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Physical Ergonomic And Mental Workload Factors Of Mobile Learning Affecting Performance Of Adult Distance Learners: Student Pers

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PHYSICAL ERGONOMIC AND MENTAL WORKLOAD FACTORS OF MOBILE LEARNING AFFECTING PERFORMANCE OF ADULT DISTANCE LEARNERS: STUDENT PERSPECTIVE

by
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ABSTRACT

Distance education is the fastest growing educational modality because of advances information technology has made over the past 25 years. Adult learners have become the fastest growing population in distance education. Adult learners, through technical tools and devices they use on the job, have become more digitally literate and mobile, making the ability to access class work on the go a necessity. Mobile learning or m-learning (learning that uses wireless, portable, mobile computing, and communication devices) is becoming an extension of distance learning, providing a channel for students to learn, communicate, and access educational material outside the traditional classroom environment. For adult learners, this modality allows them to take advantage of accessing material using mobile devices they use for job related activities. Despite the portability and readiness to information mobile devices provide its users, cognitive and physical ergonomic issues may impact learner performance. These issues may stem from information overload and physical discomfort from extended use of the mobile device which may negatively affect the overall success and satisfaction of m-learning environments.

The purpose of this study was to examine the relationship between physical ergonomic discomfort, subjective workload, physiological response, and the impact on student performance while using mobile technology to read course material. Activity Theory was used as the theoretical foundation that guided the study.

Eighty-four research participants, all over the age of 25, read a passage using one of two distance education modalities: desktop computer or mobile device. While reading the passage, one of three task load levels was imposed on participants: none, low or high. Each participant

endured three trials, repeating the same task for each trial. After each trial, participants completed an achievement test and the NASA-TLX assessment.

The results from this study provided evidence that mobile learning technologies with increased levels of task load introduced physical ergonomic discomfort and affected perceptions of mental workload in participants. The study also provided evidence that mobile learning technologies with increased levels of task load affected the performance (reading and learning) of participants. Study results provided insight into capabilities and limitations of students in their use of mobile devices for educational purposes. The limitations identified need to be further examined to aid in building successful m-learning environments with the goal of mobile device usage not affecting student performance.

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CHAPTER ONE: INTRODUCTION

According to a survey conducted by the Sloan Consortium of institutions and organizations committed to quality online education, more than 3.9 million students took at least one online course during the fall semester of 2007; a 12 percent increase over the number reported the previous year (Sloan Consortium, 2008). Distance education has become the fastest growing educational modality because of advances information technology has made over the past 25 years. This forward movement has helped propel distance education to become a learning option working adult students choose to pursue higher education. The number of students who received part or all of their education at a distance was estimated to be more than six million (Saba, 2005). According to the United States Department of Education Institute of Education Sciences, in the 2006-2007 academic year, there was an estimated 11,200 college-level programs designed to be completed totally through distance education. The statistics demonstrate how important providing education to students at a distance has become to colleges and universities.

Distance education is appealing to adult learners because institutions understand the vigorous work schedules of full-time employed students and have made classes that are usually taught in an on-campus classroom environment, available to students by way of modern day technology. Adult learners have become the fastest growing population in higher education. The rise in adult professionals' enrollment in distance education courses can be attributed to two things: new developments in technology and changes in the job market and economy. Advances in technology (such as computer-technology, high-speed network connections, and mobile technology) and an increase in Internet usage have helped foster the rise, as well as distance education programs providing an avenue for employees to stay abreast of industry trends and standards on their own time, thus keeping companies competitive in the market. For example, Marriott International Inc., one of the world's leading hospitality companies, used a blended approach to train its employees. The company featured live training classes, computer-based training, and online "nuggets" of knowledge. As a result of this change to electronic learning (e-learning), the company saved 30% on training costs for its business systems, and more than 50% for its desktop training (Fortune 500, 2001). According to Moore and Anderson (2003) the FBI's National Security Division saw a cost savings of $2 million after it replaced a training course with a distance-learning course.

Adult students, through technical tools and devices they use on the job, have become more digitally literate and mobile, making the ability to access class work on the go a necessity. Mobile learning (m-learning) is learning that uses wireless, portable, mobile computing and communication devices (namely smart phones, pocket personal computers (PCs), tablet PCs, Personal Digital Assistants (PDAs), mobile phones and iPods) to deliver content and learning support (Brown, 2005). Advances in mobile communication technologies including Wi-Fi networks, Third Generation (3G), and Worldwide Interoperability for Microwave Access (WiMAX) have enabled students to have access to class material without being subjected to a physical classroom or in front of a computer at a set point in time. Although the functionality and capabilities of mobile devices differ from each other, the devices give students a number of options to communicate with professors and fellow classmates.

As many students already own mobile devices, understanding how they can be integrated with learning is advantageous. Acknowledging its growth, researchers have looked at m-learning usability issues and pedagogy concerns. Usability refers to the ease with which a system or product can be used by its intended audience to achieve defined goals. It encompasses many elements relating to m-learning including instructional design, mobile device functionality, m-learning environment structure, and information architecture. Creators of mobile computing tools are meeting users' demand for convenient and portable devices by making them smaller and less bulky. Although these accessible devices make information readily available and attainable despite location, this may introduce ergonomic concerns. Such concerns may stem from physical attributes of the mobile device (such as using palm-size devices to receive and send course material) that may cause eye fatigue and physical discomfort, or mental overload and frustration from completing tasks not suitable for the mobile device.

Problem Statement

The shift in the student profile of distance education learners, the advancements in technology, and eminent incorporation of mobile technology into distance education programs make m-learning a learning modality that can provide students a means of engaging with course information at their leisure. Unfortunately, the impact physical and cognitive ergonomic factors have on the performance of distance education learners while using mobile learning technologies has yet to be adequately explored and investigated. The study's goal was to examine the ergonomic factors that impact students' performance and provide insight into student capabilities and limitations in their use of mobile devices for educational purposes.

Purpose of the Study

The purpose of this research was to examine the physical and cognitive difficulties distance education students experienced while using m-learning technology to access course material that affected their performance. Physical properties of the mobile device that introduced ergonomic difficulties were explored. The research objectives were:

1. To study the impact distance education modality and task load had on mobile learning
2. Study the relationship between physical ergonomic discomfort, subjective workload, physiological response, and the impact on student performance

The research was taken from the adult, working professional student point of view. Limitations identified by the study will contribute to the body of knowledge concerning implementing mobile devices in existing learning environments without hindering students' performance.

Rationale

Kukulska-Hulme (2002) conducted a study with distance learners using personal digital assistants (PDAs) to read class material. The study focused on the "benefits and constraints introduced by PDAs and examined how the tool impacted students' reading strategies." General usability issues and characteristics of how mobile technology supported reading were addressed. Ergonomic issues that were identified included:

1. Difficulties reading the text on the screen
2. Difficulties scanning the text when the font was enlarged
3. Difficulties with data entry
4. Eye ache and visual disturbance when looking at the screen

The study suggested three main issues that needed to be considered regarding the use of PDAs as a tool for reading course material:

1. Usability of the hardware (make/model of device)
2. Usability of the software
3. Usability of the text (in proportion to the size of the screen)

The research presented here is an extension of the study performed by Kukulska-Hulme. The research focused on physical and cognitive ergonomic issues of mobile devices in an m-learning environment. Although Kukulska-Hulme (2002) identified cognitive issues when using PDAs as a reading tool, the issues identified pertained to acquiring skills needed to navigate and use the PDA to obtain and read course material. The study did not address such cognitive issues as memory storage, attention or task load (the focus of this research). The significance of extending Kukulska-Hulme's (2002) research was to examine physical and cognitive ergonomic issues preventing subjects from maximizing the use of mobile devices in m-learning environments. The research addressed how much physical and cognitive load students can withstand without affecting performance capability. Extending the study also focused not just on usability, but the relationship between the user, mobile device, and educational task, and their affect on student performance.

Research Question

The rationale, previous research, and research objectives lead to two research questions:

1. Does using mobile learning technologies with increased levels of task load introduce physical ergonomic discomfort, and affect physiological levels and perceptions of mental workload in distance education students?
2. Do using mobile learning technologies with increased levels of task load affect the performance of distance education students?

Five hypotheses were tested to provide the necessary evidence to answer the research questions:

1. Null Hypothesis 1
   H_0: Increased levels of task load and the type of distance education modality engaged do not affect perceived mental workload

2. Null Hypothesis 2
   H_0: Increased levels of task load and the type of distance education modality engaged do not affect physiological response (heart rate)

3. Null Hypothesis 3
   H_0: Increased levels of task load and the type of distance education modality engaged do not increase physical discomfort

4. Null Hypothesis 4
   H_0: Increased levels of task load and the type of distance education modality engaged do not affect reading performance

5. Null Hypothesis 5
   H_0: Increased levels of task load and the type of distance education modality engaged do not affect learning performance

Theoretical Foundation

The purpose of a theoretical foundation is to guide research and define the theory used to identify variables measured in a study. The following section provides a brief overview of learning theories, Activity Theory and how it was used for this research, the conceptual framework identifying variables that were tested and how they were related, and empirical studies that have used Activity Theory to evaluate learning environments. It was the researcher's goal to leverage Activity Theory to examine the ergonomic issues students experienced while using mobile technology to access course material.

Learning theories are ideas that describe how people learn. Popular learning theories which can be applied in mobile learning environments include behaviorist, socio-cultural (collaborative), constructivist, situated, and informal and lifelong learning. Some research studies and projects have examined mobile learning from an identified theoretical perspective and Table 1 summarizes those works.

Table 1- Learning Theories (Source: Herrington & Herrington, 2007)

Theory	Example project/Research study
Behaviorist theory *Activities that promote learning as a change in observable actions*	Mobile phones and PDAs for language learning (Thornton & Houser, 2004) Classroom response systems for providing feedback on multiple choice questions (Wood, 2004)
Constructivist theory *Activities in which learners actively construct new ideas or concepts based on previous and current knowledge*	The virus game (use of PDAs to simulate the spread of a virus) (Colella, 2000) Environmental detectives (students investigate an environmental problem using GPS in pocket PC) (Klopfer & Squire, in pres) Issues related to educational media explored through videos, documentaries, animations of educational concepts and news bulletins with mobile phones (Chesterman, nd)
Situated learning theory *Activities that promote learning within an authentic context and culture*	Ambient wood (use of PDAs to explore environmental habitats) (Rogers et al., 2002) Multimedia tools at the Tate Modern (use of pocket PCs to view videos and listen to expert commentary) (Proctor & Burton, 2003) Role-playing to investigate social interactions among family and friends (mobile phone) (Owen, 2005)
Collaborative learning theory *Activities that promote learning through social interaction*	Mobile computer-supported collaborative learning (dissemination of activities, collaboration, and analysis of results using handheld computers) (Cortez, et al., 2004) Teacher trainers use PDAs to beam questions for a virtual treasure hunt to groups of teachers (Palm Inc., 2005)

Socio-cultural theories of learning (also known as collaborative learning in the literature and Figure 1) entail learning that takes place in a social context and activities promoting learning through social interaction. Learning occurs through interaction between learners and learning tasks. Communication can be between professors, administrators, tutors and other students. This theory has progressed from research on computer-supported collaborative work and learning (CSCW/L) to m-learning (mobile CSCM/L), focusing on the use of mobile technologies to promote, facilitate, and enhance interactions. Under the socio-cultural learning theory, mobile devices provide opportunities for users to obtain information and collaborate with others using e-mail, text, audio and video messages, web access, and pictures. A theoretical framework closely associated with socio-cultural theory of learning is Activity Theory. Based on the work of Vygotsky (1978) and Leont’ev (1978), the theory attempted to conceptualize learning from a socio-cultural perspective. Vygotsky based Activity Theory on subjects shaping their knowledge by interacting with artifacts or tools and others in a social environment (Yamagata-Lynch, 2003).

