Online Multimedia Learning: Predicting Learner Media Selections in the Visual and Verbal Domains

Natalie Toomey

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ONLINE MULTIMEDIA LEARNING: 
PREDICTING LEARNER MEDIA SELECTIONS IN THE VISUAL AND VERBAL 
DOMAINS

A Dissertation
Submitted to the School of Education

Duquesne University

In partial fulfillment of the requirements for
the degree of Doctor of Education

By
Natalie Toomey

December 2015
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Natalie Toomey

2015
ONLINE MULTIMEDIA LEARNING:
PREDICTING LEARNER MEDIA SELECTIONS IN THE VISUAL AND VERBAL DOMAINS

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Natalie Toomey

Approved October 6, 2015

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ABSTRACT

ONLINE MULTIMEDIA LEARNING:

PREDICTING LEARNER MEDIA SELECTIONS IN THE VISUAL AND VERBAL DOMAINS

By

Natalie Toomey

December 2015

Dissertation supervised by Misook Heo

The purpose of this study was to investigate visualizer-verbalizer tendencies through the prediction of learner selection of online, multimedia learning options based on the characteristics of cognitive ability, spatial ability, cognitive style, and learning preference. These characteristics were used to predict the selection of text only, labeled image, and image and narration learning options in two, multimedia learning behavior tests via multinomial logistic regression analysis. Results of this study found that the factor of spatial ability influenced multimedia learning options such that as spatial ability increases, the likelihood of choosing labeled image learning option increases while the likelihood of choosing the image and narration learning option decreases. Cognitive style was found to be influential such that, as cognitive style moves towards a visualizer tendency, the likelihood of selecting an image inclusive multimedia learning option
(labeled image or image and narration) increases. Learning preference was also found to be influential, as individuals expressing a learning preference for labeled images are likely to maintain this preference through selections of labeled image multimedia learning options. Gender was also investigated as a potential covariate influencing selections with no significant findings.

The overall results from this study indicate that certain learner characteristics and inherent traits do influence how learners select different multimedia learning formats for their own learning and the relevance of visualizer-verbalizer tendencies in these choices. The different influence of spatial ability supports research suggesting that the visualizer characteristic may be further sub-divided into a spatial visualizer category describing those who view imagery as distinct parts to be mentally combined into a whole, and object visualizers who view best imagery as a whole, not requiring further dissection or manipulation.

The findings of this study may further guide instructors, instructional designers, and instructional material publishers in the creation of online or technology enhanced learning materials to suit not only the overall goals of learning but also the individual learners. Online or technology enhanced learning materials may thus take advantage of the appeal of multimedia by incorporating a variety of media designed to guide learners through instructional materials which optimally take advantage of the concepts behind multimedia learning in an effort to create engaging learning opportunities to support learner interest and potentially enhance learning outcomes.
ACKNOWLEDGEMENT

I would like to acknowledge and sincerely thank my family and professors who offered me their guidance and support in this process.
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CHAPTER I

INTRODUCTION

Individual differences and how they impact learning have been the focus of educational psychology for many decades. Advances in learning technologies in the 21st century classroom have made it necessary to reevaluate the psychology of learning and learner characteristics in the context of the modern, virtual classroom (Dewar & Whittington, 2000; Irani, Telg, Sherler, & Harrington, 2003; Leutner & Plass, 1998). Much debate exists regarding the validity of identifying individual learner styles and characteristics and how or if at all this impacts the intake and processing of information and the creation of knowledge (Greener, 2010; Harris, Dwyer, & Leeming, 2003).

A number of instruments exist which are intended to measure cognitive ability as well as a wide range of posited learning styles, cognitive styles and other individual characteristics relevant to learning outcomes. Learner cognitive styles are generally defined as learners’ preferred and possibly innate way of processing information. Learning styles are then defined as an individuals preferred way of responding to information, both cognitively and behaviorally, and is seen as changeable depending on a given task or situation, rather than an innate characteristic (Evans, Cools, & Charlesworth, 2010). Neither, however, is viewed as indicative of discrete characteristics; rather learners are considered to possess a plurality of traits and abilities in addition to expressed or behavioral preferences, which guide individual knowledge acquisition (Klein, 2003).

One of many technology enabled learning environments is the online classroom. Online learning can be viewed as time and locational independent learning which takes
place via a computer, thereby taking advantage of a wide range of media resources and collaborative tools available through the Internet and modern technologies (Clark, 2005; Clark & Mayer, 2003; Means, Toyama, Murphy, Bakia, & Jones, 2010). The popularity and availability of online learning options has steadily risen over the years and has reached a point of growth, which has exceeded that of its face-to-face learning counterpart (Allen & Seaman, 2010). The very nature of online learning being enabled by the advent of the Internet allows for the use and integration of a multitude of media formats such as video, audio, and a variety of interactive tools all of which offer learners in the online environment unprecedented access and flexibility in terms of learning materials (Anderson, 2008a). In the online classroom, students are heavily if not exclusively reliant on this digital-based media in their interactions with instructors and peers as well as course content (Clark, 2005). Given the flexible nature of online media, several types of media representations may be specifically created and offered to appeal to a variety of learning preferences or styles while also addressing cognitive styles and abilities and meeting learning objectives (Kolloffel, 2012).

Multimedia and hypermedia allow the presentation of multiple informational formats and resultant multiple cognitive processing options (Brunye, Taylor, Rapp, & Spiro, 2006). Considering these possibilities within the scope of current multimedia and hypermedia-based learning delivery systems, much research has focused on cognitive load theory (CLT) which addresses the strategies and limitations of human memory in dealing with the intake of new information as a means of evaluating knowledge acquisition and the processing tendencies of learners (Brunken, Plass, & Leutner, 2008; Sweller, 2005a). With specific consideration of multimedia, the cognitive theory of
multimedia learning (CTML) focuses on the workings of the human mind and how individuals absorb and process information optimally. This theory gives attention to how learners select and process information via dual channels, visual and text/auditory, and how they translate this information into knowledge (Mayer, 2005c).

CLT has further served to inform the design of multimedia and given rise to several additional multimedia theories. These theories focus again on the concept of a limited working memory capacity and attempt to serve as guidelines in the creation of multimedia, which optimizes the efficiency of working memory (Sweller, 2005a). The CTML offers, as previously mentioned, specifics regarding the means by which humans process information; via a visual or pictorial channel also referred to as the visual-spatial sketchpad or via an auditory or verbal channel (Baddley, 1992; Mayer, 2005b). This is referred to as the dual channel assumption (Mayer, 2005c). Human cognition therefore begins with the intake of information via these channels and, if optimally employed, results in the creation of new schema retained in the long term memory (Fletcher & Tobias, 2005; Mayer, 2005b).

Further, a specific concept referred to as the multimedia principle recommends that optimal learning occurs when both the visual and verbal channels are used simultaneously. That is, learners have been observed to best take in and retain novel information when it is presented as visuals and text or visuals and narration as opposed to presenting a single element such as text, alone (Fletcher & Tobias, 2005).

Given that technology-based multimedia learning within current capabilities interacts with learners in the visual and auditory domains, the visualizer-verbalizer hypothesis can guide both instructional design and deeper understanding of learner
preferences and styles (Mayer & Massa, 2003). It may also be relevant to consider this hypothesis within the context of the perceived nature of the working memory as possessing separate processing channels for visual and verbal information (Low & Sweller, 2005). This dichotomous conceptualization of the working memory has further been supported through research and observation as possessing of a channel for the intake of visual information and a channel for the intake of verbal or language based information (Baddeley, 1992).

**Statement of the Problem**

Given the highly dynamic nature of modern, technology-inclusive and technology-based multimedia, previous assessments of learner assimilation of learning materials and learner engagement with learning materials may no longer be applicable. The ability of students to effectively interact with materials as well as their perceptions of those materials in terms of usability may have significant effects on learning outcomes and overall motivation levels in technology-based learning environments (Abrami, Bernard, Bures, Borokhovski, & Tamin, 2011). As educators and instructors, it is of key importance to constantly reevaluate instructional strategies for effectiveness as these strategies and delivery systems evolve in conjunction with increasing technological capabilities.

Studies pose contradictions in terms of learner characteristics and their responses to corresponding presentations of materials. Some studies suggest favorable learning outcomes when the materials presented are matched to a learner’s expressed and measured preference and cognitive style (Boles, Pillay, & Raj, 1999; Buehner-Brent, 1990); while others suggest that a mismatch results in a better outcome (Felder, 1996;
Furthermore, learner preferences and cognitive styles have been shown to exist as distinct factors, such that they are not necessarily matched characteristics within a single individual (Mayer & Massa, 2003). These points then serve to raise several questions regarding learner responses to and choices of learning materials.

Modern, multimedia-based learning presents greater variety of material presentation and interactivity than perhaps previous, more static or limited formats have allowed in the past. It would therefore be prudent to gain a greater understanding of how or if learner preferences, cognitive preferences, and cognitive styles function in the current online, multimedia-based learning environments.

**Purpose of the Study**

The purpose of this study was to reevaluate the concepts of learner preferences, cognitive preferences, and cognitive styles relating to multimedia learning within the context and considering the capabilities of the 21st century classroom. How learners perceive technology-based instruction and how they respond to and interact with these materials are important components to the overall success of instructional program utilizing technology-based tools and applications. It was therefore the goal of this study to evaluate these learner characteristics, with focus on the visual and verbal domains, and how these relate to and impact behaviors with online multimedia learning materials.

**Research Questions**

Given the changing nature of the presentation of instructional materials via technology-based applications, it would be a prudent step to reevaluate assessments of student interactions within the context of the 21st century learning environment. The main research question for this study was how do learning preferences, cognitive ability,
spatial ability, and cognitive style relate to learner interactions with online, multimedia-based learning materials. These questions additionally focus on the visualizer-verbalizer hypothesis, which suggests that some learners prefer visual-based learning while others prefer verbal-based learning. Components of this overall question include:

1. Do learners’ visualizer or verbalizer tendencies influence their selections of online multimedia learning resources?
   1.1. Does learners’ cognitive ability influence their selections of online multimedia learning resources?
   1.2. Does learners’ spatial ability influence their selections of online multimedia learning resources?
   1.3. Does learners’ cognitive style influence their selections of online multimedia learning resources?
   1.4. Does learners’ learning preference influence their selections of online multimedia learning resources?

2. Does gender have a relationship with visualizer or verbalizer tendency?
   2.1. Does gender have a relationship with cognitive ability?
   2.2. Does gender have a relationship with spatial ability?
   2.3. Does gender have a relationship with cognitive style?
   2.4. Does gender have a relationship with learning preference?
   2.5. Does gender have a relationship with selections of online multimedia resources?
Significance of the Study

Numerous studies have been conducted comparing varied online learning environments with face-to-face classroom instruction. Technology has, however, become so ubiquitous within educational environments that realigned research focus on online learning environments either alone or in comparison with one another would be practically more effective for the purpose of expanding research and informing practice within these types of learning environments (Abrami, Bernard, Bures, Borokhovski, & Tamin, 2011).

Furthermore, CLT has featured prominently in recent studies of technology-based learning environments relating to multimedia and web-based instruction. Refinement of effective measurement tools to assess both student perceptions and learning outcomes would potentially aid instructional design for the creation of more effective learning materials (Brunken, Plass, & Leutner, 2003). Focusing on student learning styles, cognitive abilities and styles, and spatial ability in relationship to multimedia learning further provides insight into how individuals process information and behave in such an environment additionally informing the design of learning materials (Evans, Cools, & Charlesworth, 2010).

Limitations of the Study

While this study did provide evidence that learners’ visualizer and verbalizer tendencies can predict selections of online multimedia learning options, there were some limitations. First, this study was limited to a single university student population. Although this group included both undergraduate and graduate level students engaged in varied courses of study, the majority of participants (91%) fell within the 19 to 28 age
range. It is further plausible that, in addition to a limited age range, characteristics inherent to a limited group of university students such as greater or lesser experience with or exposure to technology would bias the results in relation to the general population.

Second, the learning preference factor consisted of a single, self-report item, which may present validity issues. The addition of further items to this factor may increase its validity. Third, a portion of the included participant group (20%) did not report their SAT scores. This was associated with students who likely could not recall their score, never took the SAT test in its current version or, in the case of participants who chose to end their participation at this point, chose not to respond. While inevitably some potential participants may be deterred by such questions due to self-image or other factors, more widely inclusive cognitive ability measures may benefit future study.

Fourth, the chi-square tests of independence for the influence of gender on both the learning preference and online multimedia learning option selections (multimedia learning behavior test one) failed to meet necessary assumptions but were conducted nonetheless. It is acknowledged that the results of these tests may be biased as a result.

Fifth, individuals who chose to discontinue participation at various points in the survey (27 participants in total) were removed via listwise deletion despite recommendations that such deletion be conducted only if the relative number of cases is small or if data is missing completely at random. As neither was the case, it is acknowledged that the listwise deletion of these cases may have produced biased parameters and estimates.

Finally, the principles related to multimedia learning focused on in this study such as the multimedia principle and the modality principle are premised on learners being novices in the topic covered. Participants’ prior knowledge on the topics covered was not
determined and thus differing levels of knowledge may have influenced the outcomes.

**Delimitations of the Study**

While this study may provide useful information regarding learner tendencies and interactions with online multimedia learning options, some delimitations were noted. First, participation in the study was disproportionately female (68%) which may limit the generalizability of the overall results. Second, due to 20 percent incomplete data for the SAT score variable, as discussed in the limitations section, the decision was made to exclude this variable for all participants in subsequent analysis. As a result, the cognitive ability factor might not be viewed as a truly complete measure of cognitive ability but as a measure of verbal ability; results should thus be viewed in this context.

**Definition of Terms**

21st Century Learning Environment: A collection of learning models and pedagogy which support information exchange and interpersonal interactions while allowing for time and locational independence enhanced by the utilization of technology-based tools (Garrison, 2011) to create an authentic and diverse learning experience (Lombardi, 2007).

Active processing assumption: A component of the cognitive theory of multimedia learning which states that individuals will actively seek to organize and make sense of new information (visual or verbal) to create mental constructs and connections to preexisting schema (Brunken, Plass, & Leutner, 2003; Mayer, 2005b).

Asynchronous online learning: A way of learning online, which is independent of time and location (Romiszowski & Mason, 2004).
Behaviorism: An educational theory, which emphasizes observable and measurable changes as indicators that learning has taken place (Ally, 2008; Ertmer & Newby, 1993; Kanuka, 2008).

Blended learning: A class, which has a face-to-face meeting component while also having a 30 to 79 percent online component. The face-to-face and online components are important, integrated elements of the class (Allen & Seaman, 2010; Harasim, 2000).

Cognitive ability: A variety of dimensions, which, when combined, present an overall picture of what an individual is capable of knowing or intellectual aptitude (Dickens, 2008; Mayer & Massa, 2003).

Cognitive load: The amount of information imposed upon the working memory (Sweller, 2005).

Cognitive load theory: Theory indicating that the working memory can only process a limited amount of information at any given time and so the presentation of novel information should be limited or regulated to correspond to the innate human capacity of information intake and processing (Sweller, 2005).

Cognitive styles: The innate tendencies of individuals for processing information (Evans, Cools, & Charlesworth, 2010).

Cognitive theory of multimedia learning: A theory of how people learn from multimedia, based on an understanding that the working memory has a limited capacity (cognitive load theory) which is mitigated by theories of multimedia learning, indicating that individuals learn better and cognitive load is reduced when
information is presented both visually and verbally, allowing for a more efficient intake of novel information (Mayer, 2005b).

Cognitivism: An educational theory which emphasizes the internal process or learning and creation of knowledge and schema which are not necessarily observable or measurable (Ertmer & Newby, 1993).

Communication Privacy Management Theory: A theory of communication, which focuses on what information individuals are or are not willing to share with others (Petronio, 2002).

Completely online instruction: A class typically having no face-to-face meeting component and a minimum of 80 percent of the content and interactions online (Allen & Seaman, 2010; Harasim, 2000).

Computer mediated communication: Communicate through technology or computer mediated channels such as e-mail or instant messaging (Slagter van Tryon & Bishop, 2009; Tu & McIsaac, 2002).

Connectivism: An educational theory which emphasized learning through contact with others and developed networks of informational resources which are constantly evolving (Ally, 2008; Kop & Hill, 2008; Siemens, 2004).

Constructivism: An educational theory, which emphasizes learner self-direction in creating knowledge and understanding based on personal experiences and perceptions (Ally, 2008; Ertmer & Newby, 1993).

Dual-channel assumption: A component of the cognitive theory of multimedia learning which states that, in the working memory, there is a channel for processing visual information and a channel for processing verbal information (Mayer, 2005b).
Experiential learning theories: Concepts of learning as a cyclic and wholistic process, influenced by an individual’s experiences, environment, and interactions (Kolb, 1994).

Extraneous cognitive load: The type of cognitive load which has no direct value in creating knowledge or schema (Brunken, Plass, & Leutner, 2003; Paas, Renkl, & Sweller, 2004; Sweller, 2005a).

Germane cognitive load: The type of cognitive load defined as tasks or information which contribute to the development of knowledge and schema (Brunken, Plass, & Leutner, 2003; Paas, Renkl, & Sweller, 2004; Sweller, 2005a).

Grasha-Riechmann Student Learning Style Scales: Six learning style categories which seek to identify student characteristics and learning styles specifically in a classroom setting including social attitudes, and dispositions towards the classroom and learning (Jonassen & Grabowski, 1993; Riechmann & Grasha, 1974).

Gregorc Learning Style Model: Four learning style qualities of characteristics developed to evaluate how individuals think and develop concepts as well as how these are linked to an individual’s environment. This model is based in part on experiential learning theories as well as Kolb’s learning styles (Hawk & Shah, 2007; Jonassen & Grabowski, 1993).

Hemisphericity: A theory which suggests that cognitive style are based on right or left hemispheric brain dominance such that an individual who exhibits certain cognitive style characteristics can be ascribed as being left or right brain dominant (Buehner-Brent, 1990; Genovese, 2006; Jonassen & Grabowski, 1993).
Hypermedia: Media with links of embedded information such as audio or video files or connections to additional information (Dillon & Jobst, 2005).

Hyperpersonal Communication Model: A communication theory which focuses on text-based, computer mediated communication. This model indicates that individuals will selectively present themselves to others via text in a way which is viewed as optimal to the situation and will tend to reveal more personal information (Jiang, Bazarova, & Hancock, 2011; Walther, 2007).

Intrinsic cognitive load: The type of cognitive load imposed by the number of elements in a task and the interactivity between these elements (Brunken, Plass, & Leutner, 2003; Paas, Renkl, & Sweller, 2004; Sweller, 2005a).

Kolb’s Learning Styles: Four learning style preferences which are suggested as means by which to define an individual’s way of understanding or grasping information and how this information is processed internally. This tool is based in part on theories of experiential learning (Cassidy, 2010; Felder, 1996).

Learning management system: A system for online course delivery, which facilitates the organization of course materials and communications between students and the instructor (Caplan & Graham, 2008).

Learning styles: A pattern how individuals respond to and carry out learning tasks in terms of both behavior and cognition. These are seen as not fixed, but rather subject to change based on circumstances or learned practices (Evans, Cools, & Charlesworth, 2010).
Limited capacity assumption: A component of the cognitive theory of multimedia learning, which states that the working memory has a limited capacity by which to process new information (Mayer, 2005b).

Long-term memory: The conceptual location where knowledge and memories are stored. This memory store is not known to have a capacity limit nor a limit on the length of time information can be stored (Craik & Lockhart, 1972; Kalyuga, Ayers, Chandler, & Sweller, 2003; Sweller, 2005a; van Merrienboer & Sweller, 2005).

Modality principle: A principle which states that in multimedia learning, in certain circumstances, instruction is best accomplished through the presentation of an image with accompanying narration (Low & Sweller, 2005; Mayer & Moreno, 2002).

Multimedia: A combination of information presented in a visual formats such as images, photos, or video and in a verbal formats such as text or audio (Mayer, 2005b).

Multimedia learning: Learning through the formation of mental frameworks based on information presented both in visual formats such as images, photos, and video, and verbal formats such as text and audio (Mayer, 2005b).

Multimedia Principle: A principle, which states that individuals learn better from a combination of images and words than from words alone (Fletcher & Tobias, 2005).

Online learning: Learning via a computer (Clark, 2005; Clark & Mayer, 2003).

Redundancy principle: A principle which states that, in multimedia learning, care should be taken to not present duplicate information so as not to cause extraneous cognitive load (Sweller, 2005b).
Schema: Mental representations formed in the long-term memory as a result of processing new information (Sweller, 2005a).

Scholastic Assessment Test: A test of cognitive ability which measures academic achievement resulting in three sub-scores reporting on writing, critical reading, and mathematics skills (Frey & Detterman, 2004; Young, 2003).

Sensory memory: The initial way we take in information through our eyes, ears, or other senses. This information exists as a basic perception or sensation (Craik & Lockhart, 1972; Mayer, 2005b; Sweller, 2005a).

Social Information Processing Theory: A communication theory which focuses on how individuals create relationships through computer mediated communications and how these relationships can be of equally if not greater quality that relationships developed face-to-face (Walther, 1992; Walther, Anderson, & Park, 1994).

Social Presence Theory: A communication theory which is focused on how and the degree to which individuals are able to project themselves through a particular medium such as a computer in order to create relationships and connections with others (Stacey, 2002; Tu & McIsaac, 2002).

Split-attention principle: A principle, which states that when different forms of media are presented for learning, they should be placed in close spatial or temporal proximity (Ayers & Sweller, 2005).

Stanford-Binet Intelligence Scales: A method of measuring cognitive ability through evaluation of fluid reasoning, knowledge, quantitative reasoning, visual-spatial processing, and working memory. These measures are combined into arrive at a single IQ score (Becker, 2003; Johnson, 2005).
Synchronous online learning: A way of learning online which is has locational independence but is time dependent as regular meeting times are scheduled, mediated by technology-based tools (Clark & Mayer, 2003; McGreal & Elliott, 2008).

Visualizer/Verbalizer Behavior Observation Scale: A scale developed to evaluate visual or verbal cognitive style preferences based on response to authentic learning situations. This instrument is designed to be administered via a computer (Leutner & Plass, 1998).

Visualizer-verbalizer hypothesis: A concept referring to individuals tendencies to prefer information presented either visually as images, photos, or video for example, or verbally as text or auditory input (Mayer & Massa, 2003).

Visualizer/Verbalizer Questionnaire: A 15 self-report item questionnaire designed to evaluate visual or verbal cognitive style preferences (Jonassen & Grabowski, 1993; Leutner & Plass, 1998).

Web 2.0: A term for the Internet representative of a shift from users as passive recipients of informations to active contributors and collaborators in the creation and sharing of information on the Internet (Bennett, Bishop, Dalgarno, Waycott, & Kennedy, 2012; Hew & Cheung, 2013; Shneckenberg, Ehlers, & Adelsberger, 2011).

Web-facilitated instruction: Instruction, which is primarily face-to-face with 1 to 29 percent of content or communications taking place online (Allen & Seaman, 2010; Harasim, 2000).

Working memory: A system where individuals receive and process new information. Given its limited capacity, restrictions are imposed as to how much new
information one can process at any given time. This has also been referred to as the short term memory (Sweller, 2005a).
CHAPTER II

LITERATURE REVIEW

Online Learning

Online learning can be viewed as an extension of distance learning where learning takes place via a computer, thereby taking advantage of a wide range of media resources and collaborative tools available through the Internet and modern technologies (Clark, 2005; Clark & Mayer, 2003; Means, Toyama, Murphy, Bakia, & Jones, 2010). Online learning strategies include presentation of relevant learning materials in varied formats, employing appropriate instructional strategies, considering the needs of the learner as an individual as well as communities or virtual classrooms of learners, utilizing appropriate assessment tools, and fostering communication between all individuals engaged in the online learning process (Anderson, 2008a; Clark & Mayer, 2003).

Online learning can be said to have begun with the development of e-mail and networked, computer-based communication technologies in the early 1970’s. Since then, networks, computer capabilities, and overall acceptance of computer facilitated communication have led to the modern inception of the online classroom (Harasim, 2000). Key attributes of online learning environments include facilities allowing communication between multiple individuals, time and location independence, and computer mediated information delivery platforms allowing for multiple media formats (Clark & Mayer, 2003; Harasim, 2000). Online learning furthermore has the benefit of flexible usability options in that it may be used in either synchronous, concurrent time frames or asynchronous, time-independent circumstances and may be used with varying frequency in different learning situations (Allen & Seaman, 2010; Harasim, 2000). These
learning situations may include a web-facilitated course where educational material sharing and communications are facilitated by an online platform such as a learning management system and online activities comprise 1 to 29 percent of class time, mixed or blended classrooms where learning takes place online between 30 and 79 percent of the total class time, and completely online classes which are conducted 100 percent online (Allen & Seaman, 2010; Harasim, 2000). Figure 1 provides a comparative perspective of different learning environments based on time and distance requirements.

Figure 1. Time and location dependence of learning environments.

**Historical Perspective**

Distance learning is defined as a structured program of learning guided by an educational institution through which set learning outcomes are intended to be achieved; however learners are not directly supervised and have a level of autonomy over their
learning (Haughey, Evans, & Murphy, 2008). Although distance education has evolved from correspondence and transmission of materials via post to modern online communications and digital tools, certain basic premises have remained the same with regard to delivering high quality education at a distance. These include meaningful and comprehensive dialogues between students and instructors and the availability of engaging and rich materials to support the learning process (Haughey, Evans, & Murphy, 2008). With these ideas in mind, distance learning has sought to follow more generalized learning principles which advocate for creating learner-centered, collaborative environments based on the creation of knowledge with instructor and peer guidance, quality of materials and interactions, and opportunities for reflection and application on a personal level (Anderson, 2008a; Haughey, Evans, & Murphy, 2008).

**Learning and Technology**

In and of itself, technology or technology-based tools can be viewed as simply another means by which learning can be transmitted (Ally, 2008). Surface benefits of technology-based learning may include cost-effectiveness as well as space and time independence, allowing for the possibility of more diverse student participation (Ally, 2008; Clark & Mayer, 2003). The deeper benefits however are evidenced by the increasing breadth and flexibility of online technologies and resources. Ever increasing access to the Internet further enables online learning through flexible learning management systems, modern technologies supportive of multiple media formats, facilities allowing for rapid update and alteration of information as well as communications between students and instructors, and hyperlinking allowing for the connection of multiple information sources (Anderson, 2008a).
**Theories and Models of Online Learning**

In the process of designing and delivering online learning programs, it is wise to consider learning goals, the needs of learners, and overall objectives of any given course and to appropriately apply theories and practices of teaching and learning to achieve these objectives (Ally, 2009; Anderson, 2008a). Strategies utilized in the creation of online learning environments therefore utilize established educational theories as well as newer theories and models which take into consideration the unique attributes and impact of technology on both learners and the process of learning (Ally, 2008; Siemens, 2004).

**Educational Theories**

Instructional design for online courses can be relevantly informed by an understanding of established theories of learning (Ally, 2008; Ertmer & Newby, 1993; Kanuka, 2008). A conceptual understanding of some of these theories may aid in the selection and appropriate use of the various tools available in any given learning situation, specifically online learning (Ertmer & Newby, 1993). The following theories are commonly discussed as informing online instruction (Ally, 2008; Kanuka, 2008).

**Behaviorism**

Behaviorism emphasizes observable changes in behavior as indicators that learning has taken place. Emphasis is placed heavily on the learning environment and learner action and participation in that environment so that meaningful and measurable observations of behaviors and learning may be made (Ally, 2008; Ertmer & Newby, 1993; Kanuka, 2008). The design of instruction following the behaviorist model includes set systems of cues and patterns designed to sequentially lead learners progressively through steps of an overall learning goal. It should be the goal of the instructor to create
such an environment and ensure that students adhere to the program (Ertmer & Newby, 1993). Within the context of online learning, learning management systems (LMS) are a type of tool which allows for the creation of a standardized format for the delivery of learning materials in addition to providing set methods of interaction between students and materials, students and students, and students and instructors. An LMS can further require student participation in such a way as to result in observable and measurable behaviors through direct assessments of knowledge and completion as well as measured performance on set learning modules or guided practice activities (Kanuka, 2008). Computer based testing (CBT) is a tool which aligns with the behaviorist requirement for measurable gauges of learning as well as having the added feature of allowing for immediate feedback to students allowing for a degree of self-assessment and determination of content mastery of the steps in a learning program (Ally, 2008).

_Cognitivism_

Representing a departure from behaviorism, cognitivism arose as a theory, which placed emphasis on the internal process of learning through the creation of mental schema and memories rather than a direct and observable display of learning (Ertmer & Newby, 1993). In practice, cognitivists seek to create learning environments which aid students in making connections with previous knowledge through analogies or advance organizers for example, as a means of enabling the transfer of new information into long term memory stores for the creation of new schema and higher order thought and conceptualization (Ertmer & Newby, 1993). Emphasis is also placed on the learner and what strategies an individual uses in the process of learning, thereby taking into consideration inherent learner differences (Ally, 2008; Ertmer & Newby, 1993). Online
tools may facilitate constructivist ideals in several ways. First, the flexible nature of current technology allows for the presentation of information in several different formats (e.g., audio, visual, text, or animation) addressing the differing needs of individual learners. The presentation of materials may additionally be regulated by the instructor and offered to students in discrete chunks, preventing cognitive overload and thereby better enabling efficient transfer into long term memory stores. Simulations and other scenario-based activities prevalently exist on modern computers and the Internet further allowing learners access to means of practice through practical application of their learning (Ally, 2008).

