementary graphical-perception tasks.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Aspect judged</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Position along a continuous scale</td>
</tr>
<tr>
<td>2</td>
<td>Position on identical but non-aligned scales</td>
</tr>
<tr>
<td>3</td>
<td>Length</td>
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<tr>
<td>4</td>
<td>Angle, Slope</td>
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<td>5</td>
<td>Area</td>
</tr>
<tr>
<td>6</td>
<td>Volume, Density, Color saturation</td>
</tr>
<tr>
<td>7</td>
<td>Color Hue</td>
</tr>
</tbody>
</table>

Cleveland & McGill (1984, 1985) recommended encoding graphs with aspects highest on the hierarchical scale. They also noted that the tasks a learner performed to extract data could not always be confined to a single task (Cleveland & McGill, 1984). In other words, a learner might need to judge position along a scale for decoding a bar chart as well as judging the length of lines. Furthermore, by following their recommendations to encode graphs with aspects rated highest in their scale, it would also mean dispensing
with popular, familiar types of graphs. At the time of publication of their article (1984) Cleveland and McGill were satisfied their results had been persuasive enough that common graphs and charts were being replaced by some graph designers with other less commonly used display types they had recommended. The application of their statements and theoretical stance “to some of the most-used charts in graphical communication (bar charts, divided bar charts, pie charts and statistical maps with shading) has led to replacements (dot charts, dot charts with grouping and framed-rectangle charts” (Cleveland & McGill, 1984, p.553). Although both were optimistic about supplanting old forms of graphs and charts with more novel ones, bar charts, pie charts and statistical maps continue to be among the most popular data displays in use.

Kosslyn’s Analytic System

Stephen Kosslyn’s (1989) description of an analytic system for graphs and charts was published in 1989 in the article “Understanding Charts and Graphs.” Kosslyn primarily addressed processes of visual perception, arguing for design guidelines that, in his view, enhanced a learner’s ability to decode meaning in a display while reducing unnecessary burdens on short-term memory. When a graph or chart was subjected to syntactic, semantic and pragmatic analysis, Kosslyn (1989) believed the resulting changes to a display’s design could reduce or eliminate ambiguity that made interpretation of a chart or graph unnecessarily challenging.

Kosslyn (1989) assumed a three-step overlapping processing of visual information. A learner, in his system, first visually detected “edges and regions” (p. 190) in a display. Processes of visual perception in Kosslyn’s system are assumed to be unconscious and automatic, operating according to laws of perceptual organization as
stated in Gestalt theory. Kosslyn listed the Gestalt laws of good continuity, proximity, similarity and good form as contributing to appropriate perceptual grouping of separate elements in a display. A limited amount of information that had been visually extracted from a display could then be held in short-term memory as a learner further examined a chart or graph. Short–term memory, although only capable of retaining memory of a few elements, acted as a mediator between visual perceptual processing and information input from long-term memory stores. Kosslyn (1989) said” Short-term memory is …important because it is the locus at which conscious reorganization and reinterpretation takes place” (p. 191). Reorganization and reinterpretation is the result of the transmission of information from long-term memory to short-term memory. This process as Kosslyn’s third, overlapping step, “confers meaning to a stimulus” (Kosslyn, 1989, p.191).

**Syntactic analysis.** Testing a design for clarity was achieved in Kosslyn’s analytic system by first subjecting a display to syntactic analysis. “This analysis focuses on the properties of the lines and regions themselves…We describe the individual elements and their organization” (Kosslyn, 1989, p. 189). Among Kosslyn’s (1989) many recommendations for syntactic analysis of elements in a display was making certain that “marks” important to meaning should be made visually prominent and distinguishable from a background or other unrelated marks. Kosslyn also referred to acceptable alterations to a design that can help avoid learner perceptual illusions. “The visual system often systematically [for example,] distorts the magnitude of marks along various dimensions (such as area and intensity) [so] it may be appropriate to alter marks intentionally to compensate for the distorting properties of the visual system” (Kosslyn, 1989, p. 195).
**Semantic analysis.** Kosslyn’s (1989) semantic analysis focused “on the meanings of the configurations of lines, what they depict or signify (e.g. axes, labels, etc.)” (p. 189). In his semantic analysis, a display is examined for elements that are incongruent and therefore may cause the meaning of a message to be ambiguous. Kosslyn’s checkpoints include examining a pictorial background, for example, to decide if it is compatible with and reinforces the meaning of a graph or chart. A graph about failed heart surgeries with a pictorial background featuring a blue sky, in this case, would be better served by a pictorial background of a cardiac surgery in progress. Another part of Kosslyn’s (1989) semantic analysis required analysis of labels. The representativeness of words or pictures in labels to a graph’s or chart’s meaning, as well as the specificity or familiarity of numerical labels, were all considered important to meaning embedded in a display.

**Pragmatic analysis.** Kosslyn’s (1989) pragmatic analysis of a graph or chart addressed methods to avoid misinterpretation of an intended message in a chart or graph, use of contexts to support accurate interpretation, as well as the practical needs of a learner. Because it is the third stage of analysis, most of the issues discovered through syntactic and semantic analysis, should have resolved pragmatic issues. Part of the analysis seeks to uncover problems with details that interfere with presentation of an intended message. For example, Kosslyn (1989) said that when examining a background, the question “Does the background [otherwise] imply information not explicitly stated in the display?” (p.212) should be asked.

Questions about a display’s general context such as “Does the adjacent material on the page distract from or enhance the graph and vice-versa?” (p. 213) helps reinforces
the meaning of an intended message but also can help designers streamline visual processing through reduction of seductive detail. A graph or chart should be pragmatically analyzed to determine if the requisite amount of information is displayed so a learner can complete a task (Kosslyn, 1989) Learners “expect neither more nor less information than is necessary to answer a specific question” (Kosslyn, 1994, p. 270).

This summary of Kosslyn’s analytic system is simplified and limited. His syntactic, semantic and pragmatic analyses each require assessment of the component parts of a graph or chart, i.e. the background, the framework, the specifier and the labels, as well as analysis of other organizing principles. Kosslyn (1989) admitted that his analytic system was “intended to be at the most fine-grained, ‘picky’ level possible” (p. 214). It is doubtful that a designer would use his system with regularity for each graph or chart under development due, at the very least, to time constraints.

**Pinker’s Theory of Graph Comprehension**

Pinker's theory of graph comprehension was based on a technical report he drafted that was "circulated widely within the field and stimulated much research in response" (Lewandowsky and Behrens, 1999, p. 515). Pinker found that although quantitative information could be "communicated by nonpictorial means"(1990, p. 73) "a striking fact about human cognition is that we like to process quantitative information in graphic form" (1990, p. 73).

Trickett & Trafton (2006) summarized Pinker’s model of graph comprehension as a sequential process that begins when a learner is tasked to “extract a specific piece of information” (p. 289) from a graph. As a learner studies the graph, prior knowledge about graphs (graph schema) and “gestalt processes are activated” (p. 289) automatically.
Specific graph schemas are related to specific graph forms, such as a bar schemas or line graph schemas. Gestalt processes are the ways people cognitively group components of a visual display “together in specific, predictable ways” (Kosslyn & Chabris, 1993, p. 36) according to principles of perceptual organization expressed in Gestalt theory. Trickett & Trafton (2006) further explained that once the key features of a display are determined the learner can decide” which cognitive/interpretive strategies to use” (p. 289), extracting “necessary goal-directed visual chunks” (p. 289) that results in gathering the specific information required.

**Bottom-up and top-down processes.** Pinker's (1990) computational theory posited differences between bottom-up and top down visual processing. Bottom-up processing occurs when a learner hierarchically builds a mental representation of a graph or chart, beginning with detection of raw shapes, contours or edges in a visual display. Pinker (1990) referred to the graph information that "arrives at the nervous system as a two-dimensional pattern of intensities on the retinas" (p.76) as a visual array. An initial impression of a data display is sketchy and understood only as patterns made by elements such as lines, edges, shapes, textures or degrees of darkness. A learner’s “structural description representing a graph” (Pinker, 1990, p. 77) is both developed and constrained by recognition or levels of attention to graphic elements. The "size" of a visual description, in Pinker's theory, is limited by a learner’s capacity for processing elements in short term memory and automatic assignment of "a visual pattern into a single category"(1990, p. 89) or, in other words, a default visual description. A default visual description is data driven and is part of the bottom-up process because a viewer makes no conscious effort to categorize a pattern but does so automatically. Top-down processing
is effortful rather than automatic. Top-down visual processing occurs when a meaning of a graph is determined according to a learner’s prior knowledge, graph schemas, inferences and interrogation of the graph.

**Processing newly introduced or poorly designed graphs.** Pinker’s (1990) theory assumed that if a message in a graph was inadequately represented or if a learner did not have the necessary schema to decode a graph, top-down processes would become important to interpretation. Pinker (1990) posited that when a learner was exposed to an unfamiliar graph, a learner:

will generate a specific graph schema for it using the general graph schema. The reader will have to replace the predicates ‘pictorial content,’ ‘associated,’ ‘attribute,’ “geometric figure’ and so on by the actual visual predicates found in the visual description of the novel graph. This will be possible when the visual description has a structure similar to that of the general graph schema, with objects described in terms of attributes defined with respect to a framework and textual labels associated with each. (p. 105)

**Individual differences.** Pinker (1990) acknowledged that individual differences could account for significant differences in graph reading or interpretation. He suggested that individual differences in graph schemas could be overcome with instruction, whether individual differences represented deficits in working memory capacity or inferential abilities. Pinker (1990) specifically recommended offering learners “explicit instructions concerning the equivalences holding between quantitative trends and visual attributes” (p. 117) through instruction about how to examine visual components in graphs. He also
recommended that learners practice taught information by making their own graphs on
graph paper.

**Problems with Use of Graph Comprehension Theories and Research**

Practitioners seldom consult graph theory before designing and developing graphs
or charts. Graph theories tend to be written in language that is suitable for graph theory
experts but are foreign to graphic arts practitioners and to others who may design graphs
or charts using templates provided by common software. Kosslyn’s theoretical work, for
example, is densely written with frequent use of terminology that non-experts would find
opaque. The Lexile measure of his how-to books, such as *Graph Design for the Eye and
Mind* (Kosslyn, 2006) that is addressed to researchers, designers, students or “department
managers making monthly reports” (p. v.) would be a great deal lower than that of his
theoretical work. Although the likelihood of non-experts and graphic artists consulting
research reports or theoretical descriptions related to graph understanding is slim, “how-
to” books may transpose academically written reports into information that influence
actual practice.

**The Role of Research in Design Practice**

It is apparent there have been numerous and earnest efforts by researchers to
discover the way visual cognition operates and how to design images or statistical
displays for peak learning. Nevertheless, apart from Gestalt theory, theory is seldom
consulted or applied to practice. There is a great gulf between theory and practice that is
difficult to bridge in the real world of visual instruction. If research and theory do not
guide practice, what does? The author has identified four determinant factors as having
the greatest influence on the design of visual instruction.
Determinant Social and Political Factors: Information Graphics

Contemporary use and design of images is driven by determinant social, economic and political factors. Determinant factors include: 1) marketplace forces; 2) aesthetics; 3) societal preoccupations/ worldviews based on absolute presuppositions; and 4) the visual rhetoric of communities of practice. Each of these factors have contributed to the design, development and implementation of visual instruction. They continue to operate co-extensively and powerfully, continuously shaping the landscape of visual instruction in real-world applications. Visual and data display designs for instructional media are not, as many assume, informed by current empirical research so much as they are based on mediation by these four determinant forces. It is important to recognize the formidable roles these factors play in determining the kinds of information graphics and images that are prevalent in instructional media as well as their influence on how learners relate to and navigate available imagery.

Marketplace Forces

The limitations or capabilities of hard and soft technologies have driven eikoncentric or grammacentric shifts in society and instruction. Printing presses are examples of hard, mechanical/ technical, marketplace technologies that increased accessibility to and affordability of publications for consumers. Press technologies also determined the ways text or imagery were emphasized and displayed. The development of soft technologies, that include both media production software as well as graphic arts techniques, contributed to styles in instructional imagery. Marketplace business professionals, such as editors, marketing specialists or graphic designers, have determined styles and placement of images in instruction to a significant extent.
**Hard technologies.** New print or electronic technologies developed over the past five centuries influenced society’s orientation toward or away from eikoncentrism. The invention of the moveable type printing press, as earlier discussed, allowed mass production of inexpensive, exact replicas of text for books. This encouraged development of reading skills, which in turn sponsored a subsequent shift toward grammacentricism in Western society.

When images could only be reproduced from a costly, labor intensive woodcut or copperplate engraving process, hand-colored images were often inserted alongside blocks of text and “pictures became decorative rather than communicative” (Tversky, 1997, p.116). Consequently, instructional content was embedded in text and imagery was simply extraneous, albeit attractive detail. (Figure 37. A page featuring decorative images from an Incubula, which is a book produced before 1500 AD.)

Press technology, from the nineteenth century onward, afforded the means to cost-effectively publish text and images on the same page. Consequently, more images, information graphics and particularly statistical displays (Dalbello & Spoerri, 2006) appeared in formal and informal instruction. Modern improvements in press technology and the introduction of digital design software allowed graphic designers to experiment with text and image layout.

**Soft technologies.** Soft technologies, in the form of techniques of illustration, have contributed to ease in processing visual images and better comprehension. Techniques of illustration, such as linear perspective have increased a viewer’s perception of depth and dimension in illustrations, making a depicted object more immediately comparable to its real-life counterparts. Effective visual organization via
techniques of page layout has contributed to better visual processing of a page. Organization of elements within images, such as those found in exploded views, are historical examples of soft marketplace technologies that gave learners the opportunity to explore the underlying make-up of an object that could otherwise only be seen externally.

Figure 37. A page featuring decorative images from an Incubula, which is a book produced before 1500 AD. This Incubula page was published by an early printing press in 1465 A.D. with decorative images. From: The Divine Institutes (Divinarum institutionum) by Lactantius. (1465).
http://www.hrc.utexas.edu/exhibitions/education/modules

Linear perspective drawing and exploded views. Linear perspective drawing was introduced by “Florentine architect Brunelleschi in 1420” (Lovejoy, 2004, p. 20) as "a practical subset of geometry," (Elkins, 1994, p. xi) that provided a systematized method of illustration for rendering depth cues and the location in space of an illustrated object. Anatomical drawings prior to the invention of linear perspective, for example, were flattened and two-dimensional. Two dimensional illustrations challenged learning
because they could not, for instance, show how organs were placed in the human body. (Figure 38. Mansur’s two-dimensional drawing of human anatomy.)

The use of linear perspective drawing made renderings appear more realistic, however, and “much closer to the three-dimensional world of our experience”

Figure 38. Mansur’s two-dimensional drawing of human anatomy. From a Persian manuscript ca. 1390. Retrieved from http://www.nlm.nih.gov/dreamanatomy/da_g_X-2.html

(Heffernan, 2006, p. 22). This technique in illustration, in combination with an enhanced focus on accurate, detailed rendering, had significant advantages for learning in many different fields, but especially contributed to effective medical instruction (Park, 1997). Dimensional illustrations of anatomical features and their locations in human cavities allowed better recognition and comprehension of the structures of the human body by indicating spatial placement. (Figure 39. Drawing of female abdominal and pelvic anatomy by Vesalius - 1543.) Perspectival drawings also made identification of botanical or zoological species in the field easier for early naturalists by differentiating plant or anatomical characteristics.

Exploded views, are another instance of soft technology illustration techniques that “smartly uncover the most important information in order to maximize the visual
An exploded view depicts a living being or mechanical device as if it had undergone a slight explosion. This separation of parts from a whole picture remain particularly valuable for visually explaining assemblages and how their component parts fit together. Exploded views, developed during the time of Leonardo da Vinci, not only enable a clear view on individual features but often use lines or arrows to indicate positions (Viola & Gröller, 2005, p.). (Figure 40. Exploded view of a reciprocating motion machine by Da Vinci.)

Perspective drawing in combination with exploded views, long after the Renaissance era, continues to affect visual instruction in mechanical and natural science fields. The combination of these two techniques in medical instruction, for example allows anatomical illustrators to dimensionally represent the placement in space of body

Figure 39. Drawing of female abdominal and pelvic anatomy by Vesalius - 1543. Retrieved from http://commons.wikimedia.org/wiki/File:Vesalius%27_%22Fabrica%22_%281543%29.jpg
organs with illustration of organ position, arrangement and placement in relationship to other organs. (Figure 41. A contemporary exploded view of the brain.) The invention of these types of graphic design techniques predates research on how to best portray

Figure 40. Exploded view of a reciprocating motion machine by Da Vinci. Retrieved from: http://en.wikipedia.org/wiki/Exploded-view_drawing

information graphically. These forms of illustration have become an instructional graphic design convention.

**Marketplace Professionals.** The ways layouts or information graphics are currently designed depend less on research in the fields of instructional design or psychology and more on mediation by professionals in the marketplace such as graphic artists or marketing decision makers. Marketplace professionals in the publishing industry make decisions about the amount and types of information graphics that should be included in publications. These decisions are based on perspectives about what appeals to purchasers (Wilson, Pfister & Fleury, 1981). Illustrated textbooks, for example, have become important to sales because buyers are attracted colorful imagery.

Designs for instructional images are drafted by graphic artists who are not only responsible for designing images that correspond to a book’s content but are responsible for creating illustrations that appeal to consumers in the marketplace. Evans, Watson & Willows (1987) conducted a content analysis of teacher manuals twinned with illustrated textbooks. They also surveyed employees at nine major educational publishing houses to determine how illustrations were designed and selected for instructional content. They found that graphic artists (rather than instructional designers or content specialists) were the final producers of information based “on the instructions of the designer or art director to provide the exact composition and style of the illustrations” (p.87). “Most disturbing is the seeming irrelevance of research on illustrations to selectors and producers of textbooks. To date, research has had very little impact and has provided very few guidelines for practical application of illustrations” (Woodward, 1993, p. 132)
Although it can be assumed that authors have specific content expertise when writing for instructional publications, design of instructional imagery is ordinarily determined by graphic artists who are trained exclusively in basic artistic techniques of illustration, layout and design (Pitz, 1947). Grannis, in surveying the book publishing industry in 1967 noted that “More of the younger book designers, men and women, come today from the field of commercial [graphic] art " (1967, p. 88) and were prepared to be generalists rather than book designers. “These creative individuals are trained to stylize content to make it visually appealing. That’s how we’ve always seen their role. For centuries, making things pretty has been their primary focus” (Pietrucha, 2014, p. 202).

Although some illustrators specialize only in sub-fields such as anatomical or botanical illustration, relative ignorance about topics in other content areas, such as the sciences, history or economics have led designers to “presume that innovative creativity is more important than practical use. Consequently, it is no wonder that this leads to creativity prevailing over the usability of the information contents of a design” (Mijksenaar, 1998, p. 213). Agrawala & Berthouzoz, (2011) contended that training in design arts was insufficient to provide theoretical constructs for practice. They said, “Designers usually do not directly apply an explicitly defined set of design principles. The principles are a form of tacit knowledge that designers learn by creating and studying examples” (Agrawala & Berthouzoz, 2011, p. 61) from visual design books. Houghton & Willows (1987) in Psychology of Illustration concluded "At present, it would appear that a great deal of instructional text design is guided by intuition, prior practice, trial and error approaches, and marketability considerations" (p.v). Agrawala & Berthouzoz, (2011) added, “Design principles are usually not strict rules, but rules of thumb that might even
oppose and contradict one another” (p.61). The ways that books or documents are
designed, are additionally based on enduring publishing traditions (Misanchuk, 1992) that
are taken for granted. These include use of layout structures, such as the right justification
of text, that were originally used by scribes to save costs by completely filling an
expensive sheet of paper (Misanchuk, 1992).

Visual appeal is an important sales tool for publishing marketers. As early as
1916, Eastman, when examining journalistic magazines complained their “artists, like
editors, are ‘economically determined.’ They learn to draw pictures that will sell”
(Eastman, 1916, p. 22). “As it relates to graphic design, style suggests the dominant
visual aesthetic of a particular time and place” (Heller & Chwast, 2000, p. 9). This makes
stylistic choices that dovetail with dominant or fashionable aesthetics important to
crafting instructional publications that will be competitive in the marketplace.

Marketplace forces not only represent the means and modes of image production,
but also can affect the ways an audience values types of visual messages. Public
aesthetics are groomed by repeated exposure to certain types of images in publications/
People’s familiarity with information graphics and their designs, accordingly, affect their
assessments about how aesthetically appealing they seem.

Aesthetics

“Aesthetic preferences are ubiquitous in visual experience. Indeed, it seems nearly
impossible in many circumstances to perceive a scene without also liking or disliking it to
some degree” (Chen & Scholl, 2014, p.1444) Familiar images are assessed as more
aesthetically pleasing, more usable and more credible. Learner acceptance (or dismissal)
of images according to their aesthetic appeal is partly determined by a lightning-quick
perceptual process (Blijlevens, Carbon, Mugge, & Schoormans, 2012; Hekkert, Snelders, & Wieringen, 2003; Marković, 2012) that has been called “aesthetic appraisal” (Moshagen, & Thielsch, 2010). Aesthetics play a greater role in acceptance and use of an object or image than at first might be suspected. An aesthetic assessment by a learner that concludes an object is not beautiful can impact one’s attention to, motivation to use, and potentially, the useful life of an instructional image type.

**Aesthetic assessments.** People use aesthetic judgments to measure the worth of an image, often in terms of its value as fine art and/or its financial value (Tuch et al, 2012). Aesthetic appraisals are different than aesthetic judgments. Aesthetic appraisals are personal assessments of the beauty or appeal of images regardless of their financial worth or their perceived value to humanity or to the world of fine art (Moshagen, & Thielsch, 2010). People conduct an aesthetic appraisal, whether of informational images or fine art, using the same perceptual processes used to make aesthetic judgments, because as Davis (2005) said, “There is no separate eye-to-brain connection for the processing of images labeled art” (p.5).

**Aesthetic assessments: split-second perceptual processing.** Researchers (Jakesch, Leder, & Forster, 2013; Lindgaard, 2007; Lindgaard, Fernandes, Dudek & Brown, 2006) found that aesthetic assessment happens in as little time as the” blink of an eye,” or approximately 50 milliseconds (ms). When conducting aesthetic assessments, viewers are thought to unconsciously bypass problems of cognitive overload by visually scanning for salient or recognizable features and cues rather than engaging in a more cognitively effortful appraisal (Metzger & Flanagan, 2013).
“Mere exposure” is one reason that has been proposed for the perceptual and cognitive processing that triggers an immediate decision about whether an object is beautiful or ugly. Mere exposure is a term that essentially means “frequent” or “mass” exposure to image types or graphic compositions encountered through the course of daily living. Zanjoc (1968), a pioneer in mere exposure research, found after studying participant’s associations with words, that mere or “repeated exposure is a sufficient condition of attitude enhancement” (p. 21). Mere exposure results in familiarity with an image or word that subsequently causes a greater liking for or positive attitude toward an image or word. Even when mere exposure is subliminal, it promotes the development of a bank of prior knowledge (schema) that affects aesthetic appraisals of images that are later supposedly seen for the first time. Whether exposure to an image is overt or subliminal, (Hicks & King, 2011; Janiszewski, 1993) mere exposure not only results in familiarity but usually in liking of an image as well (Chen & Scholl, 2014).

Others, building on Zanjoc’s original study, have demonstrated that familiar images or objects are better liked and considered more aesthetically pleasing (Hicks & King, 2011; Larson, 2012; Lindegaard et al., 2006;) than images that violate familiar prototypical (typical) or conventional designs (Martindale & Moore, 1988; Reber, Schwarz & Winkielman, 2004; Martindale & Moore, 1988). The ways that graphic artists arrange visual elements to create a composition are often based on familiar graphics conventions (Robins, Holmes, & Stansbury, 2010).

**Liking due to familiarity: the role of graphics conventions and prototypical images.** Images are liked because of their familiarity. When images are designed according to graphics conventions that are in broad circulation during a given era,
viewers can readily process information embedded in these designs. Because learners have been repeatedly exposed to these design conventions, they can also efficiently navigate through popular layouts, page designs or compositions of an image. Familiarity with graphics conventions or prototypical images may also cause a learner to assess a conventional design as readily and easily processed. This enhances an aesthetic appraisal of a design or page layout. Moshagen& Thielsch, (2010) said, “The more fluently a perceiver can process an object, the more positive is his or her aesthetic response” (p. 691).

**Graphics conventions and styles.** Graphics conventions, for the purposes of this paper, are described as widely adopted formal or informal rules prescribed for visual design. Graphics conventions are strongly associated with art and design styles noticeable during a given era. “Style, in its most general sense, is a specific or characteristic manner of expression, design, construction, or execution. As it relates to graphic design, style suggests the dominant visual aesthetic of a particular time and place” (Heller & Chwast, 2000, p. 9). Sparke (1986) described style as “the particular inflection of the visual language of the object, or set of objects, that communicates the taste values of its consumer” (p. 111).

Because public aesthetic preferences (and familiarity) are strongly linked to the repeated use of styles in popular media, aesthetic preferences also are driven by marketplace forces. The public can often recognize a style as one that does not belong to its time period and tends to immediately recognize a design that represents current techniques of illustration. During contemporary times, for example, it is common to preserve negative (empty) space in a visual display. Victorian information graphics in
popular media, by contrast, were highly ornamented when “decoration was a virtue that symbolized the comfortable Victorian life-style” (Heller & Chwast, 2000, p. 16). (Figure 42. A highly ornamented Victorian era book illustration.)

![Highly ornamented Victorian era book illustration.](http://eduscapes.com/bookhistory/knowledge/2.htm)

Figure 42. Highly ornamented Victorian era book illustration. From Household Stories (1882). Retrieved from http://eduscapes.com/bookhistory/knowledge/2.htm

Specific styles used in graphic composition and layouts have been and continue to be familiar to viewers in a given historical era or context. Styles, however, like graphics “conventions are endlessly fluid, fragile and mutable” (Kostelnick, p. 17) because they tend to shift with new social thought and values. Although they can be mistaken “for timeless universals, rather than social constructs that are invented, that evolve and that undergo constant scrutiny” (Kostelnick, p. 17), graphics conventions may endure over centuries but are not entirely durable.

**Prototypical images.** Prototypical images also repeatedly appear in publications and are therefore familiar to the public but are different than images designed according to graphics conventions. While graphics conventions are familiar to viewers depending on styles embraced by a given society during time periods, a prototypical image is
familiar because versions of it are almost always recognized as visual shorthand for the object it represents.

Leder, Belke, Oeberst, & Augustin (2004) defined a prototypical object (or image) as one that “optimally represents a class of objects” (p.496) and stated that “prototypicality is the amount to which an object is representative of a class of objects. It is built through experience” (p.496). Viewers tend to categorize prototypical images with other similar images that have been widely accepted as standard (Presmeg, 1992; Howe, 2010). Prototypical images are often less complex in design than non-prototypical or novel images and are also perceived by viewers to be more easily or fluently processed (Reber, Schwarz & Winkielman, 2004). Atypical or non-conforming versions of an image are probably less fluently processed and considered less familiar, less liked and less aesthetically pleasing than those images that exhibit prototypicality. (Figure 43. Images demonstrating prototypicality or non-prototypicality.)

![Figure 43. Images demonstrating prototypicality or non-prototypicality. Prototypical sketches of chairs with properties that demonstrate a chair’s typical or prototypical structure and atypical or non-prototypical example of chair images at lower right. From: Hung & Chen (2012).](image)

Graphics conventions, prototypical images and aesthetics: adoption and acceptance through deliberate exposure. Simpler, prototypical images are generally preferred by novices viewing images, particularly in unfamiliar content areas and
therefore may be readily accepted and adopted as aesthetically appealing and useful. The aesthetic assessments of experts, by contrast, are influenced by factors of training as well as deliberate, repeated exposure, rather than incidental mere exposure. Aesthetic assessments by those who have become expert in a content area tends to be qualitatively different than those of novices. Reber, Schwarz & Winkielman (2004) said, for example, that experts who had received training in arts fields could more fluently decipher meanings and compositional elements of images. Lindell & Mueller (2011), in support, said, “Repeated exposure to complex stimuli results in higher perceptual fluency, and training in arts gives meaning to complex structures in paintings, poems, or music, which results in an additional increase in processing ease” (p. 377). Deliberate, frequent exposures to novel image types over time, encourages experts and novices to eventually adopt and accept novel images as standard images (Reber, Schwarz & Winkielman, 2004). "Tastes and preferences are not innate; they are inculcated by social habit" (Bogart, 1995, p. 221).

Historically, novel data displays, often difficult to decipher at first glance, were made more comprehensible for the public through embellishments with aesthetically appealing, familiar imagery or artful techniques. The adoption and acceptance of the earlier mentioned illustrated statistical charts and graphs into popular almanacs in the United States are an example of this process.

Incorporation of illustration into statistical displays has continued in modern times in popular media. The familiarity of pictorial images, particularly for the public, has probably not only increased aesthetic liking, but also provided clues to meaning of novel statistical displays without requiring extensive training for interpretation.
Over time, statistical charts and graphs that incorporated pictorial elements became more familiar to and accepted by the public, while abstract, unadorned statistical displays were gradually accepted as the province of experts. Experts may object to highly illustrated statistical displays because they recall aesthetics of novices. Because experts process more complex images more fluently than novices, they may also value simple images or illustrations as less accurate or having poor aesthetic value because they do not represent the complexity of a concept or process.

Regardless, dissemination of these statistical displays into either expert or popular culture were and are dependent on repeated exposure and often, repeated instruction about how to interpret more complex displays. Repeated exposure, through popular or professional media as well as instruction, results in familiarity which results in reinforcement of an aesthetic assessment that an image us beautiful. When a viewer believes that an image is beautiful, a viewer will be more likely to believe that a graph or chart can be fluently processed. When all these conditions are met, an expert or novice learner will also tend to assess an image or object as usable and credible.

**Aesthetics: usability and credibility.** Researchers investigating visual design for human computer user interfaces, among others, have found that images a learner believes are beautiful or appealing will also be perceived as useable (Casey & Poropat, 2014; Norman; Tractinsky & Hassenzahl, 2005;). Given belief in an image’s usability, a learner will consequently find that image valuable and credible (Robins, Holmes, & Stansbury, 2010). From earlier cited research, it is also known that these appraisals are influenced by familiarity. Therefore, notions of beauty and usability are
largely driven by familiarity. Familiarity is influenced by market forces through repeated placement of types of images in popular, professional or academic publications.

Tractinsky & Hassenzahl (2005) described a link between visual aesthetics and assessments of usability. They said, “Often textbooks refer to the laws of Gestalt psychology as the guidelines for a usable visual design. But the very same Gestalt psychology is a basic theory of aesthetics. In this respect, usability itself becomes a particular theory of aesthetics” (p. 67).

**Durability of judgments of usability.** Some research findings have determined that once someone has decided an object or image is aesthetically beautiful, he or she will believe it is usable, even when evidence calls its usability into question. Sonderegger & Sauer (2010), for example, presented adolescents with different kinds of cellphones and asked them to rate each for aesthetic appeal. Two cellphone prototypes were developed based on study participant ratings, with one as rated aesthetically appealing and the other as aesthetically unappealing. (Figure 44. Cellphone prototypes.)

Although the two different cellphones had identical function, and varied only according to their outside shells, research participants gave higher ratings to the cellphone that had been designed to be more aesthetically pleasing. Interestingly, in this experiment, the cellphone they felt was more aesthetically pleasing, also *became* more usable; the “visual appearance of the phone had a positive effect on performance, leading to reduced task completion times for the attractive model (Sonderegger & Sauer, 2010, p.403). Perceptions that a visually appealing product or visual presentation is more useable than one that is less aesthetically pleasing may consequently lead to a learner’s
conviction that the more aesthetically appealing product or visual presentation is more credible than one judged as less beautiful and less usable.

Figure 44. Cellphone prototypes. Two prototypes employed in experiment: (a) aesthetically appealing design; (b) aesthetically unappealing design. From: Sonderegger & Sauer, 2010, p.406.

The credibility ratings of images during an eikoncentric era, particularly in instruction, are of great consequence because “If a user rejects new information as not credible, that information will not be learned, nor can it have any other impact” (Wathen & Burkell, 2002, p. 134). Judgments of credibility have been specifically linked to aesthetic assessments.

It has been demonstrated that credibility ratings are highly influenced by aesthetic assessment of websites, for example, (Fogg, Soohoo, Danielson, Marable, Stanford, & Tauber, 2003) with consistently higher ratings given to screens that have been given more aesthetically appealing visual treatments. Robbins & Holmes (2008) called this the “amelioration effect of visual design and aesthetics on content credibility” that occurs
almost instantly when “given the same content [on two different websites] a higher aesthetic treatment will increase perceived credibility” (p.397). While studies during recent times have focused on the processing of imagery on computer screens, rather than in printed publications, Metzger & Flanagin (2013) said that “digital media do not so much change the cognitive skills and abilities people need to evaluate credibility, as the proliferation of so much information online changes how frequently people are called upon to exercise those skills and abilities” (p.210).

The proliferation of visually rich information that saturates contemporary society has therefore revised criteria for judgments about credibility. Publications that remain primarily textual have been and are still judged as credible according to the reputation of an author and his or her expertise. However, credentials and author references may be entirely absent on websites (Metzger & Flanagin, 2010) or in other media that is primarily visual. In lieu of source attributions, aesthetic visual appeal may be used instead as criteria for evaluation of credibility.

Imagery may also be rated as credible according to its prototypicality or use of graphics conventions. When familiar images are used, they may be perceived as standard, and therefore because they do not violate standards of normalcy they may also be considered credible.

**Societal Preoccupations and Worldviews based on Absolute Presuppositions.**

Methods selected for the design of visual instruction for both novices and experts arise as responses to current or shifting societal preoccupations and worldviews based on absolute presuppositions. Societal preoccupations, for the purposes of this review, is defined as foci on conditions or issues by members of a society or community that are an
abiding part of public discourse. Societal preoccupations are the subtext of more expansive worldviews. A worldview, for purposes of this review, is defined as a widely embraced system of values, beliefs and outlooks—constituted absolute presuppositions—which are accepted by members of a society in a given community, culture or during a period of time. The definition of “absolute presuppositions” is offered in the spirit of R. G. Collingwood’s (1933) term. Whereas Collingwood said that “relative presuppositions” are falsifiable, absolute presuppositions are constellations of presuppositions that are tangled together to form a general societal outlook or perspective and unconsciously operate in our cognitive backgrounds as guiding assumptions (Collingwood, 1933). With an absolute presupposition, “We don’t question it. We don’t try to verify it…. It is a thing we just take for granted” (Collingwood & Martin, 1998, p.32).

The Internet can be considered a societal preoccupation in contemporary times. Internet technology has changed the way members of society shop, spend their time and gather information. It has become a general societal preoccupation although the Internet raises specific issues for different people.

The relative benefits or disadvantages of online visual media displays with abbreviated textual content, for example, has become a matter of discourse in educational, journalism and other communities because it violates earlier publishing traditions when text was predominant. The Internet, as a societal preoccupation, has not only fostered debate but acted as a change agent for the use of information graphics in institutions that may have seemed impervious to alterations. Legal argumentation, once dependent on verbal argument alone, for example, is undergoing a shift during
contemporary times. The new societal preoccupation with the use of digital imagery, presentation software and projection has been reflected in legal communities. While exhibits have been important as courtroom displays in the past, the potential for an attorney to project electronic evidentiary images through PowerPoint-style shows is very gradually changing American courtroom procedures. Porter (2014) concluded that because “the Internet has revolutionized media and communications, replacing text with a dizzying array of multimedia” (p. 1690), “images are moving out of the evidentiary margins and are driving argument in litigation documents from pleadings to judicial opinions” (p.1687).

Societal preoccupations have influenced design, development and implementation of information graphics during other historical eras. Malin (2007), for example, studied the rise of American stereoscopic imagery in the early twentieth century, when immigration was booming, and the racial make-up of the nation was changing. Americans were societally preoccupied with the new demographics and with new streams of non-white immigrants from distant points on the globe. “Framed as a transcendent technology, the stereoscope fit into a larger climate of early twentieth-century consumption inflected by anxieties over white middle-class identity” (Malin, 2007, p.407).

Marketplace forces capitalized on this preoccupation. Stereoscope photographs were marketed as both popular leisure and instructional material to energize the sagging stereoscope industry. The three-dimensional experience of the image not only made the viewing experience seem to mimic reality, but:
stereoscopic spectators could experience Washington, DC or Rome in the same way as a higher-class traveler, and that they could peer more clearly into the exotic, low-tech, non-white lives of the Italians, Chinese, Koreans, or New Guineans captured in stereoscope images. As these scenes and people took three-dimensional form, they were to attest to the white, middle-class identity of the spectator---the possessor of a high-tech apparatus and the consumer of both high-cultured scenes and low-cultured, uncivilized racial and class others (Malin, 2007 p. 417).

Stereoscopic images, therefore, not only reflected a societal preoccupation with racial tensions that owed to demographic shifts in the United States, but alternatively promoted features of an ideal white identity. This identity was characterized as a white class of financial means, cosmopolitan outlook and modern skills through knowledge and ownership of technology.

Although societal preoccupations can be determinants in the design and use of certain types of images, societal worldviews also affect imagery design. Worldviews are based less on transient, faddish thought and more on a bedrock of rarely questioned presuppositions. Shifts in worldviews tend to be slower than shifts in societal preoccupations. In many cases, images used for learning reflect societal worldviews of a culture or given time period and are pressed into service in support of these prevailing orientations.

**Absolute Presuppositions**

Absolute presuppositions can also be associated with specialized communities or in professions. Absolute presuppositions about the nature or value of images can promote
or sustain world or community views, determining the ways images are used and what type of role they play in visual instruction.

Western eikoncentric contemporary society’s worldview is scientifically oriented. This scientific orientation may not only predict a prevailing positivism in social thought, but also portend acceptance of new, scientific inventions, discoveries and technology as betterments to society. Absolute presuppositions that attend a scientific worldview include beliefs that established facts are better than conjecture and that evidence is required for the establishment of a scientific fact. The old saw “seeing is believing” is rooted in assumptions that oral or textual explanations may be opinionated, but images, like photographs, data displays or schematic drawings, offer objective, veridical portraits of reality. (Kemp, 2012). “Convincing visuals play a major role” (Kemp, p. 44, 2012) in establishing credibility in scientific publications where “arrays of authoritative charts, graphs, and tables of data serve to create a matching ‘rhetoric of irrefutable precision’” (Kemp, p. 44, 2012). Data displays have acted as visible proofs, in these cases, playing, perhaps, a more significant role than text--- even in grammacentric eras--and during shifts between eikoncentric and grammacentric eras. Contemporary information graphics as visual evidence for scientific claims include data displays, photographs, X-rays and illustrations drafted from observations in the field or through optical equipment like microscopes or telescopes.