Figure 1 shows the basic Activity Theory model which focuses on learning using three features: a subject (learner), an object (task or activity) and tool. An activity is taken on by a subject using tools to achieve an object to produce an outcome.

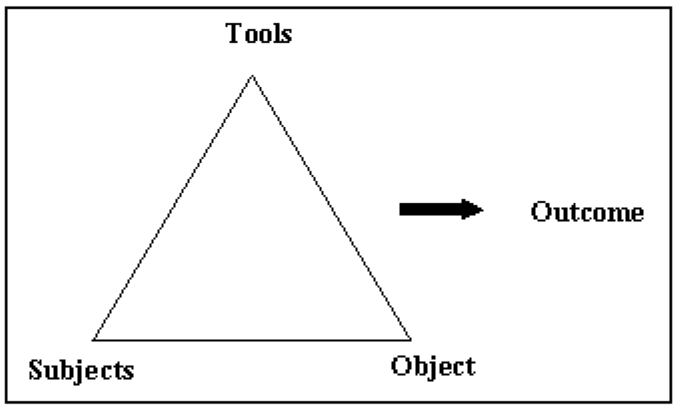

Figure 1-Basic Activity Theory (Source: Vygotsky, 1978)

Activity theory has been used to analyze human-computer interaction, interface design, education technology and teaching methods, and provides a framework to understand the learning experience of students using technology.

Engeström (1987) developed the activity system illustrated in Figure 2 to address the activity's environment by expanding on the basic model pictured in Figure 1 to include three more features: rules, community, and division of labor. Below is an example description of the elements of the expanded activity system as it applies to a mobile learning environment:

1. Tool (mediating artifact) – mobile device
2. Subject – student
3. Rules – rules governing class enrollment (admittance to university, course prerequisites, seat availability)
4. Community – students, professors, tutors, administrators
5. Division of Labor – division between students and professors
6. Object (activity) – access class material
7. Outcome – complete assignment/comprehend material

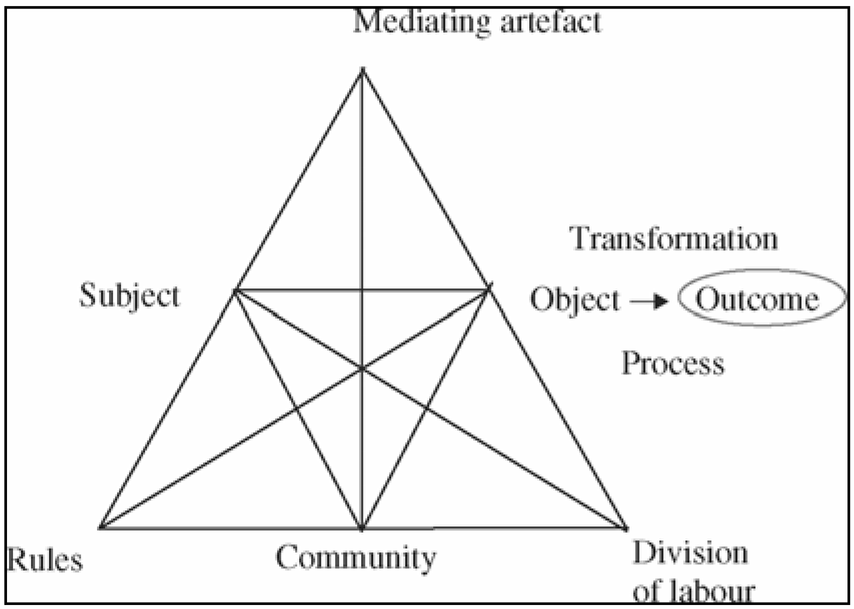

Figure 2-Activity System (Source: Engeström, 1987)

To study the relationships between elements in an activity system for the design of mobile learning environments, contradictions, which are problems, breakdowns or clashes, should be analyzed. There are four levels of contradictions that can be analyzed in an activity system:

1. Primary contradiction – found within a single node of an activity
2. Secondary contradiction – occur between constituent nodes
3. Tertiary contradiction – occur between an existing activity and a more advanced form of that activity
4. Quaternary contradiction – between the central activity and the neighboring activity

Figure 3 illustrates several potential types of contradictions that can occur in an activity system.

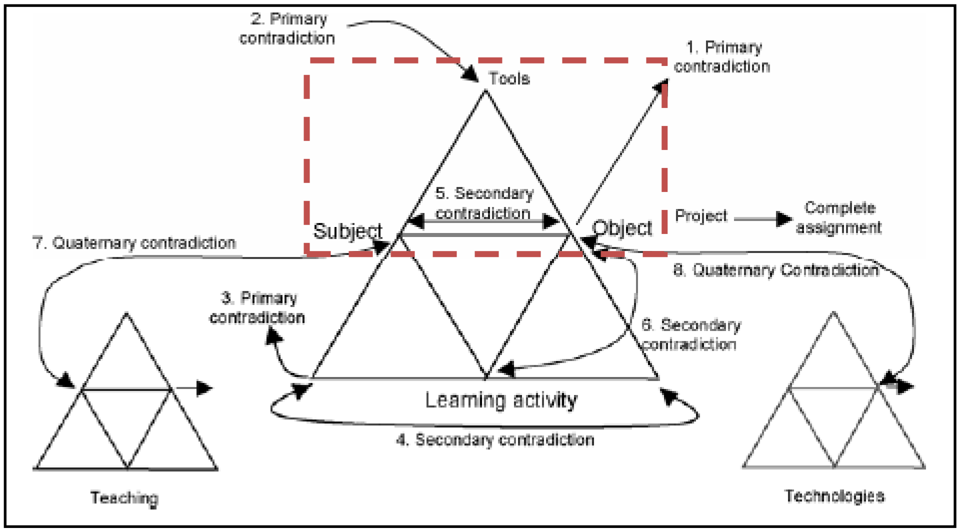

Figure 3-Potential Activity System Contradictions (Source: Engeström, 1987)

Since a mobile learning theory does not exist, for this study, the secondary contradiction (identified by the dashed box in Figure 3) was used to examine the impact distance education modality and ergonomic factors had on the performance of learners. Focusing on the impact distance education modality and ergonomic factors had on students allowed the researcher to use the secondary contradiction to examine the relationships between the activity system elements subject, tool, and object.

Contradictions can be used to identify problems in a learning environment or viewed as sources of development. They can be used to understand how incorporating a new learning technology that changes students' method or way of doing things can create problems and affect performance. Issroff and Scanlon (2002) provided two examples of using Activity Theory to examine learning technologies incorporated into learning settings. The first example was of a course preparing students to be able to communicate science ideas to an audience. A seminar conference and online discussion area that allowed smaller teams of students to debate a topic was implemented and its affect on students examined. A contradiction identified was students' perception that the rules regarding posting opinions and views on the discussion site were limiting. Another example looked at the development of a dynamic web site to support a humanities class. The traditional course had a static web site that contained course information, reading lists, and access to documents. The new dynamic site changed weekly to include lecture notes, documents, and tutorial information. A contradiction identified was inefficient and ineffective use of the web site. Students printed posted material which conflicted with university printing policy. Other researchers have used Activity Theory to derive a framework for designing mobile learning environments (Uden, 2007), define mobile learning (Wali, Winters, & Oliver, 2008), and derive a conceptual framework for mobile CSCL (Zurita & Nussbaum, 2006).

The object (task) students completed for this study was reading a passage with varying levels of task load and the outcome was performance (reading and learning). Focusing on the secondary contradiction allowed the researcher to examine the following variables at each node:

1. Student – physical discomfort, physiological response, perceived mental workload
2. Tool – distance education modality
3. Object – reading passage with varying levels of task load
4. Outcome – performance

Figure 4 illustrates the conceptual framework.

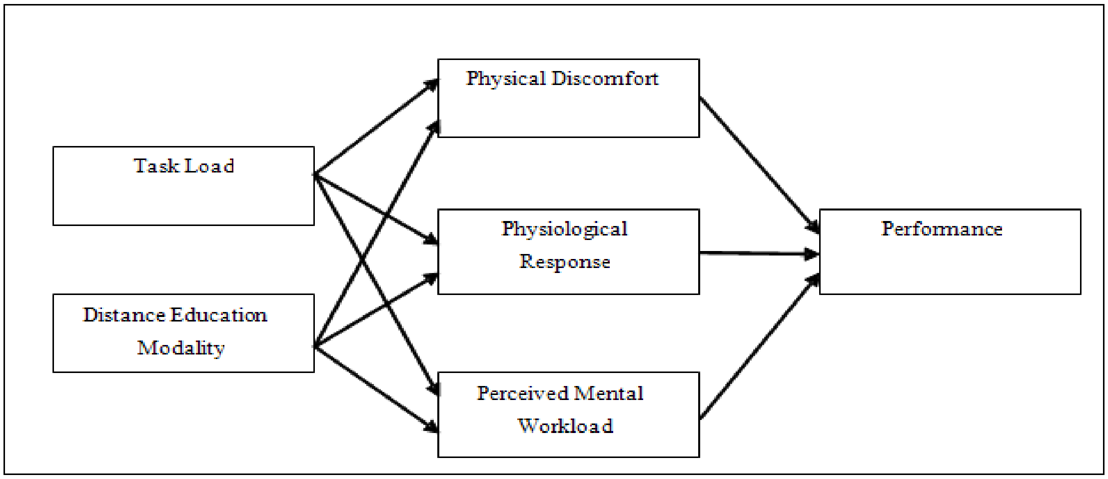

Figure 4-Conceptual Framework

The second contradiction, which looks at the relationship between nodes, focused on the relationship between the subject, object, and tool. The relationship between these nodes examined if reading a passage with varying levels of task load (object) from a distance education modality (tool) affected the physical discomfort, physiological response, and perceived mental workload of subjects. The relationship helped determine whether there was an overall affect on subjects' performance.

It was the researcher's goal to leverage the Activity Theory framework along with human computer interaction guidelines to contribute to the existing body of knowledge using the theory to study m-learning activities. Since learning occurs through interaction between learners and learning tasks (Shih & Mills, 2007), mobile devices can facilitate and enhance this interaction through the number of communication functions it offers its users. Activity Theory's emphasis on the tool in the way activities are mediated shifts the attention from the interaction between the computer, to the activity as a whole. This can help address how mobile technologies when added to a learning setting alter the design of software, learning material, and integration of material within curriculum (Scanlon & Issroff, 2005).

Significance of Present Study

Distance education has matured from television and radio broadcasting technologies to computer and web-based technologies. With users becoming more mobile and digitally literate, accessing course material using desktops and laptops has become a thing of the past. Students are now moving toward smaller, portable mobile devices. There were 1.5 billion mobile phones subscribers in June of 2005 and a predicted 3 billion subscribers by the end of 2010; a penetration rate of nearly 43% of the total global population (Informa Telecoms & Media, 2005). Mobile technology provides students the means to access course material anytime, anywhere, thus granting students the capability to customize their learning. Research has been conducted to identify design features of mobile devices critical to user satisfaction (Han, Kim, Yun, Hong, & Kim, 2004) and to determine whether students are ready to use mobile technology for learning (Peters, 2007; Waycott, Jones, & Scanton, 2005). Although m-learning provides a means to access instructional resources anywhere, there are physical and cognitive limitations that should be addressed.