**Constructivism**

The theory of constructivism is primarily based on the assumption that individuals create knowledge based on their own personal experiences and personal perceptions of their environment. Knowledge is not achieved in a discrete, single form but is instead subjective and differing for each individual (Ally, 2008; Ertmer & Newby, 1993). Knowledge structures are also described as being fluid rather than existing as fixed schema, and therefore subject to change as dictated by new experiences (Ertmer & Newby, 1993). Instructional strategies concurrent with the theory of constructivist learning emphasize enabling the learner to engage in discovery-based learning strategies through self-guided interaction with learning content as opposed to a structured or sequenced progression through learning materials, interactions with peers or instructors through which learners may build personally meaningful knowledge, and time and tools allowing for reflection in order to develop higher order concepts and thinking (Ally, 2008; Ertmer & Newby, 1993). Online learning systems may facilitate these goals via
the offering of learning content somewhat free of instructor influence or direct guidance through which students may interact in a way of their own choosing (Ally, 2008). Further tools commonly existing in an LMS for example allow for student-student and student-instructor interactions via discussion boards or other synchronous or asynchronous learning platforms, as well as learner reflection by means of blogs or online journals (Ally, 2008).

**Connectivism**

One new conceptualization of learning, which has arisen in response to the prevalence of computer and Internet resources as primary learning tools is connectivism (Ally, 2008; Siemens, 2004). Connectivism describes learning not as a wholly internalized and individual process of idea and knowledge formation, but rather as a continual process of relearning or refreshing knowledge based on rapidly changing concepts and information resources available in the current digital-age as well as creating connections with other individuals or groups as knowledge resources (Ally, 2008; Kop & Hill, 2008; Siemens, 2004). Learning is therefore posited to be not contained entirely within an individual but instead existing as a function of one’s ability to navigate the abundance of available information contained in the wide range of rapidly changing resources (Kop & Hill, 2008; Siemens, 2004). Knowledge is based on the intake, active creation of artifacts, and sharing of ideas through networked sources and is developed by the ability to identify or discard pieces of information based on their relevance to a present need or task as well as the ability to navigate to relevant information resources (Siemens, 2004). Learning is therefore a somewhat autonomous process of information identification and connection creation, existing as a process reflective of everyday life as
opposed to a discrete event occurring in a controlled learning environment such as a classroom or training event (Ally, 2008; Siemens, 2004).

From the perspective of an individual, the theory of connectivism implies that learning and knowledge are no longer conceptualized as structures, which are acquired and can then be relied upon for years or decades as relevant or accurate resources. Instead, modern technology-based resources have created immediate access to constantly changing information sources and, as a result, changed what it is to know, necessitating the need for continually evolving knowledge and emphasizing the ability to discover what is meaningful to know rather than internally retaining or memorizing knowledge (Siemens, 2004). In the process of discovering, creating, and connecting pieces of information, connections between seemingly disparate ideas may be made thereby creating entirely new ideas. Emphasis in the learning process is therefore placed on allowing the autonomous exploration of ideas and the creation of or allowance for more globally oriented and multidisciplinary learning environments, which correspond to the connectivist concept of learning (Ally, 2008; Siemens, 2004). All of the previously discussed theories are summarized in Table 1.
Table 1

**Summary of Learning Theories**

<table>
<thead>
<tr>
<th>Theory</th>
<th>Key focus</th>
<th>Strategies and tools</th>
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<tr>
<td><strong>Behaviorism</strong></td>
<td>Observable and measurable change</td>
<td>Sequential, guided learning</td>
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<td>Direct assessments</td>
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<td><strong>Cognitivism</strong></td>
<td>Making connections</td>
<td>Advance organizers</td>
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<td></td>
<td>Developing schema</td>
<td>Simulations</td>
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<td></td>
<td>Individual learning process</td>
<td>Scenario-based activities</td>
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<td></td>
<td>Application</td>
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<td><strong>Constructivism</strong></td>
<td>Personal Experience</td>
<td>Discovery-based learning</td>
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<td></td>
<td>Knowledge subject to experience</td>
<td>Self-guided learning</td>
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<td>Reflection</td>
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<td>Interaction and discussion</td>
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<td><strong>Connectivism</strong></td>
<td>Information networks</td>
<td>Resource exploration and development</td>
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<td></td>
<td>Continuous learning</td>
<td>Identification of knowledge resources</td>
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<td></td>
<td>Knowledge sharing</td>
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**Communication Theories**

In exploring how individuals best learn online, considerations of interpersonal interactions and how these align with prevailing theories supporting communication, collaboration, and social interactions have guided the research and development of theories of communication directly related to the unique context of online learning (Kreijns, Kirschner, & Jochems, 2003; Slagter van Tryon & Bishop, 2009; Stacey, 2002).

Online learning by its nature allows for computer mediated communication (CMC) which, in turn offers several channels by which students and instructors may communicate, such as e-mail, synchronous chats, and asynchronous tools including message boards and discussion threads (Slagter van Tryon & Bishop, 2009; Tu & McIsaac, 2002). Due to the inherent physical barriers which potentially exist in an online learning context notwithstanding the relevance and necessity of communication for
meaningful learning to occur, several theories and strategies have arisen to investigate and guide communication and social implications in an online environment (McInerney & Roberts, 2004; Slagter van Tryon & Bishop, 2009) which are subsequently discussed.

**Social Presence Theory**

Given the nature of online courses and the restrictions they impose on the way individuals communicate, social presence theory has emerged as a way to investigate these interactions and inform instructional practice (Slagter van Tryon & Bishop, 2009; Stacey, 2002). Social presence is defined as the extent to which an individual is able to project his or herself in a situation or through a particular medium and how this serves to develop relationships and feelings of connectedness (Stacey, 2002; Tu & McIsaac, 2002). Social presence in an online environment is primarily negotiated through text and is therefore considered to offer a low degree of social projection and interaction opportunities (Kreijns, Kirschner, & Jochems, 2003; Stacey, 2002). Online students often indicate feeling a lack of intimacy in interpersonal connections due to lack of social cues such as facial expression or body language. Communication delays often typical in an asynchronous learning environment may further impede a full sense of community between students and students and students and instructors (Slagter van Tryon & Bishop, 2009; Tu & McIsaac, 2002).

Online course activities commonly consist of discussion boards, forums, and other text-based formats through which student participants must express and share ideas (Kreijns, Kirschner, & Jochems, 2003). A lack of social presence and subsequent lack of class community development can restrict the sharing of ideas and collaboration between students as individuals have no basis by which to identify with other students through the
development of feelings of trust and respect or to develop or negotiate social relationships and hierarchies (Kreijns, Kirschner, & Jochems, 2003; McInerney & Roberts, 2004; Slagter van Tryon & Bishop, 2009). It is therefore suggested that instructors should deliberately design means by which students can establish social presence thereby fostering community and collaboration into their courses, not only as an introductory element but also as a continually recurring theme through which students are encouraged to develop meaningful relationships. This expanded social knowledge may result in trust and respect and thereby greater learning through collaboration, free idea sharing, and discussion (Kreijns, Kirschner, & Jochems, 2003; McInerney & Roberts, 2004; Slagter van Tryon & Bishop, 2009; Stacey, 2002). Adequately developed social presence combined with cognitive presence, or a sense of meaningful learning with opportunity for critical thinking, and teaching presence as a means through which the process and structure of learning is created and supported, combine together to create a functional community of inquiry as shown in Figure 2 (Anderson, 2008b).
Social Information Processing Theory

Inherent limitations of CMC are identified lack of social cues such as facial expression or voice intonation present in face-to-face communications, which may impose limitations upon social presence creation. Social information processing (SIP) theory, however, suggests that these factors do not, in fact, limit the quality or development of intimate interpersonal relationships in online environments (Walther, 1992; Walther, Anderson, & Park, 1994). Instead, given sufficient time, users will adapt text-based communication styles and content to compensate for the lack of other social cues such that these text-based communications create equally intimate and meaningful relationships between individuals (Walther, 1992). According to SIP, the lack of social channels typically available in face-to-face interactions is not a hindrance to the development of relationships and social interactions in CMC but instead time is the
primary constraint. Given adequate time, relationships of equal or greater quality will develop in a CMC environment (Walther, Anderson, & Park, 1994).

**Hyperpersonal Communication Model**

Another concept, which has sought to identify the nature of online interactions between individuals, is the hyperpersonal communication model. This model, focusing on text-based CMC, indicates that individuals selectively self-present to maximize what they perceive as socially desirable attributes or impressions concurrent with the context of a given situation (Jiang, Bazarova, & Hancock, 2011; Walther, 2007). This tendency can be attributed distinctly to both the sender of information who presents him/herself in a controlled manner, revealing attributes and attitudes considered to be optimal based on the current circumstances (Walther, 2007), and for the receiver who may internally exaggerate the attributes reported by the sender in determining the sender’s characteristics and thereby the nature of the online relationship (Jiang, Bazarova, & Hancock, 2011). This hyperpersonal relationship is permitted because text-based communication is editable, free from physical cues such as facial expression or body language, and relatively free from immediate time constraints allowing users to carefully consider and manage interactions (Walther, 2007). It is further noted that users in an online environment will tend to reveal more personal information than in a face-to-face situation, potentially further expediting the process of intimate relationship development (Jiang, Bazarova, & Hancock, 2011). To this end, users may tailor their communication style through the use formal or informal language, personal pronouns, and personal information shared to comply with the perceived social status of the recipient in relation to themselves (Walther, 2007). Lack of further information such as social cues allows for
the self-manipulation of a projected persona as well as exaggerated or imaginative perception of an individual by a receiver (Jiang, Bazarova, & Hancock, 2011; Walther, 2007). Figure 3 presents the hyperpersonal communication model.

![Hyperpersonal Communication Model Cycle](image)

Figure 3. *The hyperpersonal communication model cycle.*

**Communication Privacy Management Theory**

A further consideration for online communications reflects on the desire or willingness of individuals to share personal information with others, discussed by the communication privacy management (CPM) theory (Petronio, 2002). One supposition of CPM is that individuals maintain control and ownership over personal information, choosing what and what not to share (Petronio, 2002), which shows some correspondence with the hyperpersonal communication model where individuals selectively present themselves to others (Walther, 2007). Given the current emphasis on collaborative
learning (Kreijns, Kirschner, & Jochems, 2003) and the potential obstacles presented by CMC both in lack of social cues and the extended time frame necessary for the development of meaningful interpersonal relationships and impressions (Slagter van Tryon & Bishop, 2009) it has been suggested that investigations of what information individuals are willing to share and with whom in a learning context might accelerate the development of social relationships in an online learning environment (Furst, Reeves, Rosen, & Blackburn, 2004; Heo, 2011).

**Online Instructional Design**

Key components identified for the creation of high quality online classes include student-centered instruction, collaboration opportunities, dynamic interaction opportunities and presentations, and flexibility in terms of time and location (Caplan & Graham, 2008; Parker, 2008). It is further suggested that online instructional design should be grounded in educational theory and instructional planning models while simultaneously considering the unique nature of online learning, both in its benefits and constraints (Caplan & Graham, 2008). Some conceptualizations of online instructional design include the development of individual learning units ranging in size and content, which adhere to the scope and sequence of overall course objectives while also delivering information to multiple users, independent of location and time (McGreal & Elliot, 2008; Wiley, 2001). This goal may be achieved via courseware which allows for instructor controlled structuring and presentation of instructional units, while also facilitating collaborative goals through features such as chats, message boards and online conferencing (Clark & Mayer, 2003; Wiley, 2001). As no single, guiding methodology currently exists for online course design, the previously mentioned concepts and
strategies of structured yet student-centered design are advocated for use in thoughtful course development and implementation (Ally, 2008).

**Online Learning and Supporting Technology**

**Web 2.0**

The current conceptualization of Internet interactions, commonly referred to as Web 2.0, reflects a shift from users as passive recipients of information to active participants in the creation, modification, and sharing of information presented online (Bennett, Bishop, Dalgarno, Waycott, & Kennedy, 2012; Hew & Cheung, 2013; Shneckenberg, Ehlers, & Adelsberger, 2011). Tools which support Web 2.0 allow collective creation and sharing of information in multiple formats such as text, audio, images, and video as well as social networking which further enables individual connections, and information and idea sharing (Bennett, Bishop, Dalgarno, Waycott, & Kennedy, 2012). In an effort to connect Web 2.0 concepts and capabilities to online learning, much research and practice has focused on the creation of class group collaborations and information sharing by means of wikis, blogs, text and audio discussion boards, and media sharing platforms (Hew & Cheung, 2013). Results have been mixed as to the precise impact in terms of learning outcomes with the integration of these tools (Hew & Cheung, 2013) and it has been suggested that, in some instances, the social conceptualization of Web 2.0 may be at odds with a more individualized achievement concept of learning, resulting in varying degrees of participation with and acceptance of collaborative learning tools (Bennett, Bishop, Dalgarno, Waycott, & Kennedy, 2012). Collaborative tasks may be integrated into online learning, but often these tasks are not fully perceived by participants as being necessary or beneficial to
individual learning (Bennett, Bishop, Dalgarno, Waycott, & Kennedy, 2012). Figure 4 presents a representation of Web 2.0 compared with Web 1.0, the earlier model of web activity.

Figure 4. Web 1.0 versus Web 2.0 in terms of content contributions to the Internet.

It is further suggested that challenges integrating Web 2.0 tools into online learning environments may be in part due to a need to re-conceptualize e-learning as a more open and free flowing environment which includes a full range of Internet resources rather than centered on an institution or closed group of individuals such as a class of students and an instructor (Schneckenberg, Ehlers, & Adelsberger, 2011). A broader range of experiential learning activities might thereby be accessed in addition to providing students with translatable skills through deeper interaction with Web 2.0 capabilities which would, in turn, create greater competencies for future professional practice (Schneckenberg, Ehlers, & Adelsberger, 2011). Despite a general acceptance of
and desire to integrate Web 2.0 tools into current online learning, many recent studies are shown to be limited in their scope and recommendations have been made for more longitudinal studies to guide practice (Hew & Cheung, 2013).

**Learning Management Systems**

Learning management systems (LMSs) are currently the prevalent system used for online course delivery. LMSs support the structured organization and presentation of a course, allowing for the creation of specific modules or subcategories of information specified by an instructor, as well as permitting varied communication channels through discussion boards, video conferencing, and chats and the ability to share materials in various formats including text, audio, video, and images (Caplan & Graham, 2008). Studies suggest that LMS use can support a student-centered and collaborative approach to learning online, depending on the degree to which both instructors and students make effective use of the available tools (Malm & DeFranco, 2012; Munoz-Organero, Munoz-Merino, & Kloos, 2010). Figure 5 shows the organization and interactions capable with the LMS in addition to available tools.
Conversely, it is argued that the LMS is no longer concurrent with usage patterns in the Web 2.0 context and thereby the e-learning 2.0 context (Dalsgaard, 2006). The current inception of the LMS relies on a self-contained system which, while facilitating communication, collaboration, and idea sharing, precludes student participants from freely creating and contributing key content thereby reducing autonomy in the learning process (Dalsgaard, 2006; Thacker, 2012). It is suggested that the LMS may benefit from redefinition as a basic administrative system, which also allows student users to select and create content independently and collaboratively and from multiple perspectives, similar to a social networking application (Thacker, 2012). In addition to providing more self-directed learning opportunities, this re-imagination of the LMS may further be reflective of real-life online activities and problem solving strategies (Dalsgaard, 2006).
**Communication Functions**

With the advent of the Internet, computer-based learning has expanded in ways that allow a high degree of interaction between students and students, and students and instructors (Clark & Mayer, 2003). Emphasis on cooperative learning in an online context is supported by the constructivist perspective, which asserts that knowledge building is a social endeavor through which cognitive development occurs (Johnson & Johnson, 2004). In an online learning environment, users can be said to be interacting “through computers” using the different tools available, independent of time and space constraints (Johnson & Johnson, 2004).

Current tools available are varied and include text-based exchange formats such as chats, message boards, and threaded discussion boards, which can facilitate topic specific communications and discussions in either synchronous or asynchronous time (Clark & Mayer, 2003; Revere & Kovach, 2011). Web or online conferencing allows for more robust exchanges in that this format typically contains audio and video tools in addition to text-based communication functions as well as information sharing in the form of a shared, computer mediated workspace, similar to a whiteboard in a face-to-face setting which allows for multi-person editing and manipulation of presentations in a synchronous time setting (McGreal & Elliot, 2008; Revere & Kovach, 2011). An overview of commonly available tools in the LMS is presented in Table 2. Mobile devices and wireless technologies have allowed for further locational independence in online learning, permitting communication and participation in multiple formats resulting in a high degree of accessibility for learners (McGreal & Elliot, 2008).
Table 2

*Learning tools and their key elements in the LMS* (Revere & Kovach, 2011)

<table>
<thead>
<tr>
<th>Learning tool</th>
<th>Key elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discussion board</td>
<td>• Peer interaction</td>
</tr>
<tr>
<td></td>
<td>• Idea exchange</td>
</tr>
<tr>
<td></td>
<td>• Accountability</td>
</tr>
<tr>
<td>Wiki</td>
<td>• Collaboration</td>
</tr>
<tr>
<td></td>
<td>• Deeper learning content engagement</td>
</tr>
<tr>
<td>Blog</td>
<td>• Student contributed content</td>
</tr>
<tr>
<td></td>
<td>• Peer interaction forum</td>
</tr>
<tr>
<td>Journal</td>
<td>• Flexible privacy options (student-teacher only, small student groups, entire class)</td>
</tr>
<tr>
<td></td>
<td>• Opportunity for reflection</td>
</tr>
<tr>
<td>Chat</td>
<td>• Synchronous discussions</td>
</tr>
<tr>
<td>Video conferencing</td>
<td>• Synchronous audio/video interactions</td>
</tr>
<tr>
<td></td>
<td>• Content and application sharing</td>
</tr>
</tbody>
</table>

*Media for Learning*

Current systems further allow for the presentation of information for learning in multiple formats. These include text, images, video, animations and combinations thereof creating potentially rich, multimedia content (Abrami, Bernard, Bures, Borokhovski, & Tamin, 2011; McGreal & Elliott, 2008). These capabilities may diversify and enhance student interactions with course content and create opportunities to develop personal understanding and create meaning through self-directed or guided interaction with content (Abrami, Bernard, Bures, Borokhovski, & Tamin, 2011). It is further suggested that students, in general, tend to learn more optimally from combinations of media such as pictures and text together or narrated video for example, than from a single format alone (Brunye, Taylor, Rapp, & Spiro, 2006).
Modes of Online Learning

Asynchronous Learning

Asynchronous learning as a primary mode of online instruction is characterized as being independent of location as well as time (Romiszowski & Mason, 2004). Current LMS allow for the inclusion of a variety of instructional materials and media content in an asynchronous program, as with a synchronous program; however a main focus of studies and discussion in asynchronous online learning is the method and quality of communication between students and students, and students and instructors (Hrastinsky, Keller, & Carlsson, 2010; Romiszowski & Mason, 2004; Woo & Reeves, 2008). Given that there is an inherent delay in communication between individuals due to time independence, i.e. individuals posting or responding to communications at different times, emphasis is placed on creating multiple communication opportunities as well as requiring communication via discussion boards and other text-based tools in order to develop relationships and collaboration between students (McInerney & Roberts, 2004; Romiszowski & Mason, 2004). It is emphasized that discussion points should be deliberately designed to engage meaningful discussion and higher order thinking skills with the purpose of eliciting quality communications rather than simply allowing students to post messages for the sake of meeting a quota (Woo & Reeves, 2008). Supporting the sharing of personal knowledge as well as the creation of collective knowledge between individuals may further aid in achieving these goals (Romiszowski & Mason, 2004) and well-designed asynchronous CMC forums have been shown to inspire higher order thinking skills, deep individual reflection on concepts, and the sharing and creation of complex ideas and dialogues (Hrastinski, Keller, & Carlsson, 2010).
**Synchronous Learning**

Synchronous online learning is characterized as concurrent or occurring at the same time although not dependent on a single location as participants may connect with the course from any Internet capable system or device (Clark & Mayer, 2003). A main feature of the synchronous online class is web conferencing which allows for real-time communication between students and students, and students and instructors in addition to the exchange and group manipulation of visual information by means of “whiteboard” tools often accompanying web conferencing applications (Clark & Mayer, 2003; McGreal & Elliott, 2008). Synchronous classes may or may not also include asynchronous tools such as discussion boards (Clark & Mayer, 2003; Hrastinski, Keller, & Carlsson, 2010). Synchronous communications have been observed as tending to create more rapid social connections and networks amongst class participants as well as allowing for immediate feedback, thereby reducing frustrations attributed to communication delays in strictly asynchronous formats (Hrastinski, Keller, & Carlsson, 2010). It is further suggested that by utilizing both synchronous and asynchronous tools, creating in essence hybridized CMCs, social interactions and collaborations are maximized while simultaneously including forums for deeper reflection and more carefully constructed dialogues via asynchronous tools (Hrastinski, Keller, & Carlsson, 2010). Table 3 provides a brief comparison of synchronous and asynchronous online learning environments.
Table 3

*Features and examples of tools in asynchronous and synchronous online learning environments*

<table>
<thead>
<tr>
<th>Key Features</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Asynchronous</strong></td>
<td></td>
</tr>
<tr>
<td>• Time independence</td>
<td>• Discussion boards</td>
</tr>
<tr>
<td>• Locational independence</td>
<td>• E-mail</td>
</tr>
<tr>
<td>• Self-paced</td>
<td>• Learning modules (audio, video, text)</td>
</tr>
<tr>
<td>• Time for reflection</td>
<td></td>
</tr>
<tr>
<td><strong>Synchronous</strong></td>
<td></td>
</tr>
<tr>
<td>• Concurrent time</td>
<td>• Video conferencing</td>
</tr>
<tr>
<td>• Locational independence</td>
<td>• Instant message/chats</td>
</tr>
<tr>
<td>• Real-time discussion and collaboration</td>
<td>• Collaborative workspace (interactive whiteboards)</td>
</tr>
</tbody>
</table>

**Online Learning – Present and Future**

Advances in technology and its perceived usefulness by both learning institutions as well as students has resulted in increasing growth in the prevalence of varied forms of online courses (Allen & Seaman, 2010; Harasim, 2000). Increasingly, students are selecting to enroll in online courses at a rate exceeding that of traditional university enrollment and institutional leaders are placing greater importance on the development of online programs (Allen & Seaman, 2010). Although online learning has gained wide institutional acceptance (Allen & Seaman, 2010) further study in terms of faculty and student use and support of these systems (Kim & Bonk, 2006) as well as advancing the systems and ideologies of online learning to meet ever changing capabilities and user demands of technology and Internet resources are suggested (Dalsgaard, 2006; Thacker, 2012). The following sections discuss some common ways in which technology is being
utilized in learning environments as well as potential future directions for technology-based learning.

**Computer-assisted instruction**

**Web-facilitated**

At the most basic level of technology integration is the web facilitated course described as having 1 to 29 percent of the course content and activities taking place online and the majority of the course being face-to-face (Allen & Seaman, 2010). It has, however, been asserted that, given the ubiquity of technology and Internet use in educational settings, all face-to-face courses may now be considered as web-facilitated via, for example, e-mail communications between instructors and students or students and students, the posting of course materials online, or student use of the Internet for research or study purposes (Harasim, 2000).

**Blended Learning**

Blended learning is defined as a course, which contains a face-to-face component while also having 30 to 79 percent of content and interactions taking place online (Allen & Seaman, 2010). Rather than online resources existing as merely a repository for course information or as tools for communications outside of a regular class meeting time, online tools are fully integrated into the context of the course and students are required to actively participate in online activities in order to meet the overall course goals and requirements (Harasim, 2000). Blended learning is regarded as a means to maximize the benefits of face-to-face instruction by fostering a rapid social structure development and a sense of learning community, while also taking advantage of the learning resources and
time and location independence which can be provided through online learning (Garrison & Kanuka, 2004; Rovai & Jordan, 2004).

**Completely Online**

A completely online course is defined as a situation where networked computers are the primary platforms used for content delivery and interactions in a course (Allen & Seaman, 2010; Harasim, 2000). It is further described as having a minimum of 80 percent of course content delivered online and generally having no face-to-face meetings (Allen & Seaman, 2010). The completely online course may be synchronous or asynchronous and may, through use of the tools available in an LMS for example, serve to create a collaborative learning environment free from the constraints of time and location (Harasim, 2000; Romiszowski & Mason, 2004). A comparative chart of time spent online for web-facilitated, blended, and completely online learning environments is shown in Figure 6.
Figure 6. Percentage of online content for web facilitated, blended, and online learning environments.

Massive open online courses

One emerging trend in online education has been the massive open online course (MOOC), which has received increasing interest since its formal identification in 2008 (Liyanagunawardena, Adams, & Williams, 2013). MOOCs are generally defined as online courses, which are facilitated by experts in the respective field of study offered and have open and free registration. Learners guide themselves through the course of study and take advantage of fully integrated online resources as well as social networking resources to collaborate and meet course objectives (McAuley, Stewart, Siemens, & Cormier, 2010). MOOCs may have many hundreds if not thousands of participants from around the world (Liyanagunawardena, Adams, & Williams, 2013; McAuley, Stewart, Siemens, & Cormier, 2010). While MOOCs take advantage of Web 2.0 systems and interactions and in many instances subscribe to the connectivist educational philosophy, allowing for open and expansive educational opportunities, they are not without
MOOCs are reported as having a generally low completion rate and, due to their rapid emergence, a lack of substantial research investigating their overall effectiveness in learning (Liyanagunawardena, Adams, & Williams, 2013; McAuley, Stewart, Siemens, & Cormier, 2010). Issues regarding the implications in terms of revenues for higher education institutions have also been raised as potential concerns hindering the growth and acceptance of MOOCs by academic institutions (McAuley, Stewart, Siemens, & Cormier, 2010).

**Individual Differences**

Individuals have inherent traits and characteristics representing a wide range of factors ranging from genetics to culture to personal experiences. These differences may manifest in any number of behaviors and qualities. With a focus on education and learning, these characteristics may be evaluated and targeted to enhance learning outcomes (Jonassen & Grabowski, 2011). That is to say, it has been theorized by many in educational research that individual learners think about and process information differently and possess varying inherent skills, aptitudes, preferences, and tendencies (Irani, Telg, Scherler, & Harrington, 2003; Jonassen & Grabowski, 2011; Klein, 2003).

**Learning Preferences**

Learning preferences or learning styles can be defined as characteristic habits and behaviors possessed by individuals, affecting the way individuals carry out and respond to learning tasks. These characteristics are not viewed as fixed but rather changeable over time or based on specific tasks (Evans, Cools, & Charlesworth, 2010; Klein, 2003).
From this perspective then, learner preferences can affect selection of courses of study and learning materials presented (Jonassen & Grabowski, 1993).

Considerable research has been conducted over several decades focusing on learner differences from an educational perspective and how these differences impact learner choices and educational outcomes (Leutner & Plass, 1998). Research has given rise to several models for testing theorized sets of perceived characteristics and concepts as to how these characteristics are impacted by the style and presentation of learning materials (Felder, 1996). Some researchers suggest the identification of learner characteristics and the tailored creation of educational materials and experiences corresponding to measured learning preferences in order to best accommodate learning outcomes and learner satisfaction (e.g., McClellan & Conti, 2008). Others suggest that perceived and measured learning styles are impacted more through interactions with peers and instructors and so optimal learning is achieved by matching learning situations and communication mechanisms with learner preferences (e.g., Dewar & Whittington, 2000; Woo & Reeves, 2008). Other research still has failed to find direct correlations between learning outcomes and learning preferences (e.g., Pillay, 1998). Given this confounding array of suggestions regarding learner preferences and educational implications, it has been further posited that learning in general requires the engagement of multiple learner resources regardless of whether or not they are preferred by the learner and that, while still acknowledging these unique characteristics, learning and instruction should not be encouraged to favor distinct characteristics but rather teach students to be flexible and able to take in information in many ways, this strategy being the most representative of “real-world” scenarios (Felder, 1996; Klein, 2003).
Despite disagreement on the usefulness or uses of student learning preferences to guide educational practice, it is still important to understand that individuals possess unique traits and these traits do have some impact on learning whether through direct learning outcomes, interactions which effect learning, willingness to learn, or choices of learning materials or courses of study (Jonassen & Grabowski, 1993). The following section presents several commonly used theories and measures of learning styles which have been used to not only identify learner characteristics but also to guide instruction through a better understanding of learner needs.