Current absolute presuppositions that guide the use of images in current instruction may be arcane byproducts of persisting historical value systems. Values for artistically and highly illustrated information graphics, have persisted beyond “the golden age of statistical graphics” (Friendly, 2008). Popular media artists, visual journalists and
book designers have sometimes used this style of illustration as a matter of course in present day publications and on websites. Scientific publications, in the meantime, have trended toward the use of minimalist and generic information graphics that complement our current scientific worldview.

**Absolute presuppositions: quickness and efficiency.** If quickness and efficiency are values in the form of absolute presuppositions in science, cognitive psychology or business communities, then it also helps explain why designers of information graphics seek to quicken learner comprehension through information graphics that are visually efficient and streamlined. Pioneering audiovisual instructional research during the first half of the twentieth century emphasized the cognitive time saving quality of visual displays that promoted” advantages…[through] visual association, and systematic arrangements" (Carroll, 1954, p. 24).

Researchers often found that instructional imagery (as well as other audiovisual material) promoted "more learning in less time, more thorough learning, more systematic learning, more pleasant learning, proper balance and action of mental powers, eye and ear more highly cultivated, habits, tastes and manners improved, earlier age learning and consequent saving of time" (Carroll, 1954, p. 24). (It is difficult to know if interpretations of these findings were the result of a societal inclination toward anything that promoted quickness and efficiency, making time-savings the focus of visual instruction research or if researchers were surprised by results.)

Contemporary recommendations for the design of efficient instructional information graphics are inheritances from pioneering audiovisual research findings that reiterated the goodness of quickness and efficiency. Rune Pettersson (1989) has
recommended minimalist designs for instructional graphics. Malamed (2011) recommended that when a designer wants a learner to process imagery efficiently, realism should be reduced through elimination of details in a graphic. “Minimalism makes every phase of the human information-processing system more efficient” (Malamed, 2011, p.104). Statistician Edward Tufte (1987), who has an extensive following and is well-known for his recommendations for presenting data displays with minimal graphic details, said that graphic excellence in data displays “is that which gives to the viewer the greatest number of ideas in the shortest time with the least ink in the smallest space” (p.51).

Despite an embrace of minimalism, there are cases when the clarity and complexity of an information graphic’s message can be compromised with exclusion of detail. PowerPoint-style presentations that are immensely popular, for example, “renders obsolete some complex narrative and data forms in favour of those that are easily abbreviated or otherwise lend themselves to display on a series of slides” (Adams. 2006, p. 399).

Although minimalism in the service of “quickness and efficiency” shapes contemporary design, there are numerous examples of complex information graphics in popular media over the past modern century that mimic the earlier mentioned Victorian penchant for decorative graphics. Eckstein provided visual samples from Fortune magazine that demonstrated the use of an artistically bent, complex information graphic in the 1930’s. (Figure 45. Fortune magazine: Financial irrigation of the United States).

While the Fortune magazine information graphic is a type of illustrated conceptual map, data displays that appear regularly in popular magazines, newspapers,
websites and increasingly in textbooks are often artistically embellished information graphics. Viewing interesting visual content in infographic data displays may have the effect of prolonging attention and recalling information for longer periods of time than

Figure 45. *Fortune* magazine: Financial irrigation of the United States. Depicting the U.S. Treasury as the "reservoir" and the New Deal "pipelines" moving funds to different agencies, December 1934. Retrieved from Eckroth, 2011, p. 83.

Infographics are valued in the marketplace for their visual appeal, attention-getting qualities and potential to entertain. Different values have been adopted by scientific, cognitive psychology or business communities that affect the design process of information graphics.

**The Visual Rhetoric of Communities of Practice**

Although societal worldviews and their attendant absolute presuppositions influence the kinds of information graphics that appear in instruction or mass media, communities of practice, such as statistical communities of practice, often specify and prescribe designs for visual images. These prescriptions are not necessarily based on the
results of research findings but may just as often be based on opinion or traditions. Prescribed design methods for information graphs and use of specific types of displays or depictions may also be guided by aesthetics embraced by a given community. The visual rhetoric of communities is meant to be persuasive, and accordingly, communities of practice often promote particular visual forms and indoctrinate community members in their use.

Wenger (2009) described communities of practice as “groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly” (p.1). Wenger & Snyder (2000) earlier described communities of practice as “groups of people informally bound together by shared expertise and passion for a joint enterprise” (p.139).

Communities of practice are not only based on mutual interests, but on relationships forged because of membership. They generate a “shared repertoire of resources: experiences, stories, tools, ways of addressing recurring problems—in short a shared practice” (Wenger, 2009, p. 2). Persuasively stated beliefs, values and preferred methods for representing or communicating information constitute the rhetoric of communities of practice.

**Visual rhetoric.** Visual rhetoric can include photographs, data displays, diagrams or maps, among other information graphics, that are used as proofs or evidence for a community of practice’s claims. The visual rhetoric of communities of practice is intended, just as in any other form of rhetoric, to persuade an audience of the merits of its arguments of beliefs. Visual rhetoric can be as persuasive as verbal or written rhetoric. Kemp (2006) said that when statistics are visualized in data displays or other types of
visual evidence are presented, "We are asked, in effect, to 'see' the obvious truth. This applies to tables of data, neatly packaged to produce significant patterns, to graphs and pie charts etc. that exude an air of irrefutable precision" (Kindle Locations 4510-4512).

Visual rhetoric can be used to persuade audiences outside a community of practice about the validity of an assertion, but also can be “used to diffuse and stabilize the knowledge and theoretical concepts it represents” (Burri & Dumit, 2008, p. 303) within a community of practice. For example, an information graphic familiar to members of scientific communities of practice, such as a line graph that is frequently used to display a trend over time, effectively communicates a statistical argument to scientists. It is “owned” by the group.

Designers of visual rhetoric are motivated to provoke a rhetorical or logical, rather than aesthetic response in an audience (Foss, 2004; Burri & Dumit, 2008). Although design elements such as color, line, space or shape are manipulated in fine or commercial art to elicit an aesthetic response, the same elements are also used to support arguments with visual rhetoric. Visual scientific rhetoric, for example, has been influenced by both schools of art and methods of art. Kostelnick (2008) found that scientific rhetorical images borrow many design conventions from the twentieth century Modernist school of art that valued minimalism, fostered by a belief in “direct, unmediated communication that was objective, perceptually pure, and unburdened by past conventions” (p.119). This strategic use of minimalist depiction supports the idea of science as based in unadorned fact and logic.

Other techniques of art have been used to increase credibility of a visual, rhetorical scientific image. Tyler (2009), after reviewing a brochure portraying the
Congaree Swamp, found that design methods reinforced perceptions that the illustration of this particular swamp was scientifically factual. This was accomplished through use of "detailed illustration techniques, minor changes in scale, and a lack of tension in margin and spacing" (p. 26) as well as use of a "clearly visible organizational grid system" (p. 26) that emphasized orderliness. She also determined that the visual argument, in this case, was designed to reduce aesthetic response, which is visceral, and to enhance the rhetorical response of an audience, which is, like science, based in logic. Tyler (2009) argued that because the brochure organized visual facts according to "an argument relying on a scientific paradigm" (p. 26) it also reinforced audience acceptance of a "rational order of the universe" (p. 26).

Scientific communities of practice that generate data through experimentation frequently use data displays to present statistical proofs. Scientific communities of practice, as well as other economic or business communities that need to present data, have increasingly used data display formats as visual rhetoric over the past one hundred years.

**The Evolution of Data Displays**

Scientific illustration was included in documents prior to “the origin of the scientific article in 1665” (Gross, Harmon & Reidy, 2002, p. 46). However, during the twentieth century data displays became commonplace in popular or professional literature and increasingly de rigueur in scientific publications. Gross, Harmon & Reidy (2002) surveyed scientific articles from the seventeenth century to contemporary times. They found that during the twentieth century a mere “12% of the articles in the sample were without figures or tables, as compared with 52% in the 19th century” (p. 200) and that’
the percentage of articles with numbered visuals integrated into the main text has steadily increased over the past century” (p. 200). Although scientific and other professional communities adopted an almost exclusive use of unembellished, generic statistical displays (e.g. pie charts, fever graphs or bar charts) to visually summarize data, the tradition of embellishing data displays with icons or with pictures persisted in popular publications.

Summary: Effects of Four Determinant Factors

This presentation about the effects of four determinant on visual instruction demonstrates that even in scientific communities, the design of visual instruction is not so much dependent on scientific research as on the marketplace, aesthetics, societal preoccupations, worldviews and absolute presuppositions as well as the rhetoric of communities of practice. The false idea that research findings play the most determinant role in how visual instruction is designed and used, is essentially a bluff. The conduct of a real-world debate about the merits of traditional data displays as information graphics over popular infographics demonstrates that each of these determinant factors have been forces driving design.

The Tufte- Holmes Debate: Anatomy of an Argument

The concurrent pervasiveness of imagery and data in contemporary society created a perfect storm for what has been characterized as the “Tufte-Holmes Debate” (Few, 2011). Edward Tufte, a Yale professor and statistician, triggered a debate that took place during the 1990’s about the appropriateness of infographics for presenting statistical data. Tufte argued for minimalism in design of statistical displays. Tufte targeted Nigel Holmes’ infographics as examples of faulty data display designs. Holmes
often integrated pictorial elements such as illustrations or caricatures into statistical graphs or charts to develop visual metaphors or analogies in infographics. His target audiences are, primarily, readers of popular articles. (Figure 46. Nigel Holmes’ “Runaway Prices” as a visual metaphor comparing an Arabian on a fast-moving horse to rising oil prices in America in 1979.)

Holmes has designed infographics for *TIME, The New York Times* and the Smithsonian Institute among other organizations, so his work generally is designed for popular media readers. Both Tufte and Holmes are acknowledged as experts in their fields. The debate reflected the influence of each of the four determinant factors that was earlier discussed and justified this review’s conclusion that research findings and theory are seldom consulted for real world design.
The debate also raised many questions that remain unanswered. Because information graphics as well as infographics are now prominently featured in informal or formal learning, it is important to understand how either design style can thwart or enhance learning. Tufte argued that infographic designs threatened accurate presentation of data. His argument against the use of embellished infographics was based on a critique of Nigel Holmes’ infographic “Diamonds Were a Girl’s Best Friend.” Tufte’s use of this example may be insufficient to prove his points against infographic styles for data presentation. Alberto Cairo (2013), visual journalist, noted that Holmes’ “recognizes that this is not one of his most inspired works but also contends that Tufte picked just one graphic among hundreds and elevated an isolated anecdote to a category level to make his case” (p. 62).

**Tufte’s Position**

**Tufte: data-ink ratio.** Tufte argued for a minimalist style of statistical display that erased any extraneous ink with only essential lines or x’s or dots remaining to depict data. Tufte’s often quoted “data-to-ink ratio “was stated as a formula for graphical efficiency based on a minimum ink allocation for non-data parts of a graph or chart (Tufte, 1983). The data-to-ink ratio is “the proportion of informative ink (i.e. ink used to represent data) to total ink in the plot” (Inbar, Tractinsky & Meyer, 2007, August, p.186). Tufte opposed inclusion in a statistical display of any kind of embellishment that did not directly portray data. Tufte has recommended erasure of gridlines and axes to further improve the data-ink ratio.

This design practice has less than universal appeal as demonstrated in a recent study. Participants in a study by Inbar, Tractinsky & Meyer (2007) preferred common bar
graphs with completed bars and color rather than Tufte’s minimalist design. (Figure 47. An example of a bar chart designed according to Tufte’s data-ink ratio.)

In recent years Tufte innovated “sparklines” --- another type of minimalist graphic that can be inserted into passages of text or in tables to show trends (Townsley, 2008) as “the variation of the data without the need for explicit graphics” (Alfons, Filzmoser, Hulliger, Meindl, Schoch & Templ, 2009, p. 3). Tufte said sparklines “mean that graphics are no longer cartoonish special occasions with captions and boxes, but rather sparkline graphics can be everywhere a word or number can be: embedded in a sentence, table, headline, map, spreadsheet, graphic” (Tufte, 2012). (Figure 48. Sparklines are the small graphic elements inserted into text to display trends.)
**Sparklines**

*Dequantification*  In exchange for an enormous increase in graphical resolving power, the wordlike size of sparklines precludes the overt labels and scaling of conventional statistical displays. Most of our examples have, however, depicted *contextual methods* for quantifying sparklines: the gray bar for normal limits and the red encoding to link data points in sparklines to exact numbers; global scale bars and labels for sparkline clusters; and, probably best of all, surrounding a sparkline with an implicit data-scaling box formed by nearby numbers that label key data points (such as beginning/end, high/low). And now and then sparklines might be scaled by very small type:

Figure 48. Sparklines are the small graphic elements inserted into text to display trends. From: Data Visualization, CS-171, Harvard Flashcards | Easy Notecards, 2015.

**Tufte: against infographic embellishment.** Tufte cited Holmes’ infographic “Diamonds *Were* a Girl’s Best Friend” infographic as an example of an overly embellished and inappropriate way to display statistical information. Holmes, in this infographic, used the angle of a woman’s leg to analogically illustrate the rise and fall of diamond values over a four-year period. (Figure 49. “Diamonds *Were* a Girl’s Best Friend” by Nigel Holmes illustrates the rise and fall of diamond prices from 1978 to 1982.)
Tufte (1990), in his book *Envisioning Information*, used “Diamonds *Were* a Girl’s Best Friend” infographic as his proof text for removal of non-data descriptions in information graphics. He said:

Consider this unsavory exhibit at right—chockablock with cliché and stereotype, coarse humor, and a content-empty third dimension… It is the product of a visual sensitivity in which a thigh-graph with a fishnet-stocking grid counts as a Creative Concept… The data-thin (and thus uncontextual) chart mixes up changes in the value of money with changes in diamond prices, a crucial confusion because the graph chronicles a time of high inflation. Lurking behind chartjunk is contempt both for the information and for the audience. Cosmetic decoration, which frequently distorts the data, will never salvage an underlying lack of content. If the numbers are boring, then you’ve got the wrong numbers. Credibility vanishes
in clouds of chartjunk; who would trust a chart that looks like a video game? (p.34).

**Perceived faults.** In analyzing the perceived faults Tufte found in Holmes’ embellished infographics, two categories of fault can be described. These faults can be classified as problems with infographic design that Tufte believed would result in audience alienation and cause inaccuracy in data presentation.

**Fault one: audience alienation.** Tufte equated Holmes’ embellishment of data with imagery as “chartjunk” and argued against Holmes’ use of humor, believing that their effects were audience distancing. According to Tufte, audiences could be alienated from the material because of Holmes’ presumed “contempt both for the information and for the audience” (p.34). Holmes’ caricatures or cartoonish imagery could be associated with similar imagery in children’s books or comic strips rather than the type images that appear in serious literature.

Audiences could also be alienated due to a perception that the infographic was not credible because data was not presented in a serious manner, but rather by using the same type imagery often exhibited in popular media, such as video games or children’s books. (If problems with audience alienation were proven, it would also follow that learning from infographics would be nearly impossible because learning is, in part, dependent on learner engagement with instructional material.)

Although defining characteristics of a learner population is a first step in instructional design, Tufte did not supply a specific description of the target audience he assumed would be alienated by Holmes’ infographic. There is some evidence that Tufte never considers specific psychographic or demographic traits in a population of data
display viewers at all. In an interview with Zachry & Thralls (2004), when asked how an audience fit into his own thinking Tufte answered:

> When most people begin their advice about communication, their first grand principle is “know your audience.” In practice, that statement too often leads toward underestimating the quality and interests of the audience. The know-your-audience philosophy can be a big step down the road to pandering to the audience. I think sometimes if we anticipate too much the characteristics of the reader, we are going to censor ourselves or change our work—and I think all too often wrongly (p. 456).

**Fault two: inaccuracy in data presentation.** Tufte discredited the likelihood of infographics, such as Holmes’ infographics, to accurately portray data because of “cosmetic decoration, which frequently distorts the data” (p. 34). Empirical research has demonstrated that misunderstandings about data do occur because of inappropriate visual design. Misunderstandings in interpretation and inaccuracy in data displays, however, are as often based on wrong choices by a designer to use, for example, a bar chart when a fever graph could better demonstrate a trend.

**Tufte: aesthetics, usability, credibility in visual rhetoric.** Tufte’s insistence on minimalism in design is related to not only to his personal aesthetics. His minimalist aesthetics are the same aesthetics embraced by the scientific or statistical communities of practice. Minimalist displays constitute a part of these communities of practice’s visual rhetoric. Their visual rhetoric is also supported by larger, authoritative agencies such as the American Psychological Association (APA). The APA for example, dictates standards for the visual figures, graphs or charts in scientific and academic journals that
are nearly universally accepted by academics, scientists or statisticians, among others. APA guidelines reify the minimalist aesthetic. These guidelines, reiterated by Paiz, Angeli, Wagner, Lawrick, Moore, Anderson, Soderlund, Brizee, & Kec (2012) include the following citation:

In preparing figures, communication and readability must be the ultimate criteria. Avoid the temptation to use the special effects available in most advanced software packages. While three-dimensional effects, shading, and layered text may look interesting to the author, overuse, inconsistent use, and misuse may distort the data, and distract or even annoy readers. Design properly done is inconspicuous, almost invisible, because it supports communication. Design improperly, or amateurishly, done draws the reader’s attention from the data, and makes him or her question the author’s credibility (para. 17).

The APA guidelines thus imply that the outcome of using a minimalist data display design will be a learner’s perceptions that a minimalist data display is useful and credible---values associated with aesthetic appraisals of beauty. APA recommendations against the use of three-dimensional effects is curious and can only be explained by their adherence to a minimalist aesthetic. Although experimental studies have demonstrated that three-dimensional effects can make processing data displays more arduous than processing two-dimensional displays, other research results dispute this conclusion. At least among a student population, for example, “3-D graphs were preferred more for depicting details than trends, more for memorability than immediate use, and more for showing others than oneself. The reverse held for 2-D graphs” (Levy, Zacks, Tversky & Schiano, 1996, p. 42). In a review of graph comprehension research, Shah & Hoeffner
(2002) found that studies demonstrated there were only slight differences in accurate interpretation of three-dimensional or two-dimensional graphs or charts while other studies showed no difference "in accuracy or speed of making comparison judgments (p. 58). The case for elimination of three-dimensional effects is not made per these findings. Aesthetics can play a greater role than research findings about the design of data displays, even in a scientifically oriented organization like the APA, or for a statistician like Tufte.

**Tufte: absolute presuppositions.** Implied in Tufte’s assertions regarding the superiority of minimalist displays, is the absolute presupposition of the goodness of quickness and efficiency. Values for quickness and efficiency have been discussed earlier in detail. Suffice to say, Tufte’s proposed elimination of extraneous detail is meant to make transmission of a data message efficient. Second, the absolute presupposition that science is serious and popular media is not (particularly cartoons) underpins much of Tufte’s argument against Holmes-style infographics. A third absolute presupposition can be ascribed to Tufte, namely that all learners can be equal in deciphering data displays if effort is made. Tufte’s statement about audience analysis that” too often leads toward underestimating the quality and interests of the audience” (Zachry & Thralls, 2004, p. 456) reinforces this notion.

**Nigel Holmes’s Position**

Holmes’ infographic work is rooted in a belief that the audience he usually designs for---viewers of popular media--- are often averse to examining generic or Tuftean minimalist graphic information graphics. “Except to the trained few, figures are so anonymous, so flat, so obscure and yet at the same time so threatening” (Holmes,
that viewers are better engaged with numerical data through infographics. Holmes said that a minimalist or generic information graphic:

- gives no clue to the subject being dealt with. In certain contexts, it might be perfectly proper to display the figures without any other visual help, but soon the charts will all look the same and therefore fail to be helpful” (p. 9).

Furthermore, Holmes said he strives toward use of subtle humor to forge a connection with his audience--“a connection that attracts or embellishes or underlines a conclusion” (Holmes & Heller, 2006, p. 21).

**Holmes infographics.** Holmes has typically incorporated graphics into data displays or surrounded data displays with imagery. He uses cartoon images to create visual puns or metaphors. (Figure 50. An example of Holmes’ infographic metaphor that could be translated, as “THE WORLD is an OIL GULPER.”; Figure 51. A visual pun by Holmes that uses the iconic banker from the game of Monopoly. Who is “monopolizing bank loans?”)

Holmes infographic work is often rhetorical, because his imagery is often tied to a data trend that is written about in an article by someone with an opinion. Much of Holmes work has been for journalistic publications and reflects the rhetoric in the articles they accompany.
Holmes: audience. When Holmes was asked questions about how he took an audience into account when designing an infographic, he said, “In most cases, I believe in tailoring what I do to specific audiences. At the very least, I need to know who my audience is, so they can become part of my thinking” (Holmes & Heller, 2006, p. 15). In his book, Designers Guide to Creating Charts and Diagrams (1991), Holmes describes “Step One” in the process of designing an infographic as “Identify the reader/user of the chart” (p. 60). His audience psychographics and demographics are determined according to traits of a readership of specific journals, magazines, newspapers or other publications. Holmes generally develops an infographic not only with an audience in mind, but with the identity of a publication. Although he has been asked to critique information graphics in academic or scientific journals by editors and has been subsequently asked if an infographic could enhance the data message, Holmes said that “it does not follow that every graphic should look like TIME, or the work I do now.”
Holmes: design process to avoid inaccuracies. Rather than advising designers to include artistic, but unneeded elements in information graphics, Holmes (1991) has recommended that students of infography subject their work to a stepwise design process. They should identify target readers, review numbers so “the final chart makes the desired point by displaying the right numerical information” (p. 60) and “find the right symbol: so, the information is amplified in a visual presentation which helps tell the story” (p. 90). Although Holmes has said it is necessary to determine appropriate types of graphs or charts for specific data visualization, infographics tend to summarize information in a digestible format. They are often best at depicting simple trends and are not always appropriate to display complex data sets (Holmes & Heller, 2006).

Holmes: aesthetics, usability, credibility in visual rhetoric. Holmes’ aesthetic is populist. His aesthetic assessment of infographics implies they are beautiful, usable and credible because they capture the attention of common readers who find them humorous, novel and entertaining. Holmes works at displaying data accurately to enhance credibility of his work. Because his infographics are presentational rather than analytical, their credibility and usability lie in their ability to visually convince viewers often, of single facts (e.g., “the price of oil is rising”). His infographics are often inherently rhetorical and non-objective because they are used in support of positions in stated in the articles they illustrate.

Holmes: the marketplace. Holmes mediates information as a graphic artist. Although he has a certain amount of freedom in deciding how the data will be portrayed and what style he will use to draft an infographic, his designs can be accepted or declined by his clients. He noted, for example, that the infographic in Figure 51. that depicted the
iconic banker from the game of Monopoly was “nixed” by editors because he apparently touched a nerve (Holmes, n.d. Ii-banking | Nigel Holmes Explanation Graphics).

Figure 51. A visual pun by Holmes that uses the iconic banker from the game of Monopoly. Who is “monopolizing bank loans?” Retrieved from Holmes, N. (n.d.). Ii-banking | Nigel Holmes Explanation Graphics.

Unlike researchers who generate their own data, Holmes is tied to the demands of the marketplace and the information publications vend.

Holmes: absolute presuppositions. Holmes expressed his belief that people are sometimes threatened by numbers, but that a visual display can overcome that fear. Reflected in this, is an absolute presupposition that not all learners are equally able to comprehend/ approach scientific or mathematical information. A second implied and related presupposition is Holmes’ belief that generic data displays are distancing but art can compensate for and make data accessible.

Empirical Evidence: Tufte- Holmes Debate

Stephen Few (2011), in describing a lack of empirical evidence in support of either side of the Tufte- Holmes debate wrote, “Unfortunately, this debate has rarely been
conducted in a rational, evidence-based manner. It has mostly been fueled by people’s blind commitment to one camp or the other” (p.2). Tufte’s recommendations for minimalism in information graphic design have been dogmatically embraced in many circles where he is often cited as a top statistical display expert (Grady, 2005; Yaffa, 2011). However, empirical evidence supporting use of a data-ink ratio is lacking (Spence, 1990). Blasio, & Bisantz (2002) said, “Although Tufte’s arguments are compelling and his methods interesting, he does not supply any empirical evidence confirming that his design recommendations can lead to better task performance using the graphics” (p. 91). Their review of studies at that time revealed that research on data display interpretation had not compared minimalist statistical displays with infographics but had examined information graphics with differing data density variables, or information graphics with three-dimensional elements or background graphics. These studies neither contradicted nor confirmed Tufte’s data-ink ratio proposition. Furthermore, none of the studies they surveyed specifically compared Tuftean minimalist information graphics to Holmes-style infographics.

Spence (1990) in his study on the visual psychophysics of simple graphical elements, for example, offered evidence against Tufte’s data-ink ratio, finding that graphics such as cylinders or other “elements with high apparent dimensionality lack nothing in accuracy and maybe processed faster under some conditions” (p. 691). Spence concluded that his findings “cast some doubt on the wisdom” (p. 691) of Tufte’s recommendation for use of flat, non-dimensional pictorial elements in graphic displays. However, he exclusively contrasted variables of dimensionality (1-dimension, 2-dimension and 3-dimension) in information graphics. He found, that by a relatively small
margin, that “the best all-around candidates for displaying numerical quantities are probably bars, boxes and cylinders” (Spence, 1990, p. 691). Because Spence did not use pictorial elements his conclusions were relevant to the effects of dimensional figures on visual processing but not on the effects of Holmes-style infographics.

Few (2011) cited a rare 2010 Canadian study, “The Effects of Visual Embellishment on Comprehension and Memorability of Charts” (Bateman et al) that “created a fair degree of buzz” (p.3) after directly comparing comprehension and recall of Holmes’-style infographics to Tuftean minimalist displays. Bateman et al. (2010) said “Two issues in particular are raised: first, whether visual embellishments do in fact cause comprehension problems; and second, whether the embellishments may provide additional information that is valuable for the reader” (pp.2573-4).

The Bateman et al (2010) study, although pioneering, was limited by a small non-randomized convenience sample that included “twenty participants (9 male, 11 female), aged between 18 and 40 … recruited from a local university (7 graduate, 13 undergraduate)” (Bateman et al, 2010, p.2576). Therefore, the generality of the study is limited. When comparing Tuftean minimalist information graphics to Holmes infographics these researchers “intentionally chose the most extreme type of visual embellishment that we could – namely, the full cartoon imagery used by Holmes.” (Bateman et al., 2010, p.2582).

Bateman et al. found that that Holmes’ style infographics were better examined according to eye tracking data than minimalist or “plain” displays (Bateman et al, 2010). They also found:
There was no significant difference between plain and image charts for interactive interpretation accuracy (i.e., when the charts were visible).

There was also no significant difference in recall accuracy after a five-minute gap.

After a long-term gap (2-3 weeks), recall of both the chart topic and the details (categories and trend) was significantly better for Holmes charts.

Participants saw value messages in the Holmes charts significantly more often than in the plain charts.

Participants found the Holmes charts more attractive, most enjoyed them, and found that they were easiest and fastest to remember. (Bateman et al., 2010, p. 2580).

Stephen Few (2011) said the findings overall, however, were sufficiently ambiguous that both sides of the Tufte-Holmes debate claimed the study findings supported their points of view. Bateman et al.’s own conclusion was “our work shows that there can be strong effects from the inclusion of visual embellishments – something that has not been reported before – and that this phenomenon should be better understood overall “(2010, p.2574).

The Tufte-Holmes Debate in Context of Contemporary Instructional Design

The Tufte-Holmes debate emerged during a time (1990) when data displays were increasingly used for informational and instructional purposes in publications and on the Internet. At the same time, textbooks were beginning to adopt styles that mimicked commercial layouts, using infographic or diagrammatic visual explanations similar to those found in popular magazines, newspapers or popular coffee table publications.
(Woodward, 1993). Textbook designs were largely developed without consultation by research on effective instructional visualizations.

The debate also began as the era of CBI & WBI was dawning, making visual presentation styles more central issues than ever before for instructional design. Overuse of decorative art as embellishments on WBI or CBI pages led to instructional design studies, such as those by Mayer & Harp (1998), about seductive or distracting detail. Mayer & Harp, like Tufte, recommended that seductive detail be erased to reduce extraneous cognitive load (Sweller, 1994). Studies such as these generally seemed to support minimalist visual explanations for most learning situations, although other research during the past decade sometimes found learning was unaffected or even enhanced by images or decorative graphics that could constitute seductive detail. (Park, Moreno, Seufert. & Brünken, 2011; Lenzner, Schnotz & Muller, 2013).

The Bateman et al. study itself was about seductive detail in the guise of “The Effects of Visual Embellishment on Comprehension and Memorability of Charts”(p.2573). Bateman et al., although the first to study Nigel Holmes infographics in contrast to Tufte’s minimalist style statistical displays, are human computing professors and researchers rather than instructional designers. Therefore, they made no reference to the relatively rich body of instructional design research on seductive detail, on graph comprehension or on visual cognition although the effect of visual embellishment on measures of learning and reception is central to their research.

**ISOTYPE: An Infographic Middle Ground**

Holmes and Tufte’s presentation styles, as described, seem to be polar opposites. If Tuftean minimalist information graphics and Holmes-style infographics are located at
opposite ends of a structural spectrum, Otto Neurath’s “International System of TYPographic Picture Education” (ISOTYPE) could be positioned at the spectrum’s center. Tufte’s minimalist information graphics are non-embellished and use generic templates in design while oppositely, Holmes- style infographics embellish data with both pictorials and metaphor. ISOTYPE, though not focal in the Tufte- Holmes debate, incorporates elements of both styles.

ISOTYPE (Neurath, 2004) was popularized and developed by Otto Neurath (1882-1945) whose pictorial icons were used as numerical counters in information graphics to contextualize data. Neurath-like data displays have perpetually appeared in instructional and informational publications since their invention during the 1920’s. (Figure 52. Example of contemporary Neurath-like data display published in 2015.)

![Figure 52. Example of contemporary Neurath-like data display published in 2015.](http://www.washingtonpost.com/news/wonkblog/wp/2015/10/14/people-are-getting-shot-by-toddlers-on-a-weekly-basis-this-year/)
Otto Neurath’s ISOTYPE: Design of Contextual Information Graphics

Neurath was a prominent “social scientist, scientific philosopher and maverick leader of the Vienna Circle who championed ‘the scientific attitude’ and the Unity of Science movement” (Cat, 2014, p.1) during the early to mid-1900’s. He embedded streamlined icons into statistical ISOTYPE displays beginning in the 1920’s as a basis for an instructional, (Charles & Giraud, 2013; Molleup, 2014) pictorial “auxiliary language” (Burke, 2009 p. 212) that could be used to communicate social and economic data to working classes and among multiple cultures or nations (Dalbello & Spoerri, 2006; Hartmann, 2008; Rehkämper, 2011). It was not Neurath’s intention to develop a fully evolved pictorial language, but rather to provide supplementary language-like icons that could explain socio-political data without verbal elements (Nawar, 2012).

Neurath’s audience and goals. Neurath’s goal was to use ISOTYPEs to democratize and empower the working class through understanding of socio-economic conditions. Neurath’s simple iconic illustrations of people or industrial products, among others, were used to communicate economic, health and political information, not so much to an illiterate population,” but for such persons who miss part of essential knowledge because they have a certain fear of a table of figures” (Neurath, 1974, p. 32). This rationale was similar to Holmes’ reasoning that members of the general public are averse to reading non-contextualized data displays because they are avoidant to numerical data (Neurath, 1936; Charles & Giraud, 2013). Neurath’s pictorial language was also used to crosscut linguistic barriers to understanding because global mobility had increased after World War I. Neurath (1936) stated “words make division, pictures make
connection” (p.18) and therefore a pictorial language could communicate more universally to citizens, whether their primary language was German, Russian or Italian.

Neurath, a socialist, developed ISOTYPE “from the point of view of a specific socialist conception of adult education and sought to enhance scientific arguments” (Hartmann, 2008, p. 279) that also reflected a greater focus on the needs of the working class in pre- World War II society. “In function and impact [ISOTYPE displays] were comparable to modern mass media because they disseminated information widely about the social, political, and economic conditions of the contemporary world to the citizens of a multinational and multilingual Habsburg Empire” (Dalbello, & Spoerri, 2006, p.89). ISOTYPE displays later became increasingly familiar to popular and professional twentieth century readers in the United States due to their widespread use in informational media including government publications (Charles & Giraud, 2013), popular magazines and textbooks.

**The Vienna method of pictorial statistics.** Neurath’s “new method used ‘pictorial statistics’—statistics represented in the form of icons or symbols—and was known at that time as the ‘Vienna Method’ of pictorial statistics” (Charles & Giraud, 2013, p.584). Initially displayed in a museum setting, Neurath “adopted the idea of using for his exhibitions signs and tables, posters and even objects for hands-on experience” (Hartmann, 2008, p.281). (Figure 53. Example of ISOTYPE exhibited in a museum setting.)

Icons represented socio-political data as visually concise graphics “used to characterize social concepts: [such as] men, women, cogwheels, vacuum cleaners,
Neurath believed the use of graphics familiar to the public could overcome confusion caused by extant, non-pictorial statistical charts (Neurath, 1937). Stylistically, ISOTYPE reflected the visual economy and minimal detail that was present during the time period’s modern art. Designers and artists had been heavily influenced by the Bauhaus school of art’s repudiation of the use of ornamentation in graphic displays. ISOTYPE designs reflected the modernist tenants of the Bauhaus school that insisted “in all aspects of document design machine-like economy is good and visually prolixity suspect” (Kostelnick, 1990, p. 15). The design principles of reflected by the Bauhaus school were echoed by Tufte with his “admonition to “eradicate ‘chartjunk’ from graphs and data displays” (Kostelnick, 1990, p.15).
Gerd Arntz, a primary ISOTYPE illustrator, created iconic representations as data counters, including those of “people that were amazingly expressive, yet [were] made with the fewest marks possible” (Holmes, 2001, p. 138). (Figure 54. ISOTYPE icons that represent people.)

ISOTYPE, based on the “Vienna method,” should be designed so that 1) icons expressed a high degree of resemblance to their referents (Hartmann, 2008); 2) all meaningful details can be discerned in no more than three visual inspections (Hartmann, 2008); 3) combinations of two or more ISOTYPE icons can create compound meanings (Neurath, 1937; McLaren, 2000). (Figure 55. How meaning was accomplished by compounding ISOTYPE icons.)
Prescriptions for ISOTYPE design dictated that 4) quantity should be represented by multiple figures rather than an increase of the size of an ISOTYPE icon and that:

horizontal arrangement represents changes in quantities, while vertical arrangement shows a passage of time or a comparison between various data.

An accompanying illustration (Führungsbild) sometimes appears in the background of these infographics to enliven the composition and to add a geographical or content-related connotation (Annink, N.D.).

Dalbello & Spoerri (2006) claimed “While the ISOTYPEs are modernist and minimalist, parading as scientific and analytic representation of truth, the
anthropomorphic pictograms reflect an ornate aesthetic on the surface, appear to defy the principles of functional visualization, and present no claims to be scientific” (p. 88).

Information graphics that resemble ISOTYPE pre-dated Neurath and have been used persistently into contemporary times. Graphs and charts that use icons are synonymously termed “pictograms” or “pictographs.” (Figure 56. A Pictogram. Varieties of Apples in a food store.)

<table>
<thead>
<tr>
<th>Varities of Apples in a food store</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Delicious</td>
</tr>
<tr>
<td>Golden Delicious</td>
</tr>
<tr>
<td>Red Rome</td>
</tr>
<tr>
<td>McIntosh</td>
</tr>
<tr>
<td>Jonathan</td>
</tr>
</tbody>
</table>

Apple = 10 apples  
Half Apple = 5 apples

Figure 56. A Pictogram. Varieties of Apples in a food store. Apples and half-apples are used as numeric counters in a horizontal bar chart and to contextualize this data presentation. From: Reading of Pictographs / Making of Pictographs: Reading of Pictographs / Making of Tally Charts Worksheet

The Debate and the Myth of the General Learner

It can be discerned, from the conduct of this debate, that current practice and research is derived from an acceptance of past practice, its relation to convention as well as evolving cultural and technological forces. The ability to “settle” questions about the merits of information or infographic styles for instruction depends heavily on
understanding foundations upon which real-world design practices were derived. The problems of defining best practices in visual design for learning however, is even larger than that.

The entire discussion up to this point has highlighted scholarly theory, research and debate contentions that assume all learners/readers are the same; that at any given point in time, anyone who views an image will tend to do so in the same ways as any other learner. This attribution of “sameness” in visual learning and cognition may be modified by acknowledgment of the influence of individual differences among viewers, such as those related to visual acuity or the effect of cultural and historical differences. Although these are certainly important to consider, differences that are relatively unknown to researchers in general--- such as differences in cognitive style that predict major differences in visual cognition--- are commonly ignored in research on infographics and information graphics. One of these cognitive styles is called the field dependent- independent (FDI) cognitive style. The next section illustrates that consideration of the FDI cognitive style could radically challenge the premises of the information – infographic debate.

The Field Dependent-Independent Cognitive Style

Cognitive styles have been defined as “characteristic modes of perceiving, remembering, thinking, problem solving, and decision making reflective of information-processing regularities that develop in congenial ways around underlying personality trends” (Messick, 1994, p. 122). Learners were found to exhibit either a field dependent (FD) or field independent (FI) cognitive style, beginning in the later 1940’s, according to
their differing abilities to visually separate simple figures from complex background fields.

Theories of visual perception and visual cognition are based on common human processes of seeing and decoding visual displays, although there can be profound individual differences in the ways learners decipher visual information. Despite commonalities in biological visual processing or ability to detect line and spatial arrangements, learners, for example, are not equally successful in visually separating simple figures from complex grounds. This differing ability was detected because of perceptual research conducted during the late 1940's and became the basis for assessing and categorizing learners as field dependent (FD) or field independent (FI).