The results of this study will benefit educators and administrators of academic and corporate organizations, and manufactures by providing strategies for effective ergonomic conditions in distance education mobile learning environments. The research will aid these groups in understanding the physical and cognitive limitations and expectations of students that will help guide the instructional content, course design, and physical characteristics of mobile devices suitable for mobile learning environments. Using Activity Theory as the theoretical foundation will help focus the research on the relationship between the activity system’s subject, object, and tool, thus closing the research gap of analyzing physical and cognitive affects on mobile learning.

CHAPTER TWO: LITERATURE REVIEW

Overview of Distance Education

The annual market for distance education in 2003 was reported to be $4.5 billion, and it was expected to grow to $11billion by 2005 (Howell, Williams, & Lindsay, 2003). Distance education's popularity and growing demand for courses and degree programs stems from its accessibility. Distance education provides an avenue that allows students willing to enroll in a course, the opportunity to do so despite their location or space in time. Although sometimes used interchangeably with the term distance learning (pertaining to the learning a student does at a distance), Gallagher and McCormick (1999) defined distance education as "the process of providing education where the instructor is distant (geographically separated) from the student." Keegan (1980) highlighted six characteristics that provide a comprehensive definition of distance education and summarizes various definitions researchers have presented in the literature:

1. Separation of teacher and student
2. Influence of an educational organization especially in the planning and preparation of learning materials
3. Use of technical media
4. Provision of two-way communication
5. Possibility of occasional seminars
6. Participation in an industrialized form of education

Keegan's summary captured not only the distance separating students from professors, classmates, and administrators, but it also captured the metamorphosis distance education delivery methods have taken through the modernization of technology, pictured in Figure 5.

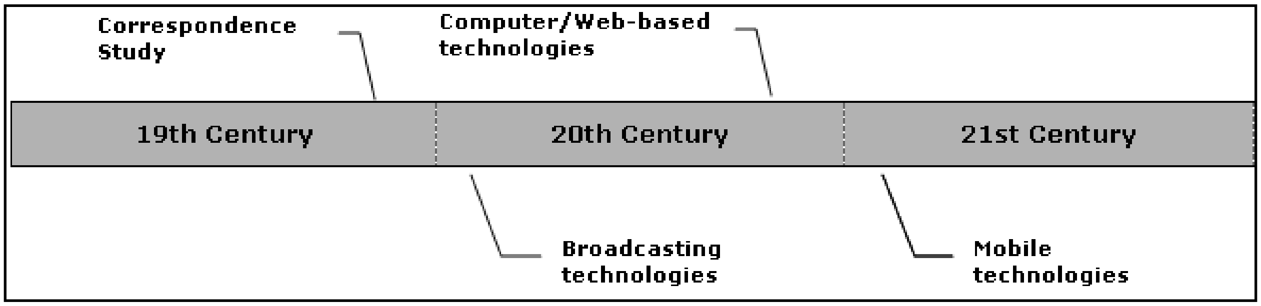

Figure 5-Timeline of Distance Education Technologies

Distance education originated in the 19th century when instructors communicated with students using the postal service. This instruction delivery method was called correspondence study. William Harper, the first President of the University of Chicago, was one of the first professors to bring college-level correspondence programs to the United States. Harper later developed a more advanced correspondence program that became an integral part of the university, allowing students to complete a maximum of 30% of coursework through mail (Gaytan, 2007). Penn State University also provided rural students with agriculture courses through a correspondence study program in the late 1890s. As its popularity expanded in colleges and universities, and with advances in technology, the delivery means of distance education progressed in the early 20th century to broadcast radio stations. By 1923 more than 10% of all broadcast radio stations were owned by educational institutions offering educational programming (Public Broadcasting Service, as cited in Casey, 2008). It was not until the 1950s that college credit courses were offered through broadcast television. In 1963, the Federal Communications Commission (FCC) created the Instructional Television Fixed Service (ITFS) which was a band of 20 television channels for educational institutions to broadcast courses (Public Broadcasting Service, as cited in Casey, 2008). During the late1960s and 1970s, distance teaching universities began forming across the globe. The Open University of the United

Kingdom at Milton Keynes was founded in 1969, the Universidade Nacional de Educacion a Distancia at Madrid in 1972 and the Fernuniversitat-Gesamthochschule in Hagen in Germany in 1975.

Beginning in the late 20th century, students began enrolling in classes and earning degrees remotely by using computer-mediated learning technologies such as two-way interactive video, two-way audio and web-based asynchronous communication, and online and offline Internet web-based instruction. Live video instruction has become the most popular and fastest growing delivery mode in the United States (Ostendorf, 1997). As innovation continues, the anticipated new wave of technology for education is pocket PC and mobile learning devices, where the student accesses course content stored on a mobile device or through a wireless server (Shachar & Neumann, 2003). M-learning provides students an "anytime, anywhere" means of connecting with professors, classmates, and educational resources without being subjected to a physical space. Imagine the possibility of a student taking a foreign language class, using their mobile device to practice conjugating verbs while waiting at a bus stop. Peters (2007) conducted a study where he interviewed manufactures of mobile devices, businesses, and education providers to report on the use of mobile devices for learning. Education providers stated students are looking for more wireless options and are ready to use SMS, PDAs and 3G mobile phones to access learning material. Recognizing this new trend, manufactures of mobile devices and software are partnering to create compatible hardware and software tools that institutions and companies can use for educational and training purposes.

Several distance education theories have emerged to outline parameters and determine factors that must be considered for the delivery method to be successful. A summary of each is described below:

- Charles Wedemeyer's American version of independent study theory focused on the characteristics that emphasized learners' independence and the adoption of technology as a method of implementing distance education.
- Michael Moore's European theory of independent study concerned two variables in educational programs: the amount of learner autonomy and the distance between teacher and learner. Both related to the means of two-way communication between teacher and student and the student's ability to accept full responsibility for the conduct of the learning program.
- The theory of Industrialized of Teaching was proposed by Otto Peters and suggested distance education can be analyzed by comparison with the industrial production of goods. Peters stated that "from many points of view, conventional, oral, group-based education was a pre-industrial form of education; implying distance teaching could not have existed before the industrial era" (Simonson, Smaldino, Albright, & Zvacek, 1999).
- Börje Holmberg first explained his Theory of Interaction and Communication as "teaching effectiveness to the impact of feelings of belonging and cooperation as well as to the actual exchange of questions, answers, and arguments in mediated communication" (Simonson et al., 1999). He later added to this theory stating distance education provided the opportunity for learners who could not and chose not to meet during face-to-face meetings the ability to be independent and promote lifeline learning.
- Hilary Perraton's theory of distance education was comprised of parts of existing theories. The statements that framed her theory focused on the method of delivery, maximizing education and increasing dialogue.
- Desmond Keegan's Equivalency Theory is composed of 5 components: concepts of equivalency, learning experiences, appropriate application, students and outcomes. This approach to distance education "advocated designing a collection of equivalent learning experiences for distant and local learners, although they may be different for each student" (Simonson et al., 1999).

Although pieces of each of the above theories can be applied to m-learning, a conceptualized theory defining m-learning does not exist. Researchers (Brown, 2005; Kukulska-Hulme, 2005; Sharples, Taylor, & Vavoula, 2007; Wali et al., 2008) have attempted to develop a theory that defines all elements (namely students, professors, mobile technology, and learning environment) of the delivery method to help ensure successful implementation and use.

For distance education to be as effective as traditional instruction, the method and technologies used must be suitable for the instructional tasks, there is student-to-student interaction, and there is timely teacher-to-student feedback (Yousuf, 2007). Previous analysis of the research conducted on distance education between 1952 and 1992 performed by Phipps and

Merisotis (cited in Shachar & Neumann, 2003) showed that distance education outcomes were not that different from those achieved in traditional classrooms. Their review reported the following:

> "With few exceptions, the bulk of these writings suggest that the learning outcomes of students using technology at a distance are similar to the learning outcomes of students who participate in conventional classroom instruction. The attitudes and satisfaction of students using distance education also are characterized as generally positive. Most of these studies conclude that, regardless of the technology used, distance education courses compare favorably with classroom-based instruction and enjoy high student satisfaction."

Understanding the appropriate instructional tasks presented through mobile technologies and addressing ergonomic issues that may impact students using these devices will help distance education administrators and professors with content delivery and implementing the use of the devices into current learning environments. The goal is for m-learning to achieve the same learning outcomes as traditional classroom and distance education (desktop and laptop machines) environments expressed in the quotation above.

The National Center for Education Statistics (NCES) predicted college enrollment will grow 16% over the next ten years, thus making distance education a valuable tool to accommodate the growing college-aged population and enrollments (Jones, as cited in Howell et al., 2003). Successful distance education programs not only benefit students but the university and society as well. Universities offering distance education courses hope to save money. Reductions in state funding for higher education are forcing administrators to find new ways to reduce expenditures (O'Malley & McCraw, 1999). While class sizes increase with students enrolling in both the online and on-campus versions of a course, overhead remains the same (cost of physical building space, building construction, and facilities maintenance). Colleges and universities are also working together to form consortiums to offer additional degrees and flexibility in course offerings (O'Malley & McCraw, 1999). The Center for Academic Transformation at Rensselaer Polytechnic Institute conducted a Program in Course Redesign with support from the Pew Charitable Trusts. The purpose of the institutional grant program was "to encourage colleges and universities to redesign their instructional approaches using technology to achieve cost savings as well as quality enhancements." The University of Central Florida participated in the program with two goals: (a) utilize classroom space more efficiently and reduce the amount of rented space needed by the university, and (b) lower instructional expenses while holding student enrollments steady. In the end, the university implemented a mixed delivery model that combined face-to-face and online class sessions that resulted in a cost savings per student of $31 while enrollments remained constant (Bishop, 2006; Twigg, 2003).

Society and the environment benefit when students choose to advance their education using distance education resources. The delivery method can be seen as an eco-friendly alternative, decreasing air pollution, traffic congestion and energy consumption because fewer people are on the roads traveling to campus.

Student Characteristics

According to Aslanian (as cited in Howell et al., 2003), approximately 42% of all students at both private and public institutions are age 25 or older. With the success of the telecommunication age and the rise of Internet use, the number of students enrolling in distance education courses continues to grow. Nontraditional students who are enrolling in distance education courses have different characteristics than the "traditional student." In this context, the traditional student is a person transitioning from high school to college, ranging from the ages of 18-24 and attends school full-time. The traditional college student is changing and the student population now includes students that are older, married, employed, and nonresidential. Students that expressed a preference for distance education over the traditional live lecture method of course delivery are generally between the ages of 26 and 50 (Minton & Willett, 2003), are computer efficient (Schacher & Neumann, 2003), and are not full-time students enrolled in a regular degree program (Dutton, Dutton, & Perry, 2002). Halsne & Gatta (2002) compared the learning styles and demographic characteristics of community college students who enrolled in a course off-campus, to those who enrolled in the same course on-campus. Their research found the female to male ratio for online courses was larger than traditional courses and that the majority of online students were working professionals who had taken previous college courses, were visual learners, and spent on average an hour more per week on class work than traditional students.