**Theories and measurements**

*Kolb’s Learning Styles*

Theories of experiential learning are referred to as the motivation behind the development of the Kolb learning style model (Kolb, 1984). Experiential learning theories are based on concepts that learning is a holistic and cyclic process influenced by interactions between individuals, their experiences in general, and their interactions with their environment. All of these variables do not exist as discreet channels by which one may access learning, but rather as points in a learning cycle, linked as harmonious components needed to achieve not only immediate learning goals but also to facilitate ongoing learning by incorporating new knowledge into one’s overall experience and dynamic creation of knowledge (Kolb, 1994). Figure 7 presents a diagram of the cyclic learning process outlined by Kolb’s experiential learning theory.
Kolb’s theory of learning styles identifies four potential preferences reflective of 1) how individuals achieve understanding of or grasp information, sometimes referred to as the prehension dimension and 2) how individuals process information internally (Cassidy, 2010; Felder, 1996). Prehension is measured on a dichotomous scale, classifying individuals as favoring concrete experience (CE) or direct interaction and experimentation with learning materials, or as favoring abstract conceptualization (AC) or conceptual analysis and thinking about learning materials (Cassidy, 2010). Internal processing preferences are then measured on a second dichotomous scale as either preferring active experimentation (AE) where the process of learning takes place externally until understanding is achieved, or reflective observation (RO) where scenarios and solutions are internally processed and only externalized after understanding has been reached (Cassidy, 2010; Felder 1996).
Individuals, having been measured to favor two of these four characteristics, are then grouped into four categories of types or learning styles: 1) *convergence*, the combination of CE and AE, 2) *divergence*, the combination of RO and CE, 3) *assimilation*, combining AC and RO, and 4) *accommodation*, which is the combination of AC and AE (Cassidy, 2010). In terms of educational experiences, the converger type may prefer lecture examples, laboratory settings, and projects for example, which may allow them to directly apply learning experiences (Felder, 1996; Hawk & Shah, 2007). The diverger type while also preferring concrete experiences such as lecture examples and demonstrations would take a more reflective approach to the assimilation of learning, favoring questions and discussion, and finding ways to relate learning to personal experiences (Felder, 1996; Hawk & Shah, 2007). The third type, assimilators, are categorized as preferring logical and direct presentation of materials through lecture or text and require time and activities which promote internal reflection and the development of concepts, such as discussions or journals (Felder, 1996; Hawk & Shah, 2007). Finally, the accommodator type favors clear and direct presentation of concepts via lecture or reading as well as clearly defined and directed tasks, which contribute to the assimilation of ideas (Felder, 1996; Hawk & Shah, 2007). Kolb’s categorization of learning styles with associated characteristics is shown in Figure 8.
The Kolb learning style inventory has been reported to have issues in terms of validity and reliability as well as with internal consistency, all of which are below .80 for each of the test subcategories (Reynolds, 2003). As a result, this has brought into question the usefulness of this particular measure (Reynolds, 2003). It is therefore suggested that this instrument would be best used as a tool for self-discovery rather than as a direct guide for the presentation or creation of instructional materials or scenarios for any particular student (Jonassen & Grabowski, 1993). Each type is also viewed as a subcomponent of the learning cycle and, despite an individual’s measured type preference, each category is considered to be an important part of the learning process (Kolb, 1994). With this concept in mind, the Kolb learning style inventory is also considered a potentially useful tool in guiding learners through all the stages of the learning cycle in order to foster more complete learning (Jonassen & Grabowski, 1993).

**Grahsa-Reichman Learning Styles**

The Grasha-Riechmann Student Learning Style Scales (GRSLSS) was developed with the idea of measuring student characteristics specifically in a classroom setting to better understand and enhance instruction and overall learning. This is based on the
concept that although a variety of standardized personality measures are often used to assess students, they do not serve as adequate or reliable predictors of student behaviors in the classroom (Riechmann & Grasha, 1974). As this measure is designed specifically with the classroom environment in mind, its primary focus is described as measuring classroom specific social interactions as well as attitudes and feelings towards classroom learning (Jonassen & Grabowski, 1993).

The GRSLSS identifies six learner styles based on three classroom characteristics, identified as attitudes towards learning, perceptions of instructors and other students, and attitudes and behaviors based on standard classroom practices and procedures (Riechmann & Grasha, 1974). The six learner characteristics are: 1) the independent learner who is a confident learner, generally preferring to work alone, 2) the dependent learner who prefers specific guidance for learning activities and prefers teacher and peer support, 3) the collaborative learner who prefers interaction with peers and instructors to facilitate learning, 4) the competitive learner who is driven by a desire to achieve the highest outcomes possible in class as well as to outperform peers, 5) the participant learner who enjoys learning and attending class, and closely follows classroom guidelines and set curricular goals, and 6) the avoidant learner who is disinterested in typical classroom learning and interactions with instructors and peers (Jonassen & Grabowski, 1993). Table 4 presents the GRSLSS learner styles with associated characteristics.
Table 4

*Grasha-Riechmann Student Learning Styles*

<table>
<thead>
<tr>
<th>Style</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Independent</td>
<td>A confident learner who prefers to work alone.</td>
</tr>
<tr>
<td>Dependent</td>
<td>A learner who prefers specific guidance and support from teachers and peers.</td>
</tr>
<tr>
<td>Collaborative</td>
<td>A learner who prefers interaction with teachers and peers to facilitate learning.</td>
</tr>
<tr>
<td>Competitive</td>
<td>A learner driven by a desire to achieve the highest possible outcomes and outperform peers.</td>
</tr>
<tr>
<td>Participant</td>
<td>A learner who enjoys attending class and learning, following along with goals and guidelines.</td>
</tr>
<tr>
<td>Avoidant</td>
<td>A learner who is disinterested in the typical classroom as well as interactions with teachers and peers.</td>
</tr>
</tbody>
</table>

The GRSLSS is suggested as a useful tool for creating or remediating classroom specific learning conditions. Some criticism exists however regarding data collection as this instrument consists entirely of self-report items. Given the power differential between teachers and students and a general desire by students to achieve good grades and successfully complete any course, there may be a tendency to respond to survey questions in a way viewed as favorable rather than to give an honest response (Grasha, 1984; Jonassen & Grabowski, 1993).

*Gregorc Learning Styles*

The Gregorc Learning Style Model (GLSM) was developed through phenomenological research of both students and teachers in a classroom setting and is additionally based Kolb’s learning styles and learning cycle (Hawk & Shah, 2007; Jonassen & Grabowski, 1993). The underlying concept behind the GLSM is that learning styles exhibited as observable behaviors are symptomatic of a deeper psychology of
learning representing how individuals think and generate concepts as well as how ideas are linked with an individual’s environment (Gregorc, 1984).

Four qualities or characteristics are identified by Gregorc (1984), which are measured as degrees along bi-polar ranges rather than as dichotomously opposed characteristics (Jonassen & Grabowski, 1993). These characteristics are additionally stated to be subject to change by an individual (Hawk & Shah, 2007), congruent with learning styles being defined as changeable (Evans, Cools, & Charlesworth, 2010). The four styles defined by the GLSM are: 1) concrete sequential characterized by a need for order and logic and benefiting from hands-on experiences in exploring concepts and creating conclusions, 2) concrete random characterized by a need for resource rich learning environments in which free exploration of materials and concepts is allowed, 3) abstract sequential characterized as reliant on the creation of mental images and schema through interaction with visual and verbal information, and 4) abstract random characterized as best learning holistically through social interactions and discussion in stimulus rich environments (Hawk & Shah, 2007; Jonassen & Grabowski, 1993). Figure 9 shows a representation of the Gregorc Learning styles and associated characteristics.

Figure 9. Gregorc Learning Style Model
The GLSM has enjoyed some popularity in use and has been reported as having high face validity. Direct measures of validity and reliability, however, have been reported as highly variable from study to study casting doubt on the overall value of this instrument (Ferro, 1995; Reio & Wiswell, 2006). As a result, an overall revision of the instrument has been suggested (Reio & Wiswell, 2006) and it is in the meantime recommended for use as a self-assessment tool rather than as a diagnostic tool to guide specific learning or instruction (Jonassen & Grabowski, 1993).

**Cognitive Ability**

Cognitive ability has been defined in a general sense as what individuals are capable of knowing (Mayer & Massa, 2003). It is an accepted view that cognitive ability is multifaceted, comprised of a variety of dimensions such as spatial ability or verbal ability which when combined, create an overall picture of intellectual aptitude (Dickens, 2008). It has been further observed that correlations exist between these various measures of ability which has led to the creation and acceptance of commonly used measures of cognitive ability (Dickens, 2008).

Current tests of cognitive ability and intelligence are based in part on the studies of psychologist Charles Spearman who observed that individuals who performed well at one task appeared to also perform well in other seemingly unrelated tasks. These performance factors in combination were used to create a measure of general intelligence known as the g factor (Deary, Penke, & Johnson, 2010). Subsequent research sought the development of tests which would combine multiple measures to identify a single g value, more commonly known as an intelligence quotient or IQ (Jonassen & Grabowski,
Modern tests of intelligence typically contain a combination of subtests measuring capabilities in areas such as language ability, spatial ability, auditory perception, memory, and speed of information processing (Deary, 2001). Such tests in an educational context are used to gain a better understanding of learning potential for individuals and help better understand the learning process and how it is impacted by individual differences (Jonassen & Grabowski, 1993).

Theories and measurements

Stanford-Binet Intelligence Scales

Psychologist Alfred Binet and physician Theophile Simon initially developed the measurements currently known as the Stanford-Binet Intelligence Scales as a means of objectively testing children with intellectual disabilities in the early 1900’s (Binet & Simon, 1948). A primary motivation was to remedy a seemingly arbitrary system at the time, which assigned labels to describe the overall ability of individuals with intellectual deficiencies (Binet & Simon, 1948). This test was later translated and revised by Lewis Terman at Stanford University and subsequent revisions and additions have resulted in the test scales widely known and used today (Becker, 2003). The Stanford-Binet measures general intelligence for individuals ranging from 2 to 85 plus years old via five subcategories measuring fluid reasoning, knowledge, quantitative reasoning, visual-spatial processing, and working memory (Johnson, 2005) to arrive at a single IQ score (Becker, 2003).

The current, fifth edition of the Stanford-Binet is reported to have very high validity and reliability coefficients (Johnson, 2005). The measurement is further praised as being easily administered and highly adaptive, offering multiple starting points for
different individuals (Becker, 2003; Johnson, 2005). The current measure additionally offers nonverbal information such as pictorial representations which has been reported to allow for an expanded age range eligible for testing, specifically children under the age of 10 with limited literacy skills (DiStefano & Dombrowski, 2006) and in general this measure is considered a useful and consistent tool for use in educational and general applications (Becker, 2003).

**SAT**

The Scholastic Assessment Test (SAT) was first administered in 1926 by the College Board and was initially categorized as an intelligence test, designed to assess the aptitude of individuals seeking admission to, at the time, a small number of private, higher educational institutions (Young, 2003). The original test consisted primarily of multiple-choice items in nine subsections with strict time limits imposed for response time, and reporting a single final score (Lawrence, Rigol, Van Essen, & Jackson, 2003; Young, 2003). Over the decades, the SAT has undergone multiple revisions the last of which occurred in 2005, providing the current model which contains three sub-sections in writing, critical reading, and mathematics (Young, 2003). The SAT has also come to be known as a test of academic achievement rather than a measure of intelligence; however studies do suggest strong correlations between the SAT and measures of general intelligence (Frey & Detterman, 2004).

The SAT has been reported to have high validity and reliability coefficients as well as a high positive correlation with college performance (Cohn, 1985). Further studies have shown a significant relationship between SAT scores and typical measures of cognitive ability (Frey & Detterman, 2003). The SAT has been criticized as being
biased against minority groups, such that certain test items are said to favor particular
groups while putting others at a disadvantage (Santelices & Wilson, 2010). The SAT has
also been criticized as favoring males, specifically citing consistent differences in scores
on the mathematics sections of the test for males and females (Nankervis, 2011).
Whether or not these biases exist directly in the test itself, exist at all, or are reflective of
other environmental influences are a matter of continued debate (Dorans, 2010; Liu,
Feigenbaum, & Dorans, 2005).

**Spatial Ability**

Spatial ability, a sub-measure of overall cognitive ability, is generally defined as the ability to mentally construct and manipulate visual images (Lohman, 1988) or essentially to develop and retain mental images (Hauptman, 2010). Several studies of spatial ability have sought to define distinct categories within the overall context of spatial ability (Feng, Spence, & Pratt, 2007; Uttal, Meadow, Tipton, Hand, Alden, Warren, & Newcombe, 2012). One of these categories is spatial orientation described as the ability to mentally distinguish different objects from each other and from background distraction. Another category is spatial visualization described as the ability to mentally view objects from different perspectives. A third category, mental rotation, is described as the ability to mentally transform or rotate objects. The category of spatial attention applies to the ability to conceptualize movements and positional orientations between objects and the resources an individual has available to devote to identifying and processing greater or lesser amounts of information (Christou, Jones, Mousoulides, & Pittalis, 2006; Hauptman, 2010; Lohman, 1988; Uttal et al., 2012).
Theories and Measurements

A variety of tasks including mental-rotation tasks, mental paper folding tasks, and useful field of view tasks, have been widely used to measure spatial abilities. These tasks have been further shown to improve generalizable spatial abilities and performance on both repeat testing of the tasks themselves as well as non-target specific tasks such as navigation and spatial geometry and other science, technology, engineering, and mathematics (STEM) related subjects (Feng, Spence, & Pratt, 2007; Hauptman, 2010; Uttal, et al., 2012; Wright, Thompson, Ganis, Newcombe, & Kosslyn, 2008).

In general, individuals may differ in terms of spatial abilities, and it has been extensively noted throughout the research literature that males tend to exhibit greater spatial abilities than females (Feng, Spence, & Pratt, 2007; Uttal, et al., 2012; Wolbers & Hegarty, 2010). Both male and female subjects have shown relatively equal response to spatial skill training and skills improvement; however, training experiments have largely not succeeded in closing the gender gap as males still show overall higher scores than females (Feng, Spence, & Pratt, 2007; Uttal, et al., 2012). One promising avenue of research has focused on action-based video games and their potential for increasing overall spatial abilities (Bavelier, Green, Poget, & Schrater, 2012; Feng, Spence, & Pratt, 2007). Feng, Spence and Pratt (2007) were able to show that action video game play, which focuses on spatial attention, had a greater impact on female subject than male subjects, resulting in indistinguishable post-test scores on useful field of view tasks. Furthermore, the video game training also resulted in significant improvements in mental rotation task scores for all of the test-group subjects (Feng, Spence, & Pratt, 2007).
Cognitive Style

Cognitive style is defined as an individual’s preferred way of processing information (Buehner-Brent, 1990; Evan, Cools, & Charlesworth, 2010). The mental processes used in information processing may include problem solving, thought, perception, imagery, and memory (Ausburn & Ausburn, 1978; Buehner-Brent, 1990). Cognitive style is described as bipolar in nature such that one individual may express a tendency towards one type of information processing strategy over another; however neither possibility is seen as superior to the other. In contrast, cognitive ability is described as unipolar, where higher scores are by definition better in that they indicate greater ability (Jonassen & Grabowski, 1993). Cognitive styles have further been observed to be stable preferences which individuals will consistently make use of and are resistant to change (Ausburn & Ausburn, 1978).

Cognitive styles research has led to the creation of several classifications or dimensions along which individuals may be measured to determine style tendencies (Ausburn & Ausburn, 1978). These dimensions are categorized as relating to information-gathering styles describing how individuals select information from the environment or learning situation such as, for example, by visual means, tactile interactions, or attention to verbal information as well as information-organizing styles which describe how individuals internally process the information they have taken in, such as categorizing information narrowly or broadly leading to concept formation (Ausburn & Ausburn, 1978; Jonassen & Grabowski, 1993).
Theories and measurements

Rather than described as discrete, individual theories, cognitive styles are generally listed as bipolar dimensions, which may be used to categorize individual differences (Jonassen & Grabowski, 1993). A variety of instruments differing in complexity and task orientation have been developed to measure each of these posited style dimensions (Ausburn & Ausburn, 1978).

Table 5 presents several cognitive style dimensions that are prevalent in research. Each consists of dichotomous dimensions or poles towards which any individual may tend to a greater or lesser degree rather than definitively and absolutely exhibiting one trait or another on any given scale (Ausburn & Ausburn, 1978; Buehner-Brent, 1990; Jonassen & Grabowski, 1993).
Table 5

*Cognitive Style Dimensions*

<table>
<thead>
<tr>
<th>Styles</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Field independent vs. field dependent</strong></td>
<td>Individuals may tend to spatially separate items as discrete elements in a scenario. Individuals may spatially view items as a whole, not easily separating distinct elements.</td>
</tr>
<tr>
<td><strong>Reflective vs. impulsive</strong></td>
<td>Individuals may tend to deliberate before responding. Individuals may tend to prefer speed and respond quickly.</td>
</tr>
<tr>
<td><strong>Sharpening vs. leveling</strong></td>
<td>Individuals may remember discrete elements distinctly or remember less distinctly and instead condense new information and merge it with previous knowledge.</td>
</tr>
<tr>
<td><strong>Breadth of categorizing</strong></td>
<td>Individuals may tend to exhibit differences in the narrowness and flexibility by which they will categorize information.</td>
</tr>
<tr>
<td><strong>Scanning vs. focusing</strong></td>
<td>Individuals tend to employ their attention and concentration differently.</td>
</tr>
<tr>
<td><strong>Tolerance for unrealistic experiences</strong></td>
<td>Individuals tend to exhibit different degrees of willingness to accept information at odds with personal experiences or knowledge.</td>
</tr>
<tr>
<td><strong>Cognitive complexity vs. simplicity</strong></td>
<td>Individuals tend to view situations in an abstract manner. Individuals tend to view situations in a concrete manner.</td>
</tr>
<tr>
<td><strong>Conceptualizing</strong></td>
<td>Individuals tend to prefer categorizing based on similarities or differences as a means of forming concepts.</td>
</tr>
<tr>
<td><strong>Constricted vs. flexible field control</strong></td>
<td>Individuals tend to response to contradictory or distracting information differently and show different abilities under these circumstances to focus on a central task.</td>
</tr>
<tr>
<td><strong>Visual vs. haptic</strong></td>
<td>Individuals tend toward visual cues to assist in information processing. Individuals tend toward physical/kinesthetic cues to assist in information processing.</td>
</tr>
<tr>
<td><strong>Cautiousness vs. risk-taking</strong></td>
<td>Individuals show task-specific tendencies to be reserved. Individuals show task-specific tendencies to take chances.</td>
</tr>
<tr>
<td><strong>Concrete vs. abstract conceptualizations</strong></td>
<td>Individuals tend to conceptualize based on concrete experiences. Individuals tend to conceptualize based on abstractions.</td>
</tr>
<tr>
<td><strong>Active experimentation vs. reflective observation</strong></td>
<td>Individuals tend to take a direct, hands-on approach to learning. Individuals tend to take an internal, thought-based approach to learning.</td>
</tr>
<tr>
<td><strong>Serialist vs. holist</strong></td>
<td>Individuals tend to take in information via a methodical, step-by-step approach. Individuals tend to first view a general picture before sequencing elements.</td>
</tr>
<tr>
<td><strong>Visualizer vs. verbalizer</strong></td>
<td>Individuals tend to prefer pictures, graphics, and diagrams. Individuals tend to prefer written or spoken words.</td>
</tr>
</tbody>
</table>
The theory of hemisphericity suggests that these many potential cognitive style dimensions may be divided in such a way as to be representative of right or left hemispheric brain dominance in individuals (Genovese, 2006). That is to say that cognitive style measures are based on a preference for or frequency of use of one style of information processing over another and each pole of a cognitive style dimension is further said to fall under a right brain or left brain dominant category (Buehner-Brent, 1990). For example, a verbal orientation and analytic processing preference are classified as characteristics of left-brain hemispheric dominance while a visual orientation and holistic processing preference are characteristics of right-brain hemispheric dominance (Buehner-Brent, 1990; Genovese, 2006; Jonassen & Grabowski, 1993).

Experimental testing done on individuals having suffered brain injury affecting the left or right hemispheres specifically has shown support for this theory in that these individuals exhibited difficulties or inabilities in performing specific tasks associated with left or right hemisphere function respectively (Genovese, 2006). Instruments have been further developed to test this theory on individuals with normal brain function; however the results of these test measures have been mixed and the development of new or improved instruments is suggested to further investigate the concept of hemisphericity (Genovese, 2006).

**Visualizer-Verbalizer Hypothesis**

The visualizer-verbalizer hypothesis is related to the visualizer/verbalizer cognitive style dimension, and states that some individuals prefer to select and process information visually while others prefer to select and process information verbally (Jonassen & Grabowski, 1993; Mayer & Massa, 2003). The development of this
hypothesis arose from the work of Paivio (1971) describing detailed characteristics of visualizers and verbalizers, how these traits relate to other cognitive style dimensions, and how these traits are impacted in the learning process (Jonassen & Grabowski, 1993; Paivio, 1979).

Visualizers have been typically described as preferring visual information such as graphs and pictures as well as possessing other cognitive style characteristics which include the use of imagery and a preference for thinking in concrete terms (Jonassen & Grabowski, 1993). More current research, however, has suggested that two distinct types of visualizers exist: those tending toward spatial visualization and those toward pictorial visualization (Kolloffel, 2012) such that low spatial ability does not necessarily preclude one being classified as a visual learner (Kolloffel, 2012; Kozhevnikov, Kosslyn, & Shephard, 2005; Hegarty & Kozhevnikov, 1999). Spatial visualizers are more precisely described as individuals who view and process images as distinct parts which are mentally integrated to create a complete mental construct. Such individuals respond to schematics e.g. visual representations of the different components of a system and overall spatial imagery, which emphasize the relationships of components of a whole system with one another (Kolloffel, 2012). Pictorial or object visualizers tend to view and process an image holistically, as a complete object rather than the sum of its parts (Kolloffel, 2012). Individuals who have exhibited characteristics of spatial visualizers tend to choose or perform well in science, technology, engineering, and mathematics (STEM) (Kolloffel, 2012; Kozhevnikov, Kosslyn, & Shephard, 2005) as these fields are inherently dependent on the spatial conceptualization of key concepts (Uttal & Cohen, 2012). This concept of two distinct types of visualizers has been further supported by
neuroimaging studies indicating different brain activity for spatial and pictorial imaging tasks (Kozhevnikov, Kosslyn, & Shephard, 2005). These two types of visualizer tendencies have also been noted to be distinct from one another such that an individual who exhibits high spatial imagery processing tendencies and skills will tend to underperform in pictorial imagery processing tasks and vice versa (Kolloffel, 2012; Kozhevnikov, Kosslyn, & Shephard, 2005; Hegarty & Kozhevnikov, 1999). Verbalizers tend to remain independent from these visual types in that no specific tendencies toward either spatial or pictorial imagery have been noted for individuals identified as verbalizers (Kozhevnikov, Kosslyn, & Shephard, 2005). Measurement tools used to assess all of these tendencies include spatial ability tests designed to gauge individual ability to mentally visualize objects (Paivio, 1979) and pictorial or object imagery tests such as grain resolution tasks and degraded picture tasks (Kozhevnikov, Kosslyn, & Shephard, 2005). Self-report questions have also frequently been used to assess visual or verbal tendencies by asking individuals to describe their thought processes and how they deal with information in terms of creation of mental imagery (Paivio, 1979; Richardson, 1977). Physiological responses have additionally been used as measurement tools, specifically lateral eye movements, to determine engagement in visualization or spatial type mental activity or in activity associated with verbal processing. These studies are congruent with the theory of hemisphericity in that they have shown evidence via the measurement of left or right eye movements, of associations between visual or verbal activities and right or left brain activity (Richardson, 1977).

The Visualizer/Verbalizer Questionnaire (VVQ) is one frequently used instrument for the assessment of visual or verbal preferences. The VVQ contains 15 self-report
items classified as indicative of visual or verbal mental processes based on an initial study of lateral eye movements relating to each question and derived from Paivio’s (1971) Ways of Thinking (WOT) questionnaire. The resulting questions ask respondents to rank their skills and preferences in the visual and verbal dimensions (Richardson, 1977). Although frequently used in research, validity and reliability test results have been highly variable for this questionnaire (Jonassen & Grabowski, 1993; Leutner & Plass, 1998).

The Visualizer/Verbalizer Behavior Observation Scale (VV-BOS) was created in response to the inconsistent validity and reliability of other visualizer/verbalizer measures and in effort to derive results from direct observations of participant behaviors in authentic learning situations, rather than exclusively on self-report questionnaire items (Leutner & Plass, 1998). Furthermore, this instrument is designed specifically as a computer-based instrument. Results suggest a higher degree of validity and reliability associated with the VV-BOS than with other self-report measures of visual or verbal learning preference (Leutner & Plass, 1998; Wirth, 2008).

**Cognitive Load Theory**

Cognitive load theory (CLT) seeks to define the interaction between human cognitive capacity and structures or sets of information (Sweller, 2005a; van Merrienboer & Sweller, 2005). Early work in cognitive sciences came to suggest that human memory resources available for the immediate perception and recall of novel information are quite limited (Miller, 1956). Further study expanding on the concept of limited memory resources developed the idea that individuals group information structures into chunks, the size of the chunks being dependent on individual levels of expertise, and that these
chunks of information resulted in the development of schema which, in turn expand the amount of new information one is able to absorb (Sweller, 1988).

Initial development of CLT arose from the investigation of these concepts of working memory limitation and schema creation and how problem solving was impacted by the presentation of different problem solving strategies and how these strategies impacted cognitive processing (Sweller, 1988). Subsequent research has noted that inexperienced or novice learners have a tendency to employ means-ends problem solving strategies where they continually compare the current state in a problem to the desired end state. This strategy has been shown to cause heavy burdens on working memory resources. Worked examples have been shown to alleviate this issue in that the solution search is eliminated and instead learners are directed along an appropriate path from initial problem state to solution thereby facilitating schema creation rather than absorbing working memory resources in means-ends comparisons (Kalyuga, Ayers, Chandler, & Sweller, 2003; Sweller, 1988). Further research in CLT has resulted in implications and guidelines for instructional design and multimedia learning through the management of cognitive load with the goal of enhancing learning capacity and effectiveness (Paas, Renkl, & Sweller, 2004; Sweller, 2005a).

Memory

Human memory is generally considered as having a range of theoretical substructures, each operating in different capacities in the process of information intake and retrieval ranging from instantaneous perception of surroundings or immediate events to retention of lifelong knowledge and recollections while also operating together to create what are defined as memories and knowledge structures (Atkinson & Shiffrin,
The subcomponents of memory are discussed in the following sections.

**Sensory memory**

Sensory memory is defined as the initial and most basic system through which we take in information through our eyes or ears or other sensory modalities (Craik & Lockhart, 1972; Mayer, 2005b; Sweller, 2005a). This exists simply as sensation and is not described as engaging any cognitive process, but is only a perception that something exists such as a sound or an image (Craik & Lockhart, 1972; Mayer, 2005b). These perceptions are further described as fleeting, lasting less than two seconds in the sensory memory and in order to potentially engage lasting memory and cognition an individual needs to consciously attend to these inputs (Craik & Lockhart, 1972).

**Working Memory**

Working memory is conceptualized as the subsystem, which temporarily stores information in order to facilitate engagement in a cognitive task (Baddeley, 1998). Investigations have shown that working memory may be further sub-divided into unique stores which process visual-spatial information and phonological information respectively (Baddeley, 1998; Sweller, 2005b) and a central executive which serves as a coordinator for these subsystems, allowing for simultaneous processing of visual and phonological information (Baddeley, 1998). Figure 10 shows a model of the working memory system.
Early conceptualizations of the limited capacity of the working memory suggested that individual items of information were stored as chunks and tests of recall after the presentation of lists of information such as a string of letters or numbers showed a remembering capacity of seven chunks, plus or minus two (Miller, 1956). More recently, however, this has been discovered to not be precisely the case. Rather than fixed units or chunks of information being the primary units which maximize or limit memory capacity, it has been shown that recall of units of information is dependent on an internal verbal rehearsal of the information presented and recall is therefore dependent upon the amount of time or verbal trace associated with each unit. The resulting trace-decay hypothesis states that the verbal trace diminishes or decays quickly and that the amount of information, which can be accurately recalled is dependent on the time it takes to internally rehearse (Schweickert & Boruff, 1985). It has been further shown that memory capacity for recall may be increased by the presentation of both non-redundant auditory and visual information, supporting the concept of partially independent visual and verbal
memory stores such that working memory resources may be maximized if both subsystems are utilized in conjunction (Frick, 1984).

Although working memory capacity constraints may seem limiting, it is suggested that they may in fact allow for more efficient and practical processing of new information given that limited capacity for novel information results in limited permutations of how that new information can be manipulated and compared, resulting in more manageable problem solving in terms of time and effort required (Sweller, 2005a). CLT addresses these characteristics of the working memory further in terms of learning and problem-solving with an aim to optimize cognitive load in a limited working memory and present more efficient learning scenarios through which cognitive resources may be maximized (Paas, Renkl, & Sweller, 2004; Sweller, 1988).

**Long-term memory**

The long-term memory represents the conceptual location where learned information or knowledge is stored (Sweller, 2005a). Information enters the long-term memory by way of the working memory through repetition and rehearsal and is organized so as to impact future behaviors and cognitive activities (Craik & Lockhart, 1972). Repeated encounters or practice with information structures such as a specific type of math problem or repetition through rote learning strategies results in information storage in the long-term memory where it is organized into schema which, in turn, impact our behaviors and additional learning (Sweller, 2005a; van Merrienboer & Sweller, 2005). The long-term memory is thought to act as a central executive, directing the working memory by guiding processes and information intake using existing schema. Existing schema, being the result of the combination of several pieces or chunks of
information into single units developed through practice and experience free limited working memory resources whereas a lack of schema such as when one is presented with novel information results in increased demands on working memory resources (Kalyuga, Ayers, Chandler, & Sweller, 2003; Sweller, 2005a). The long-term memory has neither known capacity limit nor any limit on the length of time for which information may be stored (Craik & Lockhart, 1972).