**Dissimilar Visual Processing in FDI**

FI learners and FD learners are thought to use both dissimilar visual processing and cognitive strategies when given the task of locating a hidden figure nested in a complex visual display. FI learners more quickly and successfully locate a hidden figure than FD learners. Performance on hidden figures tests not only identify learners as FI or FD but also predict differential performance in academic work, social orientation, vocational choice, reasoning style and ability to comprehend abstractions. A learner’s designation as either FD or FI was based on research that that demonstrated both individual differences in cognitive re-structuring and psychological differentiation (Witkin & Goodenough, 1981; Moran, 1985).

The fixity of the FDI cognitive style is also important to its definition. The only definitive changes in learner FDI are related to human development because children and geriatric populations tend to be more field dependent as groups than those in early or
middle adulthood (Goodenough, & Karp, 1967; Witkin, Goodenough, & Karp, 1977; Jonassen & Grabowski, 1993). Witkin, Goodenough, & Karp (1967) noted FDI was so durable, that it was mostly resistant to other researchers’ attempts to alter learners’ cognitive style—- even through extreme interventions. These interventions included use of drugs such as "as sodium amytal, Dexamphetamine, chlorpromazine, imipramine and alcohol" (Witkin, Goodenough, & Karp, 1967, p.292) or after electroconvulsive shock therapy (Pizzamiglio, & Zoccolotti, 1986).

**History of Research in Field Dependent-Independent Cognitive Style**

Field dependent-independent (FDI) differences have been continuously studied since 1947. Experimental psychologist Herman Witkin and colleagues, such as Donald Goodenough and Solomon Asch, conducted human perceptual experiments during the post- World War II era that resulted in a full-fledged articulation of a theory of a bipolar field dependent - independent (FDI) cognitive style. Although Witkin collaborated with several psychologists until his death in 1979, (Wooldridge, 1995) the articulation and development of the field dependent-independent (FDI) cognitive style is identified most closely with Witkin. Witkin recognized that differing visual perceptual skills affect learning, reasoning and social orientation. Messick (1986) chronicled Witkin's development of the FDI cognitive style over his three decades of research. He summarized the evolution of his FDI theory:

first as a dimension of field versus body orientation in the resolution of perceptual cue conflicts; then as a dimension of analytic restructuring; then as an articulated versus global field approach; and ultimately as a dimension of self-differentiation
leading to autonomy from external information sources, whether perceptual or interpersonal (Messick, 1986, p. 115).

Dimensions of the FDI cognitive style remain one of, if not the most widely researched cognitive styles in psychological and educational studies (Baker & Dwyer, 2005; Evans, Richardson & Waring, 2013; Moran, 1985; Richardson & Turner, 2000). Moran (1985) reported that from 1972 to 1985 more than 4000 studies could be attributed to investigation of the FDI cognitive style. FDI cognitive style has been considered "one of the most popular and fertile constructs in contemporary psychology studies” (Moran, 1985, p.119) and "since the mid-1960's, the term 'cognitive style' has been used virtually as a synonym for field dependence-independence" (p.120). Richardson and Turner (2000), in a retrospective examination of FDI studies proposed that “its resulting typology has been heralded for its simplicity of measurement" (p.256) which led to a "focus of more researchers than any other cognitive style" (p.257).

The popularity of research on the FDI cognitive style waned after the 1980's (Richardson & Turner, 2000). However, applied studies have persisted about the relationship of FDI to such diverse behaviors or conditions as creativity (Miller, 2007), drunk driving, autism (Jolliffe & Baron-Cohen, 1997), advertising (Matthes, Wirth, Schemer & Kissling, 2011) or E-learning (Zheng, Flygare & Dahl, 2009).

**Field Dependent-Independent Cognitive Style: Assessment**

Although numerous studies cite Witkin's use of both the Rod and Frame Test (RFT) and the Embedded Figures Test (EFT) to determine measures of FDI in learners, Witkin used a wide convergence of operations to research the FDI cognitive style. These included the use of longitudinal studies, autobiographical reports, clinical interviews as
well as personality tests or questionnaires (Kozhevnikov, 2007). Despite early, auxiliary use of self-report instruments to assess FDI and common usage of self-report surveys in research on numerous cognitive style propositions, Witkin’s founding experimental research on cognitive style was notable for primary use of the RFT and the EFT that both qualify as objective perceptual, projective tests. The “FDI construct has an extensive history of research involving measurement using instruments that do not use self-report items and that tend to be more reliable when compared with many style-oriented instruments” (Rittschof, 2010, p. 100).

The Rod and Frame test (RFT). The RFT used a tilted luminescent frame with a luminescent rod within the frame in a darkened room to test learner ability to align the rod in a vertical position. FD learners and FI learners used different, characteristic strategies to vertically align rods.

Field-dependent people tend to bring the rod into alignment with the tilted frame, reflecting use of the main axes of the frame as a basis for judging the upright. Field-independent people adjust the rod close to the upright, reflecting use of the felt position of the body (Witkin, Moore, Oltman, Goodenough., Friedman, Owen & Raskin, 1977, p. 197).

The Embedded Figures test and the Group Embedded Figures test. Witkin developed the Embedded Figures Test (EFT) during the 1950's "as a search was made for other situations that would reveal the manner in which people perceive a part within a larger field" (Witkin, 1950, p.1). Witkin, Oltman, Raskin & Karp developed the Group Embedded Figures Test (GEFT) in 1971 (Oh & Lim, 2005). The EFT and the GEFT were
adaptations of earlier tests that required discovery of a hidden figure embedded in a complex visual form.

The EFT paper and pencil version, “correlated well with the bodily oriented tests ... in that, those who were distracted by the visual field [FD learners] found it difficult to find the figure within that visual field.” (Jonassen & Grabowski, 1993, p. 92). The definitive version of the EFT was a timed test "composed of 18 pictorial items, each involving identification of non-meaningful geometric target shapes hidden within larger non-meaningful geometric shapes" (Hickcox, 1995, p. 36). The paper and pencil Group Embedded Figures Test (GEFT) was introduced in 1971 (Hickcox, 1995) as a "group-administered, 25-item test administered in three timed sections" (Jonassen and Grabowski, 1993, p. 90) wherein an individual finds and traces over a previously viewed figure inserted into a more complex figure. (Figure 57. A page from the GEFT.)

Figure 57. A page from the GEFT. A learner finds the simple form "x" and traces over the same shape with the same orientation and of the same size embedded in the complex figure below. From: Group Embedded Figures Test - Mind Garden. (n.d.).
Witkin and other researchers through the 1980's frequently used the RFT and/or the EFT (Wooldridge, 1995) or GEFT to assess measures of field dependence. The use of these tests was based on the claim that "people tend to be consistent in performance across these two tasks and others of a similar nature" (Witkin et al, 1977, p.197). Both the RFT and the EFT or GEFT require a study participant to "perceptually organize a part of the stimulus situation in the presence of a more complex or embedding background" (Pizzamiglio. & Zoccolotti, 1986, p.31). However, there have been other claims that the correlation between the two tests is weak, suggesting that each test measures a different aspect of visual processing (Evans, Richardson & Waring, 2013).

Jonassen and Grabowski (1993) noted that the GEFT is reliable ($r = .82$) and is highly correlated to the EFT ($r = .63 -.82$) on the two forms" (p. 90). Accordingly, the paper and pencil GEFT, as originally configured, remains one of the most popular instruments used to determine FDI in present-day research. The proliferation of FDI studies and rationale underlying use of the EFT or GEFT to assess learners over time has been due, in no small measure, to the "the psychometric ratings overall for Witkin's tests [that] were strong for reliability and good for validity." (Hickcox, 1995, p. 37). Variations of these simple visual perception tests originally used to assess FDI are used in contemporary studies to predict differential abilities in analysis of a visual field.

**Additional tests and assessment tools.** FDI has also been assessed using perceptual and problem-solving task tests such "tests of flexibility of closure, speed of closure (such as the Street Gestalt test), de-centering (such as Piaget's three-mountain problem), conservation, and concept-attainment tasks” (Witkin, Moore, Oltman, Goodenough, Friedman, Owen, & Raskin, 1977, p.198) as well as eye tracking tests
Brain imaging tests have also been used to study physiological differences in FD or FI learners. Imaging tests have revealed hemispheric differences in visual processing. Researchers discovered that FD learners “demonstrate greater between-hemisphere coherence and less pronounced hemispheric differentiation than their FI counterparts” (Evans, Richardson & Waring, 2013, p. 213).

Arguments Against FDI as a Cognitive Style

Academics and researchers do not always agree that the FDI construct is valid as presented by Witkin or other early researchers. Moran (1985) questioned consistency in results of studies using the RFT to assess measures of FDI. He argued:

some of the traditional measures of this construct (e.g. the stationary, dark-room model of the Rod-and-Frame Test; are unavailable commercially. As a result, researchers have been forced to use custom-built models. Inevitably, variations arise in the design and administration of these tests (p. 121).

Other arguments lodged against the FDI cognitive style formulation represent issues over the definition of cognitive style. Jonassen & Grabowski (1993) preferred use of the term “cognitive controls” to describe FDI type constructs. They argued that cognitive controls “represent patterns of thinking that control the ways that individuals process and reason about information” but “have different theories, methods, and assumptions than cognitive style” (Jonassen & Grabowski, 1993, p. 83) and are not restricted to perceptual habits. Evans, Richardson, & Waring (2013) argued that varying interpretations of FDI exist in the literature where it has been characterized as a perceptual or cognitive ability, an aspect of working memory or simple ability to disembed simple figures from complex arrays. "Confusion over what is precisely being
measured by researchers in the field and the extent to which they fully understand the
validity of the measures that they are using and, therefore, the clarity of their rationale
and utility of using a specific measure” (Evans, Richardson, & Waring, 2013, p. 211).
They also criticized practices in FDI studies saying, "It should be noted that the opposite
to FI, field dependence (FD), is often inferred rather than measured directly. It is
therefore more appropriate to discuss variations in FI rather than variations in FD"(p.
211).

Despite arguments about terminology or testing methods or limitations within the
huge body of FDI research, there is sufficient evidence to verify that a constellation of
specific traits is associated with FDI learners and that these learners are more or less
dependent on a field for perceptual or cognitive tasks of different sorts. Differential
processing of visual instruction can also be assumed and so consideration of the FDI
construct has important implications for the field of instructional design.

FDI Central Premises

The notion of an FDI cognitive style rests on at least three central premises. FDI
is considered to be a bi-polar style, it is psychologically pervasive and value neutral.

Premise one: FDI as a bi-polar style. The first, most typical, premise underlying
FDI cognitive style is that it is a bi-polar cognitive style (Witkin et al., 1977) although
learner scores on GEFT or EFT tests are distributed along a continuum. Learners who
score below the median in a hidden figures test have been classified as FD and those who
score above the median have been classified as FI. Although the most extreme examples
of either field dependence or field independence are found at either end of the spectrum,
conventional bi-polar partitioning was based on assumptions that cognitive style traits of FI and FD learners are oppositional.

Although most research measures FDI as a bi-polar construct, other researchers (Meng, & Patty, 1991; Nisiforou & Laghos, 2015) designate a third group within the FDI cognitive style continuum. By dividing a hidden figures test scale into thirds, those who score in the highest third are classified as FI, those who score in the lowest third are classified as FD and those in the middle third are classified as field neutral or field intermediate (FN). FN learners exhibit traits of either FI or FD depending on a given situation. Researchers studying the relationship of field dependence to the use and benefits of graphic organizers, for example, evaluated learners based on divisions into these three groups (Meng, & Patty, 1991). They concluded the needs of field intermediate or neutral learners are different than those of either FD or FI and that their results would have been confounded by an even split if the traditional bi-polar division of study participants had been used (Meng, & Patty, 1991).

**Premise two: psychological pervasiveness.** A second and essential premise that supports FDI cognitive style is its "psychological pervasiveness (i.e. cutting across boundaries between intelligence and personality)" (Kozhevnikov, 2007, p. 466). Scores on a hidden figures test, in other words, also predict a person will exhibit traits associated with FD or FI in multiple, seemingly unrelated aspects of personality. Therefore, a social orientation or ability to acquire conceptual knowledge is predictably different depending on whether a learner is FD or FI. Vocational preferences, for example, are also predictably different for FI or FD learners. FI learners tend to gravitate toward careers that use math or science while FD learners avoid careers in these domains preferring
careers with an emphasis on working with or helping people (Witkin, 1973). Vocational choices of FI learners not only reflect their analytical orientation, but a lesser affinity for acting in social settings than that of FD learners.

**Premise three: value neutrality.** A third premise supporting FDI as a cognitive style is that the style itself is value neutral. In other words, characteristics of either an FD or an FI learner type may work to an advantage or disadvantage in context of a given situation and neither set of characteristics can be considered good or bad. Witkin (1973) contrasted a value emphasis associated with ability or intelligence to a value free emphasis in cognitive styles:

> With abilities, virtue lies in their possession; to lack them is to be deficient. The value emphasis is thus unipolar. With cognitive styles, on the other hand, the cognitive and personal, characteristics involved allow persons at either pole a proper share in the Lord's work (p. 44).

However, Witkin’s assertion that FDI is value neutral has been contested. Scores on the EFT or GEFT are determined by *success* of field independent learners or failure of field dependent learners to readily find a simple figure embedded in a complex array. Furthermore, FI learners tend to be more adept at tackling academic subjects such as science and math than FD learners. These kinds of successes have led some researchers to describe FDI, as not only a measure of ability, but also a measure of proficiency-deficiency that favors FI learners (McKenna, 1984). That, in turn, suggests valuation.

**Characteristics of FD and FI Learners: Visual Cognition and Learning**

Differences in the ability of FD and FI learners to find simple figures in hidden figures tests also predicts differing traits in visual cognition and perception. These
differences also determine the ways FD or FI learners attend to components of visual displays as well as strategies each uses to decipher visual instruction and to attain concepts.

Visual perception of a field: FD and FI learners. According to scores on the EFT or GEFT, an FD learner cannot easily disembed a figure from a complex array and perceives a field globally and as a relatively inseparable whole (Goodenough, 1976; Jonassen & Grabowski, 1993; Wooldridge, 1995; Tinajero, Castelo, Guisande & Páramo, 2011).

In a field dependent mode of perceiving, perception is dominated by the overall organization of the field; there is relative inability to perceive parts of a field as discrete. This global quality is indicative of limited differentiation. Conversely, field-independent style of perceiving, in which parts of a field are experienced as discrete from organized background… is a relatively differentiated way of functioning (Witkin, Goodenough & Karp, 1967, p.291).

The field dependent learner is "dominated by the overall organization of the surrounding field and parts of the field are experienced as fused"(Woolridge, 1995, p. 51). Accordingly, FD learners are said to “see the forest rather than the trees” (Jonassen & Graboski, 1993; Poirel, Pineau, Jobard & Mellet, 2008) and consciously detect only the most noticeable, or interesting (salient) features in a visual display.

There is also evidence that content, rather than the sum of parts in a visual display registers subliminally, if not consciously with an FD learner. An advertising study on product placement by Matthes, Wirth, Schemer & Kissling, (2011) investigated how FD or FI viewers would respond to branded products placed unobtrusively in a music video.
or a television news story. This type of product placement is now common advertising practice since advertisers hope viewers, who often ignore commercials, will pay attention to products integrated into programming.

“In movies or television shows, product placements are embedded in a rather complex visual field. They are not presented directly to viewers; in contrast, they are somewhat hidden in moving pictures and compete against a rich array of other stimuli’ (Matthes et al., 2011, p. 87). This is the kind of visual presentation that is challenging to FD viewers who tend to view a complex field as a fusion of elements.

FI viewers, in this experiment, detected and recalled products better than FD viewers. FD viewers, however, liked the embedded product brand better than the FI participants. Because FI viewers recognized products in programming more often than FD viewers they may have recognized product placement as an advertising ploy resulting in less liking of a brand. FD learners who were less able to overtly recall product placements, unconsciously detected branded products in a complex visual field. The placement of products in programming, for FD learners, operated as subliminal messages.

**Partist or wholist strategies in visual cognition.** An FI learner more naturally distinguishes the parts of a figure from its whole than an FD learner by mentally separating a figure from its ground (Wooldridge, 1995), or in other words, by "disembedding" parts from wholes. Goodenough (1976) explained that an FI learner uses a partist strategy that involves sifting and sorting out relevant from irrelevant cues. An FI learner can see *both* the forest and the trees. The FI learner can remix the essential components of a visual display, restructuring the mix to attain and ferret out conceptual
information. An FI learner is then able to comprehend concepts portrayed in a display after identifying the most meaningful parts of the visual field.

While an FI learner processes visual displays using a partist strategy, an FD learner uses a wholist strategy, perceiving all visual cues as equally relevant (Goodenough, 1976). An FD learner views visual displays without additional analysis. For this reason, some researchers have also classified the FD learner as a passive spectator (Tinajero, Castelo, Guisande, & Páramo, 2011). The FI learner has been, by contrast, characterized as adopting the role of a participant in visual learning due to use of an engaged, methodical approach to analysis of visual displays.

**Concept attainment strategies: FI and FD learners.** Although FDI does not present in all learning conditions and is unrelated to situations that require such cognitive activities as verbal comprehension, it” is manifested specifically when the task requires breaking an existing organization and regrouping several parts separately” (Pizzamiglio & Zoccolotti, P. 1986. p. 32). Therefore, the visual processing strategies used by FDI learners are also used for example, during cognition relevant to concept attainment. Concept attainment requires synthesis of relevant chunks of information and are governed by the same type strategies FDI learners use to extract visual information, particularly in ambiguous or ill structured contexts.

FI learners are more able than FD learners to impose order on unstructured information through a process of reorganization and restructuring (Jonassen & Grabowski, 1993). They rely upon their own internal referents to analyze the component parts of an instructional message, sampling from and isolating relevant parts of information that contribute to general hypotheses or conceptual constructs.
Interacting Traits in FI or FD Learners: A Stonemason Analogy

FI learners function in concept attainment much as an unaided, novice stonemason functions when tasked with building a house without a blueprint. A hypothetical FI novice stonemason would be likely to select stones from an unsorted heap, keeping or discarding them according to their best fit to a fuzzy mental model of a completed house. This FI stonemason would develop a detailed architectural schematic throughout the stone sorting and discarding process. Similarly, when building a mental model or concept, an FI learner would be likely to analyze information chunks, according to best fit, then restructure them in new ways to accomplish a required task (Goodenough, 1976).

The FI stonemason in this example, would be likely to choose to work independently, designing a building project one stone at a time, according to reliance on his or her own internal referents. FI learners are "more likely to reorganize, restructure, or represent information to suit their own need, conceptions, or perceptions" (Jonassen & Grabowski, 1993, p. 87). Uses of internal referents in abstract problem solving "favor isolation, intellectualization and projection" (Korchin, 1986, p. 49). Also, like the hypothetical novice stonemason, FI learners tend to sample from cues in an information field, analytically selecting the most important cues---or stones--- to construct a conceptual model (Goodenough, 1976).

FD learners' concept attainment is affected by the structure of the information field as presented. All cues or chunks of information embedded in the field may seem equally relevant to an FD learner who tends to examine everything, rather than isolating significant chunks to determine structure (Tinajero & Páramo, 1998). When an FD
learner confronts ambiguous, ill-structured or unfamiliar sets of information (Jonassen & Grabowski, 1993) used to present concepts, the FD learner is likely to "go along with the dominant properties of the stimulus field" (Witkin et al, 1977). In other words, the FD learner tends to go along with whatever aspects in an information field are most noticeable or interesting (salient) and consequentially, FD reasoning is "dominated by the salient cues in concept attainment problems (Goodenough, 1976,p.675). Tinajero, Castelo, Guisande, & Páramo. (2011) noted the disadvantage this FD strategy imposes saying, "this tendency is an obstruction to intellectual tasks which demand concentration upon isolated elements within a perceptive and/or symbolic whole, or in those which involve restructuring"(p.498).

Returning to the novice stonemason analogy, an FD novice stonemason is more likely to sort stones, or conceptual chunks in an information field, according to their most salient features. These features, it should be noted, would be determined by FD preferences which could result in stones being sorted according to size, color or shape. Goodenough (1976) reported that “literature indicates that when a hypothesis-testing approach is employed by field-dependent people, they tend to ignore some cues in constructing hypotheses" (p.677), favoring some cues over others, presumably due to personal resonance. Goodenough (1976) added that "the hypotheses adopted by field-dependent subjects showed marked preferences for certain cues, even though all cues had equal objective validity over the set of problems used"(p.677).

The result of not sampling from a complete set of cues---or stones-- in concept attainment, often results in a learner’s faulty construction of models or conceptual misconceptions. Due to an FD learner's more limited ability to restructure variables, an
FD novice stonemason would predictably have less detailed blueprints in mind than an FI novice stonemason. However, FD learners need greater organization of visual material to restructure or reconfigure elements in a display, whether of stones for a house or visual information chunks.

The FD learner looks for help from others in ambiguous situations. In contrast to greater self-assuredness and self-sufficiency of an FI learner "the weight of the evidence supports the view that field-dependent subjects are more attentive to cues from other people" (Goodenough, 1976, p. 689). FD learners are more apt to seek answers from external sources or other people, rely on the consensus of others and prefer working in groups rather than individually. This FD social orientation is correlated with dependence on others for self-definition (Wooldridge, 1995; Goodenough, 1976; Goodenough, Friedman, Owen, & Raskin, 1977). For this reason, the hypothetical FD stonemason would be apt to flounder in an environment where he or she was the only worker on the site, just as he or she would find concept attainment difficult without the help of others or the availability of a clear, unambiguous instructional structure.

**FDI and the Challenge of Display Types**

The FDI traits previously mentioned, predict that the more geometrically abstract or complex a visual display becomes, the greater difficulties an FD learner will encounter when attempting to isolate meaningful elements. Statistical data displays are examples of complex, potentially ambiguous, informational tools that may be much easier for FI learners to decipher who excel at analytic and numeracy skills than FD learners who have greater difficulty.
Displays of technical information as instruction became more important during the late twentieth century as more data was generated. Data generation was due to a faster pace in technical innovation, new scientific discovery and new sociological trends. Although statistical information had been represented visually since at least the mid-1800’s, by the end of the twentieth century data displays were prominently in “technical reports, research articles, and annual reports as well as less formal documents such as fact sheets, brochures, newsletters, and even monthly power bills” (Kostelnick, 2007, p. 280). Data displays were also featured in newspapers, magazines, journals as well as in textbooks or as a part of multimedia presentations. The pervasiveness of data displays in both informal and formal instruction made FDI learners’ ability to analyze data patterns more essential than ever. It is known that FD learners have a particularly challenging time sorting through a disorganized visual display (Tinajero, Castelo, Guisande & Páramo, 2011).

It is possible that any information graphics are readily interpreted by FI learners with their analytic orientation and superiority in disembedding visual elements in a display. Their ability to re-combine disparate geometrical elements from a data display into a meaningful whole undoubtedly assists their interpretation of an information graphic. FD learners, on the other hand, may require cues beyond geometric lines, grids or shapes. Pictorial elements in infographics that suggest context and topic, may help them more successfully interpret a display. It is just as possible, however, that these pictorial elements may act as seductive detail for FD learners who tend to pay attention to the most interesting or intriguing features in a visual display while disregarding meaningful components. FD learners may not tolerate data display pictorials that may
offer meaningful clues, but also contribute more detail overall that muddies a chart or graph’s clarity.

**Summary and Research Questions**

This chapter discussed the nature of eikoncentric eras that occur when society was or is saturated by graphics which leads to increased use of visual instruction or explanation. It also identified a grammacentric era as one when society was or is centered around text for learning.

Visual instruction during the eikoncentric Western medieval era was used to illuminate learners, assuming they would experience spiritual revelation when seeing or visualizing illustrations or views of nature (Vicari, 1993; Clark, 2007). During the contemporary eikoncentric era, illustrations have likewise been used to establish the reality or validity of something (often invisible to the naked eye) with an image (Cook, 2006; Gross, Harmon, & Reidy, 2002). Scientific fields use graphs, charts, diagrams or illustrations to describe invisible entities or processes, and as data explanations.

The chapter, in review, concluded that present-day Western society represents an eikoncentric era. This state of picture-centeredness reflects a need for understanding its place in instructional design since visual instruction is on the rise. Today’s textbooks feature more graphics than ever before (Evans, Watson & Willows, 1987; Woodward, 1993; Martins, 2002) with nearly half of today’s textbook page space filled by graphics (Cook, 2012). Because visual instruction is frequently delivered over a computer or transmitted on the Internet, digital media also adds to the modern-day cache of imagery in instruction. Furthermore, mass data generated via computer technology during recent past decades contributed to development of data displays to portray statistical findings for
the benefit of both professionals and students. Data displays, as graphics, add visuality to the body of formal or informal learning publications and instructional media.

The compilation of contemporary visual instruction studies has been characterized as fragmented and “disputatious” (Anglin, Vaez, & Cunningham. 2004). Despite numerous extant studies about visual instruction as recently as 2004, Anglin, Vaez, & Cunningham commented it was “not clear how students use illustrations in instructional materials or that they even know how to use them” (p. 876).

Because a wide variety of differing images are studied in context of different tasks or under unlike conditions, contradictory research findings about visual cognition or optimal visual instruction designs can stem from lack of apt comparisons (Levie, 1987; Carifo & Perla, 2009; Wright, Milroy & Lickorish, 1999). Textual or reading research has its own complications, surely, but also has the advantage of use of a codified alphabet that does not vary except in font styles or spatial organization of text.

Graph comprehension theories have worked at describing the cognitive complexity involved in interpreting a graph or chart without complete success. Notably, these theories tend to posit a general learner without differing skills or abilities to decipher visual material. Carifio & Perla (2009) said that despite known differences in visual perception given a learner’s cognitive style, “few studies that have been done of graphs (or their associated theories) have controlled or accounted for such individual differences” (p. 420).

During its brief history, contemporary visual instruction and design research has commonly been framed by narrowly focused methodology that investigates changes in learner performance given a single, quantifiable, variable such as learner attention or
concept attainment (Tennyson & Breuer, 1997; Levie, 1987). Studies of single elements of visual displays are also representative of contemporary study design. For example, a researcher may focus on differences in single elements such as typography, color, arrows or other cuing graphics, etc. (Lee & Boling, 1999). The generality of findings in studies such as these may be limited owing to confined study parameters, as well as to the unique structural and aesthetic differences among diverse types of graphics.

The value of findings from the corpus of visual learning research literature was questioned. Despite an abundance of research in visual cognition and visual instruction, the findings have been said to be contradictory (Scaife & Rogers, 1996; Carifio & Perla, 2009). Baynes (2008) referenced E-learning as an exemplar of the limitations of contemporary visual research, arguing, “discussions of the virtual learning environment have in general focused around its instrumental functionality and ‘affordances’, rather than subjecting its interface to a visual analysis aimed at exploring how it represents and constructs informational and pedagogic space” (p. 396). The establishment of whole theories of visual cognition and instruction is rare.

Although instructional design researchers such as Clark and Mayer (2011), delivered pioneering work on how to develop twenty-first century visual material for multimedia learning, their researched recommendations may only be occasionally used. This is partly because a great deal of professional graphic work is performed by graphic designers without instructional design backgrounds or knowledge of research findings and theorem by instructional design scholars such as Clark and Mayer.

Gestalt theory is exceptional as a theory that help pilots real-life design of formal and informal visual instruction. The Clark and Meyer principles of multimedia learning,
for instance, sometimes examine and restate parts of Gestalt principles of organization. Because Gestalt principles of organization are often incorporated into a graphic artist’s training and because artists create graphics for learning, Gestalt theory may often be translated into practice.

Perhaps the greatest pitfall on the general visual research landscape is that most instructional design studies, unless directly associated with cognitive style, do not assume individual differences that affect visual learning. Theoretical and experimental work on visual information processing often begin with assumption of a universal visual learner. A learner’s cognitive style, however, can have a decided impact on perception and interpretation of a visual display. Numerous studies in other fields have, for example, described the ways that the field dependent-field independent style affects visual cognition or perception.

If research findings in visual instructional design have not benefitted practice as much as is thought, then it is important to acknowledge and discover factors that do influence real-world instruction. This literature review argued that determinant factors, other than theory and scientific proofs, continue to influence models of visual instructional design. These determinant factors include the marketplace, aesthetics, societal preoccupations, worldviews and absolute presuppositions as well as the rhetoric of communities of practice. Argument in this chapter also maintained that thought about visual cognition and instruction today is much the same as it was in the medieval eikoncentric era. This situation is due to the limitations of research findings paired with a strong influence of determinant social and political factors. Visual instructional design
practices are now, as in medieval times, based more on outside forces like the
marketplace or philosophies and beliefs, than on scientific evidence.

Continued problems with visual research and its overshadowing by determinant
factors, are, perhaps, nowhere better illustrated than in the Tufte-Holmes debate. Much of
Edward Tufte’s criticism leveled at Nigel Holmes was based on his personal aesthetic
and the rhetoric of communities of practice. Despite widespread adoption of Tufte’s data
design principles by scientists and other professionals, the basis of his argument for
minimalizing detail in a statistical display was non-scientific. Research had neither
proven nor disproven his recommendations.

When Edward Tufte triggered the debate (Tufte-Holmes debate) during the
1990’s about differing types of statistical displays, he argued that minimalist information
graphics without pictorialization were the only legitimate type of statistical display that
could accurately present data. He cited the works of Nigel Holmes as ineffective
statistical display designs. Holmes worked as a graphic artist for large magazines and
newspaper publishing houses with popular audiences. He integrated pictorial elements
such as illustrations or caricatures into statistical graphs or charts to develop visual
metaphors or analogies in infographics. Tufte claimed that any ink on a page that did not
directly portray data should be erased in any type of publication, whether popular or
academic. He favored a minimalist information graphic style that showed data trends
with the thinnest lines practical, even calling for the erasure of gridlines or axis lines to
limit ink.

Both these styles of information graphics appear in press today. Versions of the
pictogram—a pictorial statistics display brought to the forefront during the 1930’s by
Otto Neurath as ISOTYPE---also appear in today’s media. Pictograms act as a middle ground between the minimalist information graphic and an infographic, contextualizing meaning with use of iconic images as counters within a graph or chart. Less decorative than infographics and without aspirations to develop a metaphor, pictograms are still considered pictorial statistics. These would be of limited or no use for Tufte and have use for Holmes.

Although the debate still rages at the time of this writing, sides for or against pictorial enhancement in a data display have seldom been supported by the results of research. Few studies have been designed to research the merits of Tufte’s recommendations and Tufte has not developed studies of his own to test the validity of his graphic design recommendations. This state of affairs is not vastly different from the state of affairs during the first seven decades of the twentieth century or in early audio-visual research days when recommendations for data display design were based largely on opinion and/or on sketchy research findings.

Furthermore, Tufte posited the minimalist information graphic as a one-size-fits all data display, equally friendly to all visual learners. The problem of believing that all people see roughly in equivalent ways without significant individual differences in visual cognition is that is untrue.

It has been consistently demonstrated that learning from images is made easier or more difficult according to differing visual-spatial skills based on a learner’s FDI cognitive style. It is almost certain that the more abstract a visual display becomes--particularly when symbols rather than realistic illustrations make up most of a design--the more difficulty someone with visual-spatial skill problems may have comprehending
material. Abstract visual displays, such as data displays, may present great challenges to learners depending on their cognitive styles.

FD learners, for example, are "dominated by the overall organization of the surrounding field and parts of the field are experienced as fused" (Woolridge, 1995, p. 51). An FI learner more naturally distinguishes the parts of a figure from its whole than an FD learner by mentally separating a figure from its ground (Wooldridge, 1995), or in other words, by "disembedding" parts from wholes. Therefore, the FD learner and the FI learner approach a visual display in ways damaging the assumption of a universal visual learner.

Although FDI cognitive style can be assessed as FD, FN or FI using hidden figures tests, it is not unconventional to score all learners as either FD or FI depending on their score’s location on a hidden figures test spectrum. Acknowledging that as many as half of all learners (FD) will have difficulty separating salient visual details in a display from unimportant details makes it important to understand the interplay of FDI cognitive style in interpretation of data displays.

This study, in part, reexamines some of the Bateman et al. (2010) conclusions about information graphics preferences and comprehension without replicating their instrument or using, as they did, a convenience sample. This study, instead, examines the correlation of FDI cognitive style with comprehension and aesthetic assessments of minimalist information graphics, pictograms and infographics. The following research questions and related alternative hypotheses were developed given the unknown effects of FDI cognitive style on learning from minimalist or pictorial information graphics.
Research hypotheses are null, addressing the role of pictorial detail in differential FDI comprehension and aesthetic reception of minimalist information graphics or pictograms or infographics. The following research questions are listed with brief commentary and citations of supporting hypotheses.

**Research Question: 1. What is the relationship between FDI and comprehension of minimalist information graphics, pictograms, or infographics?**

This chapter cited individual differences in deciphering visual displays associated with FDI learners. These differences are stable and can be expected to manifest when FDI learners are exposed to pictographs, infographics or minimalist information graphics. Examination of a matrix of FDI characteristics that may influence comprehension of graphs and charts supports the central thesis that FDI comprehension of minimalist, pictographic and infographic information is differential.

Upon examination of the matrix of FDI traits, it can first be stated that when viewing visual displays, FD learners are "dominated by the overall organization of the surrounding field and parts of the field are experienced as fused"(Woolridge, 1995, p. 51). They consciously detect only the most noticeable, or interesting (salient) features in a visual display. Pictorials in well done pictographs and infographics are generally outstanding, interesting and reinforce the meaning of a statistical display. Comprehension of statistical displays by FD learners (who perceive a field globally and have trouble disembedding elements in a display) may be enhanced if pictographic or infographic images act as clues to meaning or the presence of additional detail may confuse FD learners. FI learners, who have less trouble isolating parts from wholes, may not require pictorial clues to meaning to comprehend any kind of graph or chart.
Pictograms and infographics have potential to clarify the intended meaning of statistical trends or patterns by contextualizing meaning with icons or other illustrations. Infographics can also expand meaning through metaphor. Pictograms contextualize meaning by embellishing statistics with images or icons as counters. Icons offer more hints about the meaning of a graph or chart than minimalist information graphics that use generic lines or shapes.

A pictographic bar graph about oranges and apples, for example, uses images of apples and oranges rather than simple bars or lines as data counters. Pictograms contextualize meaning of data better than a minimalist display because a learner will know at-a-glance that a chart picturing apples and oranges is about fruit. Images and icons in pictograms may also clarify or expand meaning depending on the use of artistic stylizations or facial expressions in counters.

Nigel Holmes’ earlier discussed infographic “Runaway Prices” (Holmes, 1979) used metaphor to expand the meaning of a graph, comparing an Arabian on a fast-moving horse with rapidly rising oil prices in the United States. This metaphor also served the rhetoric of the graph, implying that the price of Middle Eastern oil was rising so quickly during the 1970’s that the American financial burden, imposed by foreign oil distributors, was out of domestic control. A learner could theoretically ascertain the meaning of this graph by simply observing the illustration and reading the caption. Although the graph itself portrays the trend of rising oil costs, it is perhaps less essential to grasping the overall meaning of statistical data than the metaphoric illustration.

Comprehension of the meaning of data patterns or trends in a minimalist information graphic, may not only depend on a learner’s cognitive style, but also on prior
knowledge about the conventions used in graphs or charts. The shapes and lines used in minimalist information graphics seem arbitrary and abstract if a learner is not versed in their conventional uses.

This study assumes all FDI learners had reasonable exposure to the simple graphs and charts that are used to satisfy public school requirements. However, FI learners may have fewer problems than FD learners when confronted by any statistical display, given; 1) their predicted engagement in scientific or numerical work and therefore their greater predicted exposure to minimalist information graphics and 2) their advantage in being able to separate salient components from less meaningful display elements in pictorial statistical displays.

FDI research has exposed a seemingly auxiliary, but potentially significant factor in the matrix of FDI traits that influences visual cognition. FDI research has demonstrated FD learners are more socially inclined than FI learners. FD learners may, therefore, be more responsive to popular media and consequently, the type pictorial displays that appear on websites, magazines or newspapers. FD learners may, accordingly, be better able to decipher pictograms or infographics than minimalist information graphics.

FD learners, who generally select non-science careers and college majors, may also demonstrate a greater aversion to numerical information than FI learners who are drawn to careers in sciences (Witkin, 1973). Both Holmes (Holmes, 1990), Neurath (Neurath, 1974) reckoned the use of pictorial statistic displays could make data more accessible for learners who found numbers off-putting.

The widely believed contemporary adage “a picture is worth a thousand words” supports notions that pictures can clarify the meaning of textual passages quickly and
efficiently. During the medieval eikoncentric era pictures were also used to clarify meaning. However, during the medieval era, a picture’s value for clarifying meaning was attributed to a learner’s meditation for prolonged periods on details of illustration rather than through a cursory “quick and efficient inspection.” A contemporary FD learner who struggles with interpretation of visual material may prefer to quickly inspect a simple display. Because an FD learner predictably struggles to decipher a complex visual display, a prolonged inspection could result in frustration rather than apt interpretation.

Nevertheless, some recent research has supported the medieval belief that clarity of meaning is only derived when learners inspect images repeatedly. It was recently demonstrated through eye-tracking studies, for example, that charts, graphs and all other images are subject to a natural inspection process that takes time and multiple rounds of visual examination (Holsanova, Holmberg & Holmqvist, 2008; Goldberg & Helfman, 2010). It may be possible that pictograms and infographics - with greater visual/ pictorial embellishment than minimalist information graphics- invite FDI learners to engage in meditative-type inspections that allows them to “think through” the meaning of a pictorial statistical display and correctly interpret it.

Related and alternative hypotheses for Research Question 1 are based on comprehension of minimalist information graphics, pictograms and/or infographics. The null and alternative hypotheses 1,1a and 1b are stated as follows:

1. **Null hypothesis:** Learners presented with one of three information graphic types (minimalist information graphics, pictograms, or infographics) will not differ in their comprehension scores.
1a. Alternative hypothesis. FD learners will comprehend minimalist information graphics better than they do other forms of infographics.

1b. Alternative hypothesis. FI learners will not differ in comprehension of all forms of information graphics.

Research Question 2. What is the relationship between FDI learners and their aesthetic ratings for minimalist information graphics pictograms, or infographics?