Qureshi (2002) identified seven characteristics that are prevalent to the majority of distance education learners:

1. The students are adult by definition (maturity)
2. The students are all engaged in a continuing process of growth (value learning)
3. The students bring a package of experience and values (experienced)
4. The students usually come to education with set intentions (motivated)
5. The students bring mature expectations about education itself (realism)
6. The students often have competing interests (employment, family, social life)
7. The students possess set patterns of learning (developed or ingrained strategies)

Due to the flexibility distance education offers, students must be focused and motivated to maintain the balance between school, work, and home life. Gibson (as cited in Banas & Emory, 1998) explained that distance learners need to be more focused, manage time effectively, be able to work both independently and in groups, have strong self-motivation and self- discipline, and be assertive. Blocher, Sujo de Montes, Willis, and Tucker (2002) stated that a student's ability to self-monitor and self-regulate their learning, garner resources, and seek the support of peers to gain an understanding of what it takes to find the happy medium, is important and could hinder their success. For working professionals, possession of these characteristics may help balance the responsibilities they must maintain at school (assignment completion, preparation for exams, allocation for study time), on the job, and at home to prevent stress and be a successful student.

Students enroll in distance education courses for a number of reasons including career changes, job training and promotion, and a quest for lifelong learning. Dutton et al. (2002) asked study participants to rate eleven different factors in deciding whether to enroll in an online or on-campus course. Of the selections, distance education students ranked conflict between class time and work, time commuting to class, and flexibility in setting pace and time for studying as important. Students' attraction to distance education was the ability to learn and achieve the same educational goals as their on-campus classmates, but conveniently according to their schedule availability. Schedule flexibility ranked high amongst distance education students. Distance education allows individuals not geographically close to colleges and universities the ability to enroll in courses. Geography however was not the leading reason students chose distance education. Minton and Willett (2003) found that a majority of study respondents who preferred distance education lived within 20 miles of the participating education facility, which supports Dutton et al. research finding that schedule flexibility was important to distance education students.

Mobile learning is becoming an extension of distance learning, providing a channel for students to learn, communicate, and access educational material outside the traditional classroom environment. For adult learners, this modality allows them to take advantage of accessing material using mobile devices they use for job related activities. It also opens the lines of communication between professors and other classmates for discussion forums and addressing questions without the need of being at a designated location; thus helping facilitate some of the challenges of distance education such as retaining students and distance learners feeling a sense of connectedness. Despite the portability and readiness to information mobile devices provide its users, cognitive and physical ergonomic issues may impact learners. These issues may stem from information overload and physical discomfort from extended use of the mobile device which may negatively affect the overall success and of mobile learning usage.

Mobile Learning

It was estimated that the number of mobile phones in the world exceeded 1.5 billion (Prensky, as cited in Muyinda, 2007), which is almost three times the number of PCs. Between 2002 and 2003 mobile device sales grew by 40%. With the cost of mobile devices less than that of desktop and laptop computers, the number of mobile devices used around the world is expected to continue to grow. The rapid growth mobile technologies have seen over the years has enabled more than 50% of all employees to spend up to half of their time outside the office. There are an estimated 1 billion wireless Internet subscribers worldwide, and more than 525 million web-enabled phones shipped worldwide (Kristiansen, as cited in Brown, 2005). According to a special section in Fortune 500 magazine (2001), wireless methods of transmitting data and knowledge will be useful where access to the Internet is expensive (Europe and Asia) or nonexistent (underdeveloped countries). The economic cost difference of mobile devices and their accessibility attractiveness make them ideal tools to use in the education environment for many students around the globe. Smith (as cited in Kinshuk, 2003) provided a list of characteristics of handheld devices detailing the benefits of incorporating them into distance education programs: small size (for easy portability), flexibility, and price. Trinder et al. (as cited in Kukulska-Hulme, 2007) concluded in a case study an advantage of using PDAs was their "immediate readiness" (no boot up time required), which made the devices ideal to use during working times and at locations where a laptop may not be feasible. Limitations of using the devices included screen size (the need to scroll through multiple screens), data storage, security, and bandwidth. Some users find that m-learning may not be conducive for learning (physical environment like being outside in the bright sunlight) while others see the benefits of being able to learn on-the-go outweighs its disadvantages (Fozdar & Kumar, 2007).

Companies with employees who are in the field or do not have a permanent office are pushed training sessions on their mobile devices that they use daily for job related tasks. This allows employees to access training material during downtimes of the workday. For example, a new employee working on a shop floor has spare time to learn about a new inventory item. The employee can scan the barcode of the product and view or listen to an information session about the features of that product using a handheld mobile device. The knowledge session is portable, does not require the employee to leave the work environment, and is controlled by the employee, allowing them to start and stop a session or repeat information. The Royal Bank of Scotland provided phonecasts to its employees through mobile phones. The phonecasts consisted of key messages from senior management and motivational tips. Cable and Wireless (a provider of IT and communication infrastructure based in England) used podcasts and videocasts for employee training (iPods and MP3 compatible mobile phones were used). The University of Central England issued handheld devices to nursing students that were used to access medical and diagnosis information while canvassing the hospital ward. Nursing students used the devices to look up procedures and download revision notes to work at their leisure. Some companies use a blended approach to incorporate mobile technologies into their training plans. This blended approach allows students to participate in classroom training and receive “just-in-time” training modules on mobile devices outside the classroom that can be used as knowledge refreshers.

The convenience factor and economic benefits of mobile devices lend themselves to various communication environments including learning. Attwell (as cited in Imran, 2007) stated there are several advantages inherent in mobile learning; those relevant to this study include:

1. Can be used for independent and collaborative learning experiences
2. Helps overcome the digital divide
3. Helps make learning informal

A few examples of how mobile devices such as iPods, mobile phones, and PDAs are used in the education environment are discussed below.

In August 2004, the entire freshmen class at Duke University received a free iPod. In September of the same year, a Korean education firm offered free downloadable college entrance exam lectures to students who purchased an iRiver personal multimedia player (Kim, as cited in Chinnery, 2006). iPods and MP3 players are used to listen to podcasts of class lectures. A podcast is an audio or video file that can be downloaded from the Internet or online streaming content (Guertin, Bodek, Zappe, & Kim, 2007). Universities are making these files accessible to students to listen and view at their leisure. Files can be of the professor's lecture or discussion points they share after a class session. Accessing these files provided students the opportunity to listen and view them according to their schedules. Guertin et al. (2007) conducted a study of Penn State Delaware County University students to assess their use of podcasts. Students who accessed the files indicated they did so because they missed class and wanted to catch up, or wanted to check their notes for accuracy. Those students who did not use the files indicated they did not because they did not miss class, were happy with the notes they took, or simply did not have time to listen.

Cellular and mobile phones can be used in the classroom to access the Internet, send and receive short message service (SMS) text, and take pictures or record video images to share with classmates and professors. Fannon (as cited in Peters, 2007) conducted research that demonstrated younger learners were more comfortable with the thought of using mobile phones for learning than older classmates who would rather use them to schedule meetings. Fannon's research also demonstrated that "almost half the research group was prepared to use Internet-enabled telephones as their only tool for learning" (Peters, 2007). Thornton & Houser (2005) conducted a study of Japanese students learning English as a second language. The researchers sent text and video lessons to students defining new terms, story episodes using target words, and English idioms. The students rated the messages high in their educational effectiveness and stated they felt comfortable reading the text and viewing the videos on small screens.

Although Europe and Asia are 2-3 years ahead of the United States in their receptivity to m-learning, colleges and universities in the United States are beginning to embrace the delivery method. Researchers at the University of North Carolina Wilmington through Project Numina aimed to enhance student learning with handheld devices by creating a Student Response System (SRS) where students used a handheld device to respond to teacher questions during lectures. An in house study concluded that 100% participation was achieved during question and answer sessions and that the system increased classroom discussion and reduced off task behavior (Heath et al., 2005). Yousuf (2007) conducted a study to determine students' perception of m-learning and to what extent could they see themselves using mobile technology for education purposes. Student responses revealed that the majority preferred to receive administrative notices from university offices and information regarding assignment submissions, and schedule workshops and tutorial meetings using mobile devices. Fozdar & Kumar (2007) conducted a similar study that sought to determine whether m-learning could improve student retention. The study concluded that faculty-initiated contact with distance education students would help ease the feeling of isolation experienced by students and instead promote a feeling of connectedness and community with professors and classmates.

There are a few challenges that affect m-learning. First, computer mediated communication remains to be a concern, particularly the lack of social cues which affect a student's feeling of connectedness. Second, lack of a conceptualized m-learning theory. Many definitions have been derived; some technology centered, others encompassing the location of where learning takes place. An m-learning theory to define the framework and approach to incorporate the modality into an existing learning environment is necessary. Third, ergonomic issues facing m-learning have not been fully studied. Results can aid with device selection and delivery of material to students.

As we move into the 21st century, universities and companies are beginning to incorporate the use of mobile devices as another form of reaching out to students and employees. Because some course management systems like WebCT and Blackboard may not be able to adapt to mobile devices, research is underway to establish mobile learning environments. Project Numina (Heath et al., 2005) and the Multiple Representation Mobile Adaptation approach (Suhonen, Suhonen, Sutinen, & Goh, 2003) endeavored to provide information architecture for content adaptation to mobile environments and support for multiple mobile devices and platforms. Continued research in m-learning is needed to help establish learning strategies and infrastructure suitable for the distance education modality.

Ergonomics

Synonymous with the term human factors (in the United States), Chapanis defined ergonomics as “discovering and applying information about human behavior, abilities, limitations, and other characteristics to the design of tools, machines, systems, tasks, jobs, and environments for productive, safe, comfortable, and effective human use” (Sanders & McCormick, 1993). Traditionally, the field is composed of three main specialization areas: physical, cognitive and organizational. Physical ergonomics is related to human anthropometric (biomechanical) and physiological characteristics as they pertain to physical activity. Cognitive ergonomics is “focused on mental processes, such as perception, memory and information processing as they affect interactions with humans and other elements of a system” (Vicente, as cited in Karwowski, 2005). Organizational ergonomics is related to “the optimization of sociotechnical systems, including their organizational structures, policies and processes” (Karwowski, 2005). Physical and cognitive ergonomics will be the focus for this research.

During the development lifecycle of a system or product, human factors engineers (HFEs) work closely with hardware and software developers to incorporate ergonomic principles and user centered design processes into the design. Figure 6 illustrates the relationship between usability goals (meeting specific usability criteria) and user experience goals (explicating the quality of the user experience) within the user centered design process (Preece, Rogers, & Sharp, 2002).