The development of schema in the long-term memory is said to be representative of knowledge; that is, learning has taken place only if the long-term memory has been altered through the development of schema acquired over a length of time and then in turn being representative of degrees of expertise (van Merrienboer & Sweller, 2005). These schema further impact the capacity of the working memory such that information entering the working memory is instantly recognized and multiple segments of information are grouped together as a single unit (Sweller, 2005a) thereby freeing cognitive capacity for the intake of further information (van Merrienboer & Sweller, 2005). Furthermore, with repeated use, schema can become automated, executed without deliberate control further freeing cognitive resources for other tasks (Kalyuga, Ayers, Chandler, & Sweller, 2003; Sweller, 2005a; van Merrienboer & Sweller, 2005). Figure 11 presents a diagram of the different memory resources and their interactions with one another.
Types of Cognitive Load

In consideration of the limited cognitive load capacity of the working memory and in an effort to maximize this capacity through instructional strategies, CLT further identifies three unique types of cognitive load (Brunken, Plass, & Leutner, 2003; Paas, Renkl, & Sweller, 2004; Sweller, 2005a). Intrinsic cognitive load is defined by the number of elements in a task and the degree of interactivity between these elements. For example, a task requiring the interaction of two elements would be classified as having a low degree of intrinsic cognitive load whereas several elements which must all interact together for meaning to exist would be classified as a task with a high intrinsic cognitive load (Brunken, Plass, & Leutner, 2003; Paas, Renkl, & Sweller, 2004; Sweller, 2005a). Germane cognitive load consists of the information and tasks presented which contribute to the process of learning through schema development and automation and thereby the creation of knowledge and understanding (Brunken, Plass, & Leutner 2003; Paas, Renkl, & Sweller, 2004). Germane cognitive load may increase the overall cognitive load on the working memory; however it contributes positively to schema development and learning.
Finally, extraneous cognitive load is described as tasks and information presented in learning content, which have no value in terms of schema development or learning (Brunken, Plass, & Leutner 2003; Paas, Renkl, & Sweller, 2004). Extraneous tasks and information overburden the working memory and can restrict the amount of relevant information that can be processed in a learning activity (Sweller, 2005a). Together, intrinsic, germane, and extraneous cognitive loads are said to be additive, in that they all equally absorb limited cognitive resources in the working memory and therefore must be managed so as not to result in a state of cognitive overload (Brunken, Plass, & Leutner, 2003; Paas, Renkl, & Sweller, 2004; Sweller, 2005a). Table 6 presents an overview of the three different types of cognitive load.

Table 6

The three types of cognitive load

<table>
<thead>
<tr>
<th>Type of Cognitive Load</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intrinsic</td>
<td>Number of elements in a task and interactivity between elements</td>
</tr>
<tr>
<td>Germane</td>
<td>Tasks and information which contribute to knowledge and schema development</td>
</tr>
<tr>
<td>Extraneous</td>
<td>Tasks and information which have no value in schema and knowledge development</td>
</tr>
</tbody>
</table>

Measurements

Early studies of the nature of working memory sought to measure capacity through a variety of sensory inputs such as words or pictures delivered to individuals and a resulting measurement of their recall of these inputs (Craik & Lockhart, 1972; Miller, 1956; Schweickert & Boruff, 1985). Varying measures of capacity led to the concept of individual ability to chunk information through interactions between the working
memory and long-term memory, defined by the existence of schema (Craik and Lockhart, 1972; Sweller, 1988). Further study produced evidence to suggest two sub-channels of the working memory, one which processed visual information and the other phonological information measured through the presentation of concurrent visual and auditory information and tasks (Baddeley, 1992).

Studies investigating these assumptions regarding working memory from the perspective of CLT have employed a variety of objective and subjective measures as determinations of when cognitive overload is occurring (Brunken, Plass, & Leutner 2003). These have included self-report measures of stress and perceived task difficulty as subjective measures, and direct measures of brain activity, pupil dilation, and heart rate as objective measures of cognitive overload (Brunken, Plass, & Leutner 2003). Dual task activities have also been used to measure cognitive load such that a secondary task is presented to participants matching the main task (i.e. additional visual information is presented during a visual task, or additional auditory information during an auditory task) and participant interaction with or in response to the secondary task is measured to determine if and when cognitive load capacity is exceeded (Paas, Renkl, & Sweller, 2004).

**Support and Criticism**

Cognitive load theory has gained wide acceptance and popularity for its description and use of an understanding of human cognitive processes and how these understandings inform instructional design (Gerjets, Scheiter, & Cierniak, 2009; Schnitz & Kurschner, 2007; van Merrienboer & Sweller, 2005). CLT has furthermore been a primary theory used to guide the development of computer-based instruction and the
optimal use of multimedia components therein (Brunken, Plass, & Leutner 2003). One major criticism of CLT, however, lies in the reported inability to directly or empirically measure cognitive load (Brunken, Plass, & Leutner, 2003) and more specifically the inability to distinctly measure intrinsic, extrinsic, and germane cognitive load (Gerjets, Scheiter, & Cierniak, 2009; Schnitz & Kurschner, 2007). It is suggested however that the analysis of CLT is better informed by a structuralist view of theories which allows for the elements of a theory, such as types of cognitive load, to be viewed as components of a systemic whole, not necessarily measurable on their own, which are supportive of the main theoretical concept (Gerjets, Scheiter, & Cierniak, 2009). This is in opposition to more traditional views regarding the testing of theories which require direct empirical testing of theory elements in order to ascribe scientific credibility; however it is noted that such strict guidelines would render CLT, as well as most other commonly accepted theories, scientifically invalid (Gerjets, Scheiter, & Cierniak, 2009).

Further criticism of CLT suggests a discrepancy between intrinsic and germane cognitive load and learning outcomes given that all forms of cognitive load are additive (Schnitz & Kurschner, 2007). That is, in this circumstance, as intrinsic load or task difficulty increases so does the load on the working memory, thereby decreasing the capacity for germane cognitive load, resulting in a decline in ability to develop schema and automation (Schnitz & Kurschner, 2007). Intrinsic cognitive load is indicated as traditionally viewed as fixed and unchangeable in any given learning task (Schnitz & Kurschner, 2007; van Merrienboer & Sweller, 2005). Contrary to this, it is suggested that this is not the case and that intrinsic and germane loads should be manipulated in order to create an appropriate balance to optimize learning (Schnitz & Kurschner, 2007).
Cognitive Load Theory in Education

Studies of cognitive load in learning have focused on problem solving skills (Sweller, 1988) and the development of strategies to assist students in more efficiently developing problem solving abilities (Pass & van Merrienboer, 1994). To this end, studies have shown that, with novice learners in particular, means-ends problems where a problem is presented along with the solution impose a heavy cognitive load on learners in that they must expend heavy working memory resources searching for ways to arrive at the given problem solution (Kalyuga, Ayers, Chandler, & Sweller, 2003; Pass & van Merrienboer, 1994; Sweller, 1988; Zheng & Cook, 2012). Instead, worked examples where step by step instructions on how to solve problems maintain a high level of intrinsic cognitive load while reducing the extraneous cognitive load imposed by a search for unknown information (Kalyuga, Ayers, Chandler, & Sweller, 2003; Pass & van Merrienboer, 1994; Sweller, 1988). Evidence suggests that, through the use of worked example type practice problems, learners require less time to learn new concepts and report a perceived reduction in mental exertion (Pass & van Merrienboer, 1994).

Additional study has suggested benefits in terms of reduction in cognitive load by the inclusion of images in worked examples (Kalyuga, Ayers, Chandler, & Sweller, 2003; Zheng & Cook, 2012). It is cautioned however that worked examples should be well-designed keeping in mind the intrinsic as well as extraneous cognitive loads imposed, and additionally student characteristic should be considered in terms of ability level as well as levels of self-motivation which may impact the success of worked examples in instruction (Pass & van Merrienboer, 1994).
Studies of CLT in education further advocate for direct instruction as opposed to discovery learning or constructivist approaches to learning. It is suggested that direct instruction, utilizing worked examples as well as forms of instructor directed and explanatory teaching make optimal use of memory resources resulting in increased schema and automation development and thereby greater learning outcomes (Kalyuga, Ayers, Chandler, & Sweller, 2003; Kirschner, Sweller & Clark, 2006). It is further suggested that constructivist based learning ignores the fundamentals of knowledge construction as outlined by CLT resulting ineffective and even negative learning outcomes (Kirscher, Sweller & Clark, 2006). In a study of learners using computer-based games in a discovery-learning setting, increased learning outcomes were shown when direct, explanatory feedback was offered as opposed to simply corrective feedback after free exploration of concepts (Moreno, 2004).

**Multimedia**

**Cognitive Theory of Multimedia Learning**

The cognitive theory of multimedia learning (CTML) seeks to uncover how people learn from multimedia, based on several theories of human cognition including CLT, dual coding theory, and Baddeley’s (1992) proposed model of working memory (Brunken, Plass, & Leutner, 2003; Mayer, 2005a). These have contributed to the formation of three underlying assumptions of the CTML, which include the dual-channels assumption, the limited capacity assumption, and the active processing assumption (Mayer, 2005a).

The dual-channel assumption states that there is a visual channel for information processing and an auditory or verbal channel for information processing (Mayer, 2005b).
Distinctions are made in this assumption as to what precisely is processed by each of the channels, given some differences in previous theoretical conceptualizations of these channels (Brunken, Plass, & Leutner, 2003; Mayer, 2005b). The two ways through which these channels detect and process information are described as the dual-coding or presentation mode, and the dual-channel or sensory modality (Baddeley, 1992; Brunken, Plass, & Leutner, 2003; Mayer, 2005b; Paivio, 1991). The presentation mode refers to how information is directly presented, verbal information being classified as written text or spoken words, and nonverbal information classified as images, videos, or sounds not directly related to words or speech. The sensory mode refers to how individuals process information when it is first received. In this case, verbal information is classified as spoken words and background sounds and visual information as images as well as written text (Brunken, Plass, & Leutner 2003; Mayer, 2005b). CTML theory attempts to blend these two slightly differing conceptualizations, but also acknowledges a need for further study and clarification as to the precise nature of these two channels (Mayer, 2005b).

The limited capacity assumption, following assertions made by CLT (Sweller, 1988; 2005a) and evidence of the limitations of the working memory (Schweickert & Boruff, 1985) concurs with the concept that human working memory has a limited capacity for novel information and, as such, individuals are selective in the information they choose to take in (Mayer, 2005b). Instructional design, in contradiction with this assumption, has often been observed to inundate users with large quantities of media in a variety of formats under the apparent premise that learners have an unlimited capacity, particularly evidenced in computer-based formats (Mayer, 2005b). Given evidence of the limited capacity of the working memory and limited capacity of each channel of the
working memory, individuals will selectively absorb information deemed relevant (Mayer, 2005b).

The active processing assumption of CTML states that individuals will seek to make sense out of information input, visual or verbal, and will work to integrate this information to create mental constructs (Brunken, Plass, & Leutner, 2003; Mayer, 2005b). This information can be further connected to schema in the long-term memory to enhance cognitive processing (Mayer, 2005b). It is noted that these processes are restricted by the limitations of the working memory (Brunken, Plass, & Leutner, 2003); however as schema and automation are developed in the long-term memory, the capacity of the working memory is increased allowing the processing of greater amounts of information (Sweller, 2005; van Merrienboer & Sweller, 2005). The three assumptions of CTML are summarized in Table 7.

Table 7

Summary of the three assumptions of CTML

<table>
<thead>
<tr>
<th>Dual channel assumption</th>
<th>Limited capacity assumption</th>
<th>Active processing assumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two separate channels for visual and auditory information exist through which individuals process information.</td>
<td>The working memory has a limited capacity to take in and process new information.</td>
<td>Individuals seek to organize information through selective attention in order to develop mental constructs and schema.</td>
</tr>
</tbody>
</table>

The cognitive processes of the working memory interacting with multimedia are further described in the CTML as five distinct processes (Mayer, 2005b). These cognitive processes include: 1) word selection where the learner deliberately attends to a learning task and selects relevant or key words, 2) image selection where images are
deliberately selected in a learning task, 3) organization of selected words where the words or verbal information are organized into simple yet meaningful structures, 4) organization of selected images where connections are created between selected images, and 5) integration where word and image based structures are further integrated to create meaning (Mayer, 2005b). In the integration phase, prior knowledge or schema existing in long-term memory stores (Sweller, 2005) may be accessed to aid organization and concept development (Mayer, 2005b). It is further indicated that although these processes may seem linear in nature, one step leading to the next, they may occur in any order and still result in knowledge construction (Mayer, 2005b). Figure 12 presents a diagram of the cognitive processes as outlined by the CTML.

**Principles of Multimedia Learning**

Several principles have arisen as guidelines to inform multimedia instruction and learning derived from the basic definition of multimedia which is a combination of words, either spoken or printed, and images and questions as to how individuals learn from this combination of media (Mayer, 2005b). Studies have investigated the effects of various combinations of media, i.e. labeled images or narration and images to determine optimal conditions and learning outcomes as well as having drawn comparisons between multimedia and single media formats, i.e. text only, to draw conclusions and develop guiding principles regarding the benefits and limitations of multimedia learning (Brunye, Taylor, Rapp, & Spiro, 2006). Advances in computer technology both in terms of capabilities and usability, have additionally increased the ability of instructors to utilize multimedia, creating further necessity for investigating the impact of multimedia on learning (Fletcher & Tobias, 2005; Mayer, 2005b). The following section describes four principles related to multimedia for learning. Although only four principles are discussed here, many other principles are described in detail in Mayer (2005a).

**Multimedia Principle**

Derived from the definition of multimedia learning which is learning from images and words (Mayer 2005c; Mayer 1997), the multimedia principle states that individuals learn better from a combination of images and words than from words alone (Fletcher & Tobias, 2005). This concept is further based on the concept of visual and verbal channels in the working memory which, when both engaged, are able to function together harmoniously while also reducing the cognitive load on either of these channels working alone (Fletcher & Tobias, 2005; Sweller, 2005b). It is relevant to note that the arbitrary
presentation of image and verbally based media together does not necessarily equate to more optimal learning or correspond to the concepts underlying the multimedia principle. Rather, critical information is suggested to be pre-identified so as to optimally utilize the cognitive capacity of each channel within the working memory while additionally considering the spatial and temporal proximity of the information presented (Fletcher & Tobias, 2005).

*Split-Attention Principle*

The split-attention principle explains and investigates the concept that different forms of media, when presented for learning, are best presented in close spatial or temporal proximity (Ayers & Sweller, 2005). This principle is in concurrence with CLT and the concept of the limited capacity of the working memory, suggesting that if learners must search for information such as an image and associated text which are not in near or sequential proximity, further cognitive resources are utilized with an additive effect resulting in fewer resources available for the learning task at hand (Ayers & Sweller, 2005; Florax & Ploetzner, 2009). If information is presented in close spatial or temporal proximity then, learners are no longer required to engage in integration tasks (Ayers & Sweller, 2005). Figure 13 provides an example diagram in which the example on the left causes split attention and an integrated example on the right, which reduces, split attention.
Figure 13. *Comparison of an example which splits attention and an integrated version of the same example, which avoids split-attention.*

Key components of this principle include the concept that information sources should be directly related to each other yet not comprehensible when separated such that they contribute to concept development without being redundant, and that this principle applies only to tasks with high element interactivity. For example, in a relatively simple task, extraneous cognitive load created by integrated yet unrelated elements or separated elements necessitating a learner search for information is likely not to have significant impact on learning overall (Ayers & Sweller, 2005). It is further suggested that the expertise level of learners is a relevant consideration in split-attention, as lower level learners may benefit from more information whereas higher level learners may find extra information redundant, resulting in extraneous cognitive load given they possess already developed schema through which they may process a given learning task (Ayers & Sweller, 2005; Kalyuga, 2005).

An additional principle, which mirrors the split-attention principle, is the contiguity principle, which suggests that words and images are optimally presented
contiguously (Mayer, 2005d; Mayer & Anderson 1992). This principle has been used to investigate the cognitive and learning effects of animations combined with narrations as opposed to static images combined with printed text (Ayers & Sweller, 2005; Mayer, 2005d). Studies suggest that in both circumstances, static images with text supported by the split-attention principle and animation and narration supported by the contiguity principle, learning outcomes benefitted from spatial and temporal proximity of information or simultaneous presentation of animation and narration, respectively (Florax & Ploetzner, 2010; Mayer & Anderson, 1992; Mayer & Sims, 1994). An additional influence was shown to be the spatial ability of participants where those with higher levels of spatial ability achieved greater learning outcomes overall (Florax & Ploetzner, 2010) and, in the animation and narration case, showed greater benefit in terms of learning from contiguously presented information (Mayer & Sims, 1994).

**Modality Principle**

The modality principle focuses on the mode of presentation of materials, indicating that in certain instances, instruction is benefitted by the presentation of an image with narration (Low & Sweller, 2005; Mayer & Moreno, 2002). This principle, again, is based on the concept that the limited working memory contains two separate channels through which information may be processed and that, by reducing the demands on the visual channel alone by presenting narration rather than text, superior retention and learning outcomes can be achieved (Low & Sweller, 2005; Moreno, 2006). Similar to the split-attention principle, the modality principle guidelines indicate that both visual materials and narration should be directly related and not independently intelligible, the information should have a relatively high level of element interactivity or high intrinsic
cognitive load making the use of dual-mode presentation relevant, and further that redundant information or extraneous cognitive load should not be presented, such as printed text which mirrors the narration (Low & Sweller, 2005; Moreno, 2006). Figure 14 shows an example of the modality principle.

Figure 14. *The modality principle.* Neither the narrated description (right) nor the image (left) are easily understood alone. The narrated description would not be visible as shown in conjunction with the image. No redundant text is presented in the image.

Studies suggest that the modality effect can be observed across different modes of multimedia presentation such as print based materials combined with narration or computer-based graphics or animations combined with narration, with similar results of increased information retention and recall (Low & Sweller, 2005; Mayer & Moreno, 2002; Moreno 2006). Further study is suggested however in order to investigate the impact of additional conditions on the modality principle, such as with more complex computer-based images, or specific learner characteristics such as levels of expertise, spatial ability and learning preferences, or student self-regulation during the learning process (Moreno, 2006).
The redundancy principle in multimedia learning suggests that information presented to learners should be carefully managed so as not to provide unnecessary or redundant duplication of information resulting in extraneous cognitive load on working memory resources (Sweller, 2005a). Common examples of redundant information are providing duplicate information such as written text with identical narration or as text labels in a diagram in which the diagram alone is easily comprehensible as seen in Figure 15. Efforts to elaborate or provide more detailed information to learners have also been shown to exhibit a redundancy effect (Sweller, 2005b). This redundant information is suggested to interfere with learner selection of relevant information in that excessive information is provided, thereby interfering with concept integration and processing (Mayer & Moreno, 2002).
Figure 15. *The redundancy principle.* The text labels on the diagram and written figure description (left), in conjunction with the narrated description (right), provides an example of redundant information. Note that the narrated description would not actually be visible in conjunction with the diagram.

Whether or not information presented is redundant is discussed as being largely contextual. It is therefore relevant to consider learner characteristics, such as if they are experts or novices, how intelligible an image or diagram is without the inclusion of text labels or further explanation, and the degree of intrinsic load or element interactivity imposed by the complexity of an image or diagram (Sweller, 2005b). It has also been shown that a certain degree of redundancy may be beneficial in certain contexts, for example key words presented in an image in close proximity to the related image element, in conjunction with a text explanation located near the image or narration containing the same words, may serve to appropriately draw learner attention to key elements rather than creating extraneous cognitive load, resulting in greater retention of overall concepts (Mayer & Johnson, 2008). It is however emphasized that instructors should view multimedia materials with a critical eye in determining redundancy from an
objective standpoint in addition to taking into consideration potential student perspectives (Sweller, 2005b).

Summary

The main areas covered in this chapter have been online learning, individual differences, cognitive load theory, and multimedia and associated theories and principles. The section on online learning was intended to outline what such learning environments look like, what tools are available in an online environment, how theory and practice can impact learning, and what possible future directions online learning might take.

Individual learning differences including preferences and cognitive ability and style may be factors, which impact students and teachers in an online environment. Cognitive load theory and the theories and principles of multimedia for learning may also guide practice and aid in the success of learners in online environments. These combined provide the basis through which the following study will be conducted, as outlined in the subsequent methodology section.
CHAPTER III
METHODOLOGY

Introduction

The purpose of this study was to reevaluate the concepts of learner preferences, cognitive preferences, and cognitive styles relating to multimedia learning within the context and considering the capabilities of the 21st century classroom. How learners perceive technology-based instruction and how they respond to and interact with these materials are important components to the overall success of instructional program utilizing technology-based tools and applications. It was therefore the goal of this study to evaluate these learner characteristics, with focus on the visualizer and verbalizer tendencies, and how these relate to and impact interactions with online multimedia learning materials. This chapter begins with discussion of a pilot study followed by a discussion of the methodology for this dissertation study.

Pilot Study

Introduction

This section provides an overview of the pilot study as well as results and conclusions, which contributed to the methodology and design of the final dissertation study. Information gained from this pilot study suggested the need for updates to the survey instrument, for future use.

A pilot study was conducted by the researcher in order to optimize an adapted version of Mayer and Massa’s (2003) survey instrument developed in an effort to create a measurement tool of learner characteristics based on the visualizer-verbalizer hypothesis. In this original study, fourteen measures were utilized which each loaded onto one of four
factors following an exploratory factor analysis (Mayer & Massa, 2003). These factors were classified as cognitive ability, spatial ability, cognitive style, and learning preference.

Participants

The pilot study included a total of 51 participants, 24 males and 27 females, recruited as volunteers from the student population at a mid-sized, private university in a northeastern state of United States. All participants received $20 cash compensation for their participation.

Instrument

The pilot study extracted 11 of the original measures from the Mayer and Massa (2003) study (Appendix B), with factor loadings above a recommended cutoff point of .40 (Field, 2013; Guadagnoli & Velicer, 1988) in an effort to create a more parsimonious overall model. Table 8 shows the factor loading from Mayer and Massa’s (2003) exploratory factor analysis for the selected measures.
Table 8

Factor loadings for selected measures

<table>
<thead>
<tr>
<th>Measure</th>
<th>Cognitive ability</th>
<th>Spatial ability</th>
<th>Cognitive style</th>
<th>Learning Preference</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAT Verbal</td>
<td>.976</td>
<td>-.059</td>
<td>-.165</td>
<td>.124</td>
</tr>
<tr>
<td>SAT Mathematics</td>
<td>.644</td>
<td>.081</td>
<td>.060</td>
<td>.128</td>
</tr>
<tr>
<td>Vocabulary Test</td>
<td>.479</td>
<td>.157</td>
<td>-.135</td>
<td>.066</td>
</tr>
<tr>
<td>Paper Folding Test</td>
<td>.159</td>
<td>.744</td>
<td>.237</td>
<td>-.039</td>
</tr>
<tr>
<td>Card Rotation Test</td>
<td>.109</td>
<td>.694</td>
<td>-.047</td>
<td>.061</td>
</tr>
<tr>
<td>Verbal-Spatial Ability Rating</td>
<td>-.128</td>
<td>.399</td>
<td>.379</td>
<td>-.097</td>
</tr>
<tr>
<td>Verbal-Visual Learning Style Rating</td>
<td>-.037</td>
<td>.036</td>
<td>.831</td>
<td>.241</td>
</tr>
<tr>
<td>Santa Barbara Learning Style Questionnaire</td>
<td>.035</td>
<td>.093</td>
<td>.780</td>
<td>.335</td>
</tr>
<tr>
<td>Learning Scenario Questionnaire</td>
<td>.048</td>
<td>.105</td>
<td>.494</td>
<td>.159</td>
</tr>
<tr>
<td>Multimedia Learning Preference</td>
<td>.059</td>
<td>-.022</td>
<td>.191</td>
<td>.979</td>
</tr>
<tr>
<td>Multimedia Learning Behavior Test - Choice</td>
<td>.131</td>
<td>.029</td>
<td>.293</td>
<td>.425</td>
</tr>
</tbody>
</table>

Based on the data from the exploratory factor analysis, an adapted instrument was created and utilized for the pilot study. This instrument was, again, intended to investigate learner characteristics in terms of individual differences related to four factors: cognitive ability, spatial ability, cognitive style, and learning preference with focus on visualizer and verbalizer tendencies, and how these relate to and impact interactions with online multimedia learning materials. Table 9 presents a summary of the eleven measures used.
Table 9

*Eleven individual difference measures used in the pilot study*

<table>
<thead>
<tr>
<th>Section and Measure</th>
<th>Number of items</th>
<th>Type</th>
<th>Source</th>
<th>Task</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Factor 1: Cognitive Ability</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. SAT Mathematics</td>
<td>1</td>
<td>Questionnaire</td>
<td>Educational Testing Service</td>
<td>Input SAT Math score.</td>
<td>Self-reported score (200-800).</td>
</tr>
<tr>
<td>2. SAT Critical Reading</td>
<td>1</td>
<td>Questionnaire</td>
<td>Educational Testing Service</td>
<td>Input SAT Critical Reading score.</td>
<td>Self-reported score (200-800).</td>
</tr>
<tr>
<td>3. SAT Writing</td>
<td>1</td>
<td>Questionnaire</td>
<td>Educational Testing Service</td>
<td>Input SAT Writing score.</td>
<td>Self-reported score (200-800).</td>
</tr>
<tr>
<td>4. Vocabulary Test</td>
<td>10</td>
<td>Timed test</td>
<td>Adapted from SAT Prep at</td>
<td>Given a target word such as <em>variable</em> is presented in a sentence, the closest equivalent word must be selected from a list of 4.</td>
<td>Number correctly answered within 3 minutes.</td>
</tr>
<tr>
<td><strong>Factor 2: Spatial Ability</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Paper Folding Test</td>
<td>10</td>
<td>Timed Test</td>
<td>Ekstrom et al. (1976)</td>
<td>Imagine folding and unfolding a square of paper after holes have been punched in it. Select the correct pattern of holes from 5 choices.</td>
<td>Number correctly answered minus the number incorrectly answered within 3 minutes.</td>
</tr>
<tr>
<td>6. Verbal-Spatial Ability Rating</td>
<td>2</td>
<td>Questionnaire</td>
<td>Mayer &amp; Massa (2003)</td>
<td>Rate level of spatial ability and verbal ability on 5-point scales.</td>
<td>Self-rating of spatial ability minus self-rating of verbal ability (0-8), 8 indicating strong spatial ability, 0 indicating strong verbal ability.</td>
</tr>
</tbody>
</table>
Table 9 (continued)

<table>
<thead>
<tr>
<th>Section and Measure</th>
<th>Number of items</th>
<th>Type</th>
<th>Source</th>
<th>Task</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Santa Barbara</td>
<td>6</td>
<td>Questionnaire</td>
<td>Mayer &amp; Massa (2003)</td>
<td>Rate level of agreement with statements regarding visual and verbal learning modes on a 7-point scale.</td>
<td>Pro-visual ratings minus pro-verbal ratings (36-0), 36 indicating strong visual ability and 0 indicating strong verbal ability.</td>
</tr>
<tr>
<td>Learning Style</td>
<td></td>
<td>Questionnaire</td>
<td>Mayer &amp; Massa (2003)</td>
<td>Rate a preference for visual or verbal learning on a 7-point scale.</td>
<td>Selection rated (7-0), 7 indicating strongly pro-visual and indicating strongly pro-verbal.</td>
</tr>
<tr>
<td>Questionnaire</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Verbal-Visual</td>
<td>1</td>
<td>Questionnaire</td>
<td>Mayer &amp; Massa (2003)</td>
<td>Select a visual or verbal based learning mode for a given task description.</td>
<td>The number of tasks in which the visual learning mode is selected (0-5).</td>
</tr>
<tr>
<td>Learning Style</td>
<td></td>
<td>Questionnaire</td>
<td>Mayer &amp; Massa (2003)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rating</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Questionnaire</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Multimedia</td>
<td>2</td>
<td>Questionnaire</td>
<td>Adapted from Mayer &amp; Massa (2003)</td>
<td>Indicate a preference for text only, labeled image, or visual and auditory multimedia learning modes.</td>
<td>Selections are categorized as 1 for text, 2 for image and text, and 3 for image and narration.</td>
</tr>
<tr>
<td>Learning Preference</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Questionnaire</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Multimedia</td>
<td>4</td>
<td>Behavior Test</td>
<td>Adapted from Mayer &amp; Massa (2003)</td>
<td>Selection of text only, labeled image, or visual and auditory multimedia learning modes in a learning scenario.</td>
<td>Selections are categorized as 1 for text, 2 for labeled image, and 3 for image and narration.</td>
</tr>
<tr>
<td>Learning Behavior</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The original Mayer and Massa (2003) study was to investigate the multimedia principle, which states that learning is optimized by the combination of image and text (Fletcher & Tobias, 2005). This pilot study set forth to additionally examine the modality principle, which states that under certain conditions learning is optimized by the combination of image and narration (Low & Sweller, 2005). As a result, two measures were modified from the original Mayer and Massa (2003) study. A third change was additionally made, following a format change to the SAT test. All three modifications are discussed as follows.

The first of these modifications was to the multimedia learning behavior test (measure 11). The multimedia learning behavior test was designed as a short hypothetical learning scenario containing four, brief questions related to the overall learning scenario topic. Each question contained a text-based description of a concept with key terms highlighted, followed by two multimedia options for additional information or clarification (original question). Participants were then asked to choose a text-only option or a labeled image option (Figure 16, set A). Modification to this measure included the addition of an image and narration multimedia option and a different presentation strategy such that participants were asked to choose a multimedia type (text only, labeled image, narration and image) (Figure 16, set B). Upon the participants’ selection of their preferred multimedia help type, the modified measure presented the participants with their selected option only (one from the three multimedia types), whereas in the original study, participants were presented with both options (text only and labeled image) and asked to rate their degree of preference for the two options.
Eventually, the water droplets and ice crystals become too large to be suspended by the **updrafts**. As raindrops and ice crystals fall through the cloud, they drag some of the air in clouds downward, producing **downdrafts**. When downdrafts strike the ground, they spread out in all directions, producing the gusts of cool wind people feel just before the start of the rain.

**Set A. Original measure**

Select one of the following Help Screen options:
- Text only
- Labeled image

**Set B. Modified measure**

Select one of the following Help Screen options:
- Text only
- Labeled image
- Image and narration

---

**Figure 16. Multimedia learning behavior test: Set A – Mayer and Massa (2003) study, Set B – Modification for pilot study.**
The multimedia learning preference questionnaire (measure 10), which also follows the same format as the multimedia learning behavior test was additionally modified in the same way. Participants were presented with a hypothetical learning scenario, which contained a text-based description of a concept with key terms highlighted. Participants were asked to assume they needed additional assistance in understanding this concept and were presented simultaneously with two learning options: a text only option and a labeled image option. They were asked to view both options and rate them in terms of preference. The pilot study version added an image with descriptive narration option to the possible learning options, similar to what was shown in Figure 16.