Various FDI cognitive style factors may influence the way FD and FI learners assess aesthetic qualities of minimalist information graphics, pictograms or infographics. Aesthetic ratings by FDI users in this study pertained to perceived efficacy, preference for and perceived value of each CIG-T information graphic type. A combination of these variables created total scores to measure overall ratings.

Overall Aesthetic Ratings

Overall aesthetic ratings were calculated for Part 1 of the CIG-T, where participants were assigned to conditions 1, 2 or 3. They were separately calculated for Part 2 of the CIG-T where participants were all exposed to identical minimalist information graphics, pictograms and infographics using different tallies of perceived efficacy, preference and perceived value. The null and alternative hypotheses for Part 1 (2.1; 2.1a) and for Part 2 (2.5 and 2.5a) are listed below.

CIGT Part 1 Overall Aesthetic Ratings

2.1 Null hypothesis: Learners presented with one of three different information graphic types (minimalist information graphics, pictograms, or infographics) will not differ in their overall aesthetic rating scores.
2.1a. Alternative hypothesis: FD learners will differ in their overall aesthetic rating for each type of information graphics, while FI learners will not differ in their overall aesthetic rating for each type of information graphic.

CIG-T Part 2 Overall Aesthetic Ratings

2.5 Null hypothesis: Learners who simultaneously rate three different information graphic types (minimalist information graphics, pictograms, or infographics) that present the same underlying data/information will not differ in their overall aesthetic rating scores.

2.5a. Alternative hypothesis: FD learners will differ in their overall aesthetic rating for each type of information graphics, while FI learners will not differ in their overall aesthetic rating for each type of information graphic.

Perceived Efficacy: CIG-T Parts 1 and 2

The perceived efficacy of an information graphic is determined by an FDI learner’s appraisal of a data display’s aesthetic utility. Combinations of simple lines and/or shapes in a minimalist information graphic may or may not aid straightforward interpretation of a data display. The addition of pictorial details in a statistical display may or may not add clues to meaning that are practically essential for understanding a data trend or pattern. FD learners may find pictorial statistics more effectives than minimalist information graphics or may characterize such displays as cluttered and have trouble disembedding salient visual information.

Perceived efficacy ratings were calculated for Part 1 of the CIG-T, where participants were assigned to conditions 1,2 or 3. They were separately calculated for Part 2 of the
CIG-T where participants were all exposed to identical minimalist information graphics, pictograms and infographics. using different subscale questions.

The null and alternative hypotheses for Part 1 (2.2; 2.2a) and for Part 2 (2.6; 2.6a) for Research Question 2 regarding FDI assessment of an information graphic’s perceived efficacy are stated below.

**CIG-T Part 1 Aesthetic Perceived Efficacy Ratings**

2.2 **Null hypothesis:** Learners presented with one of three information graphic types (minimalist information graphics, pictograms, or infographics) will not differ in their perceived efficacy ratings.

2.2a. **Alternative hypothesis:** FD learners will perceive minimalist information graphics as more effective than other forms of information graphics.

**CIG-T Part 2 Aesthetic Perceived Efficacy Ratings**

2.6 **Null hypothesis:** Learners who simultaneously rate three different information graphic types (minimalist information graphics, pictograms, or infographics) that present the same underlying data/information will not differ in their perceived efficacy scores.

2.6a. **Alternative hypothesis:** FD learners will perceive minimalist information graphics as more effective than other forms of information graphics.

**Aesthetic Preference**

There are multiple dimensions of aesthetic liking and reasons for individual preferences in any situation. Earlier in Chapter II it was explained that a person’s familiarity with a style of illustration can make that illustration more likeable for him or her. Due to their social orientation, FD learners may be more likely to engage with
popular media than hard sciences media, and with pictograms or infographics more often than with minimalist information graphics. FI learners, given their orientation toward sciences, may have read more publications that feature minimalist information graphics. FI learners, who are more likely, therefore, to be familiar with minimalist displays than FD leaners, may find these displays more likable.

Although FD learners are less able than FI learners to disembed graphic information from a complex display, it is possible that pictures in a data display may contextualize and concretize statistical information. The presence of imagery could reduce frustration, particularly for FD learners when they work at deciphering a data display. Alternatively, pictures in pictograms or infographics may act as clutter making it difficult for FD learners to appreciate these data displays.

Streamlined minimalist data displays may not offer enough interesting detail for FD learners while FI learners may find the absence of pictorial detail more ideal and more likeable. However, if detail is perceived as clutter by FD learners, they may prefer minimalist information graphics above pictorial pictographic or infographic displays.

Aesthetic preference ratings were calculated for Part 1 of the CIG-T, where participants were assigned to conditions 1,2 or 3. They were separately calculated for Part 2 of the CIG-T where participants were all exposed to identical minimalist information graphics, pictograms and infographics using different subscale questions.

The null and alternative hypotheses for Part 1 (2.3; 2.3a, 2.3b) and for Part 2 (2.7; 2.7a) for Research Question 2 regarding FDI preference for an information graphic are stated below.
CIG-T Part 1 Aesthetic Preference Ratings

2.3 Null hypothesis: Learners presented with one of three information graphic types (minimalist information graphics, pictograms, or infographics) will not differ in their preference rating scores.

2.3.a. Alternative hypothesis: FD learners will prefer the aesthetics of infographics or pictograms over those of minimalist information graphics;

2.3.b. Alternative hypothesis: FD learners will prefer the aesthetics of minimalist information graphics over those of infographics

CIG-T Part 2 Aesthetic Preference Ratings

2.7. Null hypothesis: Learners who simultaneously rate three different information graphic types (minimalist information graphics, pictograms, or infographics) that present the same underlying data/information will not differ in their preference scores.

2.7a. Alternative hypothesis: FI learners will be more likely than FD learners to like and rate at pictogram or infographic as having greater aesthetic value than a minimalist information graphic.

Perceived Aesthetic Value.

Charts and graphs that incorporated pictorial elements became more familiar to and accepted by the public over the past century. Pictorial statistical displays primarily appeared in magazines, newspapers and some textbooks. On the other hand, abstract, unadorned statistical displays were gradually accepted as the province of experts, and particularly the province of scientific experts. FI learners, who are more scientifically oriented may not embrace the aesthetics of pictograms or infographics as often as FD
learners because they recall the aesthetics of novices. Because experts process complex images more fluently than novices, they may also value simple images or illustrations as less accurate or having poor aesthetic value because they do not represent the complexity of a concept or process.

Regardless, dissemination of these statistical displays into either expert or popular culture were and are dependent on repeated exposure and often, repeated instruction about how to interpret more complex displays. It is possible that FD learners will more commonly appraise a pictogram or an infographic, rather than a minimalist information graphic, as having greater aesthetic worth than will FI learners. Furthermore, a lower data-ink ratio in minimalist information graphics will affect FI learner’s aesthetic appraisals.

It has been demonstrated that FI learners, who have an analytic orientation, are more sensitive to the presence of rhetoric in a visual display than FD learners. This premise is partly supported by a product placement advertising study by Matthes, Wirth, Schemer & Kissling (2011). FI learners were better able to identify placement of brand name products in programming than FD learners. FI learners also recognized this product placement tactic as a manipulative, rhetorical method of persuasion while FD learners did not. Therefore, FD learners may be less likely to allow rhetoric content or bias to influence their aesthetic appraisals about minimalist information graphics, pictograms or infographics.

When asked to rate the seriousness or importance of data, given the aesthetic of an information graphic, it is likely that FDI learners will both find that infographic or
pictographic data is less serious or important than data presented in minimalist information graphics.

**Perceived Value**

Assessing how well a graph or chart is usable according to its design or aesthetic appeal helps determine its perceived value. When FDI learners agree that the design of a chart or graph renders it appropriate for use in a broad range of publication types, its value is considered greater than if its use is perceived to be confined to that of a single audience or community.

It is likely FDI learners will be able to associate minimalist information graphics, Holmes-style infographics or Neurath-style pictograms as belonging to the rhetorical venue in which they are commonly published. If this is true, minimalist information graphics will be most frequently valued for professional and scientific publications as well as for websites, popular media such as newspapers, magazines or websites. Association of pictograms or infographics will be associated with value for popular media.

Perceived value ratings were calculated for Part 1 of the CIG-T, where participants were assigned to conditions 1, 2 or 3. They were separately calculated for Part 2 of the CIG-T where participants were all exposed to identical minimalist information graphics, pictograms and infographics using different subscale questions.

The null and alternative hypotheses for Part 1 (2.4; 2.4a) and for Part 2 (2.8; 2.8a) for Research Question 2 regarding FDI assessment of an information graphic’s perceived value are stated below.
CIG-T Part 1 Aesthetic Perceived Value Ratings

2.4 Null hypothesis: Learners presented with one of three information graphic types (minimalist information graphics, pictograms, or infographics) will not differ in their perceived value scores.

2.4a. Alternative hypothesis: FI learners will be more likely than FD learners to rate a pictogram or infographic as having greater aesthetic value than a minimalist information graphic.

CIG-T Part 2 Aesthetic Perceived Value Ratings

2.8 Null hypothesis: Learners who simultaneously rate three different information graphic types (minimalist information graphics, pictograms, or infographics) that present the same underlying data/information will not differ in their perceived value scores.

2.8a. Alternative hypothesis: FD learners will be more likely than FI learners to rate a pictogram or infographic as having greater aesthetic value than a minimalist information graphic.

Choice

Learners were given the opportunity to select the information graphic- either a minimalist information graphic, pictogram or infographic- they thought they could learn best from in CIG-T Part 2 only. It was thought that aesthetic ratings of perceived efficacy and value might decide choice with all FDI learners. Preferences could be variable, influenced by personal likes and dislikes or cultural influences. Therefore, all might feel much the same about information graphics. Related hypothesis for Research Question 2 regarding FDI choice of an information graphic as “best to learn” from was stated as
2.9. **Null hypothesis:** Learners who simultaneously rate three different information graphic types (minimalist information graphics, pictograms, or infographics) that present the same underlying data/information will not differ in their choices for which is best for learning.

2.9a. **Alternative hypothesis:** FI learners will be more likely than FD learners to select pictograms or infographics as displays that are best to learn from.

**Summary: FDI and the Tufte-Holmes Debate**

This study explored differing ways FDI learners interpret, comprehend and aesthetically appraise minimalist, pictographic or infographic data displays. The objective of the study was to contribute experimental findings to a small body of research literature about the merits of various kinds of data displays, particularly given the still unsettled debate characterized as “The Tufte-Holmes Debate.” Despite a widespread acceptance of Tufte’s design recommendations for minimalist information graphics in professional scientific circles, his propositions have rarely been investigated experimentally. The influence of pictograms versus infographics on learning, similarly, have seldom been the subject of research. A dearth of literature and findings on this topic makes the role of effective design of data displays and their use in instruction uncertain. This uncertainty arises despite a greater presence in and degree of importance of statistical displays to formal or informal learning content. Furthermore, this study contributes to vast research about the influence of individuals’ levels of FDI on comprehension and reception of information graphics. This FDI sub-topic has been relatively unexplored despite the known impact of FDI on visual perception and consequently, visual learning.
CHAPTER III

METHODOLOGY

Two Phase Approach

Two testing phases were used for this study. Participants initially took the Group Embedded Figures Test (GEFT) in Phase 1 so extremely field dependent (FD) or field independent (FI) learners could be identified. Only extremely FD or FI learners were invited to take the Comparative Information Graphics Test (CIG-T) in Phase 2. Participation in both phases of this study was voluntary.

Participants

Phase 1 Participants

The principal investigator invited men and women 18 years of age and older, to participate in Phase 1 of this study using two different invitational procedures. These Phase 1 invitations invited participants to complete the GEFT online. GEFT results were used to determine which participants were extremely FD or FI and therefore eligible to take the CIG-T.

Consent. In all cases, the invitation’s anonymous hyperlink led to an informed consent page online (GEFT Landing Page). The informed consent statement included explanation of the purpose of the study, potential benefits and risks, contact phone numbers as well as procedures for the study. Participants indicated their understanding of
the informed consent and willingness to complete the first phase of the study by following the posted hyperlink to the online GEFT.

**Undergraduate student invitations.** Undergraduate students invited to participate in this study were enrolled in a rural public Midwestern university with an undergraduate student body in any given semester of approximately 11,000 undergraduates. A randomized sample of 3499 undergraduate students enrolled in the 2017 spring semester was provided to the researcher by the university’s Office of Institutional Research. These students were invited to take the Group Embedded Figures Test (GEFT) using the *Qualtrics* software distribution survey tool on May 15, 2017. (Reminders were later sent to a subset of 3325 spring semester students who had not responded to the initial invitation on June 29, 2017.)

The university’s Office of Institutional Research also provided the researcher with an additional random sample of 3500 undergraduate students enrolled in the 2017 summer semester. These students were invited to take the GEFT using the Qualtrics distribution survey tool on June 7, 2017. (Reminders to 3361 unfinished respondents were sent on June 29, 2017 and to 3322 unfinished respondents on July 4, 2017.)

**Snowball sampling.** Second, the principal investigator invited additional participants age 18 and older to take the GEFT online through snowball sampling. Snowball sampling allowed the researcher to survey field dependent-independent (FDI) participants with a broader demographic---including a broader age range---than is generally found in an undergraduate population.

Snowball sampling was accomplished through Facebook announcements that began with an invitation to participate in Phase 1 of the study. The first announcement
was posted on the investigator’s site on May 15, 2017. An additional announcement was
created on May 21, 2017. A Facebook “event” was also created and posted on May 23,
2017 on the investigator’s Facebook site. Announcements and the event were
subsequently shared through others’ Facebook or social media accounts. Those who
shared the event and invitations lived in both the United States and the United Kingdom.

Response rates. Invitations were sent to 6,999 undergraduates. There is no way
to know how many potential participants were contacted through snowball sampling.
However, a conservative estimate of potential participants exposed to social media
invitations would be around 600 (based on each of the investigator’s 265 friends sharing
with a one or two of their own friends). Therefore, it was estimated that approximately
7,599 individuals were invited to take the GEFT. Out of 7,599 invitees, 270 participants
registered or began the GEFT for a response rate of approximately 3.5 per cent.

The completion rate from a pool of registered GEFT participants was
approximately 72 per cent. A total of 195 out of 270 registered participants completed the
GEFT.

Phase 2 Participants

Although 195 participants completed the GEFT, not all were eligible for
participation in Phase 2 of the study. The principal investigator invited participants to
Phase 2 of the study based on their qualifying field dependent-independent (FDI)
cognitive style scores. The most FD and the most FI participants, determined by scores
on the Phase 1 GEFT, were individually invited to join Phase 2. Each one of these were
invited in order of their time and date of completion and were matched in sequence to a
randomly ordered list of numbers 1, 2, and 3 that corresponded to Conditions 1, 2, or 3 in the CIG-T.

**FDI spectrum.** A participant’s quantifiable test score from the online GEFT was used to locate participants on the FDI spectrum. Scores for the GEFT begin at zero (lower scores characterize the most FD participants) and end at 18 (higher scores characterize the most FI participants).

Categorization of learners as FD or FI was based on measures suggested by the GEFT manual (Demick, 2014). Witkin, Oltman, Raskin, and Carp (1971) separated FDI learners into quartiles according to scores based on normative data for a large undergraduate population (Demick, 2014). Although this normative data was related to undergraduate aged students, it was deemed appropriate for this study of post-adolescent adult participants because the FDI cognitive style is fixed for most of adult life. A total GEFT score of 0 – 9 constituted the lowest quartile, representing those participants who were the most FD. A total GEFT score of 15 – 18 constituted the highest quartile, representing those participants who were the most FI.

Out of 195 learners who completed the GEFT approximately 65 per cent, or in other words, 127 participants, were invited to enroll in Phase 2. These 127 participants were screened according to their completed GEFT scores and were subsequently categorized as extremely FD (0-9) or FI (15-18). Only extremely FD or FI learners were invited to participate in the Phase 2 of the study because they were most likely to demonstrate specific traits of either the FD or FI cognitive style when taking the CIG-T.

Each extremely FD or FI participant was randomly assigned to one of three CIG-T conditions generated by an online random number tool that randomly serialized
numbers 1, 2 and 3. Participants were matched to the random condition number sequence according to the order of the time and date they completed the GEFT. The goal of this random assignment was to have as equal a proportion of FD to FI learners as possible in each of the CIG-T’s three conditions. (Table 2. FD- FI participants invited to take the CIG-T)

Table 2. *FD- FI participants invited to take the CIG-T*

<table>
<thead>
<tr>
<th>Participants</th>
<th>Condition 1 Minimalist Information Graphics</th>
<th>Condition 2 Pictograms</th>
<th>Condition 3 Infographics</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>FD</td>
<td>17</td>
<td>18</td>
<td>18</td>
<td>54</td>
</tr>
<tr>
<td>FI</td>
<td>15</td>
<td>25</td>
<td>34</td>
<td>74</td>
</tr>
<tr>
<td>Total</td>
<td>32</td>
<td>43</td>
<td>52</td>
<td>127</td>
</tr>
</tbody>
</table>

Invitations were sent using *Qualtrics* distribution software in eleven weekly rounds on the dates indicated in the table below. An online random number calculator was used to generate a list of 500 randomly ordered numbers given numbers 1, 2 and 3 that each corresponded to one of three conditions to which FDI participants would be assigned. Each selected participant was assigned to one of three conditions that featured either minimalist information graphics or pictograms or infographics in the first part of the CIG-T. (Table 2. Rounds, dates and numbers of FD-FI invitations assigned to conditions for Phase 2 invitations.) Reminders were sent to participants who either began the CIG-T but did not complete the test or never began work on the CIG-T. Ultimately, 80 out of 127 invited participants were flagged by *Qualtrics* as completing the CIG-T.
Table 3.

**Rounds, dates and numbers of FI and FD participants assigned to each condition for Phase 2**

<table>
<thead>
<tr>
<th>Rounds</th>
<th>Dates</th>
<th>Condition 1</th>
<th>Condition 2</th>
<th>Condition 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Round1</td>
<td>May 25, 2017</td>
<td>FD-6 FI-7</td>
<td>FD-6 FI-5</td>
<td>FD-5 FI-11</td>
</tr>
<tr>
<td>Round3</td>
<td>June 3, 2017</td>
<td>FD-0 FI-0</td>
<td>FD-2 FI-2</td>
<td>FD-4 FI-4</td>
</tr>
<tr>
<td>Round4</td>
<td>June 9, 2017</td>
<td>FD-3 FI-1</td>
<td>FD-2 FI-1</td>
<td>FD-0 FI-2</td>
</tr>
<tr>
<td>Round5</td>
<td>June 24, 2017</td>
<td>FD-0 FI-1</td>
<td>FD-0 FI-5</td>
<td>FD-0 FI-5</td>
</tr>
<tr>
<td>Round6</td>
<td>June 29, 2017</td>
<td>FD-3 FI-2</td>
<td>FD-0 FI-2</td>
<td>FD-1 FI-0</td>
</tr>
<tr>
<td>Round7</td>
<td>July 3, 2017</td>
<td>FD-0 FI-1</td>
<td>FD-2 FI-2</td>
<td>FD-1 FI-5</td>
</tr>
<tr>
<td>Round8</td>
<td>July 7, 2017</td>
<td>FD-1 FI-2</td>
<td>FD-2 FI-3</td>
<td>FD-2 FI-3</td>
</tr>
<tr>
<td>Round9</td>
<td>July 10, 2017</td>
<td>FD-1 FI-0</td>
<td>FD-1 FI-1</td>
<td>FD-0 FI-2</td>
</tr>
<tr>
<td>Round10</td>
<td>July 18, 2017</td>
<td>FD-0 FI-0</td>
<td>FD-1 FI-0</td>
<td>FD-1 FI-0</td>
</tr>
<tr>
<td>Round11</td>
<td>July 26, 2017</td>
<td>FD-0 FI-1</td>
<td>FD-0 FI-2</td>
<td>FD-2 FI-0</td>
</tr>
</tbody>
</table>

**Total FD-FI**  
FD = 17  FI = 15  FD = 18  FI = 25  FD = 18  FI = 34

**Research Design**

Two research questions guided this study that included 9 null hypotheses and 11 alternative hypotheses. The research questions with null and alternate hypotheses were.

**Research Question: 1.** What is the relationship between FDI and comprehension of minimalist information graphics, pictograms, or infographics?

1. **Null hypothesis:** Learners presented with one of three information graphic types (minimalist information graphics, pictograms, or infographics) will not differ in their comprehension scores.

1a. **Alternative hypothesis.** FD learners will comprehend minimalist information graphics better than they do other forms of infographics.
**1b. Alternative hypothesis.** FI learners will not differ in comprehension of all forms of information graphics.

**Research Question 2.**

What is the relationship between FDI learners and their aesthetic ratings for minimalist information graphics pictograms, or infographics? This research question is answered via two different methodologies. Null hypotheses 2.1 through 2.4 were assessed by participants assigned to one of three conditions (minimalist information graphics, pictograms, or infographics). Ratings for these hypotheses are therefore based on the participants’ rating of only one type of information graphic. Null hypotheses 2.5 through 2.9 were assessed by all participants, all of whom were presented with three versions of information graphics that each represented the same underlying data/information.

**2.1 Null hypothesis:** Learners presented with one of three different information graphic types (minimalist information graphics, pictograms, or infographics) will not differ in their overall aesthetic rating scores.

**2.1a. Alternative hypothesis:** FD learners will differ in their overall aesthetic rating for each type of information graphics, while FI learners will not differ in their overall aesthetic rating for each type of information graphic.

**2.2 Null hypothesis:** Learners presented with one of three information graphic types (minimalist information graphics, pictograms, or infographics) will not differ in their perceived efficacy ratings.

**2.2a. Alternative hypothesis:** FD learners will perceive minimalist information graphics as more effective than other forms of information graphics.
2.3 **Null hypothesis:** Learners presented with one of three information graphic types (minimalist information graphics, pictograms, or infographics) will not differ in their preference rating scores.

2.3.a. **Alternative hypothesis:** FD learners will prefer the aesthetics of infographics or pictograms over those of minimalist information graphics;

2.3.b. **Alternative hypothesis:** FD learners will prefer the aesthetics of minimalist information graphics over those of infographics

2.4 **Null hypothesis:** Learners presented with one of three information graphic types (minimalist information graphics, pictograms, or infographics) will not differ in their perceived value scores.

2.4a. **Alternative hypothesis:** FI learners will be more likely than FD learners to rate a pictogram or infographic as having greater aesthetic value than a minimalist information graphic.

**Part 2 CIG-T Participants: Exposure to Identical Information Graphics**

2.5 **Null hypothesis:** Learners who simultaneously rate three different information graphic types (minimalist information graphics, pictograms, or infographics) that present the same underlying data/information will not differ in their overall aesthetic rating scores.

2.5a. **Alternative hypothesis:** FD learners will differ in their overall aesthetic rating for each type of information graphics, while FI learners will not differ in their overall aesthetic rating for each type of information graphic.

2.6 **Null hypothesis:** Learners who simultaneously rate three different information graphic types (minimalist information graphics, pictograms, or infographics)
that present the same underlying data/information will not differ in their perceived
efficacy scores.

2.6a. **Alternative hypothesis:** FD learners will perceive minimalist information
graphics as more effective than other forms of information graphics.

2.7. **Null hypothesis:** Learners who simultaneously rate three different
information graphic types (minimalist information graphics, pictograms, or infographics)
that present the same underlying data/information will not differ in their preference
scores.

2.7a. **Alternative hypothesis:** FI learners will be more likely than FD learners to
like and rate at pictogram or infographic as having greater aesthetic value than a
minimalist information graphic.

2.8. **Null hypothesis:** Learners who simultaneously rate three different
information graphic types (minimalist information graphics, pictograms, or infographics)
that present the same underlying data/information will not differ in their perceived value
scores.

2.8a. **Alternative hypothesis:** FD learners will be more likely than FI learners to
rate at pictogram or infographic as having greater aesthetic value than a minimalist
information graphic.

2.9. **Null hypothesis:** Learners who simultaneously rate three different
information graphic types (minimalist information graphics, pictograms, or infographics)
that present the same underlying data/information will not differ in their choices for
which is best for learning.
2.9a. **Alternative hypothesis:** FI learners will be more likely than FD learners to select pictograms or infographics as displays that are best to learn from.

**Instruments**

**The GEFT**

The GEFT online was used to measure an individual’s designation on the FDI spectrum. It is a proprietary test vended through Mindgarden, a California based academic testing company. Based on the paper and pencil version of the GEFT, the; online version uses the same figures and relationships between figures, retains similar instructions, has similar administration, uses the same timing for each section, and has the same scoring. In addition, the online version parallels the use of a pencil through the required use of an external mouse for tracing the figures on the computer screen. Preliminary analysis from GEFT Manual 2nd edition author Jack Demick shows a strong correlation between the paper-and-pencil GEFT and the GEFT Online that is equivalent to the test-retest reliability for the paper-and-pencil GEFT (Coultas, para.14,2016).

The measure of an individual’s FDI is considered stable by the age a student typically enrolls in college and will not change to any great degree thereafter, although senior citizens may become more FD as they age. As earlier mentioned, the range of ages for this CIG-T study’s participant testing began at post-adolescence, or in other words at 18 years of age and did not specify an upper age limit.

**Comparative Information Graphic Test (CIG-T)**

A two-part instrument, labeled the “Comparative Information Graphic Test” (CIG-T) was developed for this study (Appendix A. CIG-T instrument). The need to
develop the instrument arose when nothing suitable could be located that specifically gathered data about comparative participant responses to information graphics. The CIG-T was therefore developed as a pilot survey instrument for determination of FDI differences in comprehension and aesthetic ratings of minimalist information graphics, pictograms or infographics.

**CIG-T Part 1 testing design.** Three conditions in Part 1 of the CIG-T incorporated *either* 1) minimalist graphs; 2) pictograms or 3) Holmes’ infographics. A total of three graphics was presented in each of these conditions (e.g. three minimalist information graphics were presented in Condition 1, three pictograms in Condition 2 and three infographics in Condition 3).

Differential comprehension of information graphics in each of three conditions was measured using quantitative multiple-choice quizzes as well as short answer questions that were quantified with a rubric. Dependent upon their answers, participants were given a score of 1 to 4 (Table 4. Rubric for CIG-T comprehension scores; Also, in Appendix F.).

**Information graphic design.** Three types of information graphics were used in the design of this instrument. Minimalist information graphics were designed without pictorialization, including only essential visual components to portray data information. Lines and shapes were simple and minimalistic. Pictograms used icons as counters. Their design did not strictly follow Neurath’s ISOPTYPE conventions but did follow common conventions of pictogram design, some of which is borrowed from Neurath’s work. For example, more icons are used to represent greater quantities of data rather than enlarging
<table>
<thead>
<tr>
<th>Question(s)</th>
<th>Score_1</th>
<th>Score_2</th>
<th>Score_3</th>
<th>Score_4</th>
</tr>
</thead>
</table>
| **Diamonds Were a Girl's Best Friend (DIA3):** Overall Diamond Comprehension Score for CIG-T-1 (Minimalist); Score For CIG-T-2 (Pictogram); Score for CIG-T 3 (Infographic)  
*Explain the meaning of the graph in your own words* | Inaccurate or inappropriate answer (does not report meaning of the graph) or outright self-report claiming misunderstanding of the graph or chart | Short, accurate, rudimentary description of the meaning of the graph or chart | Accurate description of meaning of the graph with either some reference to specific details (x-y axis or other numerical values, etc.) and/or some limited discussion about the message embedded in the graph or chart | Accurate description of the meaning of the graph or chart with either some reference to specific details (x-y axis or other numerical values, etc.) about the graph or chart alongside well-articulated discussion about the message embedded in the graph or chart |
| **Monstrous Costs (MC3);** Overall Monstrous Costs Comprehension Score for CIG-T-1 (Minimalist); Score For CIG-T-2 (Pictogram); Score for CIG-T 3 (Infographic) All scored using rubric  
*Explain the meaning of the graph in your own words* | | | | |
| **The Cosmetic Dollar(CD3);** Overall Monstrous Costs Comprehension Score for CIG-T-1 (Minimalist); Score For CIG-T-2 (Pictogram); Score for CIG-T 3 (Infographic)  
*Explain the meaning of the graph in your own words* | | | | |
icons to represent greater quantities. Infographics used data embedded into pictorial backgrounds in Part 1 of the CIG-T and all of these had been designed by Nigel Holmes. Compared to pictograms and minimalist information graphics, Nigel Holmes’ infographics are arguably the most difficult and complex to design. Holmes’ infographics are considered the standard for this form of information graphic. Therefore, the researcher identified three well-known Nigel Holmes information graphics and generated pictograms and minimalist information graphics that were equivalent in terms of the data and content represented using Microsoft Excel software. These graphics were used in part I of the CIG-T.

Additionally, three infographics were designed and created by the investigator with assistance of and consultation with professional graphic designer Margo Sundberg for Part 2 of the CIG-T. Consultation with a professional graphic designer with more than thirty years of commercial experience was desirable because this helped assure the quality of infographics was representative of those used in contemporary publications. The investigator designed infographics that were created using Photoshop CC software for original graphic design and with recombination of public domain imagery.

Design of all types of original information graphics used in the CIG-T was based on criteria that included:

1. exclusion of as much extraneous detail in minimalist information graphics as possible with the greatest proportion of ink devoted to data presentation as recommended by Tufte (1987);
2. design of pictograms that did not adhere strictly to the Neurath ISOTYPE system but used contemporary, contextual icons as counters in pictographic displays;

3. creation of infographics that did not and could not replicate the work of Nigel Holmes but embedded statistical information in a pictorial metaphor as Holmes has done in the past and as has been represented in popular media;

4. well-articulated differences in the amount of pictorial embellishment in a display with the least amount of embellishment devoted to minimalist information graphics, more to pictograms and the most to infographics;

5. use of plausible data sets related to information graphic topics;

6. use of common graph/chart types that should be recognizable to all or most learners with a high school education;

7. likeness to contemporary information graphic types, i.e. designs of CIG-T information graphics should be reasonable facsimiles of information graphics found in journals, academic publications or popular media.
Figure 59. Example of a minimalist information graphic, a pictogram and an infographic used in Part 1 of the CIG-T
Titles used for all information graphics were identical regardless of the style of the display. The word play used in the titles of the information graphics “Winged Plight,” “Funding Nemo” or “Going Postal” were more colloquial than most minimalist information graphic or pictogram titles would be. However, the use of these identical titles was justified. First, this naming convention was a continuation of the naming convention in Part 1 of the CIG-T. Use of the same titles on all display types supported the CIG-T’s structural consistency. Importantly, because identical titles were used, text was less likely to act as a confounding factor in this study about visual learning.

CIG-T Part I. The opening portion of the CIG-T was designed to gather demographic information. It also was designed to identify the type of a participant’s prior exposure to information graphics. Queries were made about content knowledge related to information graphics that would be used in the study. This included questions about domain knowledge as well as the ability to correctly identify a given type of information graphic.

Most of these questions did not force a response. Demographic information (e.g., age, gender and educational attainment) were collected at the beginning of the CIG-T. Responses to demographic questions, for example, were not forced. CIG-T questions that polled respondents about their levels of domain knowledge were forced to control for differences in comprehension and rating scores according to prior knowledge.

The next block of CIG-T survey questions addressed participant confidence and expertise levels associated with interpretation of information graphics. Participants were asked to rate (on a scale from 1 to 10) their familiarity with a minimalist line graph, bar graph and pie chart. They were subsequently asked to identify a basic kind of chart or
graph embedded in a pictorial statistical display that included one pictogram and three infographics. Self-ratings of confidence and expertise were designed so comparisons could be made between correct FDI participant identification of a graph/chart embedded in a data display and their ranked confidence about their familiarity with a line graph, bar graph and pie chart.

Three of Nigel Holmes’ infographics were selected for use in the first part of the CIG-T (after obtaining Holmes’ permission). Holmes’ infographics included “The Cosmetic Dollar” that breaks down costs in cents per dollar for the manufacture of cosmetics using a pie chart. Holmes’ “Diamonds Were a Girl’s Best Friend” illustrates the rise and fall in average price of a one-carat D-flawless diamond from 1978 to 1982 on a line graph. The final CIG-T Holmes infographic was entitled “Monstrous Costs,” and charts the rapidly rising Senate and House campaign total expenditures from 1972 to 1982 using a bar chart. Data from these three Holmes infographics were then used to create alternate forms: pictographic data displays (Condition 2) and minimalist information graphics (Condition 1). Therefore, the same data was presented under all conditions, but the data displays were stylistically different (Figure 58: Example of data displays used in Part 1’s three conditions using “Diamonds Were A Girl’s Best Friend”).

Although the information graphics differed depending on condition, titles were identical across all three conditions to help factor out some of the influence of text on comprehension and aesthetic perspectives. Nine questions per information graphic were asked.
Condition 1: Minimalist information graphic  
Condition 2: Pictogram  
Condition 3: Holmes infographic

Figure 58. Example of data displays used in Part 1’s three conditions using “Diamonds Were A Girl’s Best Friend.”

Multiple-choice questions were used to test for accurate interpretation and comprehension of a given data display. These multiple-choice questions alongside one short answer question per data display were used to assess null hypothesis 1 and alternative hypotheses 1a and 1b.

**CIG-T Part 2 Design.** Part 2 of the CIG-T was designed to test for differences in comprehension and preference when viewing and comparing all three information graphic types. Whereas in Part 1 FDI participants saw only one type of information graphic (minimalist information graphics in Condition 1, pictograms in Condition 2 OR Holmes infographics in Condition 3), Part 2 presented the same information in three different graphic formats.

Three different versions (minimalist information graphics, pictograms and infographics) of three different data displays were presented to all learners in Part 2 of the CIG-T, regardless of the condition they were assigned to during CIG-T Part 1. Consequently, all FDI participants experienced the *same* graphics in Part 2 and were asked the *same* questions about those information graphics regardless of a participant’s originally assigned condition. The order in which these questions and information
graphics were presented was randomized to control for any effect of order when viewing
the same information in three different formats.

The three data display sets in Part 2 of the CIG-T represented data about 1) the
average cost of aquarium fish in 2005 (“Funding Nemo”); 2) changes in postage stamp
costs from 1974 to 2014 (“Going Postal”) and 3) fluctuations and declines in the

At the start of part 2 of the CIG-T, each participant was shown three versions -
minimalist information graphic, pictogram and infographic- of the same data set
represented in a visual display. They were then asked to choose the one version of the
data display from which they felt they could learn best. (Figure 59. Choices from three
different data display representations: “Going Postal;” “Funding Nemo” and “Winged
Plight.”)

Participants then were asked “Why did you choose this graph? Explain in your
own words.” Short answers defending a participant’s choice of the information graphic
best suited to their learning were thematically coded to qualitatively assess null and
alternative hypotheses related to Research Question 2. Multiple-choice questions with
answers on a Likert-style scale in CIG-T Part 2 asked participants to agree-disagree
(strongly disagree, disagree, neither agree or disagree, agree and strongly agree) with
statements regarding aesthetic preference, aesthetic perceived efficacy and aesthetic
perceived value.
Procedure

Phase 1.

Invitations to all participants included a link to the GEFT landing page hosted on the UND Qualtrics software site. A consent form (see Appendix B. Consent Form) was immediately displayed to participants on the GEFT landing page. Continuation with the survey, as was explained, signaled a participant’s agreement to consent. The consent form was followed by a visual explanation about registering to take the GEFT with a link to the test (See Appendix C. Explanation of the GEFT).

The online version of the GEFT, hosted by the Mindgarden testing website was used so students could access the test at their convenience, 24 hours a day and 7 days per week. It is a timed test that cannot be interrupted. Students were notified of the timing requirement (about 20 minutes) before beginning the GEFT.

Licenses for 300 potential participants in the Phase 1 GEFT test were purchased. Test registrations enrolled 270 participants, however, 193 participants actually completed the GEFT. The completion rate of those who registered to take the GEFT was 71.48 per cent. Participants were ages 18 years to 70 years old with a median age of 44 years old. Those who completed the GEFT included 61 males and 132 females.

The testing site was online from May 10, 2017 through September 1, 2017, but most completions were finished by July 26, 2017 when the last invitation was sent to FDI participants to take the CIG-T.)
Participants for Phase 2 were invited to take the Comparative Information Graphics Test (CIG-T) after being screened for eligibility. GEFT scores of 0 – 9 qualified.
participants as extreme FD and scores of 15-18 qualified participants as extreme FI. As explained earlier, categorization of learners as FD or FI was based on measures suggested by the GEFT manual (Demick, 2014). Witkin, Oltman, Raskin, and Carp (1971) separated FDI learners into quartiles according to scores based on normative data for a large undergraduate population (Demick, 2014). Although this normative data was related to undergraduate aged students, it was deemed appropriate for this study of post-adolescent adult participants because the FDI cognitive style is fixed for most of adult life.

A total GEFT score of 0 – 9 constituted the lowest scoring 25% of the population, representing those participants who were the most FD. A total GEFT score of 15 – 18 constituted the highest scoring 25% of the population, representing those participants who were the most FI. Anyone with a score of 10-14 was considered ineligible for the CIG-T. Only extremely FD or FI learners were invited to participate in Phase 2 of the study because they were most likely to demonstrate specific traits of either the FD or FI cognitive style when taking the CIG-T.

Each extremely FD or FI participant was randomly assigned to one of three CIG-T conditions generated by an online random number tool that randomly serialized numbers 1, 2 and 3. The goal of this random assignment was to have as equal a proportion of FD to FI learners as possible in each of the CIG-T’s three conditions.

The testing site was available online from May 10, 2017 through September 1, 2017. The nearly four-month span was used so as many participants as possible could be recruited and complete the CIG-T. The minimum recruitment goal for number of CIG-T participants was a total of 60 individuals, ideally with ten extreme FD participants and ten extreme FI participants assigned to each of three conditions.
Out of 127 invited participants who completed the GEFT, 80 were initially flagged by Qualtrics as completing the CIG-T, which represented a 62.99% completion rate. However, when doing data screening it was discovered that one participant had completed the CIG-T once, then began the test again without completing. Qualtrics counted this participant twice. Therefore, 79 FDI participants officially completed the CIG-T Part 1. (Table 5. The final distribution of 79 FDI respondents in three conditions).