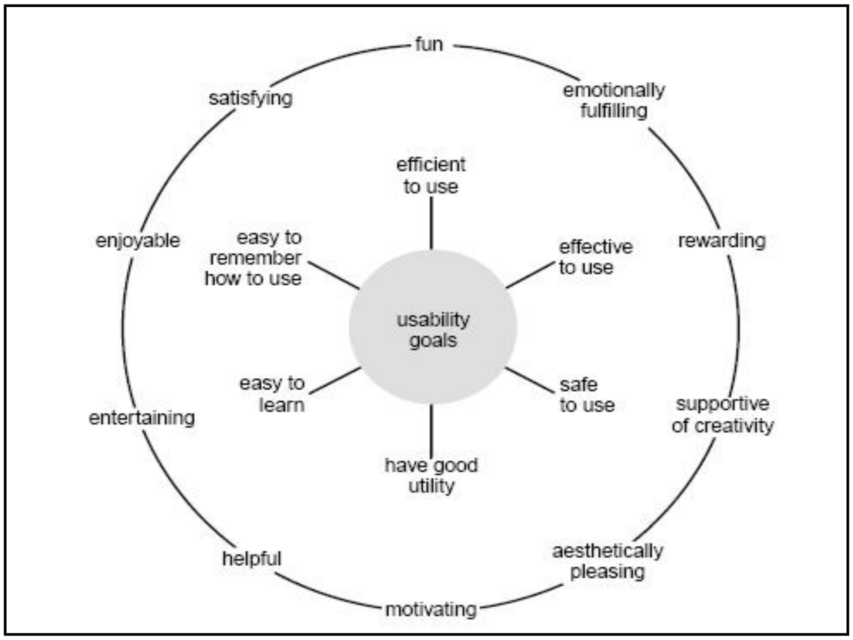

Figure 6-Usability and user experience goals (Source: Preece, Rogers, & Sharp, 2002)

Incorporating ergonomic principles and user centered design processes within the lifecycle can result in a quality design of a product for an increase in user productivity and user satisfaction. The collaboration between HFEs and developers aims to deliver a product with effectiveness, efficiency, and satisfaction in a specified context of use (Su, 2006). There are three areas in which physical and cognitive ergonomics can contribute to the instructional and effective design and use of mobile technologies for the m-learning environment:

1. Understand the physical and cognitive capabilities and limitations of students and use this knowledge to design the best possible mobile technologies
2. Understand how the design and use of mobile technologies in the m-learning environment can lead to problems for students such as stress, musculoskeletal injury, and discomfort
3. Understand m-learning environment's (instructional design) use of mobile technologies and make accommodations to enhance access and use

Addressing these items early in the design process may avoid rework, save time and money, and considers the user's experience from the beginning. The following two sections provide more detail about physical and cognitive ergonomic factors affecting m-learning.

Physical Ergonomics

Proctor and Vu (2005) identified two primary ideas in physical ergonomics: (a) to define the factors that produce unwanted strain, and (b) to design ways to eliminate or minimize the loads and forces caused by these factors to eliminate strain. As computing technology has become a part of our daily lives at the workplace, education environment, and home, researchers have long studied how to design and integrate these tools seamlessly, reducing disruption in activities and physical discomfort. Particularly with computers and its peripherals (namely mouse, keyboard, and monitor) researchers have studied physical constraints of computer usage to develop guidelines for proper use. Shieh and Lin (2000) studied the effects screen type, ambient illumination, and color had on visual performance while reading from computer screens. Mills and Weldon (1987) conducted a review of empirical studies about presentation factors (for example characters, formatting, contrast, color, and dynamic text) affecting readability of text on computer screens. Ward and Marsden (2003) examined physiological responses and arousal changes in emotion, attention, and workload to evaluate effective webpage design and software usability. These studies can be useful for guidelines concerning the physical characteristics and use of mobile devices.

Research has been conducted to identify human factors characteristics associated with handheld devices that may cause strain or limit full use by users. A technical report was produced by the Federal Aviation Administration (FAA) (Zingale, Ahlstrom, & Kudrick, 2005) that discussed advantages and disadvantages of using PDAs, smartphones, and BlackBerrys that were examined with respect to size, weight and input method. Disadvantages shared between the three devices included small screen size, low resolution and contrast. Ergonomic issues related to the design of the mobile device identified included users having to hold the device using both hands and data entry. Li, Chen, and Goonetilleke (2006) examined keyboard arrangements to determine the best design for single finger or stylus-based text entry on PDAs. Their research presented a keyboard methodology and design that aimed to reduce movement time as defined by Fitts' Law. In a study conducted by Waycott et al. (2005), graduate distance education students were each given a handheld device to read course text to determine whether the device was a useful tool and the effect the device had on reading course material. Despite students responding that the handheld device was a useful learning tool, most students found using the device to read content was difficult. During interviews, one student stated that she found the PDA "difficult to use as a reading tool as it caused eyestrain, resulting in headaches and blurred vision" (Waycott et al., 2005). Despite her comment, the same student stated that the portability of the device was beneficial and allowed her to squeeze in reading time around other responsibilities and activities. Other limitations mentioned in the study included difficulty skimming through text, battery life, flipping back and forth between applications was time consuming, and note-taking and highlighting abilities were not supported on the PDA. Results from these studies can be used to enhance physical characteristics of mobile devices to improve human-mobile interaction.

Table 2 summarizes the physical discomfort mobile device users may experience and the physical attributes of the device that lead to the discomfort from reading text, viewing videos, or data entry.

Table 2-Physical discomfort experience

Physical discomfort experienced	Cause of discomfort
Eyestrain (blurred vision)	Screen size, text size, contrast, low resolution
Headache	Screen size, text size, contrast, low resolution
Tendonitis in the upper extremities	Data entry, hand position needed to hold mobile device

Physical attributes of mobile devices that can lead to users experiencing physical discomfort and injury may stem from the interface design (screen size and display, navigation tools, and input means). To efficiently achieve usability of mobile devices for educational purposes, additional factors should also be considered (Su, 2006):

1. Cognitive and motor capabilities and constraints of users
2. Users' physical and social work environment
3. Capabilities and constraints of the chosen software and hardware, and platform for the system or product

Understanding these factors can guide mobile technology developers and HFEs to deliver a product that minimizes physical discomfort and strain experienced by users.

Cognitive Ergonomics

The aim of cognitive ergonomics is to enhance user performance of cognitive tasks by several interventions:

1. User-centered design of human-machine and human-computer interaction
2. Design of information technology systems that support cognitive tasks
3. Development of training programs
4. Work redesign to manage cognitive workload and increase human capability and reliability

Of the relevant topics in the area of cognitive ergonomics (working memory, decision making, and attention), mental workload and task load will be the focus of this research. Mental workload can be defined as “a measurable quantity of information processing demands placed on an individual by a task” (Sanders & McCormick, 1993). Task difficulty, time pressure, and physical demands contribute to subjective mental workload. If the time required by a task is more than the time available, there is mental overload. If the time required is much less than the time available, there is mental underload (Hancock & Hoffman, 1997). According to Baldwin (2003) mental workload theory assumes that:

1. People have a limited mental and attentional capacity with which to perform tasks
2. Different tasks require different amounts of processing resources from the same person
3. Two people might be able to perform a given task equally well, but it may be more difficult for one than the other

Mental workload assessment techniques can be grouped into 3 categories: behavioral measures (primary and secondary task performance), physiology measures, and subjective measures. Primary task performance measures quantify the performance outcome of a task. Secondary performance task measures assess the residual resources or capacity not utilized in the primary task. Physiological measures analyze central nervous system activity to determine mental workload. Techniques include heart rate variability, pupil diameter, respiration rate, and visual scanning. Subjective measures involve a rating scale that users complete to assess the subjective effort required to perform a task. Popular subjective measuring scales include the Cooper-Harper Scale (Cooper & Harper, 1969), NASA-Task Load Index (NASA-TLX) (Hart & Staveland, 1988), and the Subjective Workload Assessment Technique (SWAT) (Reid & Nygren, 1988).

Using mental workload assessment techniques help determine how much mental load is too much or hazardous or how little is too little so individuals are sufficiently challenged to sustain useful levels of output (Parasuraman & Hancock, 2001). Andre (2001) identified three ways mental workload assessment can be beneficial during the creation and testing of consumer products, which can also be used to address the mental workload students endure when using mobile devices as a learning tool. First, usability testing can be conducted to observe a user's frustration, concentration, confusion, and facial expression while interacting with a product. Distance education researchers can observe students receiving and sending video and text messages and course material to determine whether the content and activities impose mental workload. Second, mobile technology creators can observe users, identify the physical attribute or activity that is causing distress, and reengineer the device or device features. Third, user feedback based on emotional and physiological responses can help mobile technology developers produce a product that reduces physical load experienced. HFEs can also assist developers limit potential physical discomfort or injury to the user by considering physical and physiological effects mobile devices may cause. Table 3 (Andre, 2001) is a checklist of workload dimensions and measures that can be applied to most products and systems that distance education researchers and product designers can reference when developing and evaluating mobile devices and mobile learning environments.

Table 3-Product workload dimensions and measures

Category	Dimension	Measurement Method
Physical	Physical effort Twisting/Reaching Dexterity Force (Dis)Comfort	Subjective Observation, Instrument, Subjective Observation, Subjective Instrument, Subjective Instrument, Subjective
Physiological	Pain/Sensation Heart rate Temperature Metabolic rate	Observation, Subjective Instrument Instrument Instrument
Psychological	Cognitive demand Perceptual demand Memory demand Locus of control Familiarity Predictability	Subjective Subjective Subjective Subjective Observation, Subjective Observation, Subjective
Emotional	Stress/Anxiety Frustration Intrigue Excitement	Observation, Instrument, Subjective Observation, Subjective Observation, Subjective Observation, Subjective

At the time this research was conducted, few studies in the literature concentrated on mental workload and task load and their effect on distance education or m-learning. Understanding the mental workload experienced and task load limitations of a distance learner may benefit professors. Crosby, Auernheimer, Aschwanden, and Ikehara (2001) conducted a study that analyzed physiological data feedback of distance education students. Since professors cannot view students' nonverbal cues (frustration and confusion over a topic), researchers where looking for a way to communicate those emotions to instructors. Physiological data such as pulse, galvanic skin response, and general somatic activity were correlated with the emotion of the student through an Emotion Mouse. The study demonstrated that the physiological information provided insight regarding changes in user's emotional and subjective states while engaged in cognitive tasks. Assessing a user's mental workload can benefit distance education administrators, professors and mobile technology developers. The data can be used to determine appropriate instructional content and how that content should be presented and pushed out to students on their mobile devices. Creators of mobile computing can study the data to determine which physical attributes of a product causes discomfort or user frustration and in return design a product that improves user satisfaction and usability.

Methods, Strategies and Tools

Sanders and McCormick (1993) stated that measuring mental workload could be used for the following purposes:

1. allocating functions and tasks between humans and machines based on predicted mental workload
2. comparing alternative equipment and task designs in terms of the workloads imposed
3. monitoring operators of complex equipment to adapt the task difficulty or allocation of function in response to increases and decreases in mental workload
4. choosing operators who have higher mental workload capacities for demanding tasks

Subjective measures have the advantage of being relatively easy to administer and interpret, do not require extensive training or equipment, and do not disrupt the user while they are working. Background factors (past experience), personality, or rater’s perception of task difficulty may affect a user’s subjective rating.

The NASA-TLX has been applied successfully in areas such as simulated flight tasks, air combat, remote control vehicles, and vigilance performance tasks. The NASA-TLX assesses workload on six dimensions outlined in Table 4. The rating procedure provides an overall workload score based on a weighted average of rating on the six dimensions (Sanders & McCormick, 1993). The ratings are weighted according to their subjective importance to the rater.

Table 4-Rating scale definitions and endpoints from the NASA-TLX

Title	**Endpoints**	**Descriptions**
Mental Demand	Low/High	How much mental and perceptual activity was required (for example thinking, deciding, calculating, remembering, looking searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?
Physical Demand	Low/High	How much physical activity was required (for example pushing, pulling, turning, controlling, activating, etc.)?Was the Task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
Temporal Demand	Low/High	How much time pressure did you feel due to the rate or pace at which the task or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
Performance	Good/Poor	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?
Effort	Low/High	How hard did you have to work (mentally and physically) to accomplish your level of performance?
Frustration Level	Low/High	How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

Although researchers have determined that both the NASA-TLX and SWAT scales tend to yield similar outcomes when they are applied to the same set of data, the NASA-TLX technique, having more scales and greater resolution per scale, allows it to convey more information and appears to provide a more reliable measure (Wickens & Hollands, 2000). It is because of this reason that the NASA-TLX will be used for this research to measure the workload students experienced using mobile devices.