A final modification was made to the reporting format for the SAT test, included with measures of cognitive ability. This was adjusted to reflect a format change in the test itself from two reported sections, reading and mathematics, to three sections, mathematics, critical reading, and writing.

**Procedure**

The instrument was administered as an anonymous online survey utilizing Survey Gizmo, an online survey service. Prior to beginning the survey, participants were presented with an electronic informed consent form. Selecting the “yes” button following review of the informed consent document constituted consent and participants were redirected to the survey instrument. The instrument consisted of a total of 46 questions categorized as follows: three demographic questions, thirteen cognitive ability questions, twelve spatial ability questions, twelve cognitive style questions, and six learning preference questions. Participants were permitted to complete the survey
instrument from any computer with audio capabilities and an Internet connection, and were advised to allot 30 to 45 minutes to fully complete the survey.

**Results**

As this pilot study had a limited number of participants (51), descriptive statistics were utilized to observe overall trends and inform future adjustment to the survey instrument for the final dissertation instrument. Table 10 presents the results for the first eight continuous measures. As some trends were observed in this study based on gender, which will be discussed in the pilot study conclusions section, the results in Table 10 have also been separated by gender.

Table 10

*Descriptive statistics for the first eight pilot study measures*

<table>
<thead>
<tr>
<th>Measure</th>
<th>M</th>
<th>SD</th>
<th>N</th>
<th>M</th>
<th>SD</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. SAT Math</td>
<td>619.77</td>
<td>100.86</td>
<td>24</td>
<td>569.52</td>
<td>87.43</td>
<td>23</td>
</tr>
<tr>
<td>2. SAT Critical Reading</td>
<td>618.18</td>
<td>81.92</td>
<td>23</td>
<td>625.24</td>
<td>102.84</td>
<td>23</td>
</tr>
<tr>
<td>3. SAT Writing</td>
<td>595.91</td>
<td>81.28</td>
<td>23</td>
<td>610.24</td>
<td>96.36</td>
<td>23</td>
</tr>
<tr>
<td>4. Vocabulary Test</td>
<td>8.32</td>
<td>1.67</td>
<td>24</td>
<td>7.86</td>
<td>2.20</td>
<td>27</td>
</tr>
<tr>
<td>5. Paper Folding Test</td>
<td>5.46</td>
<td>2.17</td>
<td>24</td>
<td>4.30</td>
<td>2.00</td>
<td>27</td>
</tr>
<tr>
<td>6. Verbal-Spatial Ability Rating</td>
<td>3.75</td>
<td>0.99</td>
<td>24</td>
<td>3.48</td>
<td>0.89</td>
<td>27</td>
</tr>
<tr>
<td>7. Santa Barbara Learning Style Questionnaire</td>
<td>18.58</td>
<td>3.18</td>
<td>24</td>
<td>19.93</td>
<td>1.47</td>
<td>27</td>
</tr>
</tbody>
</table>

The results of measure nine, the learning scenario questionnaire, are shown in Figure 17. Participants were presented with a learning scenario and asked to select a multimedia learning option representative of visual or text-based help (e.g. a labeled
diagram as visual help or a paragraph description as text-based help). The pilot study learning scenario questionnaire is shown in Appendix B, section 9.

![Learning Scenario Graph](image)

**Figure 17. Results of the Learning Scenario Questionnaire:** M-Vis represents males selecting visual help, M-Verb: males selecting verbal help, F-Vis: females selecting visual help, and F-Verb: females selecting verbal help. Q1 through Q5 represent the five individual questions where “Q” indicates “Question”.

Table 11 presents the results for measure 10, the multimedia learning preference questionnaire. For this measure, participants were presented with a hypothetical learning scenario about the weather. Individuals were then asked to assume they would like additional help understanding this concept and presented with three multimedia learning options. These included a text only learning option, a labeled image learning option, and
an image and narration learning option. The pilot study multimedia learning preference questionnaire is shown in Appendix B, section 11.

Table 11

Multimedia learning preference questionnaire results

<table>
<thead>
<tr>
<th></th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Text only</td>
<td>Labeled Image</td>
</tr>
<tr>
<td>Most preferred</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Least preferred</td>
<td>17</td>
<td>3</td>
</tr>
</tbody>
</table>

The results of the multimedia learning behavior test are shown in Figure 18. For this measure, participants were presented with a hypothetical learning scenario about the weather, similar to the multimedia learning preference test. Individuals were asked to assume they would like additional help understanding the concepts presented and to select one of three multimedia learning options. These included a text only learning option, a labeled image learning option, and an image and narration learning option. The pilot study multimedia learning behavior test is shown in Appendix B, section 12.
Figure 18. *Multimedia Learning Behavior Test.* M-Text represents males selection of text only option, F-Text represents female selection of text only option, M-Image/Text represents males selection of the labeled image option, F-Image/Text represents female selection of the labeled image option, M-Image/Narr represents males selection of the image narration option, and F-Image/Narr represents females selection of the image narration option. Q1 through Q5 represent the five individual questions where “Q” indicates “Question”.
Following completion of the pilot study, reliability statistics were additionally calculated for selected measures. These results are shown in Table 12 below.

Table 12

<table>
<thead>
<tr>
<th>Measure (sub-scale)</th>
<th>Number of items</th>
<th>Cronbach’s alpha (Pilot study)</th>
<th>Cronbach’s alpha (Source)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vocabulary Test</td>
<td>10</td>
<td>.71</td>
<td></td>
</tr>
<tr>
<td>Paper Folding Test</td>
<td>10</td>
<td>.71</td>
<td>.80 (Ekstrom, French, Harman, &amp; Derman, 1976)</td>
</tr>
<tr>
<td>Verbal-Spatial Ability Rating</td>
<td>2</td>
<td>.23</td>
<td></td>
</tr>
<tr>
<td>Santa Barbara Learning Style Questionnaire</td>
<td>6</td>
<td>.74</td>
<td>.76 (Mayer &amp; Massa, 2003)</td>
</tr>
<tr>
<td>Learning Scenario Questionnaire</td>
<td>5</td>
<td>.02</td>
<td>.38 (Mayer &amp; Massa, 2003)</td>
</tr>
<tr>
<td>Multimedia Learning Behavior Test</td>
<td>4</td>
<td>.86</td>
<td>.80 (Mayer &amp; Massa, 2003)</td>
</tr>
</tbody>
</table>

For the learning scenario questionnaire, the omission of question number 4 would have resulted in an increase in the Cronbach’s alpha to .36. Unusual trends were observed during the pilot study related to this particular question, which will be discussed more fully in the pilot study conclusions section.

Conclusions

Findings of the pilot study indicated the need for several adjustments to the survey instrument in order to arrive at an improved model for use in the dissertation study. First, as trends in the original pilot study data indicated that gender might be a possible covariate in this study, the additional demographic questions were proposed with the idea of obtaining more complete information on participants should any other
previously unmeasured variables be influential factors. The additional questions are: 1) What is your year of birth? 2) What is your class status (e.g. undergraduate, graduate) and 3) What is your major area of study?

A second change was the replacement of measure six, the verbal-spatial ability questionnaire, with a card rotation test used in the original Mayer and Massa (2003) study. An example of this can be seen in Figure 19 and in Appendix A, section 6, Figure A-2. For each category, the goal was to select optimal tasks with high factor loadings while also not making the survey overly long for respondents to complete. The factor loading for the verbal-spatial ability questionnaire (.399) was slightly below the recommended cutoff of .40 in addition to presenting a low Chronbach’s alpha of .23. Given that the Card Rotation Test had a high factor loading (.694), it seemed advantageous to make this replacement in the final instrument.

A third change was made to measure nine, the learning scenario questionnaire. Trends from the learning scenario questionnaire showed a shift for female participants on question four, as shown in Figure 16. This question which deals with mechanical manipulation of an object and asked, “Which format do you prefer for following instructions on how to set time on a stopwatch?” prompting participants to select either, “a list of steps in words,” or “a labeled diagram showing the steps.” The shift from visual help to text-based help for this question was an overall trend for all participants, and particularly notable with female participants. It is also noteworthy that omission of this question would have resulted in a marked increase in the Cronbach’s alpha for the learning scenario questionnaire from .02 to .36. Due to this shift and in an effort to improve the reliability of this measure, the updated version of this section included an
additional set of learning scenario questions which conceptually match the original five questions but offer different scenarios in order to further explore this trend.

A fourth change was to adjust Likert scale items such that measure seven, the Santa Barbara learning style questionnaire and measure eight, the verbal-visual learning style rating were both be reduced from seven response options to six, removing the neutral response option in order to eliminate a central tendency bias (Fowler, Jr., 1995; DeVellis, 2012).

A fifth change was made to reduce the multimedia learning preference questionnaire from two questions to one question. The question being removed is, “Which multimedia option do you least prefer?” given the options of text only, labeled image, and image and narration. As the overall survey was designed to determine participant preferences for learning on different factors, it was determined that indication of a least preferred multimedia learning option would not contribute relevant information to the overall study. Considering also the goal of creating a more parsimonious overall model, the decision was made to eliminate this question.

Finally, results of this pilot study showed an overall trend for female participants of shifting from a preference for the image and narration learning option in the multimedia learning behavior test to the labeled image option as shown in Figure 17. As a result, an additional question was added to the original multimedia learning behavior test scenario with the goal of obtaining a more clearly defined preference for participants. An additional multimedia learning behavior test scenario was also included, with five questions, in order to provide further data for learner behaviors and explore any potential shifts in preference based on learning theme.
Dissertation Study

The remainder of this chapter will be focused on the methodology for this dissertation study. The sections to follow will include the intended survey method, research questions and hypotheses, research design, instrumentation, procedure, and variables. It was again the goal of this study to evaluate learner characteristics, with focus on visualizer and verbalizer tendencies, and how these relate to and impact interactions with online multimedia learning materials.

This study used a cross-sectional survey method to evaluate learner characteristics. A cross-sectional survey allows for different groups of individuals to be studied at the same time (McMillan & Schumacher, 2010). This study targeted university students and, while potential participants had that trait in common, this study was not targeted at any specific student groups within the university population. More specifically, any active student was allowed to participate regardless, for example, of level (e.g. undergraduate or graduate student), age, major area of study, or experience with online learning. This was followed by a correlational study used to evaluate participant selections of online multimedia learning options through a multimedia learning behavior test. In a correlational study setting, the researcher exerts no control over or manipulation of the independent variables or setting. Such a study is simply designed to observe the strength these variables may have in predicting the outcome or dependent variable (Field, 2013), in this case participant selections in a multimedia learning behavior test. A correlational study is therefore a design used to take advantage of naturally occurring circumstances and to observe if variables are correlated. The multimedia learning behavior tests were further modeled to simulate natural learning
circumstances where learners make choices from a variety of potentially available learning supplements or enhancements in order to strengthen their own understanding.

**Research Questions**

Given the changing nature of the presentation of instructional materials via technology-based applications, it would be a prudent step to reevaluate assessments of student interactions within the context of the 21st century learning environment. The main research question was how do learning preferences, cognitive ability, spatial ability, and cognitive styles relate to learner interactions with online, multimedia-based learning materials. These questions additionally focused on the visualizer-verbalizer hypothesis, which suggests that some learners prefer visual-based learning while others prefer verbal-based learning. Components of this overall question included:

1. Do learners’ visualizer or verbalizer tendencies influence their selections of online multimedia learning resources?
   
   1.1. Does learners’ cognitive ability influence their selections of online multimedia learning resources?
   
   1.2. Does learners’ spatial ability influence their selections of online multimedia learning resources?
   
   1.3. Does learners’ cognitive style influence their selections of online multimedia learning resources?
   
   1.4. Does learners’ learning preference influence their selections of online multimedia learning resources?

2. Does gender have a relationship with visualizer or verbalizer tendency?

   2.1. Does gender have a relationship with cognitive ability?
2.2. Does gender have a relationship with spatial ability?
2.3. Does gender have a relationship with cognitive style?
2.4. Does gender have a relationship with learning preference?
2.5. Does gender have a relationship with selections of online multimedia resources?

For this study, four predictor variables (cognitive ability, spatial ability, cognitive style, and learning preference) and two criterion variables (two separate aggregated multimedia learning behavior tests) were identified. Two separate multimedia learning behavior tests were presented. Each behavior test was designed as a short hypothetical learning scenario containing five, brief questions related to the overall learning scenario topic. Each question contained a text-based description of a concept with key terms highlighted, followed by three multimedia learning options for additional information or clarification. Participants were then able to choose a text-only option, a labeled image option, or an image with narrated description option. Individual participant selections resulted in each being placed into one of three categories at the time of data analysis based their most frequently selected multimedia options, those being a text-only category, a labeled image category, and an image and narration category.

For this study, the first behavior test offered a science theme, weather, and the second offered a technology theme, formatting a table within a word processing document. Both of these themes were viewed as likely familiar to most participants such that most had some familiarity with how weather systems form and some familiarity with creating Word documents. These themes were therefore thought to not be overly
complex so as to draw participant resources heavily into attempting to learn a difficult topic. It was additionally thought that both science and technology might frequently present potential learners with conceptually challenging themes that benefit from supplemental multimedia to aid understanding. Each of these Multimedia Learning Behavior Tests may be viewed in Appendix A, sections 11 and 12.

For the study of covariance: cognitive ability, spatial ability, cognitive style, learning preference, and selections of online multimedia resources (text only, labeled image, narration and image) in two multimedia learning behavioral tests are the six criterion variables. As gender was posited to be a possible covariant in this study, gender was the predictor variable.

**Hypotheses**

As it has been suggested that certain learner characteristics and dimensions may correspond with learner selections of and responses to different types of learning materials, it seemed relevant to investigate this supposition further in the context of online learning environments. In an effort to accomplish this goal, two groups of hypotheses were tested. The first group had the specific objective of investigating the selection of online multimedia for learning and how this may be related to cognitive ability, spatial ability, cognitive style, and learning preference as indicators of individual visualizer or verbalizer tendencies, as follows.

H₀₁: Learners’ visualizer or verbalizer tendencies will have no influence on their selections of online multimedia learning resources.

H₀₁₁: Learners’ cognitive ability will have no influence on their selections of online multimedia learning resources.
H01.2: Learners’ spatial ability will have no influence on their selections of online multimedia learning resources.

H01.3: Learners’ cognitive style will have no influence on their selections of online multimedia learning resources.

H01.4: Learners’ learning preference will have no influence on their selections of online multimedia learning resources.

The second set of hypotheses was intended to investigate gender as a covariate, which may influence visualizer or verbalizer tendencies, as follows.

H02: Gender will have no relationship with visualizer or verbalizer tendency.

H02.1: Gender will have no relationship with cognitive ability.

H02.2: Gender will have no relationship with spatial ability.

H02.3: Gender will have no relationship with cognitive style.

H02.4: Gender will have no relationship with learning preference.

H02.5: Gender will have no relationship with selections of online multimedia learning resources.

**Expected Results**

Given no explicit evidence was presented in the original Mayer and Massa (2003) study, it was expected that none of the predictor variables of cognitive ability, cognitive style, or learning preference would have significant predictive power in determining selections in a multimedia learning behavior test. There has been some documentation that spatial ability, however, has been shown to be an influential factor which may transfer to performance in other tasks, primarily those related to science, technology, engineering, and mathematics (Hauptman, 2010; Uttal, Meadow, Tipton, Hand, Alden,
It was therefore expected that the factor of spatial ability might emerge as a significant predictor of selections in a multimedia learning behavior test. Spatial ability is furthermore noted to tend to be greater in males than in females (Mayer & Massa, 2003; Wolbers & Hegarty, 2010). Significant gender differences were also noted in the cognitive ability measures: SAT scores and vocabulary test results (Mayer & Massa, 2003). It was therefore further expected that differences between male and female participant behaviors and multimedia learning selections would emerge. Finally, following the trends, which emerged from the initial pilot study, it was expected that most participants would preferentially select either the labeled image or image and narration multimedia learning options in the multimedia learning behavior tests.

**Research Design**

The research design was a multinomial logistic regression design employing a cross-sectional survey strategy containing four factors followed by a correlational study. The purpose of this design was to predict selections on multimedia learning behavior tests based on: 1) cognitive ability, 2) spatial ability, 3) cognitive style, and 4) learning preference. Following a series of questions and tests used to evaluate cognitive ability, spatial ability, cognitive style and learning preference, participants were directed to complete two, online multimedia learning behavior tests which consisted of two separate, hypothetical learning scenarios. Under each scenario, participants were presented with five, related questions. For more detailed information, all of these learning scenarios are located in sections 11 and 12 of Appendix A. Participants were then offered the choice of three different multimedia learning options for additional information or help for each
question; a text only option, a labeled image option, and an image with a narrated description option. Table 14 provides a basic summary of the two, multimedia learning behavior tests.

Table 13

Summary of Multimedia Learning Behavior Tests (MLBT), Criterion variables

<table>
<thead>
<tr>
<th>Learning scenario theme</th>
<th>Number of questions</th>
<th>Multimedia options</th>
<th>Method of scoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>MLBT – 1 Weather</td>
<td>5</td>
<td>• Text</td>
<td>Most frequently selected option (mode)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Labeled image</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Image and narration</td>
<td></td>
</tr>
<tr>
<td>MLTB – 2 Formatting a table in a Word document</td>
<td>5</td>
<td>• Text</td>
<td>Most frequently selected option (mode)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Labeled image</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Image and narration</td>
<td></td>
</tr>
</tbody>
</table>

No control or manipulation was exerted over the variables or presentation, rather participants were presented with the same learning scenarios in the multimedia learning behavior tests and were free to make selections as they would naturally see fit, in accordance with a correlational study setting. In addition to multinomial logistic regression, two sample t-tests were conducted on the sub-measures of cognitive ability, spatial ability, and cognitive style. Chi square tests for independence were conducted on learning preference and preferential selections in each of the multimedia learning behavior tests based on gender. The purpose of these tests was to discover if gender was a covariate, based on the results of the initial pilot study.
Participants

A total of 112 individuals participated in this study. A priori calculation for sample size using G*Power version 3.1.5 indicated that a sample size of 111 would be necessary to achieve an effect size of .3 and power of .95. Participants were recruited via flyers posted in student-frequented locations around campus, electronic flyers posted on class Blackboard sites, and in person via in-class recruitment. Participation was voluntary. The university included in the study has an enrollment of over 10,000 students and houses 11 schools and colleges, all of which were represented by participants in this study. Any active student was permitted to participate in this study, provided they were at least 18-years of age at the time of the survey. This further included undergraduate as well as graduate students engaged in any major area of study and with any amount of experience with online learning.

The previous pilot study was conducted at the same university and, as such, may have inadvertently targeted some of the same individual participants. In the final survey instrument, participants were asked, “Have you previously participated in a similar study offered by the current researcher?” in an effort to alleviate this issue and allow for the elimination of cases. Participants who responded yes were immediately informed that they were disqualified from participating in the current survey.

Instrumentation

Following the pilot study findings, a modified survey instrument was created to measure learners’ visualizer or verbalizer tendencies. This instrument included measures of cognitive ability, spatial ability, cognitive style, and learning preferences, and compared these characteristics with learning option choices in two, multimedia learning
behavior tests, as outlined previously in Tables 14. Table 15 presents an overview of the entire instrument with additions and modifications as summarized in the pilot study conclusions section, indicated in boldface. In addition, the survey instrument in its entirety is located in Appendix A.
### Modified survey instrument

<table>
<thead>
<tr>
<th>Variable type</th>
<th>Number and Measure</th>
<th>Number of Items</th>
<th>Type</th>
<th>Modification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographic Questions</td>
<td>1. Gender</td>
<td>1</td>
<td>Questionnaire</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Age</td>
<td>1</td>
<td>Questionnaire</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Class status (undergraduate or graduate)</td>
<td>1</td>
<td>Questionnaire</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Major area of study</td>
<td>1</td>
<td>Questionnaire</td>
<td>Addition</td>
</tr>
<tr>
<td></td>
<td>5. How many online classes have you previously taken?</td>
<td>1</td>
<td>Questionnaire</td>
<td>Addition</td>
</tr>
<tr>
<td></td>
<td>6. Are you currently taking any online courses?</td>
<td>1</td>
<td>Questionnaire</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7. Have you previously participated in a similar study?</td>
<td>1</td>
<td>Questionnaire</td>
<td>Addition</td>
</tr>
</tbody>
</table>

**Factor 1: Cognitive Ability**

| PV - 1 | 1. SAT Mathematics | 1 | Questionnaire |              |
| | 2. SAT Critical Reading | 1 | Questionnaire |              |
| | 3. SAT Writing | 1 | Questionnaire |              |
| | 4. Vocabulary Test | 10 | Timed test |              |

**Factor 2: Spatial Ability**

| PV - 2 | 5. Paper Folding Test | 10 | Timed test | Replacement for Verbal-Spatial Ability Rating |
| | 6. Card Rotation Test | 10 | Timed test |              |

**Factor 3: Cognitive Style**

| PV - 3 | 7. Santa Barbara Learning Style Questionnaire | 6 | Questionnaire | Adjusted from a 7-point to a 6-point Likert scale |
| | 8. Verbal-Visual Learning Style Rating | 1 | Questionnaire | Adjusted from a 7-point to a 6-point Likert scale |
| | 9. Learning Scenario Questionnaire | 10 | Questionnaire | Five additional questions |
Table 15 (continued)

<table>
<thead>
<tr>
<th>Variable type</th>
<th>Number and Measure</th>
<th>Number of Items</th>
<th>Type</th>
<th>Modification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PV - 4</strong></td>
<td>10. Multimedia Learning Preference Questionnaire</td>
<td>1</td>
<td>Questionnaire</td>
<td></td>
</tr>
<tr>
<td><strong>CV - 1</strong></td>
<td>11. Multimedia Learning Behavior Test - 1</td>
<td>5</td>
<td>Behavioral Test</td>
<td>An additional question is added</td>
</tr>
<tr>
<td><strong>CV - 2</strong></td>
<td>12. Multimedia Learning Behavior Test - 2</td>
<td>5</td>
<td>Behavioral Test</td>
<td>Addition</td>
</tr>
</tbody>
</table>

Note. Variable type: PV – Predictor variable; CV – Criterion variable
**Procedures**

The survey instrument was administered as an anonymous online survey utilizing Survey Gizmo, an online survey service. Prior to beginning the survey, participants were presented with an electronic informed consent form. Selecting the “yes” button following review of the informed consent document constituted consent and participants were automatically redirected to the survey instrument. The instrument consisted of a total of 69 questions categorized as follows: seven demographic questions, thirteen cognitive ability questions, 20 spatial ability questions, seventeen cognitive style questions, and one learning preference question, followed by two multimedia learning behavior tests with five questions each. Participants were permitted to complete the survey instrument from any computer with audio capabilities and an Internet connection, and were advised to allot 30 to 45 minutes to fully complete the survey.

**Variables**

*Predictor Variables*

Four predictor variables were utilized in this study measuring cognitive ability, spatial ability, cognitive style, and learning preference as indicators of visualizer or verbalizer tendency. For the measure of cognitive ability, participants were asked to report their SAT scores for each of the three sections administered at the time of survey: Critical Reading (M = 496, SD = 115), Mathematics (M = 514, SD = 118), and Writing (M = 488, SD = 114) (College Board, 2013). A ten question, timed vocabulary test was additionally utilized for this variable, asking participants to identify a word closest in meaning to a given word within three minutes.
Spatial ability was measured utilizing a timed, ten question paper folding test in which participants were shown sequential images of a square of paper being folded and, in the final image, having a hole punched in it. Participants were then be asked to select the correct image from five possibilities showing where the hole(s) would be in the square of paper after it had been unfolded. An example of the paper folding test is shown in Figure 19.

![Paper folding test example](image)

Figure 19. *Paper folding test example*

A card rotation test was also used as a measure of spatial ability. In this test, respondents were shown a two-dimensional shape followed by eight images of the same shape in different rotations or orientations. Respondents were asked to decide which of these eight shapes were the same as or different from the original shape understanding that the shape could not be flipped or altered in any way (French, Ekstrom, & Price, 1963). An example of the card rotation test is shown in Figure 20.
Cognitive style was assessed utilizing seven Likert-type questions asking participants to rate themselves as visual or verbal learners on a six point scale from strongly agree to strongly disagree as well as comparatively rate themselves on a six point scale ranging from strongly more verbal than visual to strongly more visual than verbal. Participants were additionally presented with ten questions offering hypothetical learning scenarios and asked to choose between two possible methods of learning material delivery, one representing a strongly visual delivery and the other a strongly verbal or text-based delivery.

Learning preference was finally measured by presenting participants with a hypothetical learning scenario followed by three multimedia learning options. These three options included a text only option, a labeled image, and an image with a narrated description option. Participants were simultaneously presented with all three options,
asked to view each option, and finally to select their most preferred option for learning from the three choices.

**Criterion variables**

The criterion variables for this study were participant selections of multimedia learning options in two, multimedia learning behavior tests. Each behavior test was designed as a short hypothetical learning scenario containing five, brief questions related to the overall learning scenario topic. Each question contained a text-based description with key terms highlighted, followed by three multimedia options for additional information or clarification. Participants were then asked to choose the text-only option, the labeled image option, or the image with narrated description option. Individual participant selections resulted in each being placed into one of three categories based on their most frequently selected learning options, those being a text-only category, a labeled image category, and an image and narration category. Each of these multimedia learning behavior tests may be viewed in Appendix A, sections 11 and 12.

**Summary**

In summary, four predictor variables measuring cognitive ability, spatial ability, cognitive style, and learning preference were used with the goal of predicting two separate criterion variables of multimedia learning behavior test selections. Table 16 below provides an additional summary of these variables.
### Table 15

**Summary of predictor variables (PVs) and criterion variables (CVs)**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Description</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PVs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cognitive Ability</td>
<td>• SAT scores for critical reading, mathematics, and writing</td>
<td>Continuous</td>
</tr>
<tr>
<td></td>
<td>• Timed, vocabulary test score</td>
<td></td>
</tr>
<tr>
<td>Spatial Ability</td>
<td>• Timed, paper folding test score</td>
<td>Continuous</td>
</tr>
<tr>
<td></td>
<td>• Verbal-Spatial ability rating</td>
<td></td>
</tr>
<tr>
<td>Cognitive Style</td>
<td>• Santa Barbara Learning Style Questionnaire</td>
<td>Continuous</td>
</tr>
<tr>
<td></td>
<td>• Verbal-Visual learning style rating</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Learning scenario questionnaire</td>
<td></td>
</tr>
<tr>
<td>Learning Preference</td>
<td>• Multimedia learning preference questionnaire</td>
<td>Categorical</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Nominal)</td>
</tr>
<tr>
<td><strong>CVs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multimedia Learning Behavior Tests</td>
<td>• Selections of three multimedia options (text only, labeled image, or image and narration) in two online learning modules</td>
<td>Categorical</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Nominal)</td>
</tr>
</tbody>
</table>

### Analysis

Composite scores for each of the factors of cognitive ability, spatial ability, and cognitive style were calculated following standardization of each variable and adding together these scores to create each factor. This method is concurrent with the unit-weighted factor score estimate procedure which selects variables with respective factor loadings above a specified cutoff level following exploratory factor analysis, in this case .40, standardizes the variable raw scores if they are measured on different scales, and sums the resulting scores to arrive at a single, composite score (DiStefano, Zhu, & Mindrila, 2009; Grice, 2001). This method is indicated as a prevalent and popular method for the purpose of scale development and conducting further analysis, utilizing factors uncovered following EFA (DiStefano, Zhu, & Mindrila, 2009; Grice, 2001).
A main goal of this study was to determine if cognitive ability, spatial ability, cognitive style, and learning preference could successfully predict selection of three multimedia learning options: text only, labeled image, or image and narration, in two multimedia learning behavior tests. Multinomial logistic regression was therefore determined to be the most appropriate method of analysis as it allows for the prediction of categorical outcomes using continuous variables (Field, 2013; Garson, 2014). The main question addressed was, can multimedia learning option selections (text only, labeled image, image and narration) be correctly predicted utilizing knowledge of cognitive ability, spatial ability, cognitive style, and learning preference?

Since this study was exploratory in nature and no prior assumptions existed as to which variables might or might not have contributed to an overall model, the enter method was used to investigate all potential IVs which significantly predicted the DV. The reference category was labeled image, as this was the most frequently selected option in the pilot study multimedia learning behavior test. This category was therefore conceptually viewed as an average point to which the other two categories could be compared.

Finally, in order to explore the second research question addressing gender as a possible covariate, two sample t-tests were performed for each of the three factors; cognitive ability, spatial ability, and cognitive style, and chi square tests for independence for learning preference and selections of online multimedia learning options (text only, labeled image, or image and narration) in two, multimedia learning behavior tests.
CHAPTER IV

RESULTS

The focus of this dissertation was directed towards answering the primary research question, how do learning preferences, cognitive ability, spatial ability, and cognitive styles relate to learner interactions with online, multimedia-based learning materials. An assumption made for this study was that some learners prefer visual-based learning while others prefer verbal-based learning (the visualizer-verbalizer hypothesis). This chapter will focus on discussing the findings related to the following research hypotheses:

H_{01}: Learners’ visualizer or verbalizer tendencies will have no influence on their selections of online multimedia learning resources.

H_{01.1}: Learners’ cognitive ability will have no influence on their selections of online multimedia learning resources.