Table 5

<table>
<thead>
<tr>
<th></th>
<th>Condition 1</th>
<th>Condition 2</th>
<th>Condition 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>FD Participants</td>
<td>15</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>FI Participants</td>
<td>6</td>
<td>18</td>
<td>20</td>
</tr>
<tr>
<td>Total FDI/conditions</td>
<td>21</td>
<td>27</td>
<td>31</td>
</tr>
</tbody>
</table>

The primary investigator checked for completed responses on the online University of North Dakota Qualtrics survey site at regular intervals of four to seven days. When as many as three CIG-T’s were completed, data was entered into a Microsoft Excel software file.

**CIG-T Survey Data**

All survey data was collected online and analyzed electronically using the Statistical Program for Social Sciences, or SPSS (Citation). CIG-T data collected through Qualtrics software and survey data was exported as an SPSS file.

Cases were numbered and labeled in order of participant completion of the CIG-T with, for example, Participant 1 corresponding to the first CIG-T completed. Seventy-nine cases of FDI were analyzed with FD participants coded as “1” and FI participants coded as “2.”
Demographic information about each participant was also represented numerically. For example, males were labeled “0” and females were labeled “1.” Because a participant was not required to answer demographic questions, there were missing data among these variables. Demographic questions polled participants about their ethnic backgrounds, highest level of educational attainment, their parents ‘or childhood caregivers’ highest level of educational attainment, their academic majors if enrolled as students and their undergraduate class status (i.e. freshman, sophomore, etc.). In addition, participants were asked to list their age.

The dependent variable for comprehension was developed by summing the correct responses to 18 comprehension questions per condition. Answers were re-coded, so all correct answers earned a score of one and all incorrect answers were scored as zero. The dependent variable for the total aesthetic score was generated by summing all subscale aesthetic items totals. Aesthetics subscales were created by summing items related to different aspects of aesthetic assessments as described below.

Data Entry and Screening

Subscales

Subscales were developed to measure responses associated with Research Question 1 and 2’s null and alternative hypotheses. The following subscales measured aesthetic assessments under the CIG-T Part 1 Condition 1, 2 or 3. Items were identical across all three conditions, with only the format of the information graphic itself being different by condition.
Part 1 Comprehension

The only test of comprehension was taken during Part 1 of the CIG-T. Each FDI participant was randomly assigned to Condition 1: Minimalist information graphics; Condition 2: Pictograms or Condition 3: Infographics. Participants answered factual questions after looking at an information graphic in his or her assigned condition using a checkbox or writing a short answer. Participants were only allowed to enter one response per question.

After a participant viewed the graphic it was not possible to go back and study it again. FDI participants wrote a short answer to Question 3: “Explain the meaning of the graph in your own words.” This answer was quantified with a rubric on a scale from 1–4 (see Table 4. Rubric for CIG-T comprehension scores).

The following questions tested comprehension of information graphs for each of three information graphs presented to learners in Condition 1: Minimalist information graphics; Condition 2: Pictograms or Condition 3: Infographics

- Explain the meaning of the graph in your own words
- What point did this graph try to make? Choose the best answer below.
- What did this graph demonstrate? Choose the best answer below.
- What was the title of this graph?
- What did numbers on the x-axis (the horizontal column of numbers) represent on this graph?

-or-

- (Cosmetic Dollar) The least cents per dollar is spent on which cosmetics cost category?
- . What did the numbers on the y-axis (the vertical column of numbers) represent on this graph?
(Cosmetic Dollar) The most cents per dollar is spent on which cosmetics cost category?

Part 1 Aesthetic Subscales

Aesthetic perceived efficacy. Aesthetic perceived efficacy (Aesth_PE) was scored by summing the responses to 6 related questions per condition on a strongly disagree to strongly agree scale or sliding scale from one to 10. Higher scores indicated that a participant felt the information graphic was effective in achieving its goal. The following questions were asked about the perceived efficacy of information graphs for each of three information graphs presented to learners in Condition 1: Minimalist information graphics; Condition 2: Pictograms and Condition 3: Infographics;

- Information was clearly communicated in the graph.
- On a scale from 1 to 10, rate how well all parts of the graph worked together to make a single message.

Aesthetic preference. Aesthetic preference (Aesth_Pr) was scored by summing responses to 6 related questions per condition. Higher scores indicated the participant better liked/appreciated an information graphic. The following questions were asked about FDI learners preferences for each of three information graphs presented to learners in Condition 1: Minimalist information graphics; Condition 2: Pictograms and Condition 3: Infographics;

- I enjoyed looking at this graph
- This is the type of graph I like to look at when I am learning something.
Aesthetic perceived value. Aesthetic perceived value (Aesth_PV) was scored by summing 9 related questions per condition. Higher scores indicated that a participant felt that an information graphic had high ethical or design value. The following questions were asked about FDI learners preferences for each of three information graphs presented to learners in Condition 1: Minimalist information graphics; Condition 2: Pictograms and Condition 3: Infographics;

- How much do you trust the information in this graph?
- The line(segments) in the graph was extremely important to me for understanding its meaning.
- The text in the graph was extremely important to me for understanding its meaning

Note that each of these subscales are theorized to be independent. That is, a participant may not prefer a graphic but may still think it is effective or valuable. For this reason, analyses were conducted with subscales as dependent variables in addition to an overall aesthetic score, as described below.

Aesthetic overall. The aesthetic overall subscale (AESTH_TOT_1) was calculated by summing the total points recorded for all aesthetic assessment subscales in Part 1 of the CIG-T (aesthetic perceived efficacy, aesthetic preference & aesthetic value). A higher score indicated that a participant had a higher generalized esteem for a given information graphic type.

Part 2 Aesthetic Subscales

Aesthetic perceived efficacy scores. Aesthetic perceived efficacy (Aesth_PE_Min; Aesth_PE_Pct; Aesth_PE_Inf) was scored by summing the responses to 24 related questions answered according to a strongly disagree to strongly agree scale.
Higher scores indicated that a participant felt the information graphic was effective in achieving its instructional goal. Question 11 was reverse coded because it was negatively worded. A high value for Question 11 thereafter produced the same type of response on every item.

All learners, without regard to originally assigned condition, viewed three versions of “Winged Plight,” “Funding Nemo” and “Going Postal.” The following questions were asked about the perceived efficacy of information graphics for each of three minimalist information graphics, pictograms and infographics presented to all learners.

*Winged Plight 1.* I can easily tell how many millions of monarch butterflies made up the population from years 2005-2015;

*Funding Nemo 1.* I can easily tell how much an aquarium fish costs;

*Going Postal 1.* I can easily tell how much the cost of a stamp changed from 1974 to 2014.

Those above were the only differing questions for each of the three versions of information graphics presented to all FDI learners. The following 5 questions were asked for every information graphic viewed;

- The line (bars) helped me understand the message of the graph
- I could pretty much guess the meaning of this graph without reading the title
- I understood the meaning of the graph
- The amount of detail in the graph is just about right for learning about the topic
- Q_11 It is difficult to sort through the clutter in this graph to get to the right information
**Aesthetic Preference scores.** Aesthetic preference (Aesth_Pr_Min; Aesth_Pr_Pct; Aesth_Pr_Inf) was scored by summing the responses to 6 related questions answered according to a strongly disagree to strongly agree scale. Higher scores indicated that a participant felt the information graphic was very likable.

All learners, without regard to originally assigned condition, viewed three versions of “Winged Plight,” “Funding Nemo” and “Going Postal.” The following questions were asked about preference for information graphics for each of three minimalist information graphics, pictograms and infographics presented to all learners.;

- I enjoyed looking at the graph;
- I like the look of this kind of graph.

**Aesthetic value scores.** Aesthetic preference (Aesth_PV_Min; Aesth_PV_Pct; Aesth_PV_Inf) was scored by summing the responses to 12 related questions answered according to a strongly disagree to strongly agree scale. Higher scores indicated that a participant felt the information graphic was valuable for multiple uses. Question 8 was reverse coded because it was negatively worded. A high value for Question 8 thereafter produced the same type of response on every item.

All learners, without regard to originally assigned condition, viewed three versions of “Winged Plight,” “Funding Nemo” and “Going Postal.” The following questions were asked about aesthetic perceived value for information graphics for each of three minimalist information graphics, pictograms and infographics presented to all learners.;

- This type of graph could be used to present serious, important data;
- This type of graph ONLY could be used to present interesting trivia;
This type of graph could be used in an academic text where facts are important;
This kind of graph could be used for just about any kind of a publication or website.

**Instrument reliability Part 1 and 2: aesthetics.** To examine the reliability of the aesthetics scales used in this study, a series of reliability tests were conducted on the overall aesthetics scales for the CIG-T Part 1 and Part 2, as well as for the subscales which comprise both overall scales. Overall reliability was tested by calculation of Chronbach’s Alpha to measure internal consistency with a reliability coefficient for variables in subscales. All subscales had adequate to high levels of internal consistency. These assessments of levels are based on accepted standards for adequate $\alpha$ coefficient between 0.65 and 0.7 and a high $\alpha$ coefficient as one that is greater than 0.7. An $\alpha$ coefficient that is less than 0.5 is deemed unacceptable.

The Part 1 construct for ‘aesthetic total’ consisted of a combination of all three subscales, (perceived aesthetic efficacy, preference and perceived aesthetic value) for all conditions. The scale had a high level of internal consistency, as determined by a Cronbach's alpha of 0.742.

The Part 1 construct for ‘perceived efficacy’ consisted of two questions for each of three information graphics. The scale had an adequate level of internal consistency, as determined by a Cronbach's alpha of 0.689. The Part 1 construct for ‘preference’ consisted of two questions for each of three information graphics. The scale had a high level of internal consistency, as determined by a Cronbach's alpha of 0.729. The Part 1 construct for ‘perceived value’ consisted of three questions for each of three information
graphics. The scale had an adequate level of internal consistency, as determined by a Cronbach's alpha of 0.683.

The Part 2 construct for ‘aesthetic total 2’ consisted of a combination of all three subscales, e.g. perceived aesthetic efficacy, preference and perceived aesthetic value for minimalist, pictographic and infographic information graphics. The scale had an inadequate level of internal consistency, as determined by a Cronbach's alpha of 0.146.

The Part 2 construct for perceived efficacy of minimalist information graphics consisted of six questions. The scale had a high level of internal consistency, as determined by a Cronbach's alpha of 0.777. The Part 2 construct for ‘perceived efficacy of pictograms’ consisted of six questions. The scale had a high level of internal consistency, as determined by a Cronbach's alpha of 0.76. The Part 2 construct for ‘perceived efficacy of infographics’ consisted of six questions. The scale had a high level of internal consistency, as determined by a Cronbach's alpha of 0.825.

The Part 2 construct for preference for minimalist information graphics consisted of two questions for each of three information graphics. The scale had a high level of internal consistency, as determined by a Cronbach's alpha of 0.871. The Part 2 construct for ‘preference for pictogram’ consisted of two questions for each of three information graphics. The scale had an acceptable level of internal consistency, as determined by a Cronbach's alpha of 0.644. The Part 2 construct for ‘preference for infographics’ consisted of two questions for each of three information graphics. The scale had a high level of internal consistency, as determined by a Cronbach's alpha of 0.779.

The Part 2 construct for perceived value of minimalist information graphics consisted of four questions for each of three information graphics. The scale had a high
level of internal consistency, as determined by a Cronbach's alpha of 0.796. The Part 2 construct for ‘perceived value of pictograms’ consisted of four questions for each of three information graphics. The scale had a high level of internal consistency, as determined by a Cronbach's alpha of 0.849. The Part 2 construct for ‘perceived value of infographics’ consisted of four questions for each of three information graphics. The scale had a high level of internal consistency, as determined by a Cronbach's alpha of 0.908.
CHAPTER IV

Results

Data were screened for outliers, normal distribution, and other assumptions of inferential statistics used to evaluate the research questions and hypotheses outlined in the previous chapters.

Demographics.

The introductory portion of the Comparative Information Graphic Test (CIG-T) asked 81 participants to voluntarily answer demographics questions. One male participant (age 37, master’s degree completed, United Kingdom, field dependent) completed the CIG-T, but also re-registered for the test without answering questions beyond demographics. His partial test was deleted and completed test was retained. Another female participant (age 22, undergraduate, USA) began answering demographic questions, but did not begin the testing portion of the CIG-T, so this case was eliminated. Therefore 79 total participants were enrolled in the CIG-T. Most of the 79 participants answered questions about their gender and highest level of education completed (n = 79). Since answers were not forced, only 42 participants elected to write in their age and 74 participants did not answer a question about their ethnic identity. Of the 79 participants who identified their gender; 40 % were males (n = 32) and 59 % were females (n = 47). Of the 79 who identified the highest level of education they had completed, those who had completed a bachelor’s degree (n = 31) represented 39 % of the study population (n = 79). Participants who completed high school (n = 22) represented 28 % of the study
population, those who had a master’s or professional degree (n = 21) represented 27% percent of the study population while those who had completed a PhD (5) accounted for 6% of the study population. Participants from a subsample (n = 42) were distributed in age groups from 18 – 79 years old. Young adults constituted the largest group of participants with 23 participants or 29 % of the subsample in the 18-29-year-old age group. The remaining 19 participants were distributed in age groups from 30 years to 79 years old. Of the participants who chose to answer a question about their ethnic identity (n = 74) 78 % (n = 58) identified themselves as “White”; 17 % (n = 13) as “Black or African American” ; 1% percent (n = 1) as “American Indian or Alaska Native”; 1% (1) as “Latino” and 1% (1) as “Other.” (Table 6. Demographics of study population and subsamples; age, gender, race, level of education; N = 79).

Because data was incomplete for age (only 42 of 79 participants reported) and because race data was not only incomplete (74 of 79 participants reported) but indicated the overwhelming majority of participants were white (58 out of 74 participants were white; 13 participants African American/Black; 3 other) these demographics were not factored into tests.

**Research Question 1: Comprehension of Information Graphic**

Research Question 1 asked “What is the relationship between field dependent - independent (FDI) and comprehension of minimalist information graphics, pictograms, or infographics?” This question examined differential FDI comprehension of information graphics, depending on one of three conditions (minimalist information graphic, pictogram or infographic) to which an FDI learner was randomly assigned. Measures of comprehension included an individual’s short text answer explaining the meaning of a
graph as well as correct answers to multiple-choice questions about the title of a graph, the labels on its x and y axes as well the point it tried to make and what it demonstrated.

Table 6.
Demographics of study population and subsamples; age, gender, race, level of education (N = 79).

<table>
<thead>
<tr>
<th>Factor</th>
<th>Frequency</th>
<th>Valid Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
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<tr>
<td>Male</td>
<td>32</td>
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<td>Female</td>
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<tr>
<td>Age</td>
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<tr>
<td>18-29 years</td>
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<td>30-39 years</td>
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<tr>
<td>% White</td>
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<tr>
<td>% African American/Black</td>
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<td>17.56</td>
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<tr>
<td>% American Indian or Alaska Native</td>
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<td>% Latino</td>
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<td>Bachelor’s Degree</td>
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<tr>
<td>Professional Degree (Law Degree, etc.)</td>
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<tr>
<td>PhD</td>
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</table>

1. Null hypothesis: Learners presented with one of three information graphic types (minimalist information graphics, pictograms, or infographics) will not differ in their comprehension scores.

1a. Alternative hypothesis. Field Dependent (FD) learners will comprehend minimalist information graphics better than they do other forms of infographics.
1b. Alternative hypothesis. Field Independent FI learners will not differ in comprehension of all forms of information graphics.

Assumptions and data screening. Participants were not equally distributed across the three experimental conditions. 21 respondents (FD and FI) completed questions under Condition 1 (minimalist information graphics); 29 respondents completed questions under Condition 2 (pictograms) and 31 respondents completed questions under Condition 3 (infographics). Part of the reason for inequality in respondents per condition was that all invitees were randomly assigned a number, but not all participants completed the CIG-T. Levene’s test of equality of error variances was used to determine if the differing number of participants influenced data results. Levene’s test was not significant, indicating that the difference in number of participants per condition was not significant for measures of comprehension. There was one outlier, as assessed by being greater than 1.5 box-lengths from the edge of the box in a boxplot. There were no multivariate outliers, as assessed by boxplot and Mahalanobis distance (p > .001), Data were normally distributed, as assessed by Shapiro-Wilk's test (p > .05).

Statistical tests. The researcher conducted a univariate two-way ANOVA (GLM) with the “COMP” score as a dependent value and FDI and conditions as independent variables. There was a statistically significant interaction between FDI and information graphic conditions for "COMP " score, F (2,73) = 3.385, p = .039, partial $\eta^2 = .085$. (Figure 60. Statistically significant interaction: FDI and information graphic conditions.)
Post hoc comparisons showed that only the “COMP” scores for FD and FI participants in Condition 3 differed significantly, $F(1, 73) = 12.344$, $p = .001$, partial $\eta^2 = .145$. For participants assigned to Condition 3, mean “COMP” score for FD participants was 15.72 (SD = 4.19) and for FI participants it was 19.45 (SD = 2.83), a statistically significant mean difference of 3.72, 95% CI [1.61, 5.83]. To examine whether prior knowledge regarding the topics of the information graphics played a role in comprehension, prior knowledge questions were summed and entered as a covariate in a two-way ANCOVA. The statistical results were unchanged, suggesting that prior knowledge was unrelated to the interaction. There was also a main effect for FDI, however, main effects are not interpretable in the presence of a significant interaction.

While interactions of this type can be difficult to interpret, the result suggests the null hypothesis can be rejected in this case; FI and FD learners DO differ in their comprehension of different graphic types. Whether they differ, however, depends on whether they are FI or FD. FI learners scored higher than FD learners under Condition 3.
(Holmes’ infographics) and this difference was statistically significant. This difference in the predicted direction is that FI learners were better at disembedding information from complex fields. Holmes graphics are the most complex/pictorially embellished and therefore should be harder for FD learners than for FI, as the results here support.

Given that the scores for both FD and FI learners were nearly identical in Conditions 1 and 2, it is likely that the interaction is between FD and FI learners in minimalist vs. infographics (i.e., at the two extremes of pictorial embellishment) and that pictograms are essentially the same as minimalist (i.e., they are essentially minimalist drawings with pictures in place of the lines and bar elements). In fact, a follow up ANOVA of FDI and Conditions 1 and 3 only (i.e., no pictogram) produced the same statistically significant interaction; F (1, 52) = 5.41, p = .024, but failed to reproduce the main effect for FDI.

This suggests that FD learners’ comprehension may decrease with the addition of pictorial embellishment/complexity, that this difference shows up only when a certain threshold of pictorial embellishment is present, and that FI learners are largely unaffected by pictorial embellishment/complexity. This difference supports both Alternative hypothesis 1a. that states FD learners will comprehend minimalist information graphics better than they do other forms of information graphics and alternative hypothesis 1b that states FI learners will not differ in comprehension of all forms of information graphics.

**Gender.** To determine whether there were any differences attributable to gender, a one-way ANOVA was run. Mean scores between men and women were not statistically significant, F (1, 77) = 2.32, p = .131. Additionally, a two-way ANOVA of gender and condition was run and a statistically significant interaction between gender and condition
was found. However, there were unequal numbers of men and women in the study (n= 32 men; n=47 women), which makes these analyses challenging to interpret. A chi-square analysis showed that men and women were not different in their classification as FD or FI. However, while women were almost equally divided between FD and FI (FD 23; FI 24), men, however, were not equally distributed in FDI in this sample. There were 21 FI men and 11 FD men. Thus, FD women (n = 23) outnumbers FD men by more than 2 to 1. This difference in group size violates the assumptions for ANOVA and additionally makes it impossible to distinguish between FDI and gender because of the disproportionate representation of FD women in the study. In other words, the statistically significant interaction of gender and comprehension is as likely to be due to FDI.

The differences in mean scores for men and women and aesthetic ratings were calculated using descriptive statistics (Table 7. Mean scores for men and women on comprehension and aesthetic variable.) Because of the confound of gender and FDI, no additional analyses for gender effects were calculated for the other dependent variables and research questions.

Research Question 2: Aesthetic Perceived Efficacy, Preference & Perceived Value

Research Question 2 examined data about the relationship between learners and their aesthetic ratings for minimalist information graphics pictograms, or infographics. All learners who completed Part 2 of the CIG-T were exposed to three identical sets of data displays. The goal of Research Question 2 was to examine differences in learners’ aesthetic assessment of the; 1) effectiveness of design in information graphics, 2) levels
of preference for minimalist information graphics, pictograms or infographics and the 3) way in which each type of information graphic was valued.

Table 7.  
*Mean scores for men and women on comprehension and aesthetic variables*

<table>
<thead>
<tr>
<th>Dependent measures</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIG-T Part 1. Comprehension</td>
<td>19.12</td>
<td>18.08</td>
</tr>
<tr>
<td>CIG-T Part 1. Total aesthetic scores</td>
<td>78.96</td>
<td>83.08</td>
</tr>
<tr>
<td>CIG-T Part 1. Total scores for perceived efficacy</td>
<td>28.87</td>
<td>30.04</td>
</tr>
<tr>
<td>CIG-T Part 1. Total scores for preference</td>
<td>17.53</td>
<td>19.59</td>
</tr>
<tr>
<td>CIG-T Part 1. Total scores for perceived values</td>
<td>32.56</td>
<td>33.44</td>
</tr>
<tr>
<td>CIG-T Part 2. Aesthetic total scores for minimalist information graphics</td>
<td>124.43</td>
<td>130.57</td>
</tr>
<tr>
<td>CIG-T Part 2. Aesthetic scores for minimalist information graphics: perceived efficacy</td>
<td>57.46</td>
<td>62.40</td>
</tr>
<tr>
<td>CIG-T Part 2. Aesthetic scores for minimalist information graphics: preference</td>
<td>18.78</td>
<td>19.15</td>
</tr>
<tr>
<td>CIG-T Part 2. Aesthetic scores for minimalist information graphics: perceived value</td>
<td>48.18</td>
<td>49.02</td>
</tr>
<tr>
<td>CIG-T Part 2. Aesthetic total scores for pictograms</td>
<td>129.31</td>
<td>129.11</td>
</tr>
<tr>
<td>CIG-T Part 2. Aesthetic scores for pictograms: perceived efficacy</td>
<td>66.87</td>
<td>66.88</td>
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<tr>
<td>CIG-T Part 2. Aesthetic scores for pictograms: perceived value</td>
<td>41.68</td>
<td>41.75</td>
</tr>
<tr>
<td>CIG-T Part 2. Aesthetic total scores for infographics</td>
<td>109.50</td>
<td>113.44</td>
</tr>
<tr>
<td>CIG-T Part 2. Aesthetic scores for infographics: perceived efficacy</td>
<td>62.06</td>
<td>66.88</td>
</tr>
</tbody>
</table>
Table 7. Continued

<table>
<thead>
<tr>
<th>CIG-T Part 2. Aesthetic scores for infographics: preference</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIG-T Part 2. Aesthetic scores for infographics: perceived value</td>
</tr>
</tbody>
</table>

CIG-T aesthetic assessments part 1. Participants assigned to Condition 1, 2 or 3 in Part 1 of the CIG-T answered questions about aesthetics by completing Likert-style disagree-agree scales with five levels (strongly disagree, disagree, neither agree or disagree, agree or strongly agree). When presented with a statement they rated their agreement with a statement on a scale from 1-10.

Variables. Answers to questions about aesthetic perceived efficacy, preferences and value were converted to variables. These variables were AESTH_PE (perceived efficacy), AESTH_Pr (preference) and AESTH_PV (perceived value). These were used as dependent values in two-way ANOVAs (GLM) with FDI and Condition as independent variables. Post hoc analyses were also performed. In addition, three separate scores (AESTH_PE + AESTH_Pr + AESTH_PV) were totaled to created one variable for total aesthetic score (AESTH_TOT_1) which was evaluated with an additional two-way ANOVA (GLM) wherein the AESTH_TOT_1 score acted as a dependent variable and FDI and conditions as independent variables.

CIG-T aesthetic assessments part 2. As stated earlier, in this part of the CIG-T, participants in all three conditions experienced the same set of three information graphics, each representing the same data. Participants were able to provide responses about their aesthetic ratings by comparing across the three different versions of information graphics, whereas in in the first part of the CIG-T, they each viewed ONLY the form of information graphic for the condition to which they had been randomly assigned. Measures of aesthetic assessments in Part 2 of the CIG-T included an
individual’s short text answer as well as Likert-type ratings of aesthetics. The short text answer described reasons a minimalist information graphic, pictogram or infographic was selected as the information graphic a participant could learn from best. A thematic analysis was used to code short answers and identify themes.

**Variables.** Answers to Likert-type questions about aesthetic perceived efficacy, aesthetic preferences, aesthetic perceived value, and overall aesthetic assessments (a summation of the three subscales as before) were converted to variables. FDI was used as an independent variable.

Dependent variables included AESTH_PE_Min, (aesthetic perceived efficacy for minimalist information graphs), Aesth_PE_Pct, (aesthetic perceived efficacy for pictograms ) AESTH_PE_Inf, (aesthetic perceived efficacy for infographics ) ; AESTH_Pr_Min (aesthetic preference for minimalist information graphs), AESTH_Pr_Pct (aesthetic preference for pictograms), AESTH_Pr_Inf (aesthetic preference for infographics); AESTH_PV_Min (aesthetic perceived value for minimalist information graphs), AESTH_PV_Pct (aesthetic perceived value for pictograms) and AESTH_PV_Inf (aesthetic perceived value for infographics). For total aesthetic scores (AESTH_TOT_2), AESTH_TOT_2 score acted as a dependent variable and FDI as the independent variable.

Part 2 aesthetic perceived efficacy, preference, perceived value and totaled ratings for minimalist information graphics, pictograms and infographics were evaluated using a one-way MANOVA as well as post hoc analyses.

**Part 1 of the CIG-T: aesthetics.** Participants were assigned to one of three conditions in this part of the CIG-T. Condition 1 exposed participants only to minimalist
information graphics, Condition 2 only to pictograms and Conditions 3 only to infographics.

2.1 Null hypothesis: Learners presented with one of three different information graphic types (minimalist information graphics, pictograms, or infographics) will not differ in their overall aesthetic rating scores.

2.1a. Alternative hypothesis: FD learners will differ in their overall aesthetic rating for each type of information graphics, while FI learners will not differ in their overall aesthetic rating for each type of information graphic.

Assumptions and data screening. A case processing summary indicated that 100% of FDI participants completed questions for the overall aesthetic rating of minimalist information graphics, pictograms and infographics. There were no extreme outliers, as assessed by inspection of a boxplot, although there were three outliers greater than 1.5 box lengths from the edge of a box. It was decided to continue testing without any other action since the outliers that were found were not extreme and not deemed to be a problem in analysis. Data were normally distributed, as assessed by Shapiro-Wilk's test (p > .05). There was homogeneity of variances, as assessed by Levene's test for equality of variances, p = .340.

Statistical tests. A two-way ANOVA was conducted to examine the effects of FDI and Condition on overall or, in other words, total aesthetic ratings. There was no statistically significant interaction between FDI and Condition for overall "Aesthetic Total 1" score, nor was there any statistically significant main effect for FDI. However, there was a statistically significant main effect for Condition; F (2, 73) = 3.49, p = .036. Specifically, those in Condition 1 (minimalist infographic) had higher (M = 87.1)
aesthetic ratings than did those in Condition 3 (M = 76.41); p = .012. No other pairwise comparisons were statistically significant, although Condition 2 tended to be consistent with Condition 1, which is consistent with anticipated trends. Further, while the interaction of FDI and Condition was not significant, the scores suggested that FD learners tended to rate Condition 3 graphics (Holmes’ information graphics) lower than did their FI counterparts, suggesting that there may be an interaction of these variables if the observed power of the study (.101) had been higher. Alternative hypothesis 2.1a received partial support.

(A one-way ANOVA was also run to determine if there were differences between men and women and their mean aesthetic ratings scores for Part 1 of the CIG-T when they were assigned to conditions. Mean scores between men and women were not statistically significant, F (1, 77) = 1.705, p = .195.)

Null hypothesis 2.1 stated that learners will not differ in their overall aesthetic rating of minimalist information graphics, pictograms, or infographics. Because there were differences among learners by condition, the null hypothesis was rejected and the alternative hypothesis that learners tend to rate minimalist graphics higher than they do Holmes infographics received support.

2.2 Null hypothesis: Learners presented with one of three information graphic types (minimalist information graphics, pictograms, or infographics) will not differ in their perceived efficacy ratings.

2.2a. Alternative hypothesis: FD learners will perceive minimalist information graphics as more effective than other forms of information graphics.
Assumptions and data screening. A case processing summary indicated that 100% of FDI participants completed questions for the perceived efficacy aesthetic rating of minimalist information graphics, pictograms and infographics. Outliers were assessed by inspection of a boxplot, normality was assessed using Shapiro-Wilk's normality test for each cell of the design and homogeneity of variances was assessed by Levene's test. There were no outliers, residuals were normally distributed ($p > .05$) and there was homogeneity of variances ($p = .492$).

Statistical tests. A two-way ANOVA was conducted by the researcher to examine the effects of FDI and conditions on aesthetic perceived efficacy using AESTH_PE. The interaction effect between FDI and conditions on aesthetic perceived efficacy was not statistically significant, $F (2, 73) = .121$, $p = .886$, partial $\eta^2 = .003$, nor were there any statistically significant main effects. The null hypothesis was retained because there were no interactions or main effects. FDI learners perceived efficacy in all information graphics in much the same way. This suggests that the difference detected in the Total Aesthetic rating may in fact not be related to ratings of efficacy, specifically.

2.3 Null hypothesis: Learners presented with one of three information graphic types (minimalist information graphics, pictograms, or infographics) will not differ in their preference rating scores.

2.3.a. Alternative hypothesis: FD learners will prefer the aesthetics of infographics or pictograms over those of minimalist information graphics;

2.3.b. Alternative hypothesis: FD learners will prefer the aesthetics of minimalist information graphics over those of infographics.
**Assumptions and data screening.** A case processing summary indicated that 100% of FDI participants completed questions for the preference aesthetic rating of minimalist information graphics, pictograms and infographics. Residual analysis was performed to test for the assumptions of the two-way ANOVA. Outliers were assessed by inspection of a boxplot. There was one outlier, as assessed as being greater than 1.5 box-lengths from the edge of the box in a boxplot. It was decided to keep the outlier because it was not as extreme as 3 box-lengths from the edge of the box. Because this study used a small sample size (N = 79) it was accepted that this outlier could represent unique values that might be seen with greater regularity in a large study population. Data were normally distributed as assessed using Shapiro-Wilk's test (p > .05) Residuals were normally distributed (p > .05) and there was homogeneity of variances as assessed by Levene's test for equality of variances (p = .881).

**Statistical tests.** A two-way ANOVA was conducted by the researcher to examine the effects of FDI and conditions on preference using AESTH_Pr. The interaction effect between FDI and conditions on aesthetic preference was not statistically significant, $F(2, 73) = 5.279, p = .756$, partial $\eta^2 = .008$. There was also no statistically significant main effect for FDI, $F(1, 73) = 1.875, p = .175$, partial $\eta^2 = .025$. (Figure 61. Mean scores for aesthetic preferences by FDI and condition.)
However, there was a statistically significant main effect for condition $F(2, 73) = 4.321, p = .017$, partial $\eta^2 = .106$. Contrasts indicated that the difference between conditions 1 and 3 and between 2 and 3 were statistically significant. The findings here suggest that the differences detected in hypothesis 2.1 (overall aesthetic rating) may be related specifically to preference.

Alternative Hypothesis 2.3a stated FD learners will prefer the aesthetics of infographics or pictograms over those of minimalist information graphics. Alternative hypothesis 2.3.b stated FD learners will prefer the aesthetics of minimalist information graphics over those of infographics. Neither alternative hypothesis received support.

2.4 Null hypothesis: Learners presented with one of three information graphic types (minimalist information graphics, pictograms, or infographics) will not differ in their perceived value scores.

2.4a. Alternative hypothesis: FI learners will be more likely than FD learners to rate a pictogram or infographic as having greater aesthetic value than a minimalist information graphic.
Assumptions and data screening. A case processing summary indicated that 100% of FDI participants completed questions for the perceived value aesthetic rating of minimalist information graphics, pictograms and infographics. Residual analysis was performed to test for the assumptions of the two-way ANOVA. Outliers were assessed by inspection of a boxplot. There were three outliers as assessed as being greater than 1.5 box-lengths from the edge of the box in a boxplot. These outliers were found under Condition 2 with two FD outliers and one FI outlier noted. It was decided to keep these outliers since none where characterized as extreme outliers (>3.0). It was also thought that because this study used a small sample size (N=79) these outliers could represent unique values that might be seen with greater regularity in a large study population.

Normality was assessed using Shapiro-Wilk's test and homogeneity of variances was assessed by Levene's test. Residuals were normally distributed (p > .05). There was homogeneity of variances, as assessed by Levene's test for equality of variances, (p = .921).

Statistical tests. A two-way ANOVA was conducted to examine the effects of FDI and conditions (minimalist information graphics, pictograms or infographics) on perceived value for information graphics. The interaction effect between FDI and conditions on aesthetic perceived value was not statistically significant, \( F(2, 73) = .791, p = .457, \) partial \( \eta^2 = .021. \)

There was no statistically significant main effect for FDI. However, as with hypothesis 2.4, there was a statistically significant main effect for condition; \( F(2, 79) = 5.55, p = .006, \) partial \( \eta^2 = .132. \) Specifically, learners rated minimalist information graphics higher on “Perceived Aesthetic Value” than pictograms and infographics. The
difference in marginal means for the "Perceived Aesthetic Value" score for minimalist information graphics (condition 1) and pictograms (condition 2) was 4.73, 95% CI [.917, 8.56] \( p = .01 \). The difference in marginal means for the "Perceived Aesthetic Value" score for minimalist information graphics and infographics was 4.41, 95% CI [.717, 8.111] \( p = .01 \). The difference in marginal mean scores for conditions 1 and 2 were not statistically significant. (Figure 62. Mean scores for main effects for Condition 1 compared to Condition 2 and 3.)

![Figure 62. Estimated marginal mean aesthetic preference scores for different types of information graphics (conditions).](image)

These findings suggest that learners tend to rate minimalist information graphics as being more valuable for learning than they do for other forms of graphics. While the interaction was not significant, the means suggested that FD and FI learners follow the same general pattern when rating minimalist information graphics or pictograms, but
differ when rating infographics for Perceived Aesthetic Value. FD learners in Condition 3 rated infographics as the least valued while FI learner ratings were lowest for pictograms. These findings also suggest the differences detected in Aesthetic Total may be significantly related to ratings of value, in particular.

Null hypothesis 2.4 was rejected due to a significant main effect in preference for one type of information graphic by FDI learners. Alternative hypothesis 2.4a and alternative hypothesis 2.4b stated “FI learners will be more likely than FD learners rate a pictogram or infographic as having greater aesthetic value than a minimalist information graphic.” Scores were not significantly different and so no support could be given to either alternative hypothesis 2.4a or 2.4b. Instead, the unspecified alternative hypothesis that learners will tend to prefer minimalist information graphics and pictograms over info graphics is supported.

**Part 2 of the CIG-T: aesthetics.** As described earlier, participants in all three conditions were exposed to three different versions of information graphics that represented the identical data and trends in Part 2 of the CIG-T. This was done in order for the researcher to detect how participants rated each of the three types when asked to compare them directly (e.g., within-subjects) rather than providing ratings of one type of graphic only and then comparing them across conditions (e.g., between-subjects) as was done in Part 1 of CIG-T aesthetics questions.

The analyses of the CIG-T Part 2 used FDI as an independent variable and aesthetic perceived efficacy, preference, perceived value and the total score for Part 2 aesthetic assessments as dependent values in different analyses. Therefore, condition is
no longer an independent variable, as all participants saw the same set of graphics in Part 2 of the CIG-T. Hypotheses 2.5 through 2.8 are addressed through Part 2 of the CIG-T.

2.5 Null hypothesis: Learners who simultaneously rate three different information graphic types (minimalist information graphics, pictograms, or infographics) that present the same underlying data/information will not differ in their overall aesthetic rating scores.

2.5a. Alternative hypothesis: FD learners will differ in their overall aesthetic rating for each type of information graphics, while FI learners will not differ in their overall aesthetic rating for each type of information graphic.

Assumptions and data screening. An SPSS case processing summary revealed data were missing for two FI participants who failed to complete Part 2 of the CIG-T. This resulted in a 4.5% reduction in cases which is less than a statistically significant difference of 5. There were two univariate outliers, as assessed by inspection of a boxplot defined as being greater than 1.5 box-lengths from the edge of the box in a boxplot. These were identified as Case 3 and Case 17. Since they did not represent extreme outliers < 3 box lengths from the edge of the box in a boxplot, they were kept in the analysis. There were no multivariate outliers in the data, as assessed by Mahalanobis distance \( p > .001 \). There was homogeneity of variances for total aesthetic cores for FD and FI participants, as assessed by Levene's test for equality of variances \( p = .928 \).

Statistical tests. A one-way ANOVA was run to determine differences between men and women and their mean aesthetic ratings scores for Part 2 of the CIG-T when they were all exposed to identical sets of information graphics. All assumptions were
Mean scores between men and women were not statistically significant, $F(1, 75) = 2.070, p = .154$.

A one-way multivariate analysis of variance (MANOVA) was run to determine differences of overall aesthetic rating of minimalist information graphics, pictograms, or infographics among learners. Three measures of overall aesthetic ratings were assessed for minimalist information graphics, pictograms and infographics. The differences between FDI on the combined dependent variables was not statistically significant, $F(3, 73) = .768, p = .516$ Wilks' $\Lambda = .969$.

Descriptive statistics indicated FD learners’ aesthetic overall scores were higher for pictograms than for minimalist information graphics or infographics. FI learners’ aesthetic preference scores were higher for pictograms than for minimalist information graphics or infographics.

Null hypothesis 2.5 stated that FD and FI learners will not differ in their overall aesthetic rating of minimalist information graphics, pictograms, or infographics. The null hypothesis was retained because there was not a statistically significant difference in the total aesthetic scores of FD or FI learners.

2.6 Null hypothesis: Learners who simultaneously rate three different information graphic types (minimalist information graphics, pictograms, or infographics) that present the same underlying data/information will not differ in their perceived efficacy scores.