Literature Review Conclusions

A review of the literature revealed the student profile of distance education students is changing with an increased number of adult, working professionals enrolling in distance education programs and courses. With adult students becoming more digitally literate and the advances in mobile technology, m-learning is a distance education modality that aims to provide students the mechanisms needed to access course information anywhere, anytime. Although m-learning provides the opportunity to obtain educational material despite location or time in space, ergonomic issues may be introduced into the learning environment. Physical and cognitive ergonomics were defined, along with measuring techniques, and identification of ergonomic issues students may endure using mobile technologies in m-learning environments. An understanding of the physical discomfort and mental workload m-learning might impose on distance education students' learning outcomes form the basis for the researcher's proposed research method.

CHAPTER THREE: RESEARCH METHOD

The purpose of Chapter Three is to provide an overview of the research approach used to test the hypotheses posited for this study, including power analysis, subject selection, research design, and procedure. The chapter details how data was collected and analyzed to draw conclusions and answer the research questions and hypotheses.

Power Analysis

A priori power analysis was performed to determine the sample size for the current study. Based on the literature review and research designs of similar studies, sample size ranged from 18 to 40 participants. The level of statistical significance however, was not provided for any of the studies. The level of statistical significance for this study was set at the conventional value $\alpha = 0.05$. To achieve the statistical power of 0.80 ($1-\beta = 0.80$, a convention proposed for general use) in the study, the effect size was defined at large (ES=0.40) for ANOVA tests (Cohen, 1992). The sample size was determined to be 84 participants.

Subject Selection

Eight-four participants took park in the study. Participants were undergraduate and graduate students from the University of Central Florida and working and retired professionals all 25 years old and older. Participants were recruited through e-mail, announcements made during class periods, and “word of mouth” from other study participants. Table 5 captures the age demographics of participants.

Table 5-Age Demographics of Participants

Sex		N		Mean		
Female		54		34.944		
Male		30		33.567		
Total		84		34.452		
Working Professionals Students		72 12				
Age Range						
	25-31	**32-38**	**39-45**	**46-52**	**53-59**	**60-65**
Desktop Computer	22	14	3	1	2	0
Mobile Device	19	15	1	0	4	3
Total	41	29	4	1	6	3

Participants were randomly assigned to experimental groups to ensure each participant had an equal chance of being assigned to any one of the six groups. Participation in the experiment was open to individuals 25 years old or older, regardless of race, sex, or nation of origin.

All participants were required to own a mobile device that they used for personal or business reasons. Participants were familiar with the use of a mobile device and desktop computer with moderate to high computer and Internet skills. Participants completed a Demographic Questionnaire regarding their laptop, desktop computer, and mobile device usage. The questionnaire contained questions pertaining to the physical characteristics and functions of their mobile device, the participant's overall satisfaction with the device, experience with web-training classes, and e-mail and Internet usage.

Research Design

Two studies' research designs (both involving reading tasks) were used to leverage the research design of the current study. Hughes, Babski-Reeves, and Smith-Jackson (2007) conducted a study that examined the effect of mental workload and time pressure on perceptions of workload and on musculoskeletal responses of the lower arm and wrist during typing. Researchers imposed mental workload on participants using verbal arithmetic tasks. Physiological measures, muscle activity, wrist posture, and key strike force were recorded. Typing performance and subjective workload were used to assess perceived levels of mental effort, time load and stress load. The SWAT was used as the workload assessment tool. The study resulted in increased muscle activation, key strike force, and wrist deviations due to increased time pressure and it was determined that mental workload increased key strike force. Mayes, Sims and Koonce (2001) conducted a study that examined comprehension and workload differences in students using visual display terminals and paper based reading. Dependent variables included reading times, comprehension of the information, and mental workload measured using the NASA-TLX. The study resulted in students reading from the visual display terminal (VDT) requiring more time to read than those reading from paper, and they experienced higher levels of mental workload. Comprehension of the information read demonstrated no difference.

This study utilized a mixed design with two between-subject factors and one within-subject factor (Myers & Well, 1995). Figure 7 provides an illustration of the research design method. The two between-subject factors were task load and distance education modality. The within-subject factor was trials.

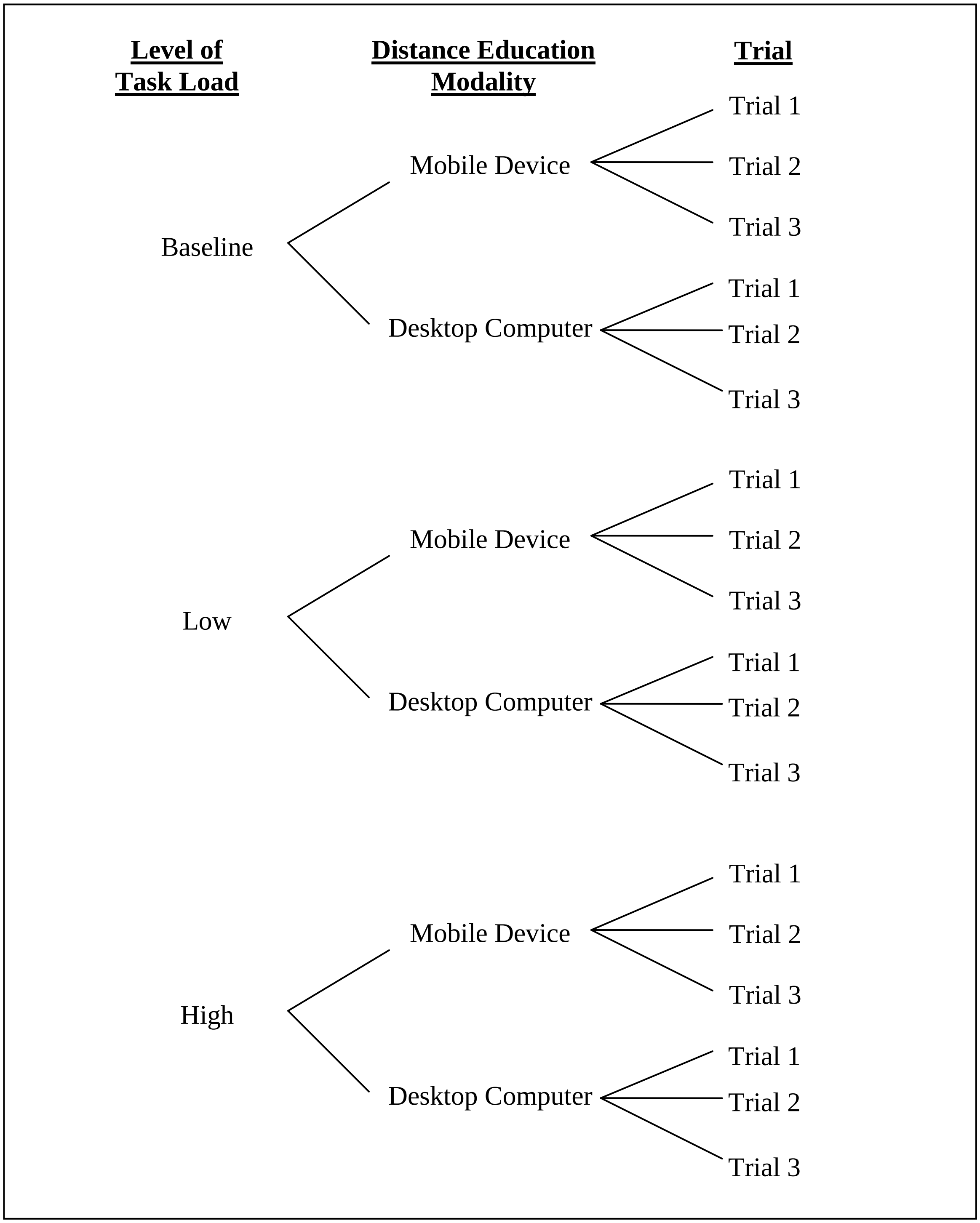

Figure 7-Research Design Method

There were six experimental groups, with 14 participants in each group. Each participant was randomly assigned to one group. To address carryover effect, all participants read the same passage, used one distance education modality, and experienced one level of task load. Each participant endured three trials, all occurring on the same day, with 2 minute breaks between each trial.

The independent variables were task load and distance education modality. Task load was imposed on participants using letter and word identification tasks in three levels:

1. Level one: baseline or no load
2. Level two: low level consisting of counting the number instances the word “ball(s)” appeared in the passage
3. Level three: high level consisting of counting the number instances the letter “h” appeared in the passage

There were two distance education modalities: a desktop computer and a mobile device (in this case, a cellular phone), both pictured in Figure 8. The desktop computer was a Dell ™ desktop with monitor, keyboard, and mouse. The mobile device was a Blackberry ™ World Edition (APPENDIX B: MOBILE DEVICE SPECIFICATIONS) phone provided to the researcher by Sprint. All participants used the same desktop computer and mobile device for all evaluation sessions.

Figure 8-Blackberry™ World Edition Phone and Dell™ Desktop Computer

The dependent variables were subjective workload, physical discomfort, physiological response, and performance. To measure participants' perceived subjective workload and physical discomfort, the NASA-TLX was administered at the end of each trial. This measured participants' perceived levels of physical, mental and temporal demand, performance, effort, and frustration levels. Physiological response (heart rate) was obtained using a Polar Electro heart rate monitor. During each trial, the monitor was strapped around the participant and the minimum, maximum, and average heart rate was recorded and used for data analysis. Performance was based on two measurements: reading and learning. During each trial, participants read aloud Dave Barry's *They Might Be Giants* (APPENDIX D: READING PASSAGE) taken from the Illinois Standards Achievement Test for Grade 8 (Illinois State Board of Education, 2008). The passage contained 946 words. Incorrect words read by the participant were recorded by the researcher. Reading time was recorded to measure how long it took participants to read the passage during each trial. Reading performance was measured using the amount of time required to read the passage and the number of mistakes made while reading the passage aloud. An achievement test was administered at the end of each trial. Questions were related to the content read and measured participants' ability to learn (comprehend) the information read immediately after interacting with the distance education modality for that particular trial. The achievement test was paper based, consisted of multiple choice questions, and was scored by the researcher. Learning gain was measured using the difference between the achievement test scores of the first and third trials. Learning performance was measured using the achievement test scores for each trial and learning gain.

Participants were interviewed at the end of the session to obtain thoughts and feelings about their experience. Questions were asked about their likeliness of using a mobile device for educational purposes and the educational activities they would engage with those devices. All trials were conducted in a private room with the door closed to prevent distraction. The trials were conducted one participant at a time with the researcher conducting the experiment.

Procedure

Before arrival to the experiment, participants were randomly assigned to one of the six experimental groups. Data collection for the study was conducted during a three-month period between October and December 2008. After reporting to the designated evaluation location, participants completed an Informed Consent Form (APPENDIX A: INFORMED CONSENT) and a Demographic Questionnaire (APPENDIX C: SUBJECT QUESTIONNAIRE). An overview of the study and instructions for the reading task were provided and questions answered. Once the participant put on the heart rate monitor the experiment began.