H_{01.2}: Learners’ spatial ability will have no influence on their selections of online multimedia learning resources.

H_{01.3}: Learners’ cognitive style will have no influence on their selections of online multimedia learning resources.

H_{01.4}: Learners’ learning preference will have no influence on their selections of online multimedia learning resources.

H_{02}: Gender will have no relationship with visualizer or verbalizer tendency.

H_{02.1}: Gender will have no relationship with cognitive ability.

H_{02.2}: Gender will have no relationship with spatial ability.

H_{02.3}: Gender will have no relationship with cognitive style.
**H₀₂.₄**: Gender will have no relationship with learning preference.

**H₀₂.₅**: Gender will have no relationship with selections of online multimedia learning resources.

The first main null hypothesis states that learners’ visualizer or verbalizer tendencies will have no influence on their selections of online multimedia learning resources. To investigate this hypothesis, in addition to the related sub-hypotheses, two of multinomial logistic regressions were conducted for two individual multimedia learning behavior tests. The factors used to predict multimedia learning resource selections were cognitive ability, spatial ability, cognitive style, and learning preference.

The second main research question states that gender will have no relationship with visualizer or verbalizer tendency. To test this hypothesis and the related sub-hypotheses, a series of two-sample t-tests were used to investigate gender as a covariate for H₀₂.₁ through H₀₂.₃. Chi-square tests of independence were used to investigate gender as a covariate for H₀₂.₄ and H₀₂.₅.

**Descriptive Statistics**

A total of 112 individuals participated in this study. Twenty-seven participants did not complete the study survey. Little’s missing completely at random test was conducted with non-significant results ($\chi^2=292.955$, df(162), $p < .001$) indicating that data was not missing completely at random. Closer look at the incomplete responses showed that nine respondents discontinued participation immediately after the demographics questions, 13 during or immediately after the cognitive ability questions, and 5 during the spatial ability tests. Considering the fact that participants were required to provide an answer to any individual question before moving on to the next, participants who were
either unwilling to share or unable to recall their SAT scores, which was the first question following the demographic questionnaire, might have quit the survey. Participants who did not possess high cognitive and/or spatial abilities or those who were sensitive in regard to their self-image might have quit during the cognitive ability or spatial ability tests.

Although the assumption of missing completely at random was not met, listwise deletion was chosen as the method to treat missing data, with the acknowledgement of the potential biased parameter estimates. Data from 85 remaining participants were included in the subsequent analyses.

The R statistical analysis software (version 3.1.2) was used for data analysis. Basic demographic information obtained from participants both before and after listwise deletion is shown in Table 16.
Table 16

*Participant demographics before and after listwise deletion.*

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>80 (58)</td>
<td>71 (68)</td>
</tr>
<tr>
<td>Male</td>
<td>32 (27)</td>
<td>29 (32)</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19-23</td>
<td>85 (67)</td>
<td>76 (79)</td>
</tr>
<tr>
<td>24-28</td>
<td>13 (10)</td>
<td>12 (12)</td>
</tr>
<tr>
<td>29-39</td>
<td>10 (5)</td>
<td>9 (6)</td>
</tr>
<tr>
<td>&gt; 40</td>
<td>4 (3)</td>
<td>3 (3)</td>
</tr>
<tr>
<td><strong>Status</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Undergraduate</td>
<td>82 (64)</td>
<td>73 (75)</td>
</tr>
<tr>
<td>Graduate</td>
<td>28 (20)</td>
<td>25 (24)</td>
</tr>
<tr>
<td>Other</td>
<td>2 (1)</td>
<td>2 (1)</td>
</tr>
<tr>
<td><strong>Previous online class participation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>57 (44)</td>
<td>51 (52)</td>
</tr>
<tr>
<td>1-9</td>
<td>42 (32)</td>
<td>38 (38)</td>
</tr>
<tr>
<td>10 or more</td>
<td>13 (9)</td>
<td>11 (10)</td>
</tr>
<tr>
<td><strong>Current online class participation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>90 (70)</td>
<td>80 (82)</td>
</tr>
<tr>
<td>1-6</td>
<td>22 (15)</td>
<td>20 (18)</td>
</tr>
</tbody>
</table>

*Note.* After deletion numbers are in boldface

Although 27 participants did not complete the full survey resulting in removal via listwise deletion, it is noteworthy that the percentages of participants associated with the different demographic characteristics remained nearly the same following deletion of cases. It may also be noted that a disproportionate number of females versus males participated in this study (68 percent versus 32 percent).

Responses to a total of 12 measures were obtained via an online survey. Descriptive statistics for the continuous measures are presented in Table 17, followed by the categorical measures in Table 18. In both tables, overall data are presented along
with data based on gender because gender was examined as a potential covariate in this study.

Table 17

Measured continuous variables with corresponding factor and variable type (PV-predictor variable)

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cognitive Ability (PV-1)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAT Mathematics</td>
<td>71</td>
<td>588.817</td>
<td>90.833</td>
</tr>
<tr>
<td>Female</td>
<td>49</td>
<td>584.306</td>
<td>95.091</td>
</tr>
<tr>
<td>Male</td>
<td>22</td>
<td>598.864</td>
<td>81.736</td>
</tr>
<tr>
<td>SAT Critical Reading</td>
<td>71</td>
<td>577.873</td>
<td>70.971</td>
</tr>
<tr>
<td>Female</td>
<td>49</td>
<td>572.122</td>
<td>75.751</td>
</tr>
<tr>
<td>Male</td>
<td>22</td>
<td>590.682</td>
<td>58.519</td>
</tr>
<tr>
<td>SAT Writing</td>
<td>68</td>
<td>577.265</td>
<td>67.699</td>
</tr>
<tr>
<td>Female</td>
<td>46</td>
<td>570.739</td>
<td>72.731</td>
</tr>
<tr>
<td>Male</td>
<td>22</td>
<td>590.909</td>
<td>54.764</td>
</tr>
<tr>
<td>Vocabulary test</td>
<td>85</td>
<td>7.671</td>
<td>1.900</td>
</tr>
<tr>
<td>Female</td>
<td>58</td>
<td>7.621</td>
<td>1.901</td>
</tr>
<tr>
<td>Male</td>
<td>27</td>
<td>7.778</td>
<td>1.932</td>
</tr>
<tr>
<td><strong>Spatial Ability (PV-2)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paper folding test</td>
<td>85</td>
<td>3.967</td>
<td>2.694</td>
</tr>
<tr>
<td>Female</td>
<td>58</td>
<td>3.772</td>
<td>2.763</td>
</tr>
<tr>
<td>Male</td>
<td>27</td>
<td>4.385</td>
<td>2.538</td>
</tr>
<tr>
<td>Card rotation test</td>
<td>85</td>
<td>32.776</td>
<td>19.885</td>
</tr>
<tr>
<td>Female</td>
<td>58</td>
<td>30.517</td>
<td>18.066</td>
</tr>
<tr>
<td>Male</td>
<td>27</td>
<td>37.629</td>
<td>22.938</td>
</tr>
<tr>
<td><strong>Cognitive Style (PV-3)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Santa Barbara learning style questionnaire</td>
<td>85</td>
<td>2.929</td>
<td>5.298</td>
</tr>
<tr>
<td>Female</td>
<td>58</td>
<td>2.931</td>
<td>5.406</td>
</tr>
<tr>
<td>Male</td>
<td>27</td>
<td>2.926</td>
<td>5.158</td>
</tr>
<tr>
<td>Visual-verbal learning style rating</td>
<td>85</td>
<td>0.271</td>
<td>2.020</td>
</tr>
<tr>
<td>Female</td>
<td>58</td>
<td>0.310</td>
<td>2.028</td>
</tr>
<tr>
<td>Male</td>
<td>27</td>
<td>0.185</td>
<td>2.039</td>
</tr>
<tr>
<td>Learning style questionnaire</td>
<td>85</td>
<td>7.271</td>
<td>2.014</td>
</tr>
<tr>
<td>Female</td>
<td>58</td>
<td>7.278</td>
<td>1.989</td>
</tr>
<tr>
<td>Male</td>
<td>27</td>
<td>7.259</td>
<td>2.105</td>
</tr>
</tbody>
</table>
Table 18

*Measured categorical variables with corresponding factor and variable type (PV-predictor variable, CV-criterion variable)*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Text only</th>
<th>Labeled image</th>
<th>Image and narration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Learning Preference (PV-4)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multimedia learning preference questionnaire(^1)</td>
<td>15</td>
<td>19</td>
<td>51</td>
</tr>
<tr>
<td>Female</td>
<td>11</td>
<td>11</td>
<td>36</td>
</tr>
<tr>
<td>Males</td>
<td>4</td>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td><strong>Behavior Tests (CVs)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multimedia learning behavior test – 1 (Mode)(^1)</td>
<td>19</td>
<td>30</td>
<td>36</td>
</tr>
<tr>
<td>Female</td>
<td>12</td>
<td>20</td>
<td>26</td>
</tr>
<tr>
<td>Male</td>
<td>7</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Multimedia learning behavior test – 2 (Mode)(^1)</td>
<td>12</td>
<td>48</td>
<td>25</td>
</tr>
<tr>
<td>Female</td>
<td>9</td>
<td>31</td>
<td>18</td>
</tr>
<tr>
<td>Male</td>
<td>3</td>
<td>17</td>
<td>7</td>
</tr>
</tbody>
</table>

\(^1\) N = 85

SAT scores, listed under the cognitive ability factor (Table 17), were incomplete for some cases. The SAT variables were therefore excluded, and the vocabulary test was used as the single measure for the cognitive ability factor. Vocabulary test score averages were fairly equivalent for both male and female participants. Males showed higher average scores than females in the measures of spatial ability, particularly in the card rotation test. This follows along with well-documented trends (e.g. Feng, Spence, & Pratt, 2007; Uttal, et al., 2012; Wolbers & Hegarty, 2010) of males tending to have greater spatial ability than females. Regarding cognitive style, both males and females showed fairly equivalent visualizer preferences. Most participants expressed a learning preference for image and narration, which was also slightly reflected in the first multimedia learning behavior test, where a majority of participants selected the image
and narration learning option. The second multimedia learning behavior test, however, showed a shifting preference for a majority of participants to the labeled image learning option.

A further comparison was made by looking at participants in each of the learning preference subgroups; those who selected text only, labeled image, or image and narration respectively as their learning preference and how these compared with selections in the multimedia learning behavior tests. These results are shown in Table 19.

Table 19

*Multimedia Learning Behavior Test selections based on learning preference*

<table>
<thead>
<tr>
<th>Learning Preference</th>
<th>Multimedia Learning Behavior Test 1 Selections</th>
<th>Multimedia Learning Behavior Test 2 Selections</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Text Only</td>
<td>Labeled Image</td>
</tr>
<tr>
<td>Text Only¹</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Labeled Image²</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>Image and Narration³</td>
<td>8</td>
<td>13</td>
</tr>
</tbody>
</table>

Note. ¹ Number of participants = 15
² Number of participants = 19
³ Number of participants = 51

No individual who indicated a text only learning preference went on to select the image and narration learning option in either of the multimedia learning behavior tests. A majority of participants indicated a learning preference for image with narration, which was reflected for this group in behavior test 1 choices; however a shift in choices is noted for this group in behavior test 2. The group who selected a labeled image learning
preference went on to consistently show a preference for labeled images in both of the behavior tests.

Variations in behavior between the different learning preference groups were observed; specifically the labeled image learning preference group showed more consistency in their choices of multimedia help options in both of the behavior tests than the other two groups. As a result of this trend, correlations were inspected for each of these groups in order to determine if any notable relationships existed. The results are shown in Table 20.

Table 20

*Correlations based on learning preference for criterion variables in multimedia learning behavior tests 1 and 2*

<table>
<thead>
<tr>
<th>Learning Preference Groups</th>
<th>Behavior Test 1</th>
<th>Behavior Test 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Text only</td>
<td>Labeled image</td>
</tr>
<tr>
<td>Cognitive ability</td>
<td>-.0877</td>
<td>.0783</td>
</tr>
<tr>
<td>Spatial ability</td>
<td>-.0682</td>
<td>-.1081</td>
</tr>
<tr>
<td>Cognitive style</td>
<td>.0783</td>
<td>.7025</td>
</tr>
</tbody>
</table>

There is a strong, positive relationship between cognitive style and selections in behavior test 1 for the labeled image group and a moderate positive relationship in the image and narration group for both behavior tests 1 and 2. There are no other notable correlations between the learning preference groups and the other criterion variables in either of the behavior tests.
Trends: Learning Style Questionnaire

In the learning style questionnaire, most participants tended to prefer the visual help option for each of the learning scenarios. Two notable shifts from a visual help preference to a verbal help preference were, however, observed for questions 4 and 8 (Figure 21).

![Learning Style Questionnaire](image)

Figure 21. Selections of verbal or visual help for each of the 10 questions in the learning scenario questionnaire

Question 4 (LSQ4) asked, “Which format do you prefer for following directions on how to set time on a stopwatch?” with the possible choices of “a list of steps in words” representing verbal help and “a labeled diagram showing the steps” representing the visual help. Question 8 (LSQ8) asked “If you were to provide directions to a familiar location, which would you most likely do?” with the possible responses of “provide a written, step-by-step list of directions from the starting point to the end point” as the
verbal help and “draw a map showing the route along with relevant landmarks” as the visual help.

**Trends: Selections of Multimedia Learning Options**

Participants in the first behavior test, with the learning scenario of how weather works, showed an overall equivalent preference for both the labeled image and image and narration options as compared to the text only option. Figure 22 shows the trend of preferential selection of help from the first multimedia learning behavior test.

![Multimedia Learning Behavior Test - 1](image)

<table>
<thead>
<tr>
<th>Multimedia Learning Behavior Test - 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of Selections</strong></td>
</tr>
<tr>
<td>Text only</td>
</tr>
<tr>
<td>Labeled image</td>
</tr>
<tr>
<td>Image and narration</td>
</tr>
<tr>
<td>MM LBT 1-1</td>
</tr>
<tr>
<td>MM LBT 1-2</td>
</tr>
<tr>
<td>MM LBT 1-3</td>
</tr>
<tr>
<td>MM LBT 1-4</td>
</tr>
<tr>
<td>MM LBT 1-5</td>
</tr>
<tr>
<td>Text only</td>
</tr>
<tr>
<td>21</td>
</tr>
<tr>
<td>16</td>
</tr>
<tr>
<td>17</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>15</td>
</tr>
<tr>
<td>Labeled image</td>
</tr>
<tr>
<td>36</td>
</tr>
<tr>
<td>29</td>
</tr>
<tr>
<td>33</td>
</tr>
<tr>
<td>37</td>
</tr>
<tr>
<td>37</td>
</tr>
<tr>
<td>Image and narration</td>
</tr>
<tr>
<td>28</td>
</tr>
<tr>
<td>40</td>
</tr>
<tr>
<td>35</td>
</tr>
<tr>
<td>38</td>
</tr>
<tr>
<td>33</td>
</tr>
</tbody>
</table>

Figure 22. *Results of each of the five learning options for the first multimedia learning behavior test*

Participants in the second behavior test, with the learning scenario of how to create a table in a Word document, showed a generally greater preference for the labeled
image option and lowest preference for the text only option. Figure 23 shows the trend of preferential selection of help from the second multimedia learning behavior test.

Figure 23. Results of each of the 5 learning options for the second multimedia learning behavior test

**Correlations: Demographic Characteristics and Multimedia Selections**

Correlations were used to investigate any possible relationships between the demographic characteristics of age, status (undergraduate, graduate, or other), past online course experience, and current online course experience with selections of multimedia learning options both in the multimedia learning preference questionnaire and selections in multimedia learning behavior tests one and two. These correlations are presented in Table 21.
As shown in Table 21, there are no notable correlations between any of the demographic characteristics and learning preference as measured by the multimedia learning preference questionnaire (MMLPQ) or selections of multimedia learning options in either of the multimedia learning behavior tests. This suggests that these preferences and selections are independent of age, status (undergraduate, graduate, other), or past or current online course experience.

**Correlations: Independent and Dependent Variables**

Correlations were further inspected to determine any relationships between the independent and dependent variables used in this study, as shown in Table 22.
Table 22

*Correlations between independent and dependent variables*

<table>
<thead>
<tr>
<th>Measure</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>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Independent Variables</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cognitive Ability</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Vocabulary Test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Spatial Ability</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Paper Folding Test</td>
<td>.0693</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Card Rotation Test</td>
<td>.0813 .4534</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cognitive Style</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Learning Style Questionnaire</td>
<td>-.0006 -.0411 .1019</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. SB Learning Style Questionnaire</td>
<td>.1261 .0355 .2700 .4453</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. VV Learning Style Rating</td>
<td>.0576 .0576 .0513 .1204 .2289</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Learning Preference</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. MM Learning Preference Questionnaire</td>
<td>.1307 .1199 .1019 .2149 .2977 .3357</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dependent Variables</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. MMLBT-1</td>
<td>.2044 .0351 .1062 .3761 .3636 .2300 .5112</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. MMLBT-2</td>
<td>.1053 -.0272 .0851 .3627 .4202 .0622 .4032 .4942</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A strong, positive correlation can be seen between the paper folding test and the card rotation test (measures 2 and 3), both of which are used as measures of spatial ability. There is also a strong positive relationship between two of the three measures of cognitive style, the learning style questionnaire and the Santa Barbara learning style questionnaire (measures 4 and 5) and additionally between these two measures and both of the dependent variables, the multimedia learning behavior tests (MMLBT). There is a moderate relationship between the visual-verbal learning style rating and the multimedia
learning preference questionnaire. Finally, strong to moderate correlations can be seen between the multimedia learning preference questionnaire (measure 7) with both of the dependent variables (measures 8 and 9) and between both of the dependent variables themselves.

**Reliability**

Reliability statistics are shown in Table 23. Each of the verbal-visual learning style ratings and the multimedia learning preference questionnaire had only one item and are thus not included.

**Table 23**

*Reliability statistics for selected sub-scales*

<table>
<thead>
<tr>
<th>Measurement (sub-scale)</th>
<th>Number of items</th>
<th>Cronbach’s alpha</th>
<th>Cronbach’s alpha (Pilot study)</th>
<th>Cronbach’s alpha (Source)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vocabulary Test</td>
<td>10</td>
<td>.48</td>
<td>.71</td>
<td>NA</td>
</tr>
<tr>
<td>Paper Folding Test</td>
<td>10</td>
<td>.80</td>
<td>.71</td>
<td>.80</td>
</tr>
<tr>
<td>Card Rotation Test</td>
<td>80</td>
<td>.94</td>
<td>NA</td>
<td>.96</td>
</tr>
<tr>
<td>Santa Barbara Learning Style Questionnaire</td>
<td>6</td>
<td>.73</td>
<td>.74</td>
<td>.76</td>
</tr>
<tr>
<td>VV Learning Style Questionnaire</td>
<td>10</td>
<td>.64</td>
<td>.02</td>
<td>.38</td>
</tr>
<tr>
<td>Multimedia Learning Behavior Test-1</td>
<td>5</td>
<td>.86</td>
<td>.86</td>
<td>.80</td>
</tr>
<tr>
<td>Multimedia Learning Behavior Test-2</td>
<td>5</td>
<td>.92</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

For this study, the Cronbach’s alpha for the vocabulary test can be seen as low and thus the reliability of this measure is called into question. The decision was made to
go forward and include this variable in subsequent analysis in an effort to not completely exclude any measure of cognitive ability. The results for cognitive ability as measured by the vocabulary test are, however, acknowledged as potentially unreliable, and caution is advised in their interpretation.

**Composite scores**

After standardizing individual variables, composite scores for each of the spatial ability and cognitive style factors were calculated. As the decision was made to exclude the SAT variable due to excessive missing data points, the vocabulary test variable was used exclusively as the measure of cognitive ability for subsequent analysis. The paper folding test and card rotation test scores were standardized and added together to create a composite score, which was used as the spatial ability factor. Likewise, the Santa Barbara learning style questionnaire, visual-verbal learning style rating, and learning preference questionnaire scores were standardized and added together to create a composite score, which was used as the cognitive style factor. Table 24 provides descriptive statistics for these composite variables.

Table 24

*Values for spatial ability and cognitive style following standardization and addition of relevant measured variables*

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spatial Ability</strong></td>
<td>85</td>
<td>0.000</td>
<td>1.728</td>
</tr>
<tr>
<td>Females</td>
<td>58</td>
<td>-0.186</td>
<td>1.658</td>
</tr>
<tr>
<td>Males</td>
<td>27</td>
<td>0.399</td>
<td>1.837</td>
</tr>
<tr>
<td><strong>Cognitive Style</strong></td>
<td>85</td>
<td>0.000</td>
<td>2.205</td>
</tr>
<tr>
<td>Females</td>
<td>58</td>
<td>0.023</td>
<td>2.146</td>
</tr>
<tr>
<td>Males</td>
<td>27</td>
<td>-0.049</td>
<td>2.367</td>
</tr>
</tbody>
</table>
Research Question 1: Predictors of Multimedia Learning Selections

To investigate how learners’ visuelizer or verbalizer tendencies (as measured by cognitive ability, spatial ability, cognitive style, and learning preference) influenced their selections of online multimedia learning resources, two multinomial logistic regressions were conducted.

Each of the two, multimedia learning behavior tests presented participants with five questions. Participants were instructed to select a learning option, which they found most helpful for understanding the concept presented in each question: text only, labeled image, or image and narration. The frequency of these choices was then evaluated to derive the most frequently chosen learning option (mode). This then was used as the criterion variable for the study. As the labeled image learning option was observed to be the most frequently selected learning option in the previously conducted pilot study, labeled image was set as the baseline for the criterion variables (multimedia learning behavior tests).

Multimedia Learning Behavior Test 1

The first analysis examined the relationship between the predictor variables and the criterion variable within the learning scenario of weather (See Appendix A, Section 9). Multinomial logistic regression using the mlogit package in R was conducted. The enter method was used to determine which predictor variables would be predictors of selection of learning options (mode) in multimedia learning behavior test 1. Even though multinomial logit models are robust to many of the assumptions required for other regression analysis, the data was inspected for multicollinearity. All tolerance statistics
were above the recommended cutoff of 0.1. One assumption advised for multinomial logistic regression is independence of irrelevant alternatives (IIA), which posits that individual choice between two alternatives will not be influenced by the introduction of additional choices (Cheng & Long, 2007; Garson, 2014). This assumption was evaluated via the Hausman-McFadden test, which compares the full model with a restricted model excluding one of the available criterion variable choices (Cheng & Long, 2007; Hausman & McFadden, 1984). The results were non-significant ($\chi^2=0, df(6), p = 1.00$), indicating that the IIA assumption was not violated.

Goodness-of-fit indices indicated that the overall model was reliable in predicting preferential selection of learning options in a multimedia learning behavior test (-2 Log Likelihood = -60.720, $\chi^2 = 59.837, df(10), p < .001$). As a further measure of goodness-of-fit, the residual deviance was non-significant ($\chi^2 = 121.440, df(158), p = .986$). The McFadden pseudo R$^2$ value (.330) fell within the suggested parameters of .2 to .4, indicating a good fit (Langer, 2000). The model correctly classified participants 65.9% of the time. Table 25 shows the results obtained for the analysis with multimedia learning behavior test 1.
Table 25

Multimedia learning behavior test 1: Multinomial logistic regression results

<table>
<thead>
<tr>
<th></th>
<th>Text only vs. Labeled image</th>
<th>95% CI for Odds Ratio</th>
<th>Image and narration vs. Labeled image</th>
<th>95% CI for Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>b(SE)</td>
<td>Wald</td>
<td>p</td>
</tr>
<tr>
<td>Constant</td>
<td>-1.086 (1.872)</td>
<td>0.337</td>
<td>.561</td>
<td></td>
</tr>
<tr>
<td>Cognitive ability</td>
<td>0.021 (0.234)</td>
<td>0.008</td>
<td>.928</td>
<td>0.646</td>
</tr>
<tr>
<td>Spatial ability</td>
<td>0.354 (0.234)</td>
<td>2.283</td>
<td>.131</td>
<td>0.900</td>
</tr>
<tr>
<td>Cognitive style</td>
<td>-0.889 (0.258)</td>
<td>11.876</td>
<td>&lt;.001</td>
<td>0.248</td>
</tr>
<tr>
<td>Learning preference</td>
<td>-3.048 (1.545)</td>
<td>3.894</td>
<td>.048</td>
<td>0.002</td>
</tr>
<tr>
<td>Learning preference</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learning preference</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: The table shows the results of a multinomial logistic regression analysis comparing multimedia learning behavior test results with different conditions.
Taking a closer look at the results for each of the predictors (Table 25), the cognitive style variable reached significance \((b = -0.889, \text{Wald } \chi^2(1) = 11.876, p < .001)\) for the preferential selection of the text only multimedia learning option. The odds ratio of 0.411, being less than 1, indicates that as cognitive style moved towards a visualizer preference with all other coefficients held constant, the likelihood of selecting the text only learning option decreased. An expressed learning preference for a labeled image also reached significance for both the selection of the text only learning option \((b = -3.048, \text{Wald } \chi^2(1) = 3.894, p = .048)\) and the selection of the image and narration learning option \((b = -1.517, \text{Wald } \chi^2(1) = 5.981, p = .014)\). The odds ratios for a learning preference of labeled image decreased the likelihood of both selection of text only (0.047) and image and narration (0.219) with all other coefficients held constant, in the multimedia learning behavior test. Otherwise stated, individuals who indicate labeled images as a learning preference were likely to select labeled images in the behavior test.

The significance of individual predictors was determined in this analysis by the Wald statistic, which has been noted as a very conservative indicator, thus it has been suggested that a less stringent \(p\) value (i.e. \(p < .1\)) may be appropriate for interpreting results (Mertler & Vannatta, 2010). Considering this recommendation, spatial ability can also be considered as a variable which reached significance \((b = -0.317, \text{Wald } \chi^2(1) = 2.895, p = .089)\) for the preferential selection of the image and narration learning option. The odds ratio of 0.728 indicates that, as spatial ability increased, the likelihood of selecting the image and narration learning option decreased with all other coefficients held constant.
Finally, the predictor for a learning preference of text only over labeled image, as related to the selection of the image and narration learning option in the multimedia learning behavior test, had relatively extreme values (Table 25). Upon further inspection of all cases in the sample group analyzed, it was noted that no individual who indicated a learning preference for text only went on to select the image and narration learning option in the first multimedia learning behavior test. This may be a likely explanation for the extreme value for this variable, as this scenario never occurred.

**Multimedia Learning Behavior Test 2**

The second analysis examined the relationship between the predictor variables and the criterion variable within the learning scenario of creating a table in a Word document (See Appendix A, Section 10). Multinomial logistic regression was again conducted using the *enter* method to determine which predictor variables would be predictors of selections of multimedia learning options (mode) in multimedia learning behavior test 2. All tolerance statistics for multicollinearity were above the recommended cutoff of 0.1. The Hausman-McFadden test results were non-significant ($\chi^2=0$, $df(6)$, $p = 1$), indicating that the IIA assumption was not violated.

Goodness-of-fit indices indicated that the overall model was reliable in predicting selection of learning options in a multimedia learning behavior test ($-2$ Log Likelihood = -62.703, $\chi^2 = 37.627$, $df(10)$, $p < .001$). As a further measure of goodness-of-fit, the residual deviance was non-significant ($\chi^2 = 125.407$, $df(158)$, $p = .974$) and the McFadden $R^2$ was 0.231. The model correctly classified subjects 63.5% of the time. Table 26 shows the results obtained from the analysis with multimedia learning behavior test 2.
Table 26

*Multimedia learning behavior test 2: Multinomial logistic regression results*

<table>
<thead>
<tr>
<th></th>
<th>( b(SE) )</th>
<th>Wald</th>
<th>( p )</th>
<th>95% CI for Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Text only vs. Labeled image</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-0.998 (1.628)</td>
<td>0.375</td>
<td>.540</td>
<td></td>
</tr>
<tr>
<td>Cognitive ability</td>
<td>-0.096 (0.201)</td>
<td>0.231</td>
<td>.631</td>
<td>0.613 0.908 1.346</td>
</tr>
<tr>
<td>Spatial ability</td>
<td>0.027 (0.204)</td>
<td>0.018</td>
<td>.893</td>
<td>0.689 1.028 1.534</td>
</tr>
<tr>
<td>Cognitive style</td>
<td>-0.388 (0.202)</td>
<td>3.690</td>
<td>.055</td>
<td>0.445 0.678 1.008</td>
</tr>
<tr>
<td>Learning preference</td>
<td>-1.230 (1.174)</td>
<td>1.097</td>
<td>.295</td>
<td>0.029 0.292 2.919</td>
</tr>
<tr>
<td>Learning preference</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(labeled image over image and narration)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learning preference</td>
<td>0.615 (0.797)</td>
<td>0.596</td>
<td>.440</td>
<td>0.388 1.849 8.813</td>
</tr>
<tr>
<td>(text only over image and narration)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Image and narration vs. Labeled image</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>0.797 (1.243)</td>
<td>0.412</td>
<td>.521</td>
<td></td>
</tr>
<tr>
<td>Cognitive ability</td>
<td>-0.135 (0.155)</td>
<td>0.758</td>
<td>.384</td>
<td>0.645 0.874 1.184</td>
</tr>
<tr>
<td>Spatial ability</td>
<td>-0.473 (0.196)</td>
<td>5.826</td>
<td>.016</td>
<td>0.425 0.633 0.915</td>
</tr>
<tr>
<td>Cognitive style</td>
<td>0.296 (0.159)</td>
<td>3.458</td>
<td>.063</td>
<td>0.984 1.344 1.836</td>
</tr>
<tr>
<td>Learning preference</td>
<td>-1.789 (0.796)</td>
<td>5.056</td>
<td>.025</td>
<td>0.035 0.167 0.795</td>
</tr>
<tr>
<td>Learning preference</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(labeled image over image and narration)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learning preference</td>
<td>-17.781 (2376.927)</td>
<td>&lt;0.001</td>
<td>.994</td>
<td>0.000 &lt;.001 Inf</td>
</tr>
<tr>
<td>(text only over image and narration)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Taking a closer look at the results for each of the predictors (Table 26), the cognitive style variable reached significance \((b = -0.388, \text{Wald } \chi^2(1) = 3.690, p = .055)\) for the preferential selection of the text only multimedia learning option. The odds ratio of 0.678, being less than 1, indicates that as cognitive style moved towards a visualizer preference and with all other coefficients held constant, the likelihood of selecting the text only learning option decreased. The spatial ability factor reached significance \((b = -0.473, \text{Wald } \chi^2(1) = 5.826, p = .016)\) for the selection of the image and narration learning option. The odds ratio of 0.63 indicates that, as spatial ability increased, the likelihood of selecting the image and narration learning option decreased, with all other coefficients held constant. The learning preference for labeled images also reached significance \((b = -1.789, \text{Wald } \chi^2(1) = 5.056, p = .025)\) for the selection of the image and narration learning option. The odds ratio of 0.167 indicates that as learning preference moves from image and narration to labeled image, the likelihood of preferentially selecting image and narration in the multimedia learning behavior test decreases, with all other coefficients held constant. Additionally, again following the suggestion of interpreting results for the Wald statistic with less stringent \(p\) values, cognitive style may be viewed as having reached significance \((b = 0.296, \text{Wald } \chi^2(1) = 3.458, p = .063)\) in predicting the selection of the image and narration learning option. The odds ratio of 1.344, being over 1, indicates that, as cognitive style moved towards a visualizer tendency and with all other coefficients held constant, the likelihood of selecting the image and narration learning option increased.