2.6a. Alternative hypothesis: FD learners will perceive minimalist information graphics as more effective than other forms of information graphics.
**Assumptions and data screening.** An SPSS case processing summary revealed data were missing for two FI participants who failed to complete Part 2 of the CIG-T. This resulted in a 4.5% reduction in cases which is less than a statistically significant difference of 5 %, (p > .05%). Assumption testing revealed no univariate outliers. One multivariate outlier was kept in analysis after calculating a Mahalanobis distance because a MANOVA is robust to violations of multivariate normality and to violations of homogeneity of variance-covariance matrices if groups are of nearly equal size. These criteria were met. Aesthetic perceived efficacy scores were normally distributed for both FD and FI, as assessed by Shapiro-Wilk's test (p > .05). To test for the assumption of multicollinearity, the dependent variables were entered into a Pearson product moment which showed AESTH_PE_MIN and AESTH_PE_Inf were significantly related. A strength greater than .80 suggested these variables were collinear.

Accordingly, two separate MANOVAs were run with perceived efficacy of pictograms and perceived efficacy of minimalist graphics as dependent variables in one MANOVA and with perceived efficacy of pictograms and perceived efficacy of infographics as dependent variables in the other.

*First corrected MANOVA: assumptions and data screening.* The dependent variable AESTH_PE_MIN was eliminated from this test. The independent variable was FDI and the dependent variables were Aesth_PE_Pct and AESTH_PE_Inf. A one-way multivariate analysis of variance was run to determine the effect of FDI on perceived efficacy of different styles of information graphics. Two measures of perceived efficacy were assessed: pictogram and infographic scores. Preliminary assumption checking revealed that data was normally distributed, as assessed by Shapiro-Wilk test (p > .05);
there were no univariate or multivariate outliers, as assessed by boxplot and Mahalanobis
distance ($p > .001$), respectively; there were linear relationships, as assessed by
scatterplot, no multicollinearity ($r = -.094$, $p = .416$); and there was homogeneity of
variance-covariance matrices, as assessed by Box's M test ($p = .003$).

First corrected MANOVA: statistical tests. There was no statistically significant
difference between the FDI learners on any of the dependent variables, $F(2, 74) = .479$, $p$
>.0005; Wilks' Λ = .987; partial $\eta^2 = .013$.

Second corrected MANOVA: assumptions and data screening. The dependent
variable AESTH_PE_Inf was eliminated from this test. The independent variable was
FDI and the dependent variables were Aesth_PE_Min and Aesth_PE_Pct.

There were no univariate outliers in the data, as assessed by inspection of a
boxplot for values greater than 1.5 box-lengths from the edge of the box. Aesthetic
efficacy scores for minimalist information graphics and pictograms were normally
distributed for FDI learners as assessed by Shapiro-Wilk's test ($p > .05$). There was no
multicollinearity, as assessed by Pearson correlation ($r = -.098$, $p = .395$). There was a
linear relationship between aesthetic efficacy scores for minimalist information graphics
and pictograms for FDI learners, as assessed by scatterplot. There were no multivariate
outliers in the data, as assessed by Mahalanobis distance ($p > .001$). There was
homogeneity of variance-covariances matrices, as assessed by Box's test of equality of
covariance matrices ($p = .574$).

Second corrected MANOVA: statistical tests. There was no statistically significant
difference between the FDI learners on the combined dependent variables, $F(2, 74) =$
1.63, $p > .0005$; Wilks' Λ = 262; partial $\eta^2 = .036$’
These results suggest the null hypothesis should be retained; FI and FD learners did not differ in their perceived efficacy of different graphic types. Means for FDI learners followed the same pattern with perceived efficacy of minimalist information graphs rated lowest and pictograms rated highest. Mean ratings in all cases were highest for perceived efficacy in pictograms and lowest for perceived efficacy in minimalist information graphs. FDI learners, according to mean scores, all perceived pictorial statistics as more efficacious than minimalist information graphics. FD learners preferred pictorial detail to a greater extent than FI learners. (Figure 63. FDI mean scores for perceived efficacy.)

![Figure 63. FDI mean scores for perceived efficacy.](image)

FI learners, who often choose science or technical careers might have been expected to perceive minimalist information graphs as more effective than pictorial statistics simply because they are often exposed to non-pictorial statistical displays during work or study. This was not the case. However, alternative hypothesis 2a that theorized FI learners will be more likely than FD learners to perceive more efficacy in a pictogram
or infographic than a minimalist information graphic was rejected because FI mean scores were lower than FD means scores when indicating the measure of perceived efficacy in pictorial information graphics a learner believed existed.

2.7. **Null hypothesis:** Learners who simultaneously rate three different information graphic types (minimalist information graphics, pictograms, or infographics) that present the same underlying data/information will not differ in their preference scores.

2.7a. **Alternative hypothesis:** FI learners will be more likely than FD learners to like and rate at pictogram or infographic as having greater aesthetic value than a minimalist information graphic.

**Assumptions and data screening.** An SPSS case processing summary revealed data were missing for two FI participants who failed to complete Part 2 of the CIG-T. This resulted in a 4.5% reduction in cases which is less than a statistically significant difference of 5 %, (p > .05%). A boxplot of aesthetic preferences for minimalist information graphics, pictograms and infographics revealed two univariate FDI outliers, defined as being greater than 1.5 box-lengths from the edge of the box in a boxplot. These were identified as Case 36 and Case 59. Since they did not represent extreme outliers < 3 box lengths from the edge of the box in a box plot, they were kept in the analysis.

Malhalonobis statistics for multilinear outliers were generated by running a regression with case number as the dependent variable. FDI, aesthetic preference for minimalist information graphics (Aesth_Pr_Min), aesthetic preference for pictograms (Aesth_Pr_Pct) and aesthetic preference for infographics (Aesth_Pr_Inf) acted as
independent variables. A new Mahalanobis distance variable to represent FDI aesthetic preference in Part 2 of the CIG-T- “MAH_AESTH_pr”- was computed using residual statistics calculation for maximum Mahalanobis distance.

The only unusually high Mahalanobis distance score, MD = 17.06 was compared to the critical value MD = 16.26 obtained from the chi-square table, F = 1.236, p > .001. Although this single Mahalanobis distance score (MD = 17.06) exceeded the chi-square critical MD value of 16.26, it was decided to keep the outlier in analysis. MANOVA is robust to violations of multivariate normality and to violations of homogeneity of variance-covariance matrices if groups are of nearly equal size (\(N\) of the largest group is no more than 1.5 times the \(N\) of the smallest group).

Aesthetic preference scores were normally distributed for both FD and FI, as assessed by Shapiro-Wilk's test \((p > .05)\) There was also a linear relationship between aesthetic preference scores and FDI. There was a small positive correlation between the Aesthetic Minimalist Preference and Aesthetic Infographic Preference variables, \(r = -.231, n = 77, p = .043\). There was multicollinearity, as assessed by Pearson correlation \(r = -.231, p = .043\) which showed AESTH_Pr_Min and AESTH_Pr_Inf were negatively correlated. However, the strength of association was .231, which is less than .80, suggesting that the assumption of collinearity was met.

There was homogeneity of variance-covariances matrices, as assessed by Box's test of equality of covariance matrices \((p = .066)\). There was homogeneity of variance-covariances matrices, as assessed by Box's test of equality of covariance matrices \((p = .066)\). There was not a statistically significant difference between FD and FI learners on
the combined aesthetic preference dependent variables, $F(3, 73) = .930, p < .05$; Wilks' $\Lambda = .963$; partial $\eta^2 = .037$.

**Statistical tests.** A one-way multivariate analysis of variance (MANOVA) was run to determine differences on aesthetic preference for information graphic styles by FD and FI learners. Three measures of aesthetic preference were assessed: minimalist information graphics, pictograms and infographics. The differences between FDI on the combined dependent variables was not statistically significant, $F(3, 73) = .930, p = .431$; Wilks' $\Lambda = .963$.

Descriptive statistics indicated FD learners’ aesthetic preference scores were higher for pictograms than for minimalist information graphics or infographics. FI learners’ aesthetic preference scores were higher for pictograms than for minimalist information graphics or infographics. (Table 8. *Mean scores for aesthetic preference.*)

<table>
<thead>
<tr>
<th></th>
<th>Condition 1 Minimalist Information Graphics</th>
<th>Condition 2 Pictograms</th>
<th>Condition 3 Infographics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FD</strong></td>
<td>18.22</td>
<td>21.68</td>
<td>17.48</td>
</tr>
<tr>
<td><strong>FI</strong></td>
<td>19.64</td>
<td>20.52</td>
<td>17.71</td>
</tr>
</tbody>
</table>

**2.8. Null hypothesis:** Learners who simultaneously rate three different information graphic types (minimalist information graphics, pictograms, or infographics) that present the same underlying data/information will not differ in their perceived value scores.
2.8a. *Alternative hypothesis*: FD learners will be more likely than FI learners to rate at pictogram or infographic as having greater aesthetic value than a minimalist information graphic.

**Assumptions and data screening.** An SPSS case processing summary revealed data were missing for two FI participants who failed to complete Part 2 of the CIG-T. This resulted in a 4.5% reduction in cases which is less than a statistically significant difference of 5%, \( p > .05 \). There were no univariate outliers in the data, as assessed by inspection of a boxplot. Malhalonobis statistics for multilinear outliers were generated by running a regression with case number as the dependent variable. Aesthetic value for minimalist information graphics (Aesth_PV_Min), aesthetic preference for pictograms (Aesth_PV_Pct) and aesthetic preference for infographics (Aesth_PV_Inf) acted as independent variables. A new Mahalanobis distance variable to represent FDI aesthetic preference in Part 2 of the CIG-T, “MAH_AESTH_PV,” was computed using residual statistics calculation for maximum Mahalanobis distance. There were no multivariate outliers in the data, as assessed by Mahalanobis distance \( p > .001 \).

Perceived value by FD learners was not normally distributed for pictograms \( p = .018 \) nor were perceived value scores by FI learners for infographics \( p = .017 \) as assessed by Shapiro-Wilk's test \( p > .05 \). It was decided to run the test regardless because the one-way MANOVA is fairly robust to deviations from normality.

There was no multicollinearity, as assessed by Pearson correlation; although there were two significant correlations, neither was stronger than .80. There was homogeneity of variance-covariances matrices, as assessed by Box's test of equality of covariance matrices \( p = .721 \).
**Statistical tests.** A one-way MANOVA was run to determine the effect of FDI on preference for minimalist information graphics, pictograms and infographics. There was no statistically significant difference between the FDI learners on the dependent variables, $F(3, 73) = .400, p < .05$; Wilks' $\Lambda = .754$; partial $\eta^2 = .016$. (Table 9. Mean scores for aesthetic perceived value of minimalist information graphics, pictograms and infographics.) The null hypothesis was retained, and the alternative hypothesis was not supported.

2.9. **Null hypothesis:** Learners who simultaneously rate three different information graphic types (minimalist information graphics, pictograms, or infographics) that present the same underlying data/information will not differ in their choices for which is best for learning.

2.9a. **Alternative hypothesis:** FI learners will be more likely than FD learners to select pictograms or infographics as displays that are best to learn from.

Table 9.

*Mean scores for aesthetic perceived value of minimalist information graphics, pictograms and infographics.*

<table>
<thead>
<tr>
<th>Information graphic type</th>
<th>FD mean score</th>
<th>FI mean score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimalist</td>
<td>49.16</td>
<td>48.08</td>
</tr>
<tr>
<td>Pictogram</td>
<td>42.68</td>
<td>40.92</td>
</tr>
<tr>
<td>Infographic</td>
<td>30.14</td>
<td>28.61</td>
</tr>
</tbody>
</table>

**Assumptions and data screening.** As this was a comparison of two categorical variables all assumptions to the test were met.

**Statistical tests.** Chi-square analyses showed no statistically significant differences in the type of graphic chosen by FD and FI learners as best for learning.
There were 35 of 35 FD learners who made a selection for “Winged Plight” and of these 51% (n = 18) selected the minimalist information graphic, 37.1 % FD learners (n = 13) selected the pictogram and 11.4% (n=4) selected the infographic. There were 44 of 44 FI learners who made a selection for “Winged Plight” and of these 47.7% (n = 21) selected the minimalist information graphic, 29.5% (n = 13) selected the pictogram and 22.7 (n = 10) selected the infographic. (Table 10. *Choices for the best information graphic for learning by FDI participants for “Winged Plight.”*) The second set of three information graphics was titled “Funding Nemo” and presented data about the cost of tropical aquarium fish. Again, participants were asked to choose the graph they thought they could learn best from.

<table>
<thead>
<tr>
<th>FDI</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Missing</td>
<td>System</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FD</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valid</td>
<td></td>
<td>Minimalist</td>
<td>18</td>
<td>51.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pictogram</td>
<td>13</td>
<td>37.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Infographic</td>
<td>4</td>
<td>11.4</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FI</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid</td>
<td></td>
<td>Minimalist</td>
<td>21</td>
<td>47.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pictogram</td>
<td>13</td>
<td>29.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Infographic</td>
<td>10</td>
<td>22.7</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

There were 35 of 35 FD learners who made a selection and of these 28% (n = 10) selected the minimalist information graphic,45.7% (n = 16) selected the pictogram and 25.7% (n = 9) the infographic. There were 43 of 44 FI learners who made a selection and of these 36% (n = 16) selected the minimalist information graphic, 34% (n = 15) selected
the pictogram and 27% (n = 12) the infographic. (Table 11. Choices for the best information graphic for learning by FDI participants for “Funding Nemo.”)

Table 11.

*Choices for the best information graphic for learning by FDI participants for “Funding Nemo”*

<table>
<thead>
<tr>
<th>FDI</th>
<th></th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Missing</td>
<td>System</td>
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</tr>
<tr>
<td>FD</td>
<td>Valid</td>
<td>Minimalist</td>
<td>10</td>
<td>28.6</td>
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<tr>
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<td></td>
<td>Pictogram</td>
<td>16</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Infographic</td>
<td>9</td>
<td>25.7</td>
<td>25.7</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>35</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>FI</td>
<td>Valid</td>
<td>Minimalist</td>
<td>16</td>
<td>36.4</td>
<td>37.2</td>
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<tr>
<td></td>
<td></td>
<td>Pictogram</td>
<td>15</td>
<td>34.1</td>
<td>34.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Infographic</td>
<td>12</td>
<td>27.3</td>
<td>27.9</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>43</td>
<td>97.7</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Missing</td>
<td>System</td>
<td>1</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>44</td>
<td>100.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The third set of three information graphics was titled “Going Postal” that presented data about the rising cost of postage stamps in the United States over a period of years. Participants were asked to choose the graph they thought they could learn best from. There were 35 of 35 FD learners who made a selection and of these 9% (n = 3) selected the minimalist information graphic, 80% (n = 28) selected the pictogram and 11% (n = 4) the infographic. There were 42 of 44 FI learners who made a selection and of these 18% (n = 8) selected the minimalist information graphic, 71% (n = 31) selected the pictogram and 7% (n = 3) the infographic (see Table 12).
Short answer themes. Short answers were thematically coded. Although the length of some answers did not surpass a sentence, some participants wrote paragraphs that compared and contrasted the information graphic they selected with the ones they did not. Themes indicated both general and individualized sentiments among learners regarding differing information graphic types. Their short answers not only offered insights into reasons for choice, but also helped illuminate underlying attitudes that may have affected ratings for aesthetic perceived efficacy, preference and perceived value.

Coded themes were:

- Simplicity in design
  - Uncluttered displays
  - No distracting details
- Ease of understanding
  - Quick route to comprehension
  - Clarity
- A forum for frustration
- Middle ground for pictorial detail

Table 12. *Choices for the best information graphic for learning by FDI participants for “Going Postal”*

<table>
<thead>
<tr>
<th>FDI</th>
<th>Missing System</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
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<td>100.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FD</td>
<td>Valid</td>
<td>Minimalist</td>
<td>3</td>
<td>8.6</td>
<td>8.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pictogram</td>
<td>28</td>
<td>80.0</td>
<td>88.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Infographic</td>
<td>4</td>
<td>11.4</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>35</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>FI</td>
<td>Valid</td>
<td>Minimalist</td>
<td>8</td>
<td>18.2</td>
<td>19.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pictogram</td>
<td>31</td>
<td>70.5</td>
<td>92.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Infographic</td>
<td>3</td>
<td>6.8</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>42</td>
<td>95.5</td>
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<tr>
<td>Total</td>
<td></td>
<td></td>
<td>44</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>
• Visual appeal
  o Colorfulness
• Context setting
• The need for labels as information
• Appropriateness and credibility

Simplicity in design. It was discovered, using thematic analysis of short answers to the open-ended questions in CIG-T Part 2, that one of the most frequently expressed justifications for a choice of a minimalist information graphic was that its design was simple and uncluttered by extraneous detail that could become distracting. Although many of these comments about simplicity were made when participants selected minimalist information graphics, they were also occasionally applied to pictograms.

Out of 35 FD participants, 18 selected the minimalist information graph for “Winged Plight” and of these, 9 used the word “simple” or “simplicity” as a reason for making that choice; 10 participants selected the minimalist information graphic for “Funding Nemo” and 6 of these learners referred to simplicity; 3 participants chose the minimalist information graphic for “Going Postal” and all 3 referred to simplicity. Out of 21 FI participants who selected the “Winged Plight” minimalist information graphic, 8 mentioned simplicity in comments. Out of 16 learners who selected the minimalist information graphic for “Funding Nemo” 6 mentioned simplicity. Of the 8 FI learners who selected the minimalist graph for “Going Postal” 5 mentioned that their choice pertained to the graph’s simplicity. This is too fine grained a report on “simplicity in design,” but counting the cases has the benefit of demonstrating the strength of the association of minimalism with simplicity. This held true for both FD and FI participants.

Other comments, particularly when a minimalist information graph was selected, often referenced the benefits of a lack of clutter in that display. For example, FD
Participant 41 said of “Winged Plight,” "I like simple line graphs or bar charts that don't have anything crazy going on around it.” FI Participant 28 reported selecting the minimalist information graphic for “Funding Nemo” because, “The graph looks to be clean, uncluttered and to the point. It doesn't have a lot of graphics that could cloud the issue at hand.” A lack of clutter was considered advantageous by FI Participant 63 who said of a minimalist information graphic, “It is less cluttered & easier to read and focus on. I like the pictures of each fish in the middle graph, but with the busy background, it seems too cluttered.”

Some FDI learners acknowledged clutter was a distraction. FI Participant 28 preferred a minimalist information graph because, “I just want to see the facts presented without lots of graphics to distract me.” FI Participant selected a minimalist graphic because” Its easiest to understand because there is only facts presented and nothing to distract from that.”

_Ease of understanding- with a quick route to comprehension due to clarity._

Although much has been said about simplicity in design as sponsoring ease in understanding, FI Participant 48 selected a pictogram because,” It has more details that make it easier to understand.” FI Participant 63 also selected a pictogram because, “To me, this is the easiest graph to follow due to the horizontal lines.” In these cases, and others, detail that highlighted meaningful or important parts of a graph made an information graphic easier to understand. “Easy” and “quick” are terms that seem to naturally go together. Some participants found that when graphs were easy to read, they could also be quickly read. FD participant 33 said of the minimalist information graphic that had been selected, “I prefer a clean, simple graph. The extra image and clip art
clutter just gets in the way of letting me focus on visually connecting the data line easily and quickly with the axes” FI Participant 34 selected a pictogram because “the images quickly tell the reader the topic of the graph.” FI Participant 16 selected a minimalist information graphic because, “This graph is clean and simple. No unnecessary patterns or graphics. I can look at the graph and interpret the data in less than a minute.”

_A forum for frustration._ FDI participants used short answers in some cases to express and describe the frustration they experienced when decoding information graphics. Comments included personal information about the difficulties participants experienced during the CIG-T and in life when trying to deal with visual material. FD Participant 49 said,” I am dyslexic and have learned to focus on text rather than images as the images can often confuse me. I would have told you this before, but I didn't see a place to let you know.” FI Participant 61 expressed frustration due to FD-like cognitive problems. The reason this learner chose a minimalist information graphic as the best learning tool was that,” It is simple and presents only the information I need. The graph on the left is beautiful, but I have to sort through too much information before I can figure out what I am looking at.” FI Participant 23 said, “I chose the plain bar graph because it does not add extra graphics that can be confusing. The first graph, I got confused with the different number of fish in each column.” FI Participant who selected a minimalist information graphic said,” My brain gets distracted by pictures easily. For me, I can just look up what the fish look like later. I like the simplicity of the graph on the right.”

_Middle ground for pictorial detail._ When pictograms were selected it was often because they represented a middle ground between an information graphic with not
enough detail and one with too much detail. FD Participant 27 said of a pictogram, “It was easy to tell that the population was on the decline + it had some visuals to make it appealing. The first was too busy with pictures and the last was too dry.” FD Participant 55 also said of a pictogram, “It isn't too cluttered but at the same time it does show the number of butterflies and the years. The first is too cluttered, and the third a little too plain.” FI Participant 35 responded similarly, saying, “The first graph was way too much to look at. It makes me want to delete the butterflies, so I can focus on the graph below them. I chose the middle graph because it has some interesting pictures that aren't distracting. The one on the right is boring.”

Visual appeal: colorfulness and graphics that are interesting and not boring.

Although many learners seemed satisfied with information graphics that were quick and easy to read, others, like those who looked for a middle ground of visual appeal in pictograms, wanted something that they assessed as aesthetically interesting. FD Participant 36 selected an infographic based on visual appeal and said, “It includes a clear graph with pictures of the Monarch and caterpillars. The pictures make it more interesting.” FI Participant 30 selected an infographic for much the same reason noting, “The pictures and bright colors draw my attention to the subject of the graph right away, and population seems like it would be a fluid, connected number, not snapshots in time.” FI Participant 67 said of an infographic, “While I usually do not like very picture-oriented graphs, this one needed the pictures to help my eyes oriented. The bold line and the numbers placed at each point makes it easy to read.” Although infographics were complimented for visual appeal, FD Participant 80 complimented a minimalist
information graphic because it was “Clean, easy to look at, aesthetically pleasing.” FD Participant 4 said of a pictogram that it was “visually appealing without being cluttered”

FD participant 8 expressed the benefit of color in a pictogram saying, “It had just enough color to make it interesting without detraction from the data.” FD Participant 18 expressed appreciation of both detail and color in a pictogram and said, “It's not as simple and more colorful than the black and white version.” FD Participant 49 selected a pictogram and reported, “The color in the graph makes it more attractive and eases use by clearly delineating the bars in the graph, and it doesn't confuse me as it isn't cluttered or left/right oriented.” FI Participant 71 said of a pictogram,” The bar graph is presented in an organized manner and the illustrator used color thoughtfully to enhance the message of the graph.” FD Participant 81 selected an infographic because,” I need color.” Not everyone appreciated color, however. FI participant 47 said, “The graph I picked was the simplest graph with the most information given in a clear view. The other two were way too colorful …”

Context setting. When imagery was deemed valuable in a display it was sometimes credited with setting context. FD Participant 34 selected a pictogram because “The butterfly images told my eye the topic of the graph immediately, and the visual distribution was easy to understand.” FD Participant 33 recognized the benefit of context setting through imagery, saying, “In this instance, we're dealing with a niche subject involving species names with which everyone will be unfamiliar, myself included. For once, having a graphical illustration of the fish itself was actually helpful in knowing what the hell we were talking about here.” FI Participant 34 spoke about the choice of a pictogram. “I chose the first graph (pictogram) for the same reasons that I chose #2 in the
last set --- the images quickly tell the reader the topic of the graph.” FD Participant 62 selected a pictogram because it was,” Less cluttered than the picture graph - but better graphics for a line graph to emphasize the topic.” On one occasion the value of context setting through imagery was limited to occasions when one is a novice. FI Participant 72 explained the choice of a pictogram by saying,” As a person who knows very little about aquarium fish, it helps me associate an actual fish to the price per fish shown in this graph. Despite the fact that the second graph (the most colorful one) also has this graphical information present, there is too much other color which makes the graph harder to read. Had I known more about aquarium fish species, I would have chosen the plain bar graph, for the same reason above. That is, the additional color and illustration is merely a distraction for someone who knows aquarium fish species well, and a simple display of information is more quickly comprehensible.”

The need for labels as information. FD problems with visual material have been recognized as problems associated with cognitive style. For some FDI learners limited labeling or data point markers foiled their efforts to interpret an information graphic. FD Participant 3 selected a pictogram as the best information graphic to learn from, and said, “The colorful, image-filled graph on the left [infographic] could have been alright if it did not have SO many images on it (one butterfly would have been plenty). It is too crowded for the information to be easily read. Same as the graph before [minimalist information graphic], the plain line graph to the right easily shows the rise and falls of populations, but not the exact data points information. The center graph, [pictogram]which I selected, includes these data points so it is the best. The butterfly images may not be necessary, but they do not distract much from the overall message.”
Participant 13 selected a pictogram, not so much because of imagery but because of labeling. “I like that the bars indicate price above. The graph is much more easy to read than the first but more interesting and detailed than the third.” FD participant 26 said about the same pictogram, “Data being on top of the bars is easy to understand. Not enough info on the chart on the right. The left one is not specific enough unless you use the data-set below the chart.” FD Participant 43 further referenced the helpfulness of labels in a pictogram noting, “It looks easier to read than the other two options. The numbers are on the tops of the bars so there is no guessing where they land on the Y axis.” FI Participant 36 selected an infographic “because it identifies the fish, of which I don't have any knowledge of, cost labeled on each fish. This graph seems to be the easiest to understand.” FI Participant 10 selected a pictogram because, “The numbers are above the number of fish, making the information easier to gather.” FD Participant 7, who selected an infographic for learning said, “I think this job did the best of breaking out the relevant information in a clear way, while also not being so flat as to pass by completely unnoticed. I found the middle image to be the least effective in this particular case, as I found it harder to track the trend line, even though I thought having the numbers was helpful. I think having the numbers at the individual data points is a big help, which was a point in favor of the more graphic graph I chose. I also liked that the graph I chose broke out the axes in a visually eye-catching, and easy-to-find way”

*Appropriateness and credibility*. Participants sometimes selected or did not select an information graphic because of the way they associated types of information graphics with specific venues. For example, FI Participant 51 selected a minimalist information graphic because, “I'm pretty analytical, so I'd rather see the data without the extra
distraction. I suppose the first one [infographic] might be appropriate in a science museum exhibit or similar circumstance, where the imagery immediately conveys useful context and provides a hook. The middle one [pictogram] lacks any aesthetic value and just seems to make things more complicated than necessary -- and the dotted line doesn't even track the values presented by the butterflies.” FI Participant 78 also selected a minimalist information graphic as the one best to learn from because although “All three of these graphs convey their information clearly. In an academic setting, I would prefer the plain one but the stacks of fish would also be acceptable. The one based on the fish tank would be more appropriate for an informal setting or non-scholarly articles but still conveys information clearly enough that it could be used anywhere.” FI Participant 45 selected a minimalist information graphic because, “The graph on the left is way too cluttered and while the graph in the middle may be simple, it seems too visually stunning for presenting information.”

FI Participant 75 revealed a personal bias for minimalist information graphics and credibility when he/she stated the reason for selecting the minimalist information graphic was because,” simple charts appear more accurate and less likely to be untrue.” FI Participant 69 selected a minimalist information graphic as well and commented (without any supporting evidence) that this graphic “can gather actual information, not cluttered with excess flair. Appears to be more trustworthy source.”

Summary. FDI cognitive style and traits of FD or FI are well documented. The results from comments in the CIG-T short answer section indicate, however, that there is more diversity within the FDI cognitive style one may have thought. It is not as if there is a straight dividing line between FD and FI. These learners were extremely FI or FD. Yet
comments about distraction, clutter or difficulty interpreting more complex visual material that are commonly associated with FD learners were often made by FI learners. The results of short answer questions reveal that there may not be as many differences as similarities between FD and FI learner aesthetic assessments. Nevertheless, these claims are not intended to discredit the reality of FDI cognitive style but are meant to highlight the mixture of traits that emerge when aesthetics are evaluated.

Some comments indicated that minimalist information graphics were better associated with trustworthiness and seriousness than pictorial statistical displays. This represents the results of immersion in a culture rather than naïve assessments of value, preference or efficacy. Some learners found benefit in an information graph that presented data so it could be assessed quickly and easily, reflecting Western cultural values for efficiency. The results of evaluation of short answer questions point to veiled cultural influences as well as to personal opinions that guide aesthetic assessments.
CHAPTER V
DISCUSSION

Summary

As stated earlier, this study had a two-fold purpose. The first was to create a general treatise about the visual instruction and instructional design timelines from the medieval eikoncentric through the contemporary eikoncentric eras. The second purpose of this study, therefore, was to test what impacts visual communication have on field dependent-independent (FDI) learners, as a case to illustrate the imprudence of proceeding on the assumption that design is based on fact and works for all.

Purpose One

Chapter II revealed key propositional statements about visual learning made in both medieval and contemporary eras. These propositions resembled each other despite their separation by centuries and greatly differing societal mindsets in almost every other way. Scholars in both time periods, for example, posited memory systems for images, described visual metaphor and analogy and proposed models of stage-like visual processing. Visual instructional design was and continues to be related to these concepts.

The societal value for and beliefs about modern visual presentations are shaped by hundreds of years of evolution in design and learning. This evolution of design and learning correspond to shifts in our cultural expectations or interpretations of visual and textual information during grammacentric or eikoncentric eras. Our field of instructional
design seldom describes this history and its complexity, focusing on discrete studies of existing practices (e.g., the modality principle, etc.) without recognizing the narrow foundations upon which they are based. Certainly, this is where we have arrived, but it does not follow that this is, to quote Leibnitz, a medieval philosopher, “the best of all possible worlds.” Although we can make incremental progress in our studies of imagery and learning by focusing on what exists now, we may be missing larger, more significant questions that would arise were we aware of the gaps in our knowledge.

Different aspects of visual instruction were discussed—some extensively—but a focus was placed on what underwrote the design and development of data displays as learning and information tools. Data displays were invented and popularized from the mid to late 1800’s. Mass computing that introduced the “Information Age” from the late 1900’s onward produced unprecedented amounts of data. New types of information graphics that filter and present raw data were developed. The most common information graphics, such as line graphs, bar charts or pie charts were increasingly used. Popular media such as newspapers, almanacs and magazines carried pictorial statistics to appeal to a customer base. Alongside an increased use of information graphics for formal or informal learning, theories of graph comprehension were developed.

Brief examples were given in Chapter II of basic theories of graph comprehension. Real-world designers of information graphics seldom consult graph comprehension theories or the research that supports them. This is partly because graph theories tend to be densely written with terminology foreign to graphic arts practitioners or to laypersons who may design graphs or charts using templates provided by common
Thus, tenants of graph theory and research findings or visual theory and research evidence rarely shape real world design.

Today’s scholars may believe scientific proofs or theories underwrite current visual instruction in all forms, including information graphics. It is apparent there have been numerous, earnest efforts by researchers to discover the ways visual cognition operates or how to design instructional imagery for optimal learning. However, research findings likely have a lesser influence on real-world design of visual instruction than other factors. The argument that much of visual instruction and information design has been guided by opinion rather than empirical evidence has been supported in this study.

**Purpose Two**

Visual and data display designs for instructional media are not, as many assume, informed by current empirical research so much as they are based on *mediation* by the earlier mentioned four determinant forces. It is important to recognize the formidable roles these factors play in determining the kinds of information graphics and images that are prevalent in instructional media. Questions about how data displays should look were publicized within scientific and academic communities during the 1990’s when the Tufte-Holmes debate emerged.

There was little, if any, scientific evidence to support Tufte’s contention that minimalist information graphics were superior to pictorial statistics for clarity, accuracy or learning. He offered a well-articulated argument in the form of books, seminars and articles to a community of experts. His arguments, like those of many others, assumed a general visual learner with equivalent abilities, given the same basic demographics such as age and level of education, to decipher minimalist information graphics. This ignored
individual differences that had been widely studied in context of field dependent-field independent cognitive style. As a case in point, FDI cognitive style studies since mid-1900’s suggest that as many as half of all learners will have difficulty detecting salient parts of a whole visual field—an individual difference which is certainly salient to the design of information graphic displays for learning purposes, yet one of hundreds of differences that have not informed the design (and empirical testing) of information graphics.

The second purpose of this study, therefore, was to test what impacts visual communication have on FDI learners. FDI cognitive style has been rigorously tested and corroborated by thousands of studies under vastly differing conditions since the post-WW II era. Witkin, for example, as a pioneer in FDI research, was a model investigator who used multiple, diverse methods to study FDI and validate FDI as a cognitive style.

The rise of unsupported principles in visual design has been in the wake of an eikoncentric era when visual information has been extensively incorporated into instruction. This has probably exacerbated negative impacts on those who may be disadvantaged by such practices. Although it is commonly accepted in education that teachers do not teach to a general READER, individual visual perception and learning differences have seldom been considered.

The second purpose of the study was to investigate how FDI cognitive style influences the way learners understand and aesthetically assess information graphics. In light of this, the Tufte-Holmes debate was of particular interest to the study. By incorporating FDI into an empirical research design, this study was meant to add data to
rare studies that *have* researched effects of minimalism or pictorial embellishment on comprehension, preference and perceived efficacy for information graphics by learners.

**Research Questions and Design**

Research Question 1, “What is the relationship between FDI and comprehension of minimalist information graphics, pictograms, or infographics?” was answered by through objective measures of comprehension of facts. The second research question, “What is the relationship between FDI learners and their aesthetic ratings for minimalist information graphics, pictograms, or infographics?” was investigated learners’ through subjective ratings for perceived efficacy, preference and perceived value for information graphics

It was expected that field dependent (FD) learners, consonant with FDI cognitive style trait descriptions, would have greater difficulty disembedding salient cues from a more detailed data display. Therefore, their comprehension scores would be highest when interpreting minimalist information graphics. However, it was also thought pictorial statistics could potentially enhance learning for some FD learners because of an association of pictures with popular media, consistent also with dual coding theories. One of the qualities of FD learners is that they tend to have “social” personalities. It was thought they might consequently learn better from popular media like infographics rather than from abstract minimalist line work found in minimalist information graphics. Field independent (FI) learners were expected to comprehend all information graphics equally well given their native abilities to disembed salient cues from a complex field.

To test these research questions, the researcher provided three different versions of information graphics, each depicting the same information: minimalist information
graphics (e.g., Tufte-type information graphics), pictograms (e.g., minimalist information graphics with pictorial elements in place of lines and bars) and infographics (Holmes-style information graphics). Three out of six infographics were infographics created by Holmes and used with his permission. The pictographs and minimalist information graphics were created from the infographics to ensure content equivalence and in recognition that these forms of information graphics are difficult to generate. Each type of information graphic was presented to one of three different groups comprising FD and FI learners in equal measure for a between groups measure of comprehension and aesthetic preferences. At the end of the survey (e.g., after experiencing and answering questions about the type of information graphics in their condition, each participant was also presented with three sets of three infographics depicting the same information (minimalist, pictogram, infographic) and asked to rate them in comparison to each other for a within-subjects comparison of aesthetics.

Findings

Research Question 1: Information Graphic Comprehension

Research Question 1 asked, “What is the relationship between FDI and comprehension of minimalist information graphics, pictograms, or infographics?” Based on the result of this study, there are four premises that can be deduced or inferred regarding this research question, each of which will be discussed individually, below. As additional premises are articulated for research question 2, some of these premises will inform and contextualize later premises.

1. FD learners are disadvantaged by infographics;
2. FI and FD learners appear to do equally well with minimalist and pictograms; 

3. FI learners can be successful across a range of information graphics but may experience “expertise reversal” effects when viewing minimalist information graphics; 

4. FD learners can be successful with both minimalist information graphics and pictograms but may experience pictorial elements as increased extraneous cognitive load, 

The results of this study suggest that FD learner comprehension scores tend to decrease as pictorialization increases, and that FI learner comprehension tends to increase as pictorialization increases. Differences in comprehension were statistically significant between FD comprehension of infographics and FI comprehension of infographics. Further, FD learners scores were highest in minimalist conditions, and lowest in infographic conditions; FI learners were the opposite. What reasons for this result can be offered?

As earlier mentioned, an FD learner cannot easily disembed a figure from a complex array and perceives a field globally and as a relatively inseparable whole (Goodenough, 1976; Jonassen & Grabowski, 1993; Wooldridge, 1995; Tinajero, Castelo, Guisande & Páramo, 2011). This FD learner difficulty is thought to be a problem with limited visual differentiation (Witkin, Goodenough & Karp, 1967). Therefore, when more detail appears in a visual display, FD learners will be unable to differentiate salient visual information from extraneous detail. The display will be seen as a fused whole. The addition of detail, predictably thwarts comprehension because of these traits.
An FD learner not only uses a wholist strategy, perceiving all visual cues as equally relevant (Goodenough, 1976) but views visual displays without additional analysis (Tinajero, Castelo, Guisande, & Páramo, 2011). Therefore, an FD learner is less likely to persist in trying to find an answer if the answer is not immediately apparent. FI learners generally do not have difficulty disembedding information, and therefore may have been able to “ignore” or parse out the visual detail, which explains why their scores were (statistically speaking) not affected by the pictorialization.

Yet it is interesting to consider also the trend in comprehension scores across conditions for both FD and FI learners; down for FD learners and up for FI learners as pictorialization increased. It is easier to explain this trend for FD learners than for FI: Why would an increased degree of pictorial detail and metaphor also appear to increase FI comprehension of infographic scores if they are simply better at “ignoring” extraneous detail? This trend suggests that pictorialization may not be extraneous; that it can have some learning salience.

This can be accounted for by the concept of a multimodal metaphor (Forceville, 2002). As discussed in Chapter II, a multimodal metaphor is a visual metaphor that includes notational and visual elements to support a metaphor. Visual metaphor in advertising has been shown to increase viewer "attention, elaboration and pleasure"(Phillips, 2003, p.303). It has been demonstrated that learners will work to solve a metaphoric puzzle (Phillips, 2003) even when a target and source domain may initially seem incongruous. Using prior knowledge to generate "a simple inference that associates the two objects; if no simple inference can be found, consumers will entertain alternatives"(Phillips, 2003, p.303). This is a finding that has been replicated in learning
as well—metaphors can be an effective learning “shortcut” to making connections between ideas (e.g., tenor and vehicle). Learner attention is maintained through engagement in puzzle solving that triggers processes of inference and elaboration. When a puzzle is solved, learners experience pleasure in their accomplishment. Therefore, it is possible that the metaphoric design of the infographics contributes to learning, but in a way that only FI learners can decode.