Using the distance education modality for their assigned experimental group, each trial consisted of the participant reading the passage aloud for comprehension. While reading the passage, the task load level assigned to that experimental group was imposed on the participant (for those participants that experienced low and high task load levels, the researcher recorded the number of times they saw the word “ball(s)” or the letter “h” immediately after they completed reading the passage). Incorrect words read by participants were recorded by the researcher as well as the amount of time it took participants to read the passage and participants’ minimum, maximum, and average heart rate. After reading the passage, the untimed achievement test was administered. Next, participants completed the NASA-TLX assessment. Participants received a two minute rest period between each trial. At the conclusion of all three trials, participants were interviewed and thanked for their time.

The data collected was analyzed using Statistical Package for the Social Sciences (SPSS™) 17.0. To study the posited hypotheses, the two independent variables were tested using statistics procedures, including descriptive analysis, mixed effects analysis of variance (ANOVA), and pairwise comparisons. The interview results were used to examine response patterns and to better explain statistical findings.

CHAPTER FOUR: RESULTS AND DISCUSSION

Chapter Four presents the statistical procedures (descriptive analysis, mixed effects ANOVA, and pairwise comparisons) performed and analysis of results. Using the results, the five hypotheses posited for this study were addressed, along with interview results used to support the analysis of each hypothesis and answer the research questions.

Participant Demographic Information

All 84 participants owned a mobile device that they used for either personal or business needs and were familiar with its functions. All participants also owned either a personal desktop computer or laptop. Over half the respondents send e-mail and access the Internet more than 21 times a week. Only eight participants have accessed course material using their mobile device. Table 6 captures demographic information participants provided on the Demographic Questionnaire to include length of use and satisfaction with their current mobile device, and academic courses and training classes taken that have used the Internet.

Table 6-Participants' Demographic Information

Length of ownership		***Mobile device usage***		***Satisfied with mobile device***	
	N		**N**		**N**
< 3 months	4	Barely	3	Neutral	13
3-6 months	12	Below average	4	Somewhat dissatisfied	2
6-12 months	21	Average	30	Somewhat satisfied	34
12-24 months	25	Above average	23	Very satisfied	35
2 > years	22	Heavy	24		
Number of academic courses taken in which Internet was used		***Number of Web-based training classes taken***			
	N		**N**		
Zero	12	Zero	13		
One	7	One	7		
Two	5	Two	11		
Three or more	60	Three or more	53		

Analysis of Perceived Mental Workload

Hypothesis 1

H_0: Increased levels of mental workload and the type of distance education modality engaged do not affect perceived mental workload

To determine whether modality and task load affected participants' perceived mental workload, a mixed effects ANOVA with two between subject factors (modality and task load) and one within subject factor (trials) was conducted. The dependent measure was the mean weighted workload (WWL) score computed using the weights and ratings of the NASA-TLX six dimensions. The ANOVA is shown in Table 7.

Table 7-NASA-TLX WWL Score Analysis of Variance

Source	Df	Mean Square	F	Sig.
Between-Subjects Effects				
Modality	1	2753.087	4.254	0.042*
Load	2	4602.353	7.112	0.010*
Modality * Load	2	75.065	0.116	0.891
Error	78	647.124		
Within-Subjects Effects				
Trials	2	241.639	4.164	0.017*
Trials * Modality	2	6.939	0.12	0.887
Trials * Load	4	89.417	1.541	0.193
Trials * Modality * Load	4	52.11	0.898	0.467
Error (Trials)	156	58.025		

The ANOVA resulted in a significant main effect for modality, $F(1, 78) = 4.254$, $p < 0.05$. Figure 9 depicts the mean WWL score of participants for both distance education modalities. The plot indicates the mean WWL score of participants was greater for those who used the mobile device than those that used the desktop computer.

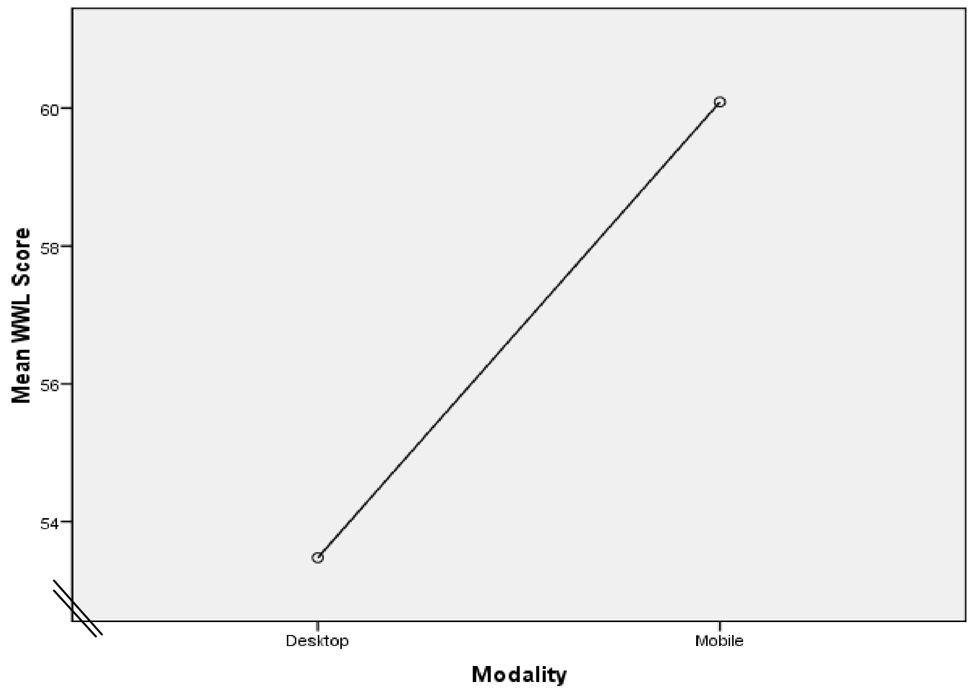

Figure 9-Plot of Mean WWL Score for Both Modalities

Mobile device users perceived higher levels of mental workload than desktop computer users. Reasons for this included having to read the passage from the mobile device's small screen, scrolling limitations, and a preference for desktop computers. Despite the mean WWL score for participants using the mobile device being higher, the majority of these participants responded they would engage with a mobile device to access course material. During the interview of users that used the mobile device for the study, 29 participants stated they would use a mobile device for educational purposes, while 13 stated they would not. Comments participants shared for not wanting to use a mobile device for educational purposes included "educational stuff requires more processing and you cannot do that on the go," "cannot take notes," and "I like the classroom environment better." Although the use of a mobile device may result in higher levels of perceived mental workload, participants indicated they want to take advantage of the convenience and portability mobile devices provide (for example participants stated they always carry their mobile device with them and using the device would make it easier to reach classmates and professors on the go instead of using a laptop). This response is consistent with Trinder et al. (as cited in Kukulska-Hulme, 2007) in that the immediate readiness mobile devices offer is advantageous.

In addition, the ANOVA resulted in a significant main effect for task load, $F(2, 78) = 7.112$, $p < 0.05$. Figure 10 portrays the mean WWL score of participants for each task load level. The plot indicates the mean WWL score of participants was significantly lower for task load level none than task load level high and low.

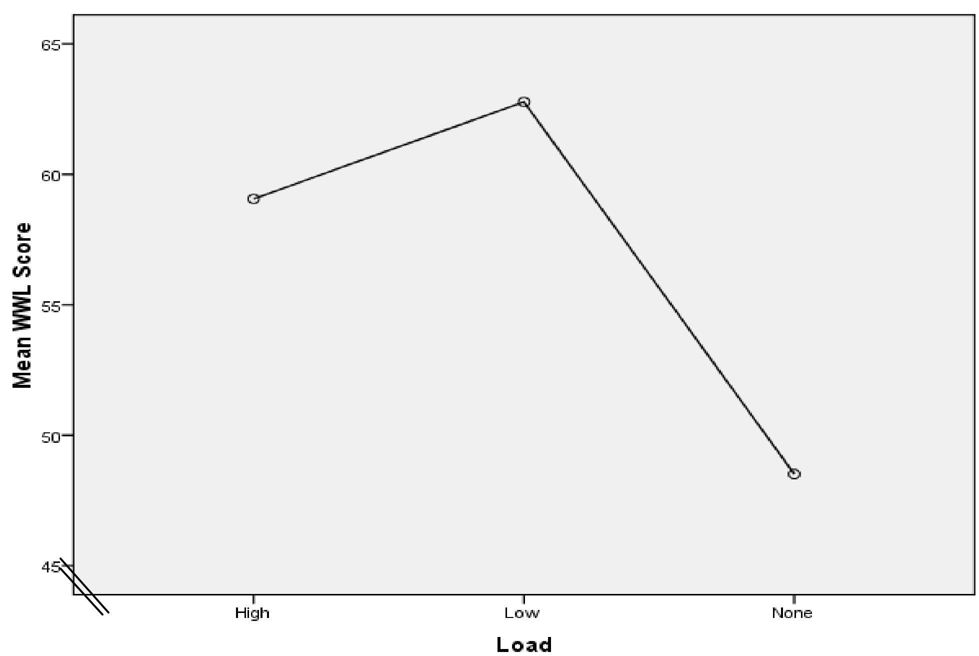

Figure 10-Plot of Mean WWL Score for Task Load Levels

Further analysis was conducted using the Tukey Honestly Significant Differences (HSD) test to perform a pairwise comparison of task load levels. Table 8 reveals the mean WWL score for task load level none is significantly different from task load levels low and high.

Table 8-NASA-TLX WWL Score Pairwise Comparison

	(I) Load	(J) Load	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	High	Low	-3.7190476	3.92526657	.612	-13.0975331	5.6594378
		None	10.5500000*	3.92526657	.024*	1.1715145	19.9284855
	Low	High	3.7190476	3.92526657	.612	-5.6594378	13.0975331
		None	14.2690476*	3.92526657	.001*	4.8905622	23.6475331
	None	High	-10.5500000*	3.92526657	.024*	-19.9284855	-1.1715145
		Low	-14.2690476*	3.92526657	.001*	-23.6475331	-4.8905622

Mobile device users that experienced higher levels of task load perceived higher levels of mental workload. This was expected and consistent with depicting the consumed versus residual resources of individuals completing multiple tasks illustrated in Figure 11 (the greater the demand for resources made by the primary task, the fewer resources available for the secondary task – thus affecting performance on the secondary task) (Kahneman, 1973). It is because of this imbalance that participants expressed higher levels of mental workload.

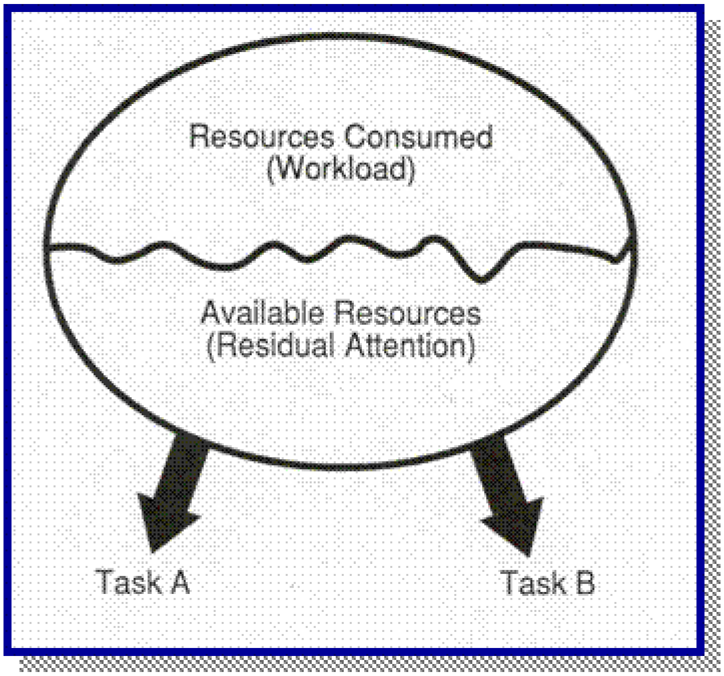

Figure 11-Consumed versus Residual Resources (Source: Kahneman, 1973)

Participants who experienced no task load perceived significantly lower levels of mental workload than those that experienced low and high task load levels. It is interesting to note the mean WWL score for task load level low was higher than task load level high. Reasons for this could stem from individual differences (participant's emotional state, fatigue, motivation), adaptability to the task, and impression of the task (Meshkati, Hancock, Rahimi, & Dawes, 1995).