Finally, as in multimedia learning behavior test 1, the predictor for a learning preference of text only over labeled image, as related to the selection of the image and
narration learning option in the multimedia learning behavior test, had relatively extreme values (Table 26). Upon further inspection of all cases in the sample group analyzed, it was noted that no individual who indicated a learning preference for text only went on to select the image and narration learning option in the second multimedia learning behavior test. This may again be a likely explanation for the extreme value for this variable, as this scenario never occurred.

Summary

The aforementioned analyses with the data from the two, multimedia learning behavior tests were conducted to investigate the first research question: do learners’ visualizer or verbalizer tendencies influence their selections of online multimedia learning resources. The findings from these analyses provide convincing evidence to reject the main null hypothesis (H₀₁), suggesting that learners’ visualizer or verbalizer tendencies do have influence on their selections of online multimedia learning resources. Addressing each of the sub-hypotheses, no convincing evidence to reject the null hypothesis regarding the factor of cognitive ability as a predictor of the online multimedia learning material selection (H₀₁.₁) was found. This suggests that learners’ cognitive ability have no influence on their selections of online multimedia learning options. Convincing evidence to reject null hypotheses regarding the factors of spatial ability (H₀₁.₂), cognitive style (H₀₁.₃), and learning preference (H₀₁.₄) as predictors of the online multimedia learning material selection, however, were found. This then suggests that learners’ spatial ability, cognitive style, and learning preference have influence on the selection of online learning options.
Research Question 2: Gender as a Covariate

Additional analyses were conducted to investigate the second research question: does gender have a relationship with indicators of visualizer or verbalizer tendency and selection of visual or verbal learning resources. Two-sample t-tests were performed for cognitive ability, spatial ability, and cognitive style factors. Chi square tests for independence were conducted for learning preference and preferential selections.

**Gender and Cognitive Ability**

Prior to conducting the t-test, cognitive ability data from each group was inspected for the assumptions of independence, approximate normality, and homogeneity of variance. The two groups were assumed to be independent. To test the data for approximate normality, skewness, kurtosis, and Shapiro-Wilk test results were examined, as shown in Table 27.

Table 27

*Skewness, kurtosis, and Shapiro-Wilk values for cognitive ability*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>Shapiro-Wilk</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Females (N=57)</td>
<td>-0.701</td>
<td>0.069</td>
<td>0.911</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Males (N=27)</td>
<td>-0.391</td>
<td>-1.142</td>
<td>0.886</td>
<td>.006</td>
</tr>
</tbody>
</table>

Initial inspection of the female group showed a violation of the approximate normality assumption resulting in the removal of one outlier. Following this removal, skewness and kurtosis values fell within the threshold of |1.96| despite a significant Shapiro-Wilk value, thus approximate normality was assumed. Homogeneity of variances was assessed for cognitive ability between female and male participants. The Levene’s test results, $F=0.731(56,26)$, $p = .325$ showed the variance between groups to be
equivalent. A density plot shown in Figure 24 shows the distributions of female and male cognitive ability scores.

![Density plot showing distributions of female and male cognitive ability scores](image)

**Figure 24. Distribution of female versus male cognitive ability scores**

The results of the two sample t-test for cognitive ability were non-significant ($t(82)=-0.071, p = .944$) between the female group (M=7.747) and the male group (M=7.778). The power of this test was 0.564 with an effect size of .5 at $p < .05$, computed using the *pwr* package in R. These findings did not provide convincing evidence to reject the null hypothesis $H_{0.2.1}$, suggesting that gender has no relationship with cognitive ability.
Gender and Spatial Ability

Spatial ability data from each group was inspected for the assumptions of independence, approximate normality, and homogeneity of variance prior to the t-test. The two groups were assumed to be independent. To test the data for approximate normality, skewness, kurtosis, and Shapiro-Wilk test results were examined, as shown in Table 28.

Table 28

*Skewness, kurtosis, and Shapiro-Wilk values for spatial ability.*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>Shapiro-Wilk</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Females (N=58)</td>
<td>0.014</td>
<td>-0.548</td>
<td>0.989</td>
<td>.868</td>
</tr>
<tr>
<td>Males (N=27)</td>
<td>0.027</td>
<td>-0.763</td>
<td>0.959</td>
<td>.342</td>
</tr>
</tbody>
</table>

Skewness and kurtosis values fell within the threshold of |1.96| and Shapiro-Wilk values were non-significant, thus approximate normality was assumed. Homogeneity of variances was assessed for spatial ability between female and male participants. The Levene’s test results, F=0.815(57,26), p =.512 showed the variance between groups to be equivalent.

The results of the two sample t-test for spatial ability were non-significant (t(83)=1.409, p = .166) between the female group (M=-0.186) and the male group (M=0.399). The power of this test was computed as 0.564 with an effect size of .5 at p < .05. These findings did not provide convincing evidence to reject the null hypothesis H_{02.2}, suggesting that gender has no relationship with spatial ability.
Gender and Cognitive Style

Cognitive style data from each group was inspected for the assumptions of independence, approximate normality, and homogeneity of variance prior to the t-test. The two groups were assumed to be independent. To test the data for approximate normality, skewness, kurtosis, and Shapiro-Wilk test results were examined, as shown in Table 29.

Table 29
Skewness, kurtosis, and Shapiro-Wilk values for cognitive style.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>Shapiro-Wilk</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Females (N=58)</td>
<td>-0.147</td>
<td>-0.395</td>
<td>0.989</td>
<td>.880</td>
</tr>
<tr>
<td>Males (N=27)</td>
<td>0.351</td>
<td>-0.542</td>
<td>0.974</td>
<td>.703</td>
</tr>
</tbody>
</table>

Skewness and kurtosis values fell within the threshold of |1.96| and Shapiro-Wilk values were non-significant, thus approximate normality was assumed. Homogeneity of variances was assessed for cognitive style between female and male participants. The Levene’s test results, F=0.822(57,26), p = .528 showed the variance between groups to be equivalent.

The results of the two sample t-test for spatial ability were non-significant (t(83)=0.133, p = .895) between the female group (M=0.023) and the male group (M=-0.049). The power of this test was computed as 0.564 with an effect size of .5 at p < .05. These findings did not provide convincing evidence to reject the null hypothesis $H_{02.3}$, suggesting that gender has no relationship with cognitive style.
Gender and Learning Preference

As learning preference is a categorical variable, a chi-square test of independence was employed to investigate gender as a covariate. Table 30 shows the percentage of males and females who selected the three different learning preference choices.

Table 30

Percentages of learning preference choices

<table>
<thead>
<tr>
<th></th>
<th>Text only</th>
<th>Labeled image</th>
<th>Image and narration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Females</td>
<td>19</td>
<td>19</td>
<td>62</td>
</tr>
<tr>
<td>Males</td>
<td>15</td>
<td>30</td>
<td>55</td>
</tr>
</tbody>
</table>

This data meets the assumption of independence as each case can only contribute to a single cell; however, it fails to meet the assumption that each scenario should contain at least 5 expected cases, as only 4 males (15%) expressed a preference for the text only option. The decision was made to proceed with analysis however, understanding that the results may be biased due to this failed assumption. The chi-square test was conducted with a non-significant result ($\chi^2(2) = 1.248, p = 0.536$) thus it failed to reject the null hypothesis $H_{0.2.4}$. This suggests that gender has no relationship with learning preference.

Gender and online multimedia learning resources

Each of the multimedia learning behavior tests was similarly analyzed via chi-square tests of independence. Learning option percentages for both multimedia learning behavior test one and test two are shown in Table 31.
Table 31

*Percentage of learning option choices for multimedia learning behavior tests (MMLBT)*

*one and two*

<table>
<thead>
<tr>
<th>MMLBT-1</th>
<th></th>
<th></th>
<th>MMLBT-2</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Text only</td>
<td>Labeled</td>
<td>Image and narrative</td>
<td>Text only</td>
<td>Labeled</td>
</tr>
<tr>
<td>Females</td>
<td>21</td>
<td>34</td>
<td>45</td>
<td>16</td>
<td>53</td>
</tr>
<tr>
<td>Males</td>
<td>26</td>
<td>37</td>
<td>37</td>
<td>11</td>
<td>63</td>
</tr>
</tbody>
</table>

The data from both tests meet the assumption of independence as each case can only contribute to a single cell; however, test 2 fails to meet the assumption that each scenario should contain at least 5 expected cases, as only 3 males (11%) selected the text only option. The decision was made to proceed with analysis however, understanding that the results for test 2 may be biased due to this failed assumption. Neither chi-squared test for MMLBT-1 ($\chi^2(2) = 0.524, p = 0.769$) nor MMLBT-2 ($\chi^2(2) = 0.712, p = 0.700$) produced significant result, failing to reject the null hypothesis $H_{0.5}$. Based on the results, it is concluded that gender has no relationship with selections of online multimedia learning resources.

**Summary**

The above tests were conducted to investigate the second main research question: does gender have a relationship with indicators of visualizer or verbalizer tendency. The hypothesis for this question ($H_02$) has been supported as no convincing evidence was found to indicate that gender significantly influences a visualizer or verbalizer tendency. Addressing the sub-hypotheses, no significant gender differences were found to influence
cognitive ability (H_{0.1}), spatial ability (H_{0.2}), cognitive style (H_{0.3}), learning preference (H_{0.4}), or selections of online multimedia learning resources (H_{0.5}).

It is important to note the disproportionate number of female participants (68 percent) versus male participants (32 percent) in this study. The main rationale for investigating gender as a possible covariate was based on results from the pilot study where the genders were more equally represented (53 percent female versus 47 percent male). This disproportionate representation of gender in the main study may have influenced the results such that no significant differences were found based on gender. Conversely, the small sample size obtained for the pilot study (51 total participants) may have resulted in the observation of notable, gender-based trends and differences, which did not emerge with a larger sample group.
CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study was to reevaluate learner preferences, cognitive abilities, and cognitive styles relating to multimedia learning within the context of the 21st century classroom. How learners perceive technology-based instruction and how they respond to and interact with these materials are important components to the overall success of instructional program. This study evaluated learners’ visualizer or verbalizer tendencies, measured by learning preferences, cognitive ability, spatial ability, and cognitive styles, as related to preferential selections of online, multimedia-based learning materials. This study thus investigated which of the aforementioned factors successfully predicted preferential selections of online, multimedia-based learning materials.

Summary of Procedures

An online, multimedia learning survey based on Mayer and Massa’s (2003) study was adopted with the purpose of evaluating a population of university students. Data collection began in January 2015 and was completed in April 2015. Any active student at the target university, aged 18 or over was invited to participate, and participation in this study was voluntary.

The multimedia learning survey included a questionnaire measuring cognitive ability, two tests measuring spatial ability, three questionnaires measuring cognitive style, and one questionnaire measuring learning preference (predictor variables). The survey also contained two, multimedia learning behavior tests where participants were presented with two brief learning scenarios. In each scenario, participants were asked to select a learning option (text only, labeled image, and image and narration), which they felt
would be most helpful in understanding each of the concepts presented (criterion variable). Descriptive statistics were provided in the Results section (Chapter 4) and included means, frequencies, and percentages where applicable in order to provide a clear picture of the participants and data collected. Data analysis included two-sample t-tests, chi-square tests of independence, and multinomial logistic regressions. The data obtained from the multimedia learning survey was evaluated to determine if a learner’s visualizer or verbalizer tendency could successfully predict her/his selections of multimedia learning materials and, therefore, contribute to the research literature related to multimedia in online learning.

**Participant Demographics**

Study participants were both graduate and undergraduate students from a mid-sized, private university in a northeastern state of United States. The university houses 11 schools and colleges, all of which were represented by participants in this study. Participants were recruited via flyers posted in commonly frequented locations on campus, directing them to an online survey. Additional participation was solicited via electronic flyers posted to class Blackboard pages. Blackboard is the learning management system used by the target university. Participation was also solicited through direct, face-to-face classroom recruitment and flyer distribution by the researcher. A total of 119 individuals participated and, of these, 85 completed the survey and tests and were included in the final data analyses.

Of the 85 participants included in the study, 68% were female, 75% identified themselves as undergraduate students, and 79% ranged in age from 19 to 23. University enrollment data indicates that 57% of enrolled students are female and 60% are
undergraduates, thus both females and undergraduates are somewhat overrepresented in this study. Participants were also asked to provide information regarding their online class participation. A little more than half of the participants indicated that they had no previous online class experience. Of those who indicated previous online class experience, most had participated in less than 10 online courses. The majority of participants indicated that they were not currently, at the time of the survey, enrolled in an online course. Online courses at this university are primarily available for a limited number of graduate and adult learning programs, which provides a likely explanation for the generally limited online learning experience indicated by study participants.

**Summary of Findings**

The study investigated how individual learning preferences in terms of visualizer or verbalizer tendencies relate to learner interactions with online, multimedia-based learning materials. In an effort to respond to this overall question, individual cognitive ability, spatial ability, cognitive style, and learning preference were measured and used as gauges of visualizer or verbalizer tendency. Multinomial logistic regressions were conducted to determine which of these factors and thus, a visualizer or verbalizer tendency, successfully predict selections of text exclusive or visual inclusive learning options in two, multimedia learning behavior tests.

The second goal of this study was to investigate whether or not gender influences a visualizer or verbalizer tendency. To respond to this question, two-sample t-tests and chi-square tests of independence were utilized to determine if any differences based on gender were apparent in the four measures of visualizer-verbalizer tendency or in selections of multimedia learning options. The analysis results obtained from this data
are presented as follows for each of the two research questions and associated sub-questions.

**Question 1. Visualizer-verbalizer hypothesis**

Multinomial logistic regressions were used to analyze data and respond to the first research question. The four factors listed in the accompanying sub-questions as follows were used to determine visualizer or verbalizer tendencies and predict selections of online multimedia learning options in multimedia learning behavior tests. The overall findings provide support for the idea of visualizer or verbalizer tendencies and that these tendencies influence selections of multimedia learning options.

**Question 1a. Cognitive ability**

Results following multinomial logistic regressions did not provide convincing evidence that cognitive ability, as an indicator of visualizer or verbalizer tendency, successfully predicts selections of online multimedia learning options. As noted in the descriptive statistics section of chapter 4, a decision was made to exclude the SAT score variable from cognitive ability, leaving the vocabulary test variable as the only measure of this factor. It may therefore be more accurately stated that a vocabulary test is not a predictor of selections of online, multimedia learning options. The vocabulary test also had low reliability (.48) as measured by Cronbach’s alpha, in this study. Additional or alternative measures of cognitive ability, which measure a greater breadth of participant abilities and show stronger reliability, may thus yield different results. It is therefore advised to interpret these conclusions for cognitive ability with caution.
**Question 1b. Spatial ability**

For the factor of spatial ability, results from multinomial logistic regressions provided convincing evidence to suggest that spatial ability, as an indicator of visualizer or verbalizer tendency, successfully predicts selections of online multimedia learning options. As spatial ability increases, the likelihood of choosing labeled image learning option increases while the likelihood of choosing the image and narration learning option decreases.

**Question 1c. Cognitive style**

For the factor of cognitive style, results from multinomial logistic regressions provided convincing evidence to suggest that cognitive style, as an indicator of visualizer or verbalizer tendency, successfully predicts selection of online multimedia learning options. As cognitive style moves towards a visualizer tendency, the likelihood of selecting an image inclusive multimedia learning option (labeled image or image and narration) increases.

**Question 1d. Learning preference**

For the factor of learning preference, results from multinomial logistic regressions provided convincing evidence to suggest that learning preference, as an indicator of visualizer or verbalizer tendency, successfully predicts selections of online multimedia learning options. Individuals expressing a learning preference for labeled images are likely to maintain this preference through selections of labeled image multimedia learning options.

In further exploring the greater consistency in multimedia selections observed for the labeled image learning preference group, a strong correlation was also noted between
cognitive style and learning preference in behavior test one (.7025) but the same strong relationship did not hold true in behavior test 2 (.0158). A general shift was observed for each of the learning preference groups between behavior test 1 and behavior test 2 such that participants in both the text only and image with narration learning preference groups showed a shift towards choosing the corresponding multimedia learning option in behavior test 1 to choosing the labeled image multimedia learning option in behavior test 2. This may indicate that, through experience in this type of multimedia learning environment, participants come to favor labeled images as a perceived better way to enhance their own learning. It should also be noted, however, that the number of participants in each learning preference group was not proportional (text only group = 15, labeled image group = 19, image and narration group = 51) which may have influenced the results.

**Question 2. Gender as a covariate**

To respond to the second research question regarding the influence of gender on visualizer or verbalizer tendency as well as on selections of online multimedia learning options, two-sample t-tests were first conducted to investigate the influence of gender on cognitive ability, spatial ability, and cognitive style. Chi-square tests were then conducted to investigate the influence of gender on learning preference and on online multimedia learning option selection. No differences for gender were found for any of these factors or measures resulting in an overall lack of support for the influence of gender on visualizer or verbalizer tendency.

Study participants were disproportionately female (68 percent) which may have influenced these findings regarding gender as a covariate. The primary rationale for
investigating gender as a covariate arose from trends observed in the pilot study showing notable differences between female and male participant behaviors. The pilot study had a nearly equal proportion of females and males (53 percent versus 47 percent) but had an insufficient number of participants (a total of 51 participants) for meaningful inferential analyses. Taking all of this into consideration, the lack of significant results for gender as a covariate in this study should be viewed cautiously and future study with more equally proportioned gender groups may yield different results.

Findings Related to the Literature

Spatial Ability

The relationship of individual’s spatial ability to learning outcomes using technology-based multimedia has been the subject of continued examination (Höffler, 2010; Kalyuga, 2012; Kollöffel, 2012; Plass, Chun, Mayer, & Leutner, 2003). While study results have been mixed as to the precise nature of this relationship, some research has suggested a compensating effect, which indicates that learners with low-spatial ability might benefit from dynamic visualizations such as animations or audiovisual multimedia while learners with high spatial ability respond well to static images (Höffler, 2010; Höffler & Leutner, 2011; Kalyuga, 2012). These observations may lend additional support to the suggestion that the visualizers be further sub-divided into two, distinct categories. The first of these sub-categories consists of spatial visualizers who tend to view imagery as distinct parts to be mentally combined into a whole. These individuals respond best to spatial imagery such as diagrams or schematics. The second category is object visualizers who tend to mentally process images as a whole and thus best respond to imagery, which does not require mental dissection or manipulation (Kollöffel, 2012).
The results of this study lend support to overall finding that spatial ability influences response to or, in this case, selection of multimedia learning options. In this study, participants with high spatial ability tended to select labeled images for learning rather than images with narration. Participants with lower spatial ability who selected images with narration may therefore have exhibited the compensating effect and may perhaps be classified as object visualizers. While a majority of study participants showed a greater preference for the mixed format learning options, low spatial ability learners may potentially be most receptive to images with accompanying verbal explanations. This is discussed by the modality principle of multimedia learning which indicates that, in some circumstances, presenting narration rather than text may result in superior retention and learning outcomes (Low & Sweller, 2005; Moreno, 2006).

**Cognitive style**

Cognitive style is defined as an individual’s preferred way of processing information (Buehner-Brent, 1990; Evan, Cools, & Charlesworth, 2010) and provides an explanation of the mental processes used in information processing including problem-solving, thought, perception, imagery, and memory (Ausburn & Ausburn, 1978; Buehner-Brent, 1990). The findings from this study provide evidence that individuals indicating a visualizer tendency are more likely select multimedia learning options, which contain images rather than text alone. This lends further support to the idea that cognitive style tends to guide individuals’ preferential selection of learning options.

**Learning preference**

Learning preferences are defined as characteristic habits and behaviors possessed by individuals, affecting the way they carry out and respond to learning tasks. These
characteristics are not viewed as fixed but rather changeable over time or based on specific tasks (Evans, Cools, & Charlesworth, 2010; Klein, 2003). This study found that, in the learning scenario presented by the multimedia learning behavior tests, individuals tended to select multimedia learning options corresponding with their self-expressed learning preference. This study thus supports the concept that learner preferences guide learning behaviors.

**Visualizer-Verbalizer Hypothesis**

Overall, this study provides evidence to support the visualizer-verbalizer hypothesis indicating that some individuals prefer to learn visually while others prefer to learn verbally (Jonassen & Grabowski, 1993; Mayer & Massa, 2003). The visual multimedia learning options (the labeled image options and the image and narration options) presented in the multimedia learning behavior tests capitalized on the concept of an auditory and a visual channel in the working memory. More specifically, the labeled image relied upon visual processing resources, while the image and narration option offered an auditory explanation of an image while also reducing the overall visual content by removing text labels. The idea of the latter option was derived from the modality principle which indicated that, in some cases, learning may be improved by substituting written text explanations of an image with a narrated explanation. Most participants selected learning options containing an image and expressed visualizer tendencies both in measures of cognitive style and learning preference. The differences noted for high and low spatial ability participants, however, may lend further credence to the idea of distinct types of visualizers and how they develop schema (Kollöffel, 2012).
Application of Findings

The findings of this study may serve to shed light on factors influencing learners in seeking out online multimedia learning options in technology-supported learning environments. This may further guide instructors, instructional designers, and instructional material publishers in the creation of online or technology enhanced learning materials to suit not only the overall goals of learning but also the individual learners.

One of the main findings of this study shows that learners preferentially seek out mixed multimedia learning options. Instructors and instructional designers may thus be advised to provide or create image-inclusive learning materials. The multimedia learning options presented in this study sought to adhere to the general principles guiding multimedia learning design, such as the split attention principle, the modality principle, and the redundancy principle. It is therefore important to note that multimedia learning should be designed with careful consideration of these principles and their relationship to overall memory resources and thus meaningful, long-term learning outcomes.

The results of this study regarding spatial ability may have further implications regarding not only the preferential selection of multimedia learning options, but also regarding the concept of a visualizer tendency. Evidence in the literature suggests that the visualizer tendency may be further subdivided to spatial or object visualizers. Studies have further shown that individuals with high spatial ability are better able to regulate and focus attention, make inferences from limited materials, and may have greater overall working memory capacity (Kollöffel, 2012; Plass, Chun, Mayer, & Leutner, 2003). If such individuals possess adequate resources to process exclusively visual information
(e.g., labeled images), dual-mode presentations (e.g., images with narration) may have no impact on learning or possibly a negative impact.

Spatial ability may have further implications regarding the design of subject specific learning materials. For example, science, technology, engineering, and mathematics (STEM) fields tend to heavily rely upon materials drawing visual memory resources related to spatial ability such as diagrams and schematics (Kollöffel, 2012). Not surprisingly, these fields tend to be studied and professionally pursued by individuals with high, innate spatial ability (Wai, Lubinski, & Benbow, 2009). Innate ability, however, may not be the only factor influencing success in or pursuit of STEM programs of study. It has been suggested that completion of programs in STEM fields may be reliant upon personal interest rather than exclusively on achievement (Maltese & Tai, 2011). The creation of multimedia learning materials in alternative formats such as image and narration may therefore benefit and serve to include a more diverse range of learners, particularly those not inherently possessing high spatial ability and thus potentially impact overall interest and learning outcomes in STEM.

Finally, it may also be relevant to consider different types of multimedia and that there may be no one format which is best for each individual. During this study, only the labeled image learning preference group showed consistency between this learning preference and their corresponding selections of labeled image help options in the multimedia learning behavior tests. While this may be indicative of a characteristic of this group, it can also shed light on changeable behaviors of other individuals or the idea that different multimedia presentations lend themselves to different topics and learning scenarios. It is important to note that this study was conducted in an environment not
necessarily reflective of an authentic learning situation. Learners may thus prefer more than one multimedia option to assist their learning. Instructors and instructional designers and material developers may thus take this, as well as student characteristics, and the demands of the topic or content into account.

Overall, the results of this study show that learners will tend to gravitate towards multimedia as a mix of images and verbal/text based material. In the interest of creating more engaging and interactive learning environments, it may thus be wise to take advantage of this with the goal of not only learner engagement but also improved learning outcomes. Instructors and instructional material developers and publishers can further incorporate a variety of multimedia, designed to guide learners through instructional materials, which optimally take advantage of the principles and theories behind multimedia.

Online learning materials and resources are fairly ubiquitous at present, but may not fully or optimally take advantage of the media resources and affordances enabled by modern technology. E-books, for example, capitalize on the benefits of mobile technology and transportability (Lam, Lam, Lam, & McNaught, 2009) but do not always take advantage of transformative learning opportunities afforded by technology. Many educational e-books are simple a digital replication of paper books and do not include multimedia enhancements such as diagrams and brief instructional videos. Other instructional materials such as course or general educational websites and distinct learning modules may further benefit from the inclusion of varied multimedia learning options based on students characteristics and the demands of the subject matter to create dynamic and transformative learning opportunities. The inclusion of multimedia may
also have additional benefits outside of the classroom where an instructor is not available as a guide, such as asynchronous environments in higher education or flipped classrooms in K-12 learning. Richer, multimedia enhanced materials can provide more explicit information in varied formats which may not only appeal to student interest, but also improve understanding and learning outcomes in guided as well as independent learning contexts.

**Implications for Future Research**

This study focused on visualizer or verbalizer tendencies and how these tendencies predict selections of online multimedia learning options. This study did not, however account for actual learning outcomes. Some research has suggested that individuals may not in fact tend to self-select learning materials which result in improved learning outcomes and may profit from more directed learning (Klein, 2003; Kollöffel, 2012). Future study may therefore benefit from the inclusion of a learning outcome variable to further shed light on whether or not learner tendencies and choices positively impact knowledge acquisition.

**Limitations of the Study**

While this study did provide evidence that learners’ visualizer and verbalizer tendencies can predict selections of online multimedia learning options, there were some limitations. First, this study was limited to a single university student population. Although this group included both undergraduate and graduate level students engaged in varied courses of study, the majority of participants (91%) fell within the 19 to 28 age range. It is further plausible that, in addition to a limited age range, characteristics inherent to a limited group of university students such as greater or lesser experience with
or exposure to technology would bias the results in relation to the general population. Second, the learning preference factor consisted of a single, self-report item, which may present validity issues. The addition of further items to this factor may increase its validity. Third, a portion of the included participant group (20%) did not report their SAT scores. This was associated with students who likely could not recall their score, never took the SAT test in its current version or, in the case of participants who chose to end their participation at this point, chose not to respond. While inevitably some potential participants may be deterred by such questions due to self-image or other factors, more widely inclusive cognitive ability measures may benefit future study. Fourth, the chi-square tests of independence for the influence of gender on both the learning preference and online multimedia learning option selections (multimedia learning behavior test one) failed to meet necessary assumptions but were conducted nonetheless. It is acknowledged that the results of these tests may be biased as a result. Fifth, individuals who chose to discontinue participation at various points in the survey (27 participants in total) were removed via listwise deletion despite recommendations that such deletion be conducted only if the relative number of cases is small or if data is missing completely at random. As neither was the case, it is acknowledged that the listwise deletion of these cases may have produced biased parameters and estimates. Finally, many of the principles related to multimedia learning focused on in this study such as the multimedia principle and the modality principle are premised on learners being novices in the topic covered. Participants’ prior knowledge on the topics covered was not determined and thus differing levels of knowledge may have influenced the outcomes.
Delimitations of the Study

While this study may provide useful information regarding learner tendencies and interactions with online multimedia learning options, some delimitations were noted. First, participation in the study was disproportionately female (68%) which may limit the generalizability of the overall results. Second, due to 20 percent incomplete data for the SAT score variable, as discussed in the limitations section, the decision was made to exclude this variable for all participants in subsequent analysis. As a result, the cognitive ability factor might not be viewed as a truly complete measure of cognitive ability but as a measure of verbal ability; results should thus be viewed in this context.

Summary

The purpose of this study was to evaluate the concept of learners having a visualizer or verbalizer tendency and how this tendency might impact individuals’ selection of online multimedia learning options to aid in their overall understanding and learning. The findings suggest that spatial ability, cognitive style, and learning preference, as measures of visualizer or verbalizer tendency, do influence the selection of online multimedia learning options. It was further found in this study group that gender was not influential in any of the measures of visualizer-verbalizer tendency or in selections of online multimedia learning options.