Alternatively, it is possible that FI learners found commonplace minimalist information graphics boring and hardly worth inspection. Based on this premise, they may have answered comprehension questions too quickly and therefore inaccurately. Pictorial statistics and particularly infographics with an embedded metaphor, on the other hand, presented more visual information and a puzzle to be solved. This scenario would be one of interest to FI learners but would be daunting for FD learners who, as passive spectators (Tinajero, Castelo, Guisande, & Páramo, 2011) would find it difficult to become engaged with and persist in solving a visual puzzle. As we will see later, however, this is somewhat at odds with FD and FI learner expressed preferences for the different types of information graphics.

Expertise reversal effect may also help explain FI comprehension scores that were lower than those of FD learners for minimalist information graphics (Kalyuga, Ayres, Chandler & Sweller, 2003). Expertise reversal effect occurs because of the imposition of extraneous cognitive load through instruction that affects experts who have gained a significant level of domain knowledge. Experts develop schemas for knowledge that allow them to automatically approach a problem with at-hand information about how to solve it. However, when presented with information designed for novices, it can cause
cognitive overload because expert and novice schemas are very different. Any kind of instruction, including data displays, that help novices understand can become a disadvantage to experts (Kalyuga, Ayres, Chandler & Sweller, 2003). Because infographics are so common and involve metaphoric information, FI learners may have “expert” skills in infographic comprehension. Thus, when presented with the task of analyzing a simple minimalist information graph they may have struggled to interpret this “typical” form of information graphic.

**Research Question 2: Aesthetic Perceived Efficacy, Preference and Perceived Value.**

Aesthetic scores measuring perceived efficacy, preference for, and perceived values of information graphics were generated from responses to questions in both Part 1 (which presented different information graphics depending on what condition the learner was assigned to) and Part 2 of the Comparative Information Graphic Test (CIG-T) (in which all learners were exposed to the same forms of information graphics). Whereas Research Question 1 tested FDI learners for their objective measures of comprehension, aesthetics measured subjective reactions to information graphics. How would FDI affect these subjective responses?

**Null hypothesis 2.1** stated that learners would not differ in their overall aesthetic rating of minimalist information graphics, pictograms, or infographics. There was a statistically significant main effect for condition, suggesting learners rated minimalist information graphics (condition 1) the highest.

This finding, and the findings regarding Research Question 1, suggest the following premises regarding this research question:
• Learners rate the aesthetics of minimalist information graphics higher than infographics, regardless of FDI.

• Learners’ aesthetic ratings of information graphics may be inversely related to pictorial embellishment.

• Learners’ aesthetic ratings of information graphics do not necessarily reflect which ones they learn best from (i.e., FD learners learn best from minimalist and rate them the highest, but FI learners may learn best from infographics, yet rate minimalist information graphics the highest).

FD learners tended to have wider disparity in their overall rating for each type of information graphic in conditions, with pictorial representation resulting in lower ratings, consistent with their comprehension scores. Learners overall rated minimalist information graphics highest in ratings of preference and perceived value, yet FI learners appeared to learn better from infographics (although this difference was not statistically significant).

The premise that “learners’ aesthetic ratings of information graphics do not necessarily correspond to the ones they learn best” from is supported by comparison of comprehension scores and aesthetic ratings. When considering their comprehension scores, FD learners scored lowest on comprehension of infographics. This is not unexpected given their cognitive style and problems with differentiation. Aesthetic assessments, on the other hand, are subject to attitudes. Lower aesthetic ratings of infographics by FD learners that occurred, might be related to frustration they may have experienced when trying to comprehend and interpret detail-rich infographics. The presence of extra detail in an infographic coupled with FD visual differentiation problems could easily sponsor a subconscious conversion of extra detail into seductive detail. This
explanation is corroborated by choices made by FD learners for a “best information
graphic for learning” during Part 2 of the CIG-T. FD learners frequently (n = 21 out of 35
for “Winged Plight”; 26 out of 35 for “Funding Nemo”; 31 out of 35 for “Going Postal”;) selected minimalist information graphics or pictograms which both incorporate minimal to moderate detail.

Although FI learners tended to comprehended infographics and pictograms better than they did minimalist information graphics, their overall aesthetic ratings for pictograms (M = 81.61); and infographics (M = 78.55) were less than their highest overall rating of minimalist information graphics (M = 87.66) in conditions.

It may seem that FI learners would give higher ratings for infographics considering their facility in comprehending them. However, FI affinity for math and science (Witkin, 1973) may also predict they have higher aesthetic opinions of minimalist information graphs, which would appear with regularity in their instructional material, journals or other professional publications.

Examination of these FDI comprehension scores and aesthetic ratings support the premise that FD learners rate and learn from minimalist best. In tandem, although FI learners MAY learn best from infographics, their ratings of infographics are lower than their ratings of any other kind of information graphic, suggesting that minimalist information graphics are a good choice for both learners where it is not feasible to generate multiple versions.

**Null hypothesis 2.2.** Because there were no differences found in the aesthetic subscale for “efficacy,” the findings from this hypothesis suggest the following additional premise:
• The lower aesthetic ratings for information graphic types found in 2.1 may not be due to perceptions of efficacy, specifically.

**Null Hypothesis 2.3.** Because there was a difference in the aesthetic subscale score for “preference,” the findings from this hypothesis suggests the following premises:

- FD and FI learners tend to prefer the same types of information graphics
- FD and FI learners tend to prefer minimalist information graphics over those with pictorial elements
- The different in the overall aesthetic ratings detected in hypothesis 2.1 are at least partially due to preference.

**Null hypothesis 2.4.** Because statistically significant differences were found by condition for the aesthetic subscale for “value,” the findings suggest the following additional premises:

- FD and FI learners tend to value the same types of information graphics
- Learners tend to value minimalist information graphics over those with pictorial elements
- The aesthetic preferences detected in hypothesis 2.1 are at least partially due to value and preference rather than perceived efficacy.

Learners rated minimalist information graphics higher on “Perceived Aesthetic Value” than pictograms and infographics. Perceived aesthetic value ratings are not thought to be measures of liking, but measures of perceived credibility/trustworthiness of the data presented in the context of a display and/or the value for use of an information graphic in multiple settings. The valuation of minimalist information graphics over
pictorial statistical displays may suggest learners believe the plain truth is told by minimalist information graphics whereas pictorial displays are ‘less serious’.

As mentioned earlier, Goldsmith (1987) thought publishers were initially reluctant to incorporate pictures into adult reading material suspecting this was partly because “it was felt adults might be embarrassed to be seen in public with an illustrated reading book” (p. 53). Beyond the conflict of potential embarrassment, learners may also have valued minimalist information more because they are associated with the rhetoric of scientific and professional communities. In this way, minimalist information graphics are seen as communicating authoritative information.

Part 2. CIG-T testing. Null hypotheses 2.5 through 2.8 tested learner responses to aesthetic questions for three types of information graphic, each based on the same underlying data, presented simultaneously. Whereas learners in part one of the CIG-T only saw the form of information graphic specific to their condition, all learners simultaneously saw and rated all three types of graphics side-by-side in part two of the CIG-T.

All four hypotheses were evaluated with MANOVAs, none of which were statistically significant. This suggests the following premise relating to these hypotheses:

- FI and FD learners do not rate information graphic types differently when comparing them side-by-side.

and lends further support to the previous premise that “FI and FD learner preferences do not reflect which graphics they tend to learn best from.”

Null hypothesis 2.9. Although the statistical tests did not indicate differences, the findings from this hypothesis suggest the following premises:
FI and FD learners hold similar beliefs about which kinds of information graphics they will learn best from.

Learner beliefs about their ability to learn from different forms of information graphics are not related to their actual comprehension scores when learning from information graphics.

FDI participants were presented with three different versions of a minimalist information graphic, pictographic and infographic data display and were told:

“Data can be presented in different styles of graphs. Three versions of the same graph are shown below. You can see each one as a full-sized graph by clicking on the image. Choose the graph that you think you could learn BEST from.”

Although FD learners best comprehended minimalist information graphics, they selected either infographics or pictograms (48% of FD learners) almost as often as they selected minimalist information graphics for “Winged Plight;” Although FI learners appeared to learn best from infographics, only 23% of FI learners selected the infographic as the information graphic from which they could learn best for “Winged Plight.” This supports the premise that FI and FD learners hold similar beliefs about their ability to learn from information graphic types inasmuch as their choices did not rigorously adhere to the reality of their abilities in comprehension tests.

The second set of three information graphics titled “Funding Nemo” presented data about the cost of tropical aquarium fish. Again, participants were asked to choose the graph they thought they could learn best from. Nearly half of all FD learners (45.7%) selected the minimalist information graphic as the best information graph they could
learn from, although, it seems only this half were able to judge their own abilities
inasmuch as they learned best from a minimalist information graphic. Only 27% of FI
learners selected the infographic, from which they learned best. A majority of learners
selected the minimalist information graphic or the pictogram as the one they believed
they learned best from.

The third set of three information graphics, titled “Going Postal,” presented data
about the rising cost of postage stamps in the United States over a period of years.
Participants were asked to choose the graph they thought they could learn best from. This
single set of information graphics produced results unlike those in the previous examples.
Both FD and FI learners almost overwhelmingly selected the pictogram (FD=80%; FI=71
%) although, as has been stated before, nobody comprehended pictograms better. This
supported the premise that FI and FD learners hold similar beliefs about their ability to
learn from information graphic types and that learner beliefs about their ability to learn
from different forms of information graphics are not related to their actual comprehension
when learning from those different types of information graphics.

One explanation for these findings comes from the Dunning-Kruger effect
(Kruger & Dunning, 1999), which has empirically shown that novices tend to
overestimate their ability and knowledge, and that experts tend to estimate or slightly
underestimate their ability or knowledge.

Short answer themes. Short answers were thematically coded. Although the
length of some answers did not surpass a sentence, some participants wrote paragraphs
that compared and contrasted the information graphic they selected with the ones they did
not. Themes indicated both general and individualized sentiments among learners
regarding differing information graphic types. Choices of an information graph did not always relate to the goal of learning according to the report. The way an information graphic “looked” had more to do with assessment as was reported in the earlier thematic analysis. Aside from pictograms, FD learners seemed to be the most likely to choose a minimalist graph - which they did learn best from according to results in Part 1 of the CIG-T. The reason for this is probably because they are aware of their limitations in understanding embellished information graphics, they logically default to a choice to learn from a minimalist information graphic without clutter or distracting detail. FI learners as a group never selected an infographic as best to learn from, although this is the information graphic they most clearly comprehended. Inasmuch as FI learners are able to learn from a variety of information graphics, preference, perceived efficacy and value probably contributed to their choices more than issues of whether they could comprehend an information graphic.

Implications

Most FDI studies have proven durability and fixity of the FDI cognitive style. Even if we accept that intensive training could help FD learners gain the traits of FI learners, the idea that FD or FI learners can exit the confines of their cognitive style is unlikely. Each of us will retain our FD or FI cognitive style characteristics throughout a lifetime. Instructional designers need to seek ways to make visual learning accessible for all while realizing that at least some of research that guides practice may be confounded by non-recognition of FDI. If we accept that the style is real and that it affects the whole educational population, then effective visual aids for learning are more likely to be developed.
This study corroborated other empirical evidence that FDI cognitive style has meaningful impacts on the processing of text and imagery. FD learners had greater difficulty comprehending pictorially, detail-rich pictorial statistics than they did comprehending minimalist information graphics. The FD learner also seemed to show more accurate judgement in selection of minimalist information graphics or minimally enriched pictograms for best comprehension. Given their challenges in visual interpretation, they may have a better projection of the kind of trouble they may have understanding complex visual material. FI learners, whose selections seemed to be based on reasons alternate to comprehension, have greater luxuries in learning from an array of information graphics. Since they were probably capable of deciphering all the information graphics presented in the choice portion of Part 2 of the CIG-T, aesthetic dimensions of preference, perceived value and perceived efficacy possibly played the most significant role for their choices.

These differences have significant implications for FD learners. Implications are also significant for those who design learning materials for the 25–50% of the population who score on the FD side of the continuum. The advantage extreme FI learners had over extreme FD learners can be seen when the percentage of correct answers are converted to equivalent grades, from “A “to “F.” The standard percentage associated with school grades is 90–100% =A; 80–89%=B; 70–79% = C; 60–69 % = D; and 59% and lower = F (see Table 13). The scores of FI learners for all information graphics tended to cluster around a grade between a D and a low C (between 66% and 72%). The scores of FD learners when processing minimalist and pictogram information graphics was roughly equivalent to the performance of FI learners (between 67% and 69%). However, when
learning from infographics, FD learners’ performance was equivalent to a failing grade of F (58%). Put another way, the use of infographics for learning purposes has the potential to change the academic status of 25% of all learners from passing to failing.

Table 13.

**FDI comprehension scores and school grade based on standard percentage**

<table>
<thead>
<tr>
<th>FD Participants/Conditions</th>
<th>Mean comprehension score</th>
<th>Percentage correct out of 27 points</th>
<th>School grade based on standard percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition 1. minimalist information graphics</td>
<td>18.66</td>
<td>69.11%</td>
<td>D</td>
</tr>
<tr>
<td>Condition 2. pictograms</td>
<td>18.11</td>
<td>67.07%</td>
<td>D</td>
</tr>
<tr>
<td>Condition 3. infographics</td>
<td>15.72</td>
<td>58.22%</td>
<td>F</td>
</tr>
<tr>
<td>Total mean comprehension</td>
<td>17.60</td>
<td>65.18%</td>
<td>D</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FI Participants/Conditions</th>
<th>Mean comprehension score</th>
<th>Percentage correct out of 27 points</th>
<th>School grade based on standard percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition 1. minimalist information graphics</td>
<td>18.00</td>
<td>66.66%</td>
<td>D</td>
</tr>
<tr>
<td>Condition 2. pictograms</td>
<td>19.38</td>
<td>71.77%</td>
<td>C</td>
</tr>
<tr>
<td>Condition 3. infographics</td>
<td>19.45</td>
<td>72.03%</td>
<td>C</td>
</tr>
<tr>
<td>Total mean comprehension</td>
<td>18.50</td>
<td>68.51%</td>
<td>D</td>
</tr>
</tbody>
</table>

FDI cognitive style is seen as value neutral, or in other words, a style that is not indicative of intelligence but rather, unipolar and indicative of traits that work well in some situations but not in others (Witkin, 1973). However, given the rise of imagery in the eikonocentric era, a sizable portion of learning situations may disadvantage FD
learners, as indicated by consistent findings that FD learners tend to struggle, academically (e.g., McKenna, 1984). Furthermore, low scores across all conditions by both FD and FI learners argues against a “natural” visually literacy in either FD or FI learners. This raises the question of what other individual differences may exist (given other forms of visual learning materials).

Recognition of authentic differences in visual cognition become very important in an era when stand-alone information graphics or other visual material may act as the only provision for learning. Strategies need to be developed for design of visual material that will make the most sense for all so that a great portion of the learner population is not marginalized and disadvantaged in contemporary learning.

Implications for the design of visual instruction.

Regarding the design of visual instruction for field-dependent learners, there are several implications that can be derived both from the field of research and from this study in particular.

**Implications from the field.** “The field dependent/global learner has a short attention span, is easily distracted, and likes informal learning situations” (Wooldridge, 1995, p. 51). Accordingly, the types of informal learning visual displays that appear in familiar, popular media may engage and lengthen the attention span of an FD learner who is “sensitive to social cues without being alerted to them” (Wooldridge, 1995, p. 51). FI learners have longer attention spans, prefer formal learning to informal learning and can draw from a pool of information sources (Woolridge, 1995). They may be familiar with various kinds of visual displays associated with formal math or science instruction since they often express early academic interest in these fields of study. They are more likely
and able to re-conceptualize visual displays whereas FD learners tend to use visual displays, and any other instructional material, as opportunities to accrue information encoding “the information in their own memories as it is presented without reorganization, restructuring, or revision” (Jonassen & Grabowski, 1993, p. 87).

Because FD learners do not share the ability of FI learners to restructure or recombine elements in a visual field, they require well-organized, structured visual displays for learning. “In particular, it has been suggested that those illustrations, texts, presentations and general learning tools which do not offer a clear structure will present a greater difficulty to extremely field-dependent subjects” (Tinajero, Castelo, Guisande & Páramo, 2011, p. 498). Organization of visual material that highlights the most important features or message in a visual display may be essential for FD learners since they tend to “take information exactly as it is presented to them” (Tinajero et al., p. 498).

Furthermore, FD learners who attend to the most interesting (salient) details in a visual display may be particularly susceptible to the seducing effects of extraneous embellishments that constitute seductive detail.

**Implications from this study.** Results for comprehension in this study corroborated other evidence that FD learners have greater difficulty than FI learners when interpreting detailed, information graphics, such as infographics. Infographics contain both pictorial detail and metaphor making them information rich, complex, and more attuned to interpretation by an FI learner who is better able to extract salient cues from detailed visual material. Both FD and FI learners are generally successful at comprehending minimalist information graphics. One solution, therefore, is to confine instruction to the use of minimalist information graphics, which may operate as universal
learning tools. This solution has limited value for learners, however. It may meet the needs of extreme FD learners, but may disaffect others when it does not challenge or engage them.

A better approach to visual instruction is to first decide if use of an information graphic is necessary or useful. This may seem obvious, but in an eikoncentric era imagery may be overvalued - and the addition of imagery or information graphics may not elucidate instructional content. Quantifiable concepts, for example, may be basic but also quite complex and will need more than an information graphic to explain their depth.

When an information graphic is used and incorporates imagery, the instructional designer should question if and how imagery is appropriately connected to data. Infographics often use metaphor to enrich the point it demonstrates with data. However, use of decorative or metaphoric imagery that is distantly related to data—such as a picture of a baseball flying through the air when data communicates the increasing average speed of drivers on highways—can promote confusion. It could also operate as seductive, rather than salient detail.

When an information graphic clearly organizes data and provides structure, this may help FD learners who find it difficult to structure information on their own. When considering how to structure an information graphic, well-tested principles such as the “contiguity principle” articulated by Clark and Mayer (2011) should be included in design to assist clarity of visual organization. The contiguity principle indicates that text (or labels or data markers) should be co-located with the image it describes. This can not only work well in print material, where data markers or other labels can be integrated with pictorial content (as long as it does not create visual clutter) but could be very
successful in E-learning. Learners could be given control to add or remove detail when an information graphic is displayed electronically. As earlier stated, call-out boxes or other captions or labels could be clicked on to explain each part of an information graphic, for example. Other learning enhancing detail could be added or reduced under learner control. Options such as these allow each FDI learner to customize their own learning.

Control over detail allows an FD learner, in particular, to avoid extraneous cognitive overload via seductive or unnecessary detail in a visual display. Extraneous cognitive load has an impact on learners when, through too much detail, a visual design cannot make the distinction between salient elements.

A picture is not worth a thousand words for everybody. Future research is needed to further establish the parameters by which FD and FI learners are impacted by various information graphic displays and elements. Until and if that research shows otherwise, it would seem that designers of learning materials should privilege minimalist information graphics over other forms so that FD learners are not disadvantaged.

**Limitations**

The limitations of this study were first, among any other, the size of the study population. This study enrolled 79 participants with an uneven, although random, distribution across conditions. A study population of this size makes it difficult to generalize. When outliers were detected, these cases were kept with scores counted in tests. Only one of the outliers exceeded the critical value on the Chi-square table. These outliers were not dismissed because it was thought that in a larger study population these outlier scores might not act as outliers, but simply represent a normal range of values.
Furthermore, this was the first time with a new instrument this study was performed. The Comparative Information Graphics Test (CIG-T) was used for the first time in this study because it was developed for that purpose. Therefore, it cannot be established that the instrument is well-designed without further investigation. The “Going Postal” set of information graphics yielded very unexpected results wherein 72-80 % of all learners selected the pictographic version as the information graphic they could learn best from. This indicated that reasons for the overwhelming choice of a “Going Postal” pictogram over the other two information graphics should be researched before continued use.

Holmes’ infographics were examples of artwork that was produced during the 1980’s and 1990’s. These infographics represented issues and ideas that are not necessarily contemporary. The three sets of infographics generated by the investigator with help of a commercial artist, in addition, should probably been screened before further use. They were created according to design guidelines and practices familiar to both designers, but not according to empirical evidence (of which little exists). The accuracy of some information graphics was questioned by some FI learners.

Notably, it was difficult to recruit a larger population because only extremely FD or FI learners were invited to take the CIG-T. These participants also had to be willing to take two tests-first the GEFT to qualify or disqualify them from Phase 2 of the study. Then they were required to take the CIG-T. The CIG-T probably took each participant more than 30 minutes to complete, which represented a significant commitment of time. There is really no way around identifying where a learner falls on the FDI spectrum, but two-phase studies make recruitment difficult.
A final stated limitation is of the type that plagues all visual research. There are many types of visual representations and it is often as difficult to compare an apple to an orange as it is to compare one information graphic to another. The variety of graphic characteristics from color to artistic style influences the results of research. articulated over the past fifty years. As earlier stated, problems with visual research “may reflect to some degree the difficulty and complexities of the research and theory construction problems” (Carifio & Perla, 2009, p.404). Because a wide variety of differing images are studied in context of different tasks or under unlike conditions, contradictory research findings about visual cognition or optimal visual instruction designs can stem from lack of apt comparisons (Levie, 1987; Carifo &Perla, 2009; Wright, Milroy& Lickorish,1999).

As was earlier stated, textual or reading research has its own complications, surely, but also has the advantage of the use of a codified alphabet that does not vary except in font styles and size or spatial organization of text. However, studies about the effect of seductive detail, for example, could be undertaken using diagrams, graphs, realistic pictures or maps. Any of these studies could require participants to accomplish different cognitive tasks in the guise of interpreting visual material. Scaife and Rogers (1996) noted, “past research spans a wide area from map design to technical illustration to the value of pictures for children learning science, with a mélange of methodologies, explanatory frameworks and mechanisms” (p.187). Therefore, it becomes very difficult to isolate the characteristics of an information graphic so one can be produced for repeated studies and the ability to generalize based on those findings.
Future Research Opportunities

This study represented an early attempt to examine the reception and interpretation by FDI learners of information graphics. As was earlier stated in the limitations section of this dissertation, a small population of 79 is not ideal for testing. Furthermore, although it was felt that the design for this study was sound, this study selected only extremely field dependent or field independent learners as participants. Research examining three groups of FD learners by incorporating field-neutral participants might finesse understandings, not only about cognitive style, but also about the type of visual instruction that is most likely to accomplish learning. Alternatively, treating FDI as a continuous variable (e.g., including all learners) would allow for additional measures of prediction (e.g., regression). The CIG-T can be used as a starting point, at least, for new research into information graphic design, however the instrument needs additional validation and testing.

Comprehension and choice were a part of this study wherein learners were able to choose the information graphic they thought would be best for their own learning. Although most of the measures in the CIG-T were quantified, qualitative studies would be valuable for identifying reasons learners choose to learn from one graphic or another. This study demonstrated to a small extent that learners do not always choose to learn from an information graphic that has been optimal for their own learning. A qualitative study could give more traction to understanding reasons learners choose specific information graphics over others and may be helpful to development of an excellent instrument for further research.
Eye-tracking studies that adopt a similar methodology to the scanpath study using a naturalistic newspaper reading task by Holsanova, Holmberg and Holmqvist (2008) are recommended to investigate the way different FDI learners inspect information graphics. Understanding the patterns FD learners and FI learners use could suggest ways to train FD learners to process infographics. Promising research in reading comprehension and ocular-muscular movements has shown that the ability to track words across a page can be improved through specific eye-training exercises—it is possible that the same could be true for some FD learners.

Future research should also consider what the optimal amount of detail is in an instructional graphic for FDI learners, and for different learning outcomes. Research on seductive detail could provide a good starting point in this regard. While extraneous cognitive load/seductive detail suggest that meaningless detail be avoided, what happens when detail is necessary—at what specific point do FD and FI learners become overwhelmed? Different types of information graphics with different levels of detail could be used to measure the amount of time and/or effort needed by FDI learners to successfully comprehend/interpret the data embedded in a display. FD learners may be at a disadvantage in interpreting information graphics as detail increases.

Similarly, the inclusion of metaphorical information should be studied for its contribution to learning. What design parameters guide the creation of metaphor, and for what purpose? Well-designed infographics may embed metaphor in a way that speeds up comprehension of “the big picture” in the data, as has been suggested by dual-coding theory. Such uses could theoretically overcome FD-FI learner comprehension of at least
the main concepts in an infographic. Alternatively, well-designed metaphoric content
could help lead learners (both FD and FI) through highly complex ideas and concepts.

Conclusions

This study investigated comprehension and aesthetic perceptions of different
kinds of information graphics at a time when instructional and professional media are
filled by data representations. A student, professional or someone who needs to determine
how much residential electricity they have used in a heating season will encounter
numerous kinds of information graphics in their lives. Because data displays are so
prevalent in society’s media, the need to interpret and comprehend information graphics
has become increasingly important. Studies of the FDI cognitive style have demonstrated
that FD learners are often disadvantaged when it comes to interpreting visual displays. It
is especially difficult for these learners to decipher detail-rich visual information. FDI
cognitive style has been characterized as “value neutral. “: Value neutral means that as
FD or FI learner type may work to an advantage or disadvantage in context of a given
situation and neither set of FDI characteristics can be considered good or bad. It has been
considered a cognitive style without impunity. However, considering the difficulties that
arise for an FD learner in an eikoncentric society at a time when instructional (formal and
informal) material are filled by visual displays, it does seem disabling.

Unsurprisingly, FD learner comprehension scores for minimalist information
graphics were highest numerically, their comprehension scores for infographics lowest
numerically, and those comprehension scores for infographics were significantly lower
than those of FI learners. When asked what information graphic they thought would be
best for learning, many chose the minimalist information graphic for the reason that it
was simple and did not include distracting details leading to confusion. Pictograms contributed minor detail to a display which was appreciated by FD learners because the pictogram had more visual appeal than the minimalist information graphics. More importantly, the data markers and labeling in a pictogram were not always found on minimalist information graphics but were very beneficial to FD learners for clarifying meaning.

FI learners who are thought to be capable of comprehending any information graphic with relative ease, had lower comprehension scores for minimalist information graphics than FD learners. They scored highest on information graphics and higher on pictograms. This was somewhat surprising given the relatively straightforward visual cognition processing that takes place when interpreting a simple, minimalist information graphic. However, it was posited that these lower measures of comprehension for FI learners were the result of the non-existence of a multimodal metaphor in minimalist information graphics and the presence of one in infographics. The expertise-reversal phenomena was also considered a reasonable explanation for lower comprehension scores on minimalist information graphics.

FD and FI learners were not dissimilar in their reasons for choosing a best information graphic to learn from. Their many different reasons for choosing one over another could be related to preference or perceived value or efficacy, but their choices were justified in much the same way. However, FD learners tended to choose minimalist information graphics unless they were too boring or lacked explanatory markers and lines in which case they chose pictograms. FI learners often reverted to the choice of a minimalist information graphic, even though in conditions, their comprehension score
was numerically lowest for these. FD learners more quickly chose minimalist information graphics or pictograms. It may have been out of the knowledge they would be unnecessarily frustrated by a complicated information graphic—which seems like more of a disorder than a value neutral cognitive style.

Despite thousands of existing studies, it is important to launch research on FDI cognitive style for the sake of those who are immersed in an eikoncentric era where instruction becomes increasingly visual and have value neutral issues with deciphering something as simple as a utility insert. As visual instruction becomes more prevalent in media and textbooks, solutions for design of information graphics should be encouraged based on consideration of cognitive style. There is not a general universal visual learner with equivalent skills in deciphering visual information.
APPENDICES

Appendix A

CIG-T Part 1 and Part 2

CIG-T Part 1 demographics and preliminary questions. All CIG-T participants completed the demographics/ preliminary questions section below.

- Thanks for participating in this study about graphs and charts. Your help is very much appreciated.
- Before beginning, please answer a few questions about yourself.
- Your name and email will NOT be published at all. This information will help identify your results and allow us to contact you if needed.

- What is your email address? *(PLEASE USE THE SAME EMAIL ADDRESS YOU USED FOR THE FIRST TEST)*

- What is your age?

- What is the highest level of education you have completed:
  - High School
  - Bachelor Degree
  - Master Degree (MA or MS) or Advanced Professional Degree (Law Degree, etc.)
  - PhD
  - MD
<table>
<thead>
<tr>
<th>Question</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are you currently enrolled in college or university?</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>No</td>
</tr>
<tr>
<td>What is your class status?</td>
<td>Freshman</td>
</tr>
<tr>
<td></td>
<td>Sophomore</td>
</tr>
<tr>
<td></td>
<td>Junior</td>
</tr>
<tr>
<td></td>
<td>Senior</td>
</tr>
<tr>
<td></td>
<td>Enrolled in Graduate School</td>
</tr>
<tr>
<td>What major have you declared?</td>
<td></td>
</tr>
<tr>
<td>(If you have not declared a major, what major are you considering?)</td>
<td></td>
</tr>
</tbody>
</table>
Which statement fits you best?

- I am the first person in my family to attend college
- At least one of my parents or someone who helped raise me attended college

Condition: I am the first person in my family to attend college

Select the statement that best represents the amount of college education achieved by each of the people who helped raise you during childhood/adolescence.

If a category does not apply, leave it blank.

<table>
<thead>
<tr>
<th>Education Level</th>
<th>Father</th>
<th>Mother</th>
<th>Other person who helped you</th>
<th>Other person who helped raise you</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Some college</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Associate Degree</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Bachelor Degree</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Master Degree or advanced professional degree</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Doctoral Degree</td>
<td></td>
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</tr>
</tbody>
</table>

How would you describe your ethnic background? (Choose all that apply)

- White
- Black or African American
- American Indian or Alaska Native
- Asian
- Latino
- Other (Please Explain)
- Prefer not to answer

What is your gender?

- Male
- Female
- Other (Please Explain)
On a scale from 1 to 10, how familiar are you with this kind of graph? Slide the bar from the left.

Believers Around the World
Size of Major World Religion Adherents by Percentage in 2012

On a scale from 1 to 10, how familiar are you with this kind of graph? Slide the bar from the left.
HOW MANY AMERICANS WANT GENETICALLY MODIFIED FOOD

On a scale from 1 to 10, how familiar are you with this kind of graph? Slide the bar from the left.

What is this image? Click on the most appropriate answer.

A Histogram  A Bar Graph  A Line Graph  A Scatterplot
What is this image? Click on the most appropriate answer.

A Histogram  A Bar Graph  A Line Graph  A Donut Chart

What is this image? Click on the most appropriate answer.

A Donut Chart  A Scatterplot  A Line Graph  A Histogram
### Domain Knowledge

**R9** On a scale from 1 to 10, rate how much do you know about each of the following subjects?

<table>
<thead>
<tr>
<th>Subject</th>
<th>Nothing</th>
<th>A Little</th>
<th>A Lot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butterflies</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diamond Values</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Campaign Spending in the USA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Postage Stamps</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugar Consumption</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Tropical Fish</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Household Energy Consumption</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseball History</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Cosmetics Industry</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Worldwide Religions</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Tree Frogs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Automobile Safety Ratings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foreign Policy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bees</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Part 1: Conditions 1, 2 and 3

Below are the questions participants in Conditions 1, 2 and 3 answered.

Condition 1
When you are finished looking at this graph click on the NEXT button to answer questions. Remember---once you click on the NEXT button, you cannot return to the graph.

Diamonds Were A Girl's Best Friend
Average price of a one carat D-flawless

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Price in Dollars</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3000</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>4000</td>
<td></td>
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<tr>
<td>5000</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>6000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

How much do you trust the information in this graph?

Choose one:
Not at all  
Very little  
No opinion  
Somewhat  
Completely
Rate the graph.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly agree</th>
<th>Somewhat agree</th>
<th>Neither agree nor disagree</th>
<th>Somewhat disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information was clearly communicated in the graph.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I enjoyed looking at this graph.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>This is the type of graph I like to look at when I am learning something.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>The line in the graph was extremely important to me for understanding its meaning.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>The text in the graph was extremely important to me for understanding its meaning.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

Explain the meaning of the graph in your own words.

What point did this graph try to make? Choose the best answer below.

- Diamonds always hold their value
- Diamonds used to be worth more and were a better investment until prices fell
- Only rich women can afford diamonds
- Diamonds are only for show but have never been as valuable as people think
- The graph just presented information without making a point
What did this graph demonstrate? Choose the best answer below.

- Diamond prices have steadily increased over a period of years
- Diamond prices have steadily decreased over a period of years
- Diamond prices went up and then down over a period of years
- Diamond prices went down and then up over a period of years
- The number of women buying diamonds each year has steadily increased over a period of years
- The number of women buying diamonds each year has steadily decreased over a period of years
- The number of women buying diamonds each year went up and then down over a period of years
- The number of women buying diamonds each year went down and then up over a period of years

What was the title of this graph?

- Diamonds Overseas and at Home
- Diamonds Were a Girl’s Best Friend
- The Rising Cost of Diamonds
- Diamond Rings: Changing Values

What did numbers on the x-axis (the horizontal column of numbers) represent on this graph?

- Years
- Costs in Millions
- Costs in Dollars
- Number of Diamonds Sold
What did the numbers on the y-axis (the vertical column of numbers) represent on this graph?

- Years
- Costs in Millions
- Costs in Dollars
- Number of Diamonds Sold

On a scale from 1 to 10, rate how well all parts of the graph worked together to make a single message.

Not at All Well

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>

Not at all well
When you are finished looking at this graph click on the NEXT button to answer questions.

Remember—once you click on the NEXT button, you cannot return to the graph.

Monstrous Costs
Total House and Senate Campaign Expenditures in Millions

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Millions of Dollars</td>
<td>0</td>
<td>50</td>
<td>100</td>
<td>150</td>
<td>200</td>
<td>250</td>
</tr>
</tbody>
</table>

How much do you trust the information in this graph?

Choose one

<table>
<thead>
<tr>
<th>Not at all</th>
<th>Very little</th>
<th>No opinion</th>
<th>Somewhat</th>
<th>Completely</th>
</tr>
</thead>
<tbody>
<tr>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>

367
Rate the graph.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly agree</th>
<th>Somewhat agree</th>
<th>Neither agree nor disagree</th>
<th>Somewhat disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information was clearly communicated in the graph.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I enjoyed looking at this graph.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>This is the type of graph I like to look at when I am learning something.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The line in the graph was extremely important to me for understanding its meaning.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The text in the graph was extremely important to me for understanding its meaning.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Explain the meaning of the graph in your own words below.


What point did this graph try to make? Choose the one best answer.
- Housing in Washington DC is ridiculously high priced
- Congressmen are monsters
- Tax levies are out of control
- The cost of federal campaign spending has escalated monstrously
- The graph did not have a point. It just had information

What did this graph demonstrate? Choose the best answer below.
- The cost of paying white house employees got out of hand over a period of years
- Housing in Washington DC became much more available as the years went on
- Political campaign spending increased greatly over a period of time
- The federal tax rate continued to increase until it was higher than ever before
- Housing in Washington DC became less available over a period of years
- Salaries for senators and representatives in Washington DC increased so much, they became outrageous
- A greater percentage of senators and representatives relied on campaign funds to make a living than ever before

What was the title of this graph?
- Eating Up Tax Payer Dollars
- Federal Tax Bites
- Monstrous Costs
- High Cost of Paying White House Employees
What did numbers on the x-axis (the horizontal column of numbers) represent on this graph?

- Years
- Costs in Millions
- Tax Assessments
- Houses Sold in Washington DC

What did the numbers on the y-axis (the vertical column of numbers) represent on this graph?

- Years
- Costs in Millions
- Tax Assessments
- Houses Sold in Washington DC

On a scale from 1 to 10, rate how well all parts of the graph worked together to make a single message.
When you are finished looking at this graph click on the NEXT button to answer questions. Remember--- once you click on the NEXT button, you cannot return to the graph.

THE COSMETICS DOLLAR
WHERE IT GOES

- Promotion: 10¢
- Packaging: 11¢
- Pretax Profit: 10¢
- Ingredient: 8¢
- Interest & Other: 5¢
- Retailer Heat, Lights, Salaries, Wages & Profits: 60¢

How much do you trust the information in this graph?

Choose one: not at all, very little, no opinion, somewhat, completely.
Rate the graph.

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Somewhat agree</th>
<th>Neither agree nor disagree</th>
<th>Somewhat disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information was clearly communicated in the graph.</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>I enjoyed looking at this graph.</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>This is the type of graph I like to look at when I am learning something.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The segments were extremely important to me for understanding its meaning.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The text in the graph was extremely important to me for understanding its meaning.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Explain the meaning of the graph in your own words.

What point did this graph try to make? Choose the best answer below.

- Cosmetics cost too much
- Manufacturers are trying to hike up their share of the cosmetic dollar
- Retailers account for the majority of costs in cosmetic spending
- Cosmetic ingredients have become unaffordable
- It did not try to make a point. It just showed information
What did this graph demonstrate? Choose the best answer below.

- More cents in a dollar are spent on cosmetics promotion than any other category
- How many cents from every dollar is spent on cosmetics manufacturing and retail
- The trend toward higher retail costs of cosmetics is ongoing
- Making cosmetics is not as expensive as people might think
- Cosmetics ingredients are the most expensive part of making and selling cosmetics
- It costs about a dollar to manufacture and sell cosmetics
- Cosmetics manufacturing costs have really gone down over time

What was the title of this graph?

- Cosmetics in the Store
- The High Cost of Lipstick
- The Rising Cost of Cosmetics
- The Cosmetics Dollar

The least cents per dollar is spent on which cosmetics cost category?

- Ingredients
- Pretax profit
- Retail rent, light, salaries, wages & profit
- Interest & other
- Salaries & wages
Condition 2.

It is important to read the instructions carefully before you look at charts or graphs and answer the questions. You will answer questions about three charts or graphs. You can take as much time as you want to look at a chart or graph BUT...

Once you click the NEXT button you CANNOT return to the chart or graph to look at it again.

This survey should take about 30 minutes to complete.

If you are ready to start, click on the NEXT button below.
When you are finished looking at this graph click on the NEXT button to answer questions.

Remember--- once you click on the NEXT button, you cannot return to the graph.