Lastly the ANOVA resulted in a significant effect for the trials, $F(2, 156) = 4.164$, $p < 0.05$. Figure 12 illustrates the mean WWL score of participants across the trials. The plot indicates the mean WWL score decreased as the number of trials increased and participants' perceived mental workload of completing the task decreased over time.

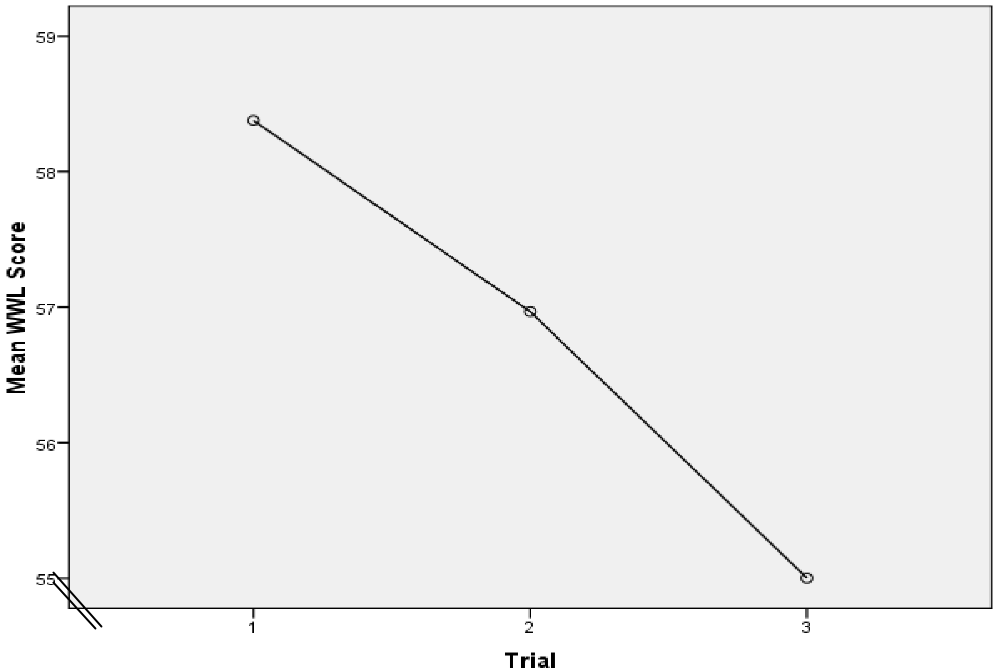

Figure 12-Plot of Mean WWL Score Across Trials

APPENDIX F: NASA-TLX AND SECONDARY TASK ANALYSIS details the ANOVA conducted of the secondary tasks for task load levels low and high. The ANOVA resulted in no significant effects, indicating there was not a significant treatment effect.

Analysis of Physiological Response

Hypothesis 2

H_0: Increased levels of mental workload and the type of distance education modality engaged do not affect physiological response

To evaluate if modality and task load affected participants' physiological response, a mixed effects ANOVA with two between subject factors (modality and task load) and one within subject factor (trials) was conducted. The dependent measure was average heart rate. The ANOVA is shown in Table 9.

Table 9-Physiological Response Analysis of Variance

Source	df	Mean Square	F	Sig.
Between-Subjects Effects				
Modality	1	634.921	1.475	0.228
Load	2	33.921	0.079	0.924
Modality * Load	2	97.968	0.228	0.797
Error	78	430.55		
Within-Subjects Effects				
Trials	2	191.313	25.838	0.000*
Trials * Modality	2	3.456	0.467	0.628
Trials * Load	4	6.296	0.85	0.495
Trials * Modality * Load	4	8.879	1.199	0.313
Error (Trials)	156	7.404		

The ANOVA results indicated the only significant effect was for the trials, $F(2, 156) = 25.838$, $p < 0.05$. Figure 13 shows the mean heart rate of participants while reading the passage across trials. The plot illustrates the heart rate of participants decreased as trials increased.

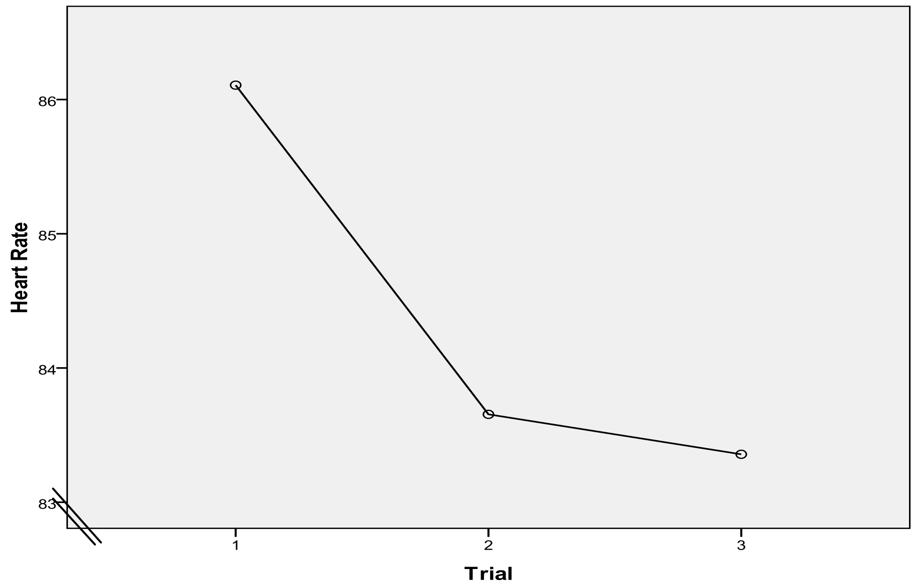

Figure 13-Plot of Mean Heart Rate Across Trials

The intent of the physiological measurement was to examine how participants responded to an imposed task load and if they could maintain performance. A decrease in the average heart rate across trials suggested participants became more comfortable with the task. Looking at individual participant results, there were a few participants that were expressive while reading the passage; their tone corresponded to the tone of the passage thus affecting their heart rate slightly. However overall, average heart rate of participants decreased across trials and was not affected by the distance education modality used or imposed task load level. Because of time constraints and equipment availability, physiological response was measured using the Polar Electro heart rate monitor. Although heart rate is one of the simplest physiological measures used, Meshkati et al., (1995) suggested it lacks generalizability and sensitivity. Future research should use spectral analysis of heart rate variability to determine whether physiological response is affected by increased levels of mental workload and type of distance education modality engaged.

Analysis of Physical Discomfort

Hypothesis 3

H_0: Increased levels of mental workload and the type of distance education modality engaged do not increase physical discomfort

To determine whether modality and task load affected participants' perceived physical demand. A mixed effects ANOVA with two between subject factors (modality and task load) and one within subject factor (trials) was conducted. The dependent measure was the NASA-TLX physical demand rating (APPENDIX F: NASA-TLX AND SECONDARY TASK ANALYSIS details the analysis conducted on the other five NASA-TLX dimensions). The ANOVA is shown in Table 10.

Table 10-NASA-TLX Physical Demand Rating Analysis of Variance

Source	df	Mean Square	F	Sig.
Between-Subjects Effects				
Modality	1	11780.671	11.539	0.001*
Load	2	2170.321	2.126	0.126
Modality * Load	2	592.266	0.58	0.562
Error	78	1020.978		
Within-Subjects Effects				
Trials	2	87.869	1.038	0.357
Trials * Modality	2	19.409	0.229	0.795
Trials * Load	4	119.548	1.412	0.233
Trials * Modality * Load	4	168.325	1.988	0.099
Error (Trials)	156	84.692		

The ANOVA resulted in a significant effect for modality, $F(1, 78) = 11.539$, $p < 0.05$. Figure 14 illustrates the mean physical demand rating of participants for both distance education modalities. The plot indicates the mean physical demand rating was greater for those participants that used the mobile device than those that used the desktop computer.

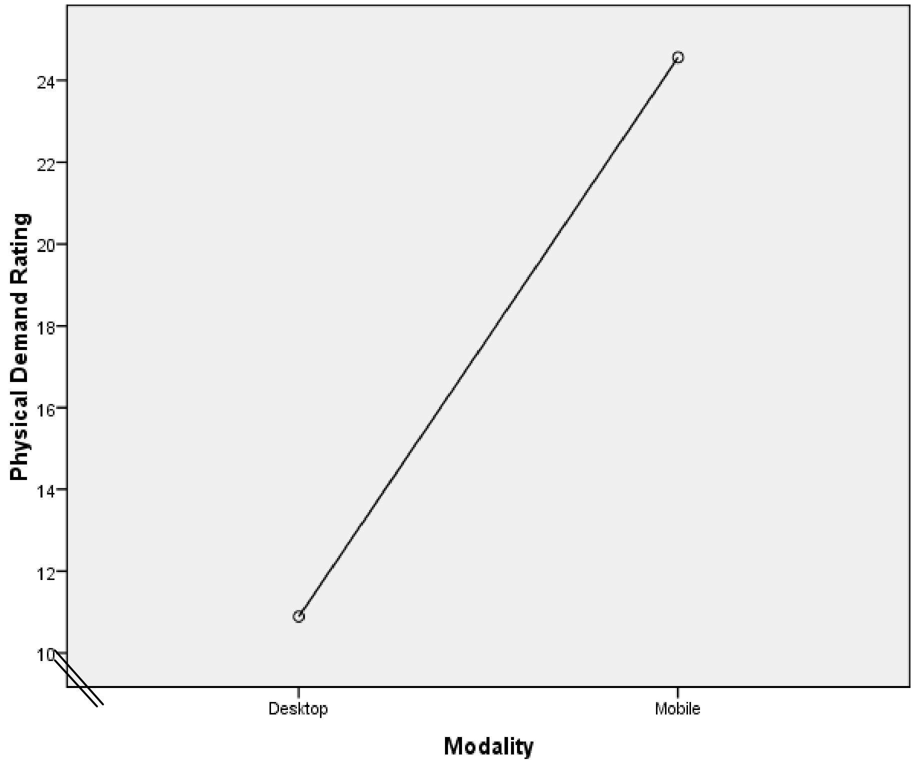

Figure 14-Plot of Mean Physical Discomfort Rating for Both Modalities

Participants that used the mobile device during the experiment experienced higher levels of physical demand than those that used the desktop computer. Table 16 captures the physical discomfort participants endured using the desktop computer and mobile device. The items listed in Table 11 are consistent with the physical discomfort users experienced in Zingale, Ahlstrom, & Kudrick (2005) due to the small size of the device, low resolution, and contrast of the screen.

Table 11-Physical Discomfort Experienced by Participants

Modality	Discomfort	N
Desktop Computer	Eye fatigue	8
	Lower back pain	1
	Shoulder and neck pain	