The study findings present practical implications for a better understanding of learner behavior related to multimedia in online and technology-supported learning materials. In general, learners may gravitate more heavily towards mixed learning formats, which provide images along with labels or verbal explanations. This implies
that learners may be more engaged if mixed multimedia learning materials are provided and thus have greater opportunity to enhance their own learning and understanding.

The results of this study have been presented in context with the literature relating to multimedia learning, online and technology-supported learning materials, and individual learner characteristics. The findings support the literature indicating that individuals possess innate tendencies, which guide their learning behaviors. This study therefore provides a further extension of this line of study by expanding upon the influence of learner characteristics and how these may influence behaviors and be targeted by practitioners in the context of modern, technology-enhanced learning.
REFERENCES


doi:10.1080/03043799908923572


*Educational Psychology: An International Journal of Experimental Educational*


doi:10.5465/AME.2004.13837468


doi:10.1016/j.iheduc.2004.02.001


doi:10.3200/GNTP.166.4.467-482


doi:10.1080/00193089.1984.10533841


doi:10.1111/j.1468-2958.2010.01393.x


*Educational Psychologist, 32*, 1-19. doi:10.1207/s15326985ep3201_1


Learning and Instruction, 12(1), 107-119. doi:10.1016/S0959-4752(01)00018-4

Mayer, R. E., & Sims, V. K. (1994). For whom is a picture worth a thousand words?
Extensions of a dual-coding theory of multimedia learning. Journal of 
Educational Psychology, 86, 389-401. doi:10.1037//0022-0663.86.3.389

digital practice. Retrieved from 
https://oerknowledgecloud.org/sites/oerknowledgecloud.org/files/MOOC_Final_0 
.pdf


Anderson (Ed.), The Theory and Practice of Online Learning (2nd Ed., pp. 142-

creation of a sense of community. Educational Technology & Society, 7(3), 73-


APPENDIX A

INSTRUMENT

Demographic Questions

1. What is your gender?
   - Male
   - Female
2. Please select your year of birth.
   - (Choice of options)
3. Please select you class status
   - Undergraduate
   - Graduate
   - Other (Please specify in the comments section below)
4. What is your major area of study? (e.g. English, Computer Science, Unknown, etc.)
5. How many online courses have you previously taken? (e.g. 0 courses, 4 courses, 9 courses, etc.)
6. How many online courses are you currently taking? (e.g. 0 courses, 1 course, 3 courses, etc.)
7. Have you previously participated in a similar study?

Cognitive Ability Questions

1. What score did you receive on the SAT Math section? (200-800)
2. What score did you receive on the SAT Critical Reading section? (200-800)
3. What score did you receive on the SAT Writing section? (200-800)
4. Vocabulary Test

For the following section, select a word from the list of choices, which has the closest equivalent meaning to the underlined word. You will have 3 minutes to complete this section.

a. The wind is **variable** today.
   - mild
   - steady
   - shifting
   - chilling

b. **Enigma** most nearly means
   - mystery
   - blessing
   - burden
   - madness

c. She **coveted** the beautiful dress.
   - despised
   - abjured
   - desired
   - enshrouded

d. We swam in the **placid** waters.
   - choppy
   - tranquil
   - murky
   - pristine

e. **Noxious** fumes came from the sewer.
   - deleterious
   - wholesome
   - aromatic
   - billowing

f. He was **blatantly** rude.
   - gladly
   - unfortunately
   - secretly
   - obviously

g. That vase is **fragile**.
   - durable
   - brawny
   - delicate
   - gossamer
i. Success requires **tenacity**.
   - savvy
   - irresolution
   - persistence
   - conformity

j. A jury needs time to **deliberate**.
   - ponder
   - guess
   - observe
   - construct

k. Her **altruism** was admired.
   - wealth
   - magnanimity
   - intelligence
   - malevolence
Spatial Ability Questions

5. Paper Folding Test

In the following test you are to imagine the folding and unfolding of pieces of paper. In each problem in the test there are some figures drawn at the left of a vertical line and there are others draw at the right of the line. The figures at the left of the line represent a square of paper being folded, and the last of these figures has one or two small circles drawn on it to show where the paper has been punched. Each hole is punched through all the thicknesses of paper at that point. One of the five figures at the right of the vertical line shows where the hole(s) will be when the paper is completely unfolded. You are to decide which one of these figures is correct and select the letter choice below corresponding to that figure. In these problems all of the folds that are made are shown in the figure at the left of the line, and the paper is not turned or moved in any way except to make the folds shown in the figures. You will have 3 minutes to complete this test.
Figure A-1. Paper folding test
6. Card Rotation Test

In the following test you are to imagine a given shape as being representative of a flat, two-dimensional card. Each shape may be rotated but cannot be flipped. You will be shown 10 different shapes each of which will be followed by 8 identical shapes. Some of these shapes will have only been rotated, in which case you are asked to click on the shape(s) which you think are the same as the original and only the orientation has been changed. For shapes you think are different from the original and have been flipped, do not click the image. A green box and checkmark will appear around the images you have selected as the same. A brief example is shown below.

You will have 3 minutes to complete this test.
Figure A-2. Card rotation test
Cognitive Style Questions

7. Santa Barbara Learning Style Questionnaire

a. I prefer to learn visually.

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Moderately agree</th>
<th>Slightly agree</th>
<th>Slightly disagree</th>
<th>Moderately disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
</tbody>
</table>

b. I prefer to learn verbally.

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Moderately agree</th>
<th>Slightly agree</th>
<th>Slightly disagree</th>
<th>Moderately disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
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<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
</tbody>
</table>

c. I am a visual learner.

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Moderately agree</th>
<th>Slightly agree</th>
<th>Slightly disagree</th>
<th>Moderately disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
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<td>o</td>
<td>o</td>
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</tbody>
</table>

d. I am a verbal learner.

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Moderately agree</th>
<th>Slightly agree</th>
<th>Slightly disagree</th>
<th>Moderately disagree</th>
<th>Strongly disagree</th>
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</tbody>
</table>

e. I am good at learning from labeled pictures, illustrations, graphs, and animations.

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Moderately agree</th>
<th>Slightly agree</th>
<th>Slightly disagree</th>
<th>Moderately disagree</th>
<th>Strongly disagree</th>
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</tbody>
</table>

f. I am good at learning from printed text.

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Moderately agree</th>
<th>Slightly agree</th>
<th>Slightly disagree</th>
<th>Moderately disagree</th>
<th>Strongly disagree</th>
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</tbody>
</table>
8. Verbal-Visual Learning Style Rating

In a learning situation sometimes information is presented verbally (e.g., with printed or spoken words) and sometimes information is presented visually (e.g., with labeled illustrations, graphs, or narrated animations. Please select your learning preference.

<table>
<thead>
<tr>
<th>Strongly more verbal than visual</th>
<th>Moderately more verbal than visual</th>
<th>Slightly more verbal than visual</th>
<th>Slightly more visual than verbal</th>
<th>Moderately more visual than verbal</th>
<th>Strongly more visual than verbal</th>
</tr>
</thead>
<tbody>
<tr>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
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</tbody>
</table>
9. Learning Scenario Questionnaire

a. Which format do you prefer in learning a scientific description of an atom?
   - a paragraph describing each part
   - a labeled diagram showing each part

b. Which format do you prefer in learning a scientific description of how a bicycle tire pump works?
   - an essay describing what happens when you pull up on the handle and when you push down on the handle
   - a series of labeled diagrams showing the status of each part of the pump when you pull up on the handle and when you push down on the handle

c. Which format do you prefer for following directions for how to get somewhere on a new college campus?
   - verbal directions including when to turn left and when to turn right in getting from the starting point to the stopping point
   - a map showing the roads and buildings along with a line from the starting point to the stopping point

d. Which format do you prefer for following instructions on how to set time on a stopwatch?
   - a list of steps in words
   - a labeled diagram showing the steps

e. Which format do you prefer for describing the mathematical test scores for 6th grade boys and girls for the last 5 years?
   - a list of the scores for boys in one sentence and a list of the scores for girls in another sentence
   - a line graph with one line showing the scores for boys and another line showing the scores for girls

f. Which format do you prefer in learning how the different components of a microwave work?
   - a paragraph describing of each part
   - a labeled diagram showing each part

g. Which format would you prefer for learning how to create a monthly budget using an Excel spreadsheet?
   - a paragraph describing how to create a basic spreadsheet and how to input income and expenses
   - a series of labeled diagrams showing how to set up a basic spreadsheet and input income and expenses
h. If you were asked to provide directions to a familiar location familiar to me, which would you most likely do?
   o draw a map showing the route along with relevant landmarks
   o provide a written, step-by-step list of directions from the starting point to the end point

i. Which format do you prefer for following the steps necessary to assemble an office chair?
   o a step-by-step list of written instructions
   o a step-by-step series of diagrams

j. Which format do you prefer for describing the population changes for the 10 largest U.S. cities over the past 10 years?
   o a list of city population statistics for 10 years ago in one sentence followed by the current city population statistics in another sentence
   o a bar graph showing each city’s population from 10 years ago as one bar and the current population displayed as another bar next to it
Learning Preference

10. Multimedia Learning Preference Questionnaire

Please read this text:

Cool, moist air moves over a warmer surface and becomes heated. Warmed moist air near the earth’s surface rises rapidly. As the air in this updraft cools, **water vapor** condenses into **water droplets** and forms a cloud.

Suppose you need help understanding this text. You are given the choice to click on a link and select one of the following three options:

- (a) [Multimedia learning preference test options](#)
- (b) [Figure A-3](#)
- (c) [Multimedia learning preference test options](#)

Figure A-3. *Multimedia learning preference test options*, which include from top to bottom: (a) a text only option, (b) a labeled image option, and (c) an image and narration option.

Cool, moist air moves over a warmer surface and becomes heated. Warmed moist air or water vapor rises as updrafts, forming clouds.
a. Which help screen do you prefer most?
   o Screen 1 (text only)
   o Screen 2 (labeled image)
   o Screen 3 (image and narration)
Learning Behavior Tests

11. Multimedia Learning Behavior Test – Scenario 1 (MLBT-1)

Note: For this section, the only multimedia option that will appear to participants is the one they select.

a. Please read this text:

The cloud's top extends above the **freezing level**. At this altitude, the air temperature is well below freezing so the upper portion of the cloud is composed of tiny **ice crystals**.

Select one of the following Help Screen options:

- Text only
- Labeled image
- Image and narration

---

*ice crystals* MEANS moisture in the air that is in solid form such as in the part of a cloud above the freezing level

*freezing level* MEANS at some point above the surface of the earth there is an imaginary line in the sky so that above the line water in a cloud will freeze into ice crystals and below the line water in a cloud will stay as water droplets

---

Figure A-4, MLBT - Scenario 1, Question 1: (a) a text only option, (b) a labeled image option, and (c) an image and narration option
Please read this text:

Eventually, the water droplets and ice crystals become too large to be suspended by the **updrafts**. As raindrops and ice crystals fall through the cloud, they drag some of the air in clouds downward, producing **downdrafts**. When downdrafts strike the ground, they spread out in all directions, producing the gusts of cool wind people feel just before the start of the rain.

Select one of the following Help Screen options:
- Text only
- Labeled image
- Image and narration

![Diagram of updraft and downdrafts](image)

**Figure A-5. MLBT - Scenario 1, Question 2**: (a) a text only option, (b) a labeled image option, and (c) an image and narration option
b. Please read this text:

Within the cloud, the rising and falling air currents cause **electrical charges** to build. The charge results from the collision of the cloud's rising water droplets against heavier, falling pieces of ice. The **negatively-charged particles** fall to the bottom of the cloud and most of the **positively-charged particles** rise to the top.

Select one of the following Help Screen options:
- Text only
- Labeled image
- Image and narration

---

An electrical charge refers to when the negatively and positively charged particles in material have been separated. Negatively charged particles fall to the bottom. Positively charged particles rise to the top.

---

Figure A-6. *MLBT - Scenario 1, Question 3*: (a) a text only option, (b) a labeled image option, and (c) an image and narration option
c. Please read this text:

A **stepped leader of negative charge** moves downward in a series of zig-zag steps. It nears the ground. A **positively charged leader** travels upward from such objects as trees and buildings. The two leaders generally meet about 165 feet above the ground. Negatively-charged particles then rush from the cloud to the ground along the path created by the leaders. It is not very bright.

Select one of the following Help Screen options:
- Text only
- Labeled image
- Image and narration

![Diagram](image)

**Figure A-7. MLBT - Scenario 1, Question 4:** (a) a text only option, (b) a labeled image option, and (c) an image and narration option
d. Please read this text:

As the **leader stroke** nears the ground, it induces an opposite charge, so positively charged particles from the ground rush upward along the same path. This upward motion of current is the **return stroke**. It produces the bright light that people notice as a flash of lightening.

Select one of the following Help Screen options:
- Text only
- Labeled image
- Image and narration

---

"leader stroke" MEANS that negatively-charged particles travel all the way from the cloud to the ground.

"return stroke" MEANS that positively-charged particles travel all the way from the ground to the cloud.

---

Figure A-8. *MLBT - Scenario 1, Question 5*: (a) a text only option, (b) a labeled image option, and (c) an image and narration option.
12. Multimedia Learning Behavior Test – Scenario 2 (MLBT-2)

Please select the computer operating system you are most familiar with.

- PC
- Mac

*Note: As the steps in this learning module vary based on operation system, participants are asked to select the system with which they are most familiar and directed to the corresponding series in this module.*

a. Please read this text: (PC and Mac)

When working on a table, it is important to know the names of the different components. The **table selector** is the small box located at the upper-left corner of a table, used to select an entire table. A **cell** is a box which can contain text or an image. A **row** represents a horizontal selection of cells and a **column** represents a vertical selection of cells.

Select one of the following Help Screen options:

- Text only
- Labeled image
- Image and narration
“table selector” MEANS the small box with arrows located in the upper-left corner of a table which can be clicked to select the entire table.
“cell” MEANS an individual box which can contain text or an image.
“row” MEANS a horizontal selection in a table which can contain several cells.
“column” MEANS a vertical selection in a table which can contain several cells.

Figure A-9. MLBT - Scenario 2, Question 1 (PC version): (a) a text only option, (b) a labeled image option, and (c) an image and narration option.
“table selector” MEANS the small box with arrows located in the upper-left corner of a table which can be clicked to select the entire table.

“cell” MEANS an individual box which can contain text or an image.

“row” MEANS a horizontal selection in a table which can contain several cells.

“column” MEANS a vertical selection in a table which can contain several cells.

Figure A-10. *MLBT - Scenario 2, Question 1 (Mac version)*: (a) a text only option, (b) a labeled image option, and (c) an image and narration option.
b. Please read this text: (PC)

One useful formatting option is the merge cells option which can be found in the layout ribbon under table tools. Clicking anywhere within a table will cause the table tools to appear. Several cells can be selected or an entire row or column followed by clicking on merge cells which will create a single cell that still fits the rest of the table.

Please read this text: (Mac)

One useful formatting option is the merge cells option which can be found in the table layout ribbon which will appear to the right of the tables tab. Clicking anywhere within a table will cause the table layout to appear. Several cells can be selected or an entire row or column followed by clicking on merge cells which will create a single cell that still fits the rest of the table.

Select one of the following Help Screen options:

- Text only
- Labeled image
- Image and narration
“merge cells” MEANS the option in the layout ribbon of the table tools which causes several selected cells to be joined into one single cell.

“layout ribbon” MEANS a selection of tools usually appearing at the top of the window being used and grouped together for a specific purpose, in this case to control how a table is arranged.

“table tools” MEANS the set of tools located in the ribbons at the top of the Word screen which help users manipulate the appearance and content of a table.

Figure A-11. *MLBT - Scenario 2, Question 2 (PC version)*: (a) a text only option, (b) a labeled image option, and (c) an image and narration option.
“merge cells” MEANS the option in the layout ribbon of the table tools which causes several selected cells to be joined into one single cell.

“table layout ribbon” MEANS a selection of tools usually appearing at the top of the window being used and grouped together for a specific purpose, in this case to control how a table is arranged.

“tables tab” MEANS the set of tools located in the ribbons at the top of the Word screen which help users manipulate the appearance and content of a table.

Figure A-12. MLBT - Scenario 2, Question 2 (Mac version) : (a) a text only option, (b) a labeled image option, and (c) an image and narration option.
c. Please read this text: (PC)

The overall appearance of a table can be changed using the **table styles** selector which can be found on the **design ribbon** under table tools. Clicking on the small down arrow at the bottom-right corner of table styles will activate a drop down menu of the many style options available. A user can **mouse over** a selected style and see a preview of that new style in his/her table before making a final selection.

Please read this text: (Mac)

The overall appearance of a table can be changed using the **table styles** selector which can be found on the **table ribbon**. Clicking on the small triangle at the right side of the table styles will allow a user to scroll through the many style options available. A user can also select the triangle at the bottom center of the table styles to activate a **drop down menu** where several more styles than can be viewed with the scrolling option, can be seen simultaneously.

Select one of the following Help Screen options:

- Text only
- Labeled image
- Image and narration
“table styles” MEANS the tool which can be used to select a variety of preset styles to apply to a table
“design ribbon” MEANS a selection of tools usually appearing at the top of the window being used and grouped together for a specific purpose, in this case to control the appearance of a table
“mouse over” MEANS moving the computer mouse selector over a location but not clicking on that location

The table design ribbon can be used to make adjustment to the appearance of a table. Table styles menu shows several different styles that may be applied. The dropdown menu activated by clicking the bottom right corner allows many more styles to be seen at once. Mousing over a style will allow a user to preview a style, shown in the yellow box, without actually making a change from the original style

Figure A-13. *MLBT - Scenario 2, Question 3 (PC version)*: (a) a text only option, (b) a labeled image option, and (c) an image and narration option
“table styles” MEANS the tool which can be used to select a variety of preset styles to apply to a table

“tables ribbon” MEANS a selection of tools usually appearing at the top of the window being used and grouped together for a specific purpose, in this case to control the appearance of a table

“drop down menu” MEANS a menu of choices which appears below a location clicked by a user

Figure A-14. *MLBT - Scenario 2, Question 3 (Mac version)* : (a) a text only option, (b) a labeled image option, and (c) an image and narration option
d. Please read this text: (PC)

Users can also create a customized style for a table. One way to accomplish this is by right-clicking on the table selector and choosing the “Borders and shading” option from the dropdown menu which will appear. This will result in a borders and shading pop-up window. Here, several different borders may be selected or deselected. The borders that are selected to appear will be highlighted in blue and clicking on a border choice will select or deselect it.

Please read this text: (Mac)

Users can also create a customized style for a table. One way to accomplish this is by right-clicking on the table selector and choosing the “Borders and shading” option from the dropdown menu which will appear. This will result in a borders and shading pop-up window. Here, several different borders may be selected or deselected. The borders which are selected to appear will be highlighted and clicking on a border choice will select or deselect it.

Select one of the following Help Screen options:
- Text only
- Labeled image
- Image and narration
“borders” MEANS the lines which appear vertically and horizontally in and around a table. While they may be selected to appear invisible, they still exist to define the rows, columns, and cells of a table.

Right clicking on the table selector will cause a menu to appear. From this menu, borders and shading can be selected. This will bring up an additional window where the borders currently shown in the table can be seen, highlighted in blue.

Figure A-15. MLBT - Scenario 2, Question 4 (PC version) : (a) a text only option, (b) a labeled image option, and (c) an image and narration option
“borders” MEANS the lines which appear vertically and horizontally in and around a table. While they may be selected to appear invisible, they still exist to define the rows, columns, and cells of a table.

Figure A-16. MLBT - Scenario 2, Question 4 (Mac version): (a) a text only option, (b) a labeled image option, and (c) an image and narration option
e. Please read this text: (PC)

**Shading** options may be selected under the shading tab. Here, a color can be selected using the dropdown menu under fill and can be applied to the entire table or to selected columns, rows, or individual cells. Colors can be previewed in the shading window before making a final choice.

Please read this text: (Mac)

**Shading** options may be selected under the shading tab. Here, a color can be applied to the entire table or to selected columns, rows, or individual cells. Colors can be previewed in the shading window before making a final choice.

Select one of the following Help Screen options:
- Text only
- Labeled image
- Image and narration
“shading” MEANS a range of colors which may be applied to all or selected parts (i.e. a cell, column, or row) of a table.

By clicking on the shading tab, colors can be selected under the fill dropdown menu. A color can be applied to all or part of your table. Color selections will be shown in the preview area.

Figure A-17. MLBT - Scenario 2, Question 5 (PC version) : (a) a text only option, (b) a labeled image option, and (c) an image and narration option
“shading” MEANS a range of colors which may be applied to all or selected parts (i.e. a cell, column, or row) of a table.

(a)

By clicking on the shading tab, colors can be selected and applied to all or part of your table. Color selections will be shown in the preview area.

(b)

(c)

Figure A-18. MLBT - Scenario 2, Question 5 (Mac version) : (a) a text only option, (b) a labeled image option, and (c) an image and narration option
APPENDIX B
PILOT STUDY INSTRUMENT

Demographic Questions

1. What is your gender?
   - Male
   - Female
2. How many online courses have you previously taken? (e.g. 0 courses, 4 courses, 9 courses, etc.)
3. How many online courses are you currently taking? (e.g. 0 courses, 1 course, 3 courses, etc.)

Cognitive Ability Questions

1. What score did you receive on the SAT Math section? (200-800)
2. What score did you receive on the SAT Critical Reading section? (200-800)
3. What score did you receive on the SAT Writing section? (200-800)
4. Vocabulary Test

For the following section, select a word from the list of choices, which has the closest equivalent meaning to the underlined word. You will have 3 minutes to complete this section.

a. The wind is variable today.
   - mild
   - steady
   - shifting
   - chilling

b. Enigma most nearly means
   - mystery
   - blessing
   - burden
   - madness

c. She coveted the beautiful dress.
   - despised
   - abjured
   - desired
   - enshrouded

d. We swam in the placid waters.
   - choppy
   - tranquil
   - murky
   - pristine

e. Noxious fumes came from the sewer.
   - deleterious
   - wholesome
   - aromatic
   - billowing

f. He was blatantly rude.
   - gladly
   - unfortunately
   - secretly
   - obviously

g. That vase is fragile.
   - durable
   - brawny
   - delicate
   - gossamer
i. Success requires **tenacity**.
   - savvy
   - irresolution
   - persistence
   - conformity

j. A jury needs time to **deliberate**.
   - ponder
   - guess
   - observe
   - construct

k. Her **altruism** was admired.
   - wealth
   - magnanimity
   - intelligence
   - malevolence
Spatial Ability Questions

5. Paper Folding Test

In the following test you are to imagine the folding and unfolding of pieces of paper. In each problem in the test there are some figures drawn at the left of a vertical line and there are others draw at the right of the line. The figures at the left of the line represent a square of paper being folded, and the last of these figures has one or two small circles drawn on it to show where the paper has been punched. Each hole is punched through all the thicknesses of paper at that point. One of the five figures at the right of the vertical line shows where the hole(s) will be when the paper is completely unfolded. You are to decide which one of these figures is correct and select the letter choice below corresponding to that figure. In these problems all of the folds that are made are shown in the figure at the left of the line, and the paper is not turned or moved in any way except to make the folds shown in the figures. You will have 3 minutes to complete this test.
Figure B-1. Paper folding test
6. Verbal-Spatial Ability Rating

a. Please rate your verbal ability (check one):

<table>
<thead>
<tr>
<th>Very high</th>
<th>Somewhat high</th>
<th>Average</th>
<th>Somewhat low</th>
<th>Very low</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b. Please rate your spatial ability (check one):

<table>
<thead>
<tr>
<th>Very high</th>
<th>Somewhat high</th>
<th>Average</th>
<th>Somewhat low</th>
<th>Very low</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Cognitive Style Questions

7. Santa Barbara Learning Style Questionnaire

a. I prefer to learn visually.

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Moderately agree</th>
<th>Slightly agree</th>
<th>Slightly disagree</th>
<th>Moderately disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b. I prefer to learn verbally.

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Moderately agree</th>
<th>Slightly agree</th>
<th>Slightly disagree</th>
<th>Moderately disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

c. I am a visual learner.

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Moderately agree</th>
<th>Slightly agree</th>
<th>Slightly disagree</th>
<th>Moderately disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

d. I am a verbal learner.

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Moderately agree</th>
<th>Slightly agree</th>
<th>Slightly disagree</th>
<th>Moderately disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
e. I am good at learning from labeled pictures, illustrations, graphs, and animations.

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Moderately agree</th>
<th>Slightly agree</th>
<th>Slightly disagree</th>
<th>Moderately disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>

f. I am good at learning from printed text.

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Moderately agree</th>
<th>Slightly agree</th>
<th>Slightly disagree</th>
<th>Moderately disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>

8. Verbal-Visual Learning Style Rating

In a learning situation sometimes information is presented verbally (e.g., with printed or spoken words) and sometimes information is presented visually (e.g., with labeled illustrations, graphs, or narrated animations. Please select your learning preference.

<table>
<thead>
<tr>
<th>Strongly more verbal than visual</th>
<th>Moderately more verbal than visual</th>
<th>Slightly more verbal than visual</th>
<th>Slightly more visual than verbal</th>
<th>Moderately more visual than verbal</th>
<th>Strongly more visual than verbal</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>
9. Learning Scenario Questionnaire

a. Which format do you prefer in learning a scientific description of an atom?
   o a paragraph describing each part
   o a labeled diagram showing each part

b. Which format do you prefer in learning a scientific description of how a bicycle tire pump works?
   o an essay describing what happens when you pull up on the handle and when you push down on the handle
   o a series of labeled diagrams showing the status of each part of the pump when you pull up on the handle and when you push down on the handle

c. Which format do you prefer for following directions for how to get somewhere on a new college campus?
   o verbal directions including when to turn left and when to turn right in getting from the starting point to the stopping point
   o a map showing the roads and buildings along with a line from the starting point to the stopping point

d. Which format do you prefer for following instructions on how to set time on a stopwatch?
   o a list of steps in words
   o a labeled diagram showing the steps

e. Which format do you prefer for describing the mathematical test scores for 6th grade boys and girls for the last 5 years?
   o a list of the scores for boys in one sentence and a list of the scores for girls in another sentence
   o a line graph with one line showing the scores for boys and another line showing the scores for girls
Learning Preference

10. Multimedia Learning Preference Questionnaire

Please read this text:

Cool, moist air moves over a warmer surface and becomes heated. Warmed moist air near the earth's surface rises rapidly. As the air in this updraft cools, water vapor condenses into water droplets and forms a cloud.

Suppose you need help understanding this text. You are given the choice to click on a link and select one of the following three options:
Cool, moist air moves over a warmer surface and becomes heated. Warmed moist air or water vapor rises as updrafts, forming clouds. Below the freezing level indicated by the dashed line, water exists as water droplets. Above the freezing level, water exists as ice crystals.

Figure B-2. Multimedia learning preference test options, which include from top to bottom: (a) a text only option, (b) a labeled image option, and (c) an image and narration option.
a. Which help screen do you prefer most?
   - Screen 1 (text only)
   - Screen 2 (labeled image)
   - Screen 3 (image and narration)

b. Which help screen do you prefer least?
   - Screen 1 (text only)
   - Screen 2 (labeled image)
   - Screen 3 (image and narration)
Learning Behavior Test

11. Multimedia Learning Behavior Test

*Note: For this section, the only multimedia option that will appear to participants is the one they select.*

a. Please read this text:

Eventually, the water droplets and ice crystals become too large to be suspended by the updrafts. As raindrops and ice crystals fall through the cloud, they drag some of the air in clouds downward, producing downdrafts. When downdrafts strike the ground, they spread out in all directions, producing the gusts of cool wind people feel just before the start of the rain.

Select one of the following Help Screen options:
- Text only
- Labeled image
- Image and narration
An updraft is a body of air moving upward because it is warmer than the surrounding air. Downdrafts are bodies of cooler air dragged down by raindrops and ice crystals. These produce wind gusts when they reach the ground.
b. Please read this text:

Within the cloud, the rising and falling air currents cause electrical charges to build. The charge results from the collision of the cloud's rising water droplets against heavier, falling pieces of ice. The negatively-charged particles fall to the bottom of the cloud and most of the positively-charged particles rise to the top.

Select one of the following Help Screen options:
- Text only
- Labeled image
- Image and narration
An electrical charge refers to when the negatively and positively charged particles in material have been separated. Negatively charged particles fall to the bottom. Positively charged particles rise to the top.

Figure B-4. Question 2: (a) a text only option, (b) a labeled image option, and (c) an image and narration option
A stepped leader of negative charge moves downward in a series of zig-zag steps. It nears the ground. A positively charged leader travels upward from such objects as trees and buildings. The two leaders generally meet about 165 feet above the ground. Negatively-charged particles then rush from the cloud to the ground along the path created by the leaders. It is not very bright.

Select one of the following Help Screen options:
- Text only
- Labeled image
- Image and narration

Figure B-5. Question 3: (a) a text only option, (b) a labeled image option, and (c) an image and narration option.
As the leader stroke nears the ground, it induces an opposite charge, so positively charged particles from the ground rush upward along the same path. This upward motion of current is the return stroke. It produces the bright light that people notice as a flash of lightening.

Select one of the following Help Screen options:
- Text only
- Labeled image
- Image and narration

Figure B-6. Question 4: (a) a text only option, (b) a labeled image option, and (c) an image and narration option

Negatively charged particles travel all the way from the cloud to the ground on the leader stroke. Positively charged particles move upward on the same path from the ground to the cloud on the return stroke.