Diamonds Were A Girl's Best Friend
Average price of a one carat D-flawless

| Years | 1978 | $25000 | 1979 | $28000 | ... | 1980 | $25000 | ... | 1981 | $25000 | ... | 1982 | $12000 |
|-------|------|--------|------|--------|-----|------|--------|-----|------|--------|-----|--------|
|       |      |        |      |        |     |      |        |     |      |        |     |        |

Average Price in Dollars

$10,000 per diamond ring

How much do you trust the information in this graph?

<table>
<thead>
<tr>
<th>Choose one</th>
<th>Not at all</th>
<th>Very little</th>
<th>No opinion</th>
<th>Somewhat</th>
<th>Completely</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>
How much do you trust the information in this graph?

Choose one

Rate the graph.

<table>
<thead>
<tr>
<th>Information was clearly communicated in the graph.</th>
<th>Strongly agree</th>
<th>Somewhat agree</th>
<th>Neither agree nor disagree</th>
<th>Somewhat disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I enjoyed looking at this graph.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>This is the type of graph I like to look at when I am learning something.</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>The number of diamond rings in the graph was extremely important to me for understanding its meaning.</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>The text in the graph was extremely important to me for understanding its meaning.</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
What point did this graph try to make? Choose the best answer below.

- Diamonds always hold their value
- Diamonds used to be worth more and were a better investment until prices fell
- Only rich women can afford diamonds
- Diamonds are only for show but have never been as valuable as people think
- The graph just presented information without making a point

What did this graph demonstrate? Choose the best answer below.

- Diamond prices have steadily increased over a period of years
- Diamond prices have steadily decreased over a period of years
- Diamond prices went up and then down over a period of years
- Diamond prices went down and then up over a period of years
- The number of women buying diamonds each year has steadily increased over a period of years
- The number of women buying diamonds each year has steadily decreased over a period of years
- The number of women buying diamonds each year went up and then down over a period of years
- The number of women buying diamonds each year went down and then up over a period of years

What was the title of this graph?

- Diamonds Overseas and at Home
- Diamonds Were a Girl’s Best Friend
- The Rising Cost of Diamonds
- Diamond Rings; Changing Values
What did numbers on the x-axis (the horizontal column of numbers) represent on this graph?
- Years
- Costs in Millions
- Costs in Dollars
- Number of Diamonds Sold

What did the numbers on the y-axis (the vertical column of numbers) represent on this graph?
- Years
- Costs in Millions
- Costs in Dollars
- Number of Diamonds Sold

On a scale from 1 to 10, rate how well all parts of the graph worked together to make a single message.

Not at All Well

Not at all well
When you are finished looking at this graph click on the NEXT button to answer questions.

Remember--- once you click on the NEXT button, you cannot return to the graph.

### Monstrous Costs
Total House and Senate of Campaign Expenditures in Millions

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td></td>
<td>300 Million</td>
<td>250 Million</td>
<td>200 Million</td>
<td>120 Million</td>
<td>80 Million</td>
<td>60 Million</td>
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</tbody>
</table>

**Millions of Dollars**

---

**How much do you trust the information in this graph?**

<table>
<thead>
<tr>
<th>Choose one</th>
<th>Not at all</th>
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Rate the graph.

<table>
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<tr>
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<th>Strongly disagree</th>
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<tbody>
<tr>
<td>Information was clearly communicated in the graph.</td>
<td>○</td>
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<tr>
<td>I enjoyed looking at this graph.</td>
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<td>○</td>
<td>○</td>
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</tr>
<tr>
<td>This is the type of graph I like to look at when I am learning something.</td>
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<tr>
<td>The pictures in the bars were extremely important to me for understanding its meaning.</td>
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<tr>
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<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

Explain the meaning of the graph in your own words below.

What point did this graph try to make? Choose the one best answer.

- ○ Housing in Washington DC is ridiculously high priced
- ○ Congressmen are monsters
- ○ Tax levies are out of control
- ○ The cost of federal campaign spending has escalated monstrously
- ○ The graph did not have a point. It just had information

380
What did this graph demonstrate? Choose the best answer below.

- The cost of paying white house employees got out of hand over a period of years
- Housing in Washington DC became much more available as the years went on
- Political campaign spending increased greatly over a period of time
- The federal tax rate continued to increase until it was higher than ever before
- Housing in Washington DC became less available over a period of years
- Salaries for senators and representatives in Washington DC increased so much, they became outrageous
- A greater percentage of senators and representatives relied on campaign funds to make a living than ever before

What was the title of this graph?

- Eating Up Tax Payer Dollars
- Federal Tax Bites
- Monstrous Costs
- High Cost of Paying White House Employees

What did numbers on the x-axis (the horizontal column of numbers) represent on this graph?

- Years
- Costs in Millions
- Tax Assessments
- Houses Sold in Washington DC
What did the numbers on the y-axis (the vertical column of numbers) represent on this graph?

- Years
- Costs in Millions
- Tax Assessments
- Houses Sold in Washington DC

On a scale from 1 to 10, rate how well all parts of the graph worked together to make a single message.
When you are finished looking at this graph click on the NEXT button to answer questions. Remember--- once you click on the NEXT button, you cannot return to the graph.

THE COSMETICS DOLLAR WHERE IT GOES

Retailer Heat, Lights, Salaries, Wages & Profits .40c
Ingredients .08c
Ingredients .10c
Ingredients .10c
Interest & Other .02c
Packaging .15c
Promotion .10c

How much do you trust the information in this graph?

Choose one

<table>
<thead>
<tr>
<th></th>
<th>Not at all</th>
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<td>○</td>
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</tr>
<tr>
<td>The segments were extremely important to me for understanding its meaning.</td>
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<tr>
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<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

Explain the meaning of the graph in your own words.

What point did this graph try to make? Choose the best answer below.

- Cosmetics cost too much
- Manufacturers are trying to hike up their share of the cosmetic dollar
- Retailers get more money than anyone from cosmetic sales
- Cosmetic ingredients have become unaffordable
- It did not try to make a point. It just showed information
What was the title of this graph?
- Cosmetics in the Store
- The High Cost of Lipstick
- The Rising Cost of Cosmetics
- The Cosmetics Dollar

The least cents per dollar is spent on which cosmetics cost category?
- Ingredients
- Pretax profit
- Retail rent, light, salaries, wages & profit
- Interest & other
- Salaries & wages

The most cents per dollar is spent on which cosmetics cost category?
- Ingredients
- Pretax profit
- Retail rent, light, salaries, wages & profit
- Interest & other
- Salaries & wages

On a scale from 1 to 10, rate how well all parts of the graph worked together to make a single message.

Not at All Well | Perfectly
---|---
0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10
Condition 3.

When you are finished looking at this graph click on the NEXT button to answer questions. Remember---once you click on the NEXT button, you cannot return to the graph.

DIAMONDS WERE A GIRL’S BEST FRIEND
Average price of a one-carat D-flawless

$60,000
$50,000
$40,000
$30,000
$20,000


TIME Chart by Nigel Holmes
Source: The Diamond Registry

How much do you trust the information in this graph?

Choose one

Not at all   Very little   No opinion   Somewhat   Completely
### Rate the graph.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly agree</th>
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<th>Somewhat disagree</th>
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</tr>
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</tr>
<tr>
<td>I enjoyed looking at this graph.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>This is the type of graph I like to look at when I am learning something.</td>
<td></td>
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</tr>
<tr>
<td>The line in the graph was extremely important to me for understanding its meaning.</td>
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<tr>
<td>The text in the graph was extremely important to me for understanding its meaning.</td>
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</tr>
</tbody>
</table>

### Explain the meaning of the bar graph in your own words.

[Text box for answer]

---

387
What point did this graph try to make? Choose the best answer below.
- Diamonds always hold their value
- Diamonds used to be worth more and were a better investment until prices fell
- Only rich women can afford diamonds
- Diamonds are only for show but have never been as valuable as people think
- The graph just presented information without making a point

What did this graph demonstrate? Choose the best answer below.
- Diamond prices have steadily increased over a period of years
- Diamond prices have steadily decreased over a period of years
- Diamond prices went up and then down over a period of years
- Diamond prices went down and then up over a period of years
- The number of women buying diamonds each year has steadily increased over a period of years
- The number of women buying diamonds each year has steadily decreased over a period of years
- The number of women buying diamonds each year went up and then down over a period of years
- The number of women buying diamonds each year went down and then up over a period of years

What was the title of this graph?
- Diamonds Overseas and at Home
- Diamonds Were a Girl’s Best Friend
- The Rising Cost of Diamonds
- Diamond Rings : Changing Values
What did numbers on the x-axis (the horizontal column of numbers) represent on this graph?

- Years
- Costs in Millions
- Costs in Dollars
- Number of Diamonds Sold

What did the numbers on the y-axis (the vertical column of numbers) represent on this graph?

- Years
- Costs in Millions
- Costs in Dollars
- Number of Diamonds Sold

On a scale from 1 to 10, rate how well all parts of the graph worked together to make a single message.
When you are finished looking at this graph click on the NEXT button to answer questions. Remember---once you click on the NEXT button, you cannot return to the graph.

MONSTROUS COSTS
Total House and Senate campaign expenditures, in millions

How much do you trust the information in this graph?

<table>
<thead>
<tr>
<th>Not at all</th>
<th>Very little</th>
<th>No opinion</th>
<th>Somewhat</th>
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</tbody>
</table>

Choose one
Rate the graph.

<table>
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<th></th>
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<tr>
<td>Information was clearly communicated in the graph.</td>
<td>○</td>
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<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I enjoyed looking at this graph.</td>
<td>○</td>
<td>○</td>
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</tr>
<tr>
<td>This is the type of graph I like to look at when I am learning something.</td>
<td>○</td>
<td>○</td>
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<tr>
<td>The jagged bars were extremely important to me for understanding its meaning.</td>
<td>○</td>
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</tbody>
</table>

Explain the meaning of the graph in your own words below.


What point did this graph try to make? Choose the one best answer.

- Housing in Washington DC is ridiculously high priced
- Congressmen are monsters
- Tax levies are out of control
- The cost of federal campaign spending has escalated monstrously
- The graph did not have a point. It just had information.

Which of the following is true, based on the image (choose the best answer)?

- The cost of paying white house employees got out of hand over a period of years
- Housing in Washington DC became much more available as the years went on
- Political campaign spending increased greatly over a period
- The federal tax rate continued to increase until it was higher than ever before
- Housing in Washington DC became less available over a period of years
- Salaries for senators and representatives in Washington DC increased so much, they became outrageous
- A greater percentage of senators and representatives relied on campaign funds to make a living than ever before

What was the title of this graph?

- Eating Up Tax Payer Dollars
- Federal Tax Rates
- Monstrous Costs
- High Cost of Paying White House Employees
What did numbers on the x-axis (the horizontal column of numbers) represent on this graph?

- Years
- Costs in Millions
- Tax Assessments
- Houses sold in Washington DC

What did the numbers on the y-axis (the vertical column of numbers) represent on this graph?

- Years
- Costs in Millions
- Tax Assessments
- Houses sold in Washington DC

How well did all parts of the graph work together to make a single message?

[Scale from Not at all well to Perfectly well]
When you are finished looking at this graph click on the NEXT button to answer questions. Remember--- once you click on the NEXT button, you cannot return to the graph.

![The Cosmetics Dollar Graph](image)

How much do you trust the information in this graph?

<table>
<thead>
<tr>
<th></th>
<th>Not at all</th>
<th>Very little</th>
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<tr>
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Rate the graph.

<table>
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<th>Statement</th>
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<td></td>
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</tbody>
</table>

Explain the meaning of the graph in your own words.
CD4
What point did this graph try to make? Choose the best answer below.

- Cosmetics cost too much
- Manufacturers are trying to hike up their share of the cosmetic dollar
- Retailers get more money than anyone from cosmetic sales
- Cosmetic ingredients have become unaffordable
- It did not try to make a point. It just showed information

CD5
What did this graph demonstrate? Choose the best answer below.

- The graph demonstrated that more cents in a dollar are spent on cosmetics promotion than any other category
- The graph demonstrated how many cents from every dollar is spent on cosmetics manufacturing and retail
- The graph demonstrated that the trend toward higher retail costs of cosmetics is ongoing
- The graph demonstrated making cosmetics is not as expensive as people might think
- The graph demonstrated that cosmetics ingredients are the most expensive part of making and selling cosmetics
- The graph demonstrated that it costs about a dollar to manufacture and sell cosmetics
- The graph demonstrated that cosmetics manufacturing costs have really gotten cheaper

CD6
What was the title of this graph?

- Cosmetics in the Store
- The High Cost of Lipstick
- The Rising Cost of Cosmetics
- The Cosmetics Dollar
The least cents per dollar is spent on which cosmetics cost category?
- Ingredients
- Pretax profit
- Retail rent, light, salaries, wages & profit
- Interest & other
- Salaries & wages

The most cents per dollar is spent on which cosmetics cost category?
- Ingredients
- Pretax profit
- Retail rent, light, salaries, wages & profit
- Interest & other
- Salaries & wages

On a scale from 1 to 10, rate how well all parts of the graph worked together to make a single message.
Data can be presented in different styles of graphs.

Three versions of the same graph are shown below.

You can see each one as a full sized graph by clicking on the image.

Choose the graph that you think you could learn BEST from.

Why did you choose this graph? Explain in your own words.

NEXT, answer a few questions about each of the three styles of graphs.
Rate how much you agree or disagree with the following statements about the graph above.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly disagree</th>
<th>Somewhat disagree</th>
<th>Neither agree nor disagree</th>
<th>Somewhat agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I can easily tell how many millions of monarch butterflies made up the population from years 2009-2015</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I enjoyed looking at the graph</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>The pictures helped me understand the message of the graph</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I could pretty much guess the meaning of this graph without reading the title</td>
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<tr>
<td>I understood the meaning of the graph</td>
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<tr>
<td>I like the look of this kind of graph</td>
<td>○</td>
<td>○</td>
<td>○</td>
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</tr>
<tr>
<td>This type of graph could be used to present serious, important data</td>
<td>○</td>
<td>○</td>
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<tr>
<td>This type of graph could ONLY be used to present interesting trivia</td>
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</tr>
<tr>
<td>This type of graph could be used in an academic text where facts are important</td>
<td>○</td>
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</tr>
<tr>
<td>The amount of detail in the graph is just about right for learning about the topic</td>
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<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>It is difficult to sort through the clutter in this graph to get to the right information</td>
<td>○</td>
<td>○</td>
<td>○</td>
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<tr>
<td>This kind of graph could be used for just about any kind of a publication or website</td>
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<td>○</td>
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<td>○</td>
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Rate how much you agree or disagree with the following statements about the graph above.

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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>I enjoyed looking at the graph</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Rate how much you agree or disagree with the following statements about the graph above.

<table>
<thead>
<tr>
<th>I can easily tell how many millions of monarch butterflies made up the population from years 2005-2015</th>
<th>Strongly disagree</th>
<th>Somewhat disagree</th>
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Why did you choose this graph? Explain in your own words.

NEXT, answer a few questions about each of the three styles of graphs.
Answer a question about the graph above by choosing how much you disagree or agree with a statement below

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<tr>
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<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

**Funding Nemo**

Average price per fish of six popular aquarium fish in USA 2015

<table>
<thead>
<tr>
<th>Fish</th>
<th>$0.00</th>
<th>$5.00</th>
<th>$10.00</th>
<th>$15.00</th>
<th>$20.00</th>
<th>$25.00</th>
<th>$30.00</th>
<th>$35.00</th>
<th>$40.00</th>
<th>$45.00</th>
<th>$50.00</th>
<th>$55.00</th>
<th>$60.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue-Green DamselFish</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
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<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
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<tr>
<td>Clown</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
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<td>○</td>
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<tr>
<td>Breeding</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
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<td>○</td>
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<td>○</td>
<td>○</td>
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<td>○</td>
</tr>
<tr>
<td>Cleaner Common Wrasse</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
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<td>○</td>
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<td>○</td>
</tr>
<tr>
<td>Flame Angelfish</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
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<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Blue Tang</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
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Popular aquarium fish
Answer a question about the graph above by choosing how much you disagree or agree with a statement below

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![Funding Nemo Graph](image)
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Three versions of the same graph are shown below.

You can see each one as a full sized graph by clicking on the image.

Choose the graph that you think you could learn BEST from.

Why did you choose this graph? Explain in your own words.

NEXT, answer a few questions about each of the three styles of graphs.
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<thead>
<tr>
<th>I can easily tell how much the cost of a stamp changed from 1974 to 2014</th>
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**GOING POSTAL**

**AMERICAN FIRST CLASS STAMP PRICE HIKES FROM 1974 TO 2014**

<table>
<thead>
<tr>
<th>Years</th>
<th>Prices Changed</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1974</td>
<td>.10¢</td>
<td>15¢</td>
</tr>
<tr>
<td>1976</td>
<td>.10¢</td>
<td>15¢</td>
</tr>
<tr>
<td>1978</td>
<td>.10¢</td>
<td>15¢</td>
</tr>
<tr>
<td>1980</td>
<td>.10¢</td>
<td>15¢</td>
</tr>
<tr>
<td>1982</td>
<td>.10¢</td>
<td>15¢</td>
</tr>
<tr>
<td>1984</td>
<td>.10¢</td>
<td>15¢</td>
</tr>
<tr>
<td>1986</td>
<td>.10¢</td>
<td>15¢</td>
</tr>
<tr>
<td>1988</td>
<td>.10¢</td>
<td>15¢</td>
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<tr>
<td>1990</td>
<td>.10¢</td>
<td>15¢</td>
</tr>
<tr>
<td>1992</td>
<td>.10¢</td>
<td>15¢</td>
</tr>
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<td>1994</td>
<td>.10¢</td>
<td>15¢</td>
</tr>
<tr>
<td>1996</td>
<td>.10¢</td>
<td>15¢</td>
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<td>15¢</td>
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<tr>
<td>2000</td>
<td>.10¢</td>
<td>15¢</td>
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<td>2002</td>
<td>.10¢</td>
<td>15¢</td>
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<td>2004</td>
<td>.10¢</td>
<td>15¢</td>
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<td>2006</td>
<td>.10¢</td>
<td>15¢</td>
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<tr>
<td>2008</td>
<td>.10¢</td>
<td>15¢</td>
</tr>
<tr>
<td>2010</td>
<td>.10¢</td>
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</tr>
<tr>
<td>I could pretty much guess the meaning of this graph without reading the title</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I understood the meaning of the graph</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I like the look of this kind of graph</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>This type of graph could be used to present serious, important data</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>This type of graph ONLY could be used to present interesting trivia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>This type of graph could be used in an academic text where facts are important</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The amount of detail in the graph is just about right for learning about the topic</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>It is difficult to sort through the clutter in this graph to get to the right information</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>This kind of graph could be used for just about any kind of a publication or website</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![Graph showing American First Class stamp price hikes from 1974 to 2014](image)
Answer a question about the graph above by choosing how much you disagree or agree with a statement below.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly disagree</th>
<th>Somewhat disagree</th>
<th>Neither agree or disagree</th>
<th>Somewhat agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I can easily tell how much the cost of a stamp changed from 1974 to 2014</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I enjoyed looking at the graph</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I understood the meaning of the graph better than in other graphs because there were no pictures</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I could pretty much guess the meaning of this graph without reading the title</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I understood the meaning of the graph</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I like the look of this kind of graph</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>This type of graph could be used to present serious, important data</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>This type of graph ONLY could be used to present interesting trivia</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>This type of graph could be used in an academic text where facts are important</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>The amount of detail in the graph is just about right for learning about the topic</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>It is difficult to sort through the clutter in this graph to get to the right information</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>This kind of graph could be used for just about any kind of a publication or website</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
Appendix B. Consent Form

UNIVERSITY OF NORTH DAKOTA
Institutional Review Board
Informed Consent Statement

Title of Project:

Principal Investigator: Debra Jenkins, 701.771.1011, cigt.study@gmail.com or jenkinses@gondtc.com

Advisor: Richard Van Eck

Purpose of the Study:
The purpose of this research study is to investigate how different people comprehend and respond to different types of data displays.

Procedures to be followed:
There are two phases to this study. In the first phase, you will be asked to complete a timed test online known as the Group Embedded Figures Test or GEFT. This test is available 24 hours a day and 7 days a week. It takes about 20 minutes to complete and must be completed in one sitting.

Some individuals will also be invited to participate in phase 2. If you complete Phase 1 and are invited to participate in Phase 2, you will receive an email with further instructions. You will then complete another survey. Called the Comparative Information Graphic Test or CIG-T. This test is available 24 hours a day and 7 days a week online. You will be asked to answer questions about different data displays. The test will take about 30 minutes to complete.

Risks:
There are no risks in participating in this research beyond those experienced in everyday life.

Benefits:

- You may learn more about the way you like or dislike different data displays. You may also learn about your preferred type of display and how well you understand different types. You may also learn about how pictures affect the way you comprehend, like or find hidden messages in these displays.
- This research may provide a better understanding of how the visual design of data displays affects learning. An ongoing debate about the best way to design a data display has yet to be settled. Because people support one side or another without very much scientific evidence, your participation in the study may provide some findings that explain the best way for graphic artists to design graphs or charts.
**Duration:**
The GEFT is a timed test that all participants will take. Along with instructions, the GEFT will take approximately 30 minutes. These participants will be invited to take the CIG-T. The CIG-T will take about 30 minutes to complete.

**Statement of Confidentiality:**
Your confidentiality will be maintained with your name and email address kept in a secure digital file. Although your name and email address will be used to communicate with you, if research is published no information that would identify you will be included. When you have completed a test your results will be assigned to such identifiers as Participant 1, 2, 3, etc.

All survey responses that we receive will be treated confidentially and stored on a secure server. However, given that the surveys can be completed from any computer (e.g., personal, work, school), we are unable to guarantee the security of the computer on which you choose to enter your responses. As a participant in our study, we want you to be aware that certain "key logging" software programs exist that can be used to track or capture data that you enter and/or websites that you visit.

**Right to Ask Questions:**
The researcher conducting this study is Debra Jenkins. You may ask any questions you have now before taking either the GEFT or CIG-T or later if you have questions, concerns, or complaints about the research. Please contact Debra Jenkins during the day by emailing her at cigt.study@gmail.com or by calling her at 701-771-1011, or contacting her advisor, Dr. Richard Van Eck at 701.777.3528.

If you have questions regarding your rights as a research subject, you may contact The University of North Dakota Institutional Review Board at (701) 777-4279. You may also call this number with problems, complaints, or concerns about the research. Please call this number if you cannot reach research staff, or you wish to talk with someone who is an informed individual who is independent of the research team.

General information about being a research subject can be found on the Institutional Review Board website “Information for Research Participants” http://und.edu/research/resources/human-subjects/research-participants.cfm

**Compensation:**
You will be entered into a random drawing for one of ten $25 Amazon.com gift cards for Phase 1 and, if selected, for Phase 2 (a total of two cards will be available: one for Phase 1 and one for Phase 2).

You may withdraw from the study at any time without losing any course points assigned by your instructor. If you choose not to participate, please consult your course instructor on other methods to earn course points.
Voluntary Participation:
You do not have to participate in this research. You can stop your participation at any time. You may refuse to participate or choose to discontinue participation at any time without losing any benefits to which you are otherwise entitled.

You do not have to answer any questions you do not want to answer.

You must be 18 years of age older to consent to participate in this research study.

Completion of the survey implies that you have read the information in this form and consent to participate in the research. If you do not wish to participate, please close the browser now.

Please print a copy of this form for your records or future reference.
Appendix C. GEFT Landing Page

Please Note: You may only take the test once. Also you MUST complete the test in one sitting—it takes about 20 minutes to complete.

When you follow the link below, you will be taken to a page that looks like this:

You will need to fill in ALL the fields in the green shaded box to the right in order to create a login and begin the test. Then you will click "create" and the test will automatically begin.

Please click on the link below to get started:

http://transform.mindgarden.com/login/key/b60e-5915e0aab8b62
## Appendix D. CIG-T Variable Table

<table>
<thead>
<tr>
<th>Comprehension (Dependent Variable)</th>
<th>( \text{COMP} = DIA3 + MC3 + CD3 + DIA4 + DIA5 + MC4 + MC5 + CD4 + CD5 + DIA6 + MC6 + CD6 + DIA7 + MC7 + CD7 + DIA8 + MC8 + CD8 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aesthetic Overall (Dependent Variable)</td>
<td>( \text{AESTH_Tot_1} = \text{AESTH_PE} + \text{AESTH_Pr} + \text{AESTH_PV} )</td>
</tr>
<tr>
<td>Aesthetic Perceived Efficacy</td>
<td>( \text{AESTH_PE} = DIA2_1 + MC2_1 + CD2_1 + DIA9 + CD9 + MC9 )</td>
</tr>
<tr>
<td>Aesthetic Preference</td>
<td>( \text{AESTH_Pr} = DIA2_2 + DIA2_3 + MC2_2 + MC2_3 + CD2_2 + CD2_3 )</td>
</tr>
<tr>
<td>Aesthetic Perceived Value</td>
<td>( \text{AESTH_PV} = DIA1 + DIA2_4 + DIA2_5 + MC1 + MC2_4 + MC2_5 + CD1 + CD2_4 + CD_5 )</td>
</tr>
<tr>
<td>Aesthetic for All Information Graphic Type</td>
<td>( \text{AESTH_Min} = \text{AESTH_Min_PE} = \text{AESTH_Min_Pr} + \text{AESTH_Min_PV} )</td>
</tr>
<tr>
<td>( \text{AESTH_Min_PE} )</td>
<td>( \text{AESTH_Min_Pr} = \text{AESTH_Pct_PE} = \text{AESTH_Pct_Pr} + \text{AESTH_Pct_PV} )</td>
</tr>
<tr>
<td>( \text{AESTH_Min_PV} )</td>
<td>( \text{AESTH_Pct} = \text{AESTH_Inf_PE} = \text{AESTH_Inf_Pr} + \text{AESTH_Inf_PV} )</td>
</tr>
<tr>
<td>( \text{AESTH_Pct_PE} )</td>
<td>( \text{AESTH_Pct_Pr} = \text{WP4_1} + \text{WP4_3} + \text{WP4_5} + \text{WP4_10} + \text{WP4_11} + \text{FN4_1} + \text{FN4_3} + \text{FN4_4} + \text{FN4_5} + \text{FN4_9} + \text{FN4_11} + \text{GP4_1} + \text{GP4_3} + \text{GP4_4} + \text{GP4_5} + \text{GP4_10} + \text{GP4_11} )</td>
</tr>
<tr>
<td>( \text{AESTH_Pct_Pr} )</td>
<td>( \text{AESTH_Pct_PV} = \text{WP3_1} + \text{WP3_3} + \text{WP3_5} + \text{WP3_10} + \text{WP3_11} + \text{FN3_1} + \text{FN3_3} + \text{FN3_4} + \text{FN3_5} + \text{FN3_9} + \text{FN3_11} + \text{GP3_1} + \text{GP3_3} + \text{GP3_4} + \text{GP3_5} + \text{GP3_10} + \text{GP3_11} )</td>
</tr>
<tr>
<td>( \text{AESTH_Pct_PV} )</td>
<td>( \text{AESTH_Inf_PE} = \text{WP2_1} + \text{WP2_3} + \text{WP2_5} + \text{WP2_10} + \text{WP2_11} + \text{FN2_1} + \text{FN2_3} + \text{FN2_4} + \text{FN2_5} + \text{FN2_9} + \text{FN2_11} + \text{GP2_1} + \text{GP2_3} + \text{GP2_4} + \text{GP2_5} + \text{GP2_10} + \text{GP2_11} )</td>
</tr>
<tr>
<td>( \text{AESTH_Inf_Pr} )</td>
<td>( \text{AESTH_Inf_PV} = \text{WP2_2} + \text{WP2_6} + \text{FN2_2} + \text{FN2_6} + \text{GP2_2} + \text{GP2_6} )</td>
</tr>
<tr>
<td>( \text{AESTH_Inf_PV} )</td>
<td>( \text{AESTH_Inf_PV} = \text{WP2_7} + \text{WP2_8} + \text{WP2_9} + \text{WP2_12} + \text{FN2_7} + \text{FN2_8} + \text{FN2_10} + \text{FN2_12} + \text{GP2_7} + \text{GP2_8} + \text{GP2_9} + \text{GP2_12} )</td>
</tr>
<tr>
<td>Research Question/Hypotheses</td>
<td>Independent Variables</td>
</tr>
<tr>
<td>------------------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td><strong>Research Question: 1. What is the relationship between FDI and comprehension of minimalist information graphics, pictograms, or infographics?</strong></td>
<td>--</td>
</tr>
<tr>
<td>1. Null Hypothesis: FD and FI learners will not differ in their comprehension of minimalist information graphics, pictograms, or infographics.</td>
<td>FDI Condition</td>
</tr>
<tr>
<td>1a. Alternative Hypothesis. FD learners will comprehend minimalist information graphics better than they do other forms of infographics.</td>
<td></td>
</tr>
<tr>
<td>1b. Alternative Hypothesis. FI learners will not differ in comprehension of all forms of information graphics.</td>
<td></td>
</tr>
<tr>
<td><strong>Research Question 2. What is the relationship between FDI learners and their aesthetic ratings for minimalist information graphics pictograms, or infographics?</strong></td>
<td>--</td>
</tr>
<tr>
<td>2.1 Null Hypothesis: FD and FI learners will not differ in their overall aesthetic rating of minimalist information graphics, pictograms, or infographics.</td>
<td>FDI Condition</td>
</tr>
<tr>
<td>2.1a Alternative Hypothesis: FD learners will differ in their overall aesthetic rating for each type of information graphics, while FI learners will not differ in their overall aesthetic rating for each type of information graphic.</td>
<td></td>
</tr>
<tr>
<td>2.2 Null Hypothesis: FD and FI learners will not differ in their perceived efficacy of minimalist information graphics, pictograms, or infographics.</td>
<td>FDI Condition</td>
</tr>
<tr>
<td>2.2a Alternative Hypothesis: FD learners will perceive minimalist information graphics as more effective than other forms of information graphics.</td>
<td></td>
</tr>
<tr>
<td>2.3 Null Hypothesis: FD and FI learners will not differ in their preference for minimalist information graphics, pictograms, or infographics.</td>
<td>FDI Condition</td>
</tr>
<tr>
<td>2.3.a Alternative Hypothesis: FD learners will prefer the aesthetics of infographics or pictograms over those of minimalist information graphics; 2.3.b Alternative Hypothesis: FD learners will prefer the aesthetics of minimalist information graphics.</td>
<td></td>
</tr>
</tbody>
</table>
Appendix E. Research Questions, Variables and Statistical Tests

<table>
<thead>
<tr>
<th>Research Question/Hypotheses</th>
<th>Independent Variables</th>
<th>Dependent Variables</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Research Question: 1. What is the relationship between FDI and comprehension of minimalist information graphics, pictograms, or infographics?</strong></td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td><strong>1. Null Hypothesis</strong>: Learners will not differ in their comprehension of minimalist information graphics, pictograms, or infographics.</td>
<td>FDI Condition</td>
<td>COMP</td>
<td>Two-Way ANOVA (GLM) Posthoc analyses</td>
</tr>
<tr>
<td><strong>1a. Alternative Hypothesis</strong>: FD learners will comprehend minimalist information graphics better than they do other forms of infographics.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>1b. Alternative Hypothesis</strong>: FI learners will not differ in comprehension of all forms of information graphics.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Research Question 2. What is the relationship between FDI learners and their aesthetic ratings for minimalist information graphics pictograms, or infographics?</strong></td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td><strong>2.1 Null Hypothesis</strong>: Learners will not differ in their overall aesthetic rating of minimalist information graphics, pictograms, or infographics.</td>
<td>FDI Condition</td>
<td>AESTH_Tot</td>
<td>Two-Way ANOVA (GLM) Posthoc analyses</td>
</tr>
<tr>
<td><strong>2.1a Alternative Hypothesis</strong>: FD learners will differ in their overall aesthetic rating for each type of information graphics, while FI learners will not differ in their overall aesthetic rating for each type of information graphic.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2.2 Null Hypothesis</strong>: Learners will not differ in their perceived efficacy of minimalist information graphics, pictograms, or infographics.</td>
<td>FDI Condition</td>
<td>AESTH_PE</td>
<td>Two-Way ANOVA (GLM) Posthoc analyses</td>
</tr>
<tr>
<td>---</td>
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</tr>
<tr>
<td><strong>2.2a Alternative Hypothesis</strong>: FD learners will perceive minimalist information graphics as more effective than other forms of information graphics.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2.3 Null Hypothesis</strong>: Learners will not differ in their preference for minimalist information graphics, pictograms, or infographics.</td>
<td>FDI Condition</td>
<td>AESTH_Pr</td>
<td>Two-Way ANOVA (GLM) Posthoc analyses</td>
</tr>
<tr>
<td><strong>2.3.a. Alternative Hypothesis</strong>: FD learners will prefer the aesthetics of infographics or pictograms over those of minimalist information graphics;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2.3.b Alternative Hypothesis</strong>: FD learners will prefer the aesthetics of minimalist information graphics over those of infographics.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2.4 Null Hypothesis</strong>: Learners will not differ in their ratings of perceived value for minimalist information graphics, pictograms, or infographics;</td>
<td>FDI Condition</td>
<td>AESTH_PV</td>
<td>Two-Way ANOVA (GLM) Posthoc analyses</td>
</tr>
<tr>
<td><strong>2.4a. Alternate hypothesis</strong>: FI learners will be more likely than FD learners rate a pictogram or infographic as having greater aesthetic value than a minimalist information graphic.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix E cont.

<table>
<thead>
<tr>
<th>Part 2 CIG-T Below</th>
<th>FDI</th>
<th>AESTH_Min</th>
<th>AESTH_Pct</th>
<th>AESTH_Inf</th>
<th>One-Way MANOVA Posthoc analyses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2.5 Null Hypothesis:</strong> Learners will not differ in their overall aesthetic rating of minimalist information graphics, pictograms, or infographics.</td>
<td>FDI</td>
<td>AESTH_Min</td>
<td>AESTH_Pct</td>
<td>AESTH_Inf</td>
<td>One-Way MANOVA Posthoc analyses</td>
</tr>
<tr>
<td><strong>2.5a Alternative Hypothesis:</strong> FD learners will differ in their overall aesthetic rating for each type of information graphics, while FI learners will not differ in their overall aesthetic rating for each type of information graphic.</td>
<td>FDI</td>
<td>AESTH_Min</td>
<td>AESTH_Pct</td>
<td>AESTH_Inf</td>
<td>One-Way MANOVA Posthoc analyses</td>
</tr>
<tr>
<td><strong>2.6 Null Hypothesis:</strong> Learners will not differ in their perceived efficacy of minimalist information graphics, pictograms, or infographics.</td>
<td>FDI</td>
<td>AESTH_Min</td>
<td>AESTH_Pct</td>
<td>AESTH_Inf</td>
<td>One-Way MANOVA Posthoc analyses</td>
</tr>
<tr>
<td><strong>2.6a Alternative Hypothesis:</strong> FD learners will perceive minimalist information graphics as more effective than other forms of information graphics.</td>
<td>FDI</td>
<td>AESTH_Min</td>
<td>AESTH_Pct</td>
<td>AESTH_Inf</td>
<td>One-Way MANOVA Posthoc analyses</td>
</tr>
<tr>
<td><strong>2.7 Null Hypothesis:</strong> Learners will not differ in their ratings of preference for minimalist information graphics, pictograms, or infographics;</td>
<td>FDI</td>
<td>AESTH_Min</td>
<td>AESTH_Pct</td>
<td>AESTH_Inf</td>
<td>One-Way MANOVA Posthoc analyses</td>
</tr>
<tr>
<td><strong>2.7a. Alternate hypothesis:</strong> FI learners will be more likely than FD</td>
<td>FDI</td>
<td>AESTH_Min</td>
<td>AESTH_Pct</td>
<td>AESTH_Inf</td>
<td>One-Way MANOVA Posthoc analyses</td>
</tr>
</tbody>
</table>
learners to like and rate at pictogram or infographic as having greater aesthetic value than a minimalist information graphic.

| 2.8. Null Hypothesis: Learners will not differ in their ratings of perceived value of minimalist information graphics, pictograms, or infographics; | FDI | AESTH_Min_PV AESTH_Pct_PV AESTH_Inf_PV |
| 2.8a. Alternate hypothesis: FD learners will be more likely than FI learners to rate at pictograms or infographics as having greater aesthetic value than a minimalist information graphic | One-Way MANOVA Posthoc analyses |

| 2.9 Null Hypothesis: Learners will not believe any information graphic is better than another information graphic for their learning | FDI | Choice |
| | | Chi square analysis |
Table 4.
Rubric for CIG-T comprehension scores

<table>
<thead>
<tr>
<th>Question(s)</th>
<th>Score_1</th>
<th>Score_2</th>
<th>Score_3</th>
<th>Score_4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Diamonds Were a Girl's Best Friend (DIA3)</strong>; Overall Diamond Comprehension Score for CIG-T-1 (Minimalist); Score For CIG-T-2 (Pictogram); Score for CIG-T 3 (Infographic) Explain the meaning of the graph in your own words</td>
<td>Inaccurate or inappropriate answer (does not report meaning of the graph) or outright self-report claiming misunderstanding of the graph or chart</td>
<td>Short, accurate, rudimentary description of the meaning of the graph or chart</td>
<td>Accurate description of meaning of the graph with either some reference to specific details (x-y axis or other numerical values, etc.) and/or some limited discussion about the message embedded in the graph or chart</td>
<td>Accurate description of the meaning of the graph or chart with reference to specific details (x-y axis or other numerical values, etc.) about the graph or chart alongside well-articulated discussion about the message embedded in the graph or chart</td>
</tr>
<tr>
<td><strong>Monstrous Costs (MC3)</strong>; Overall Monstrous Costs Comprehension Score for CIG-T-1 (Minimalist); Score For CIG-T-2 (Pictogram); Score for CIG-T 3 (Infographic) All scored using rubric Explain the meaning of the graph in your own words</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>The Cosmetic Dollar (CD3)</strong>; Overall Monstrous Costs Comprehension Score for CIG-T-1 (Minimalist); Score For CIG-T-2 (Pictogram); Score for CIG-T 3 (Infographic) Explain the meaning of the graph in your own words</td>
<td></td>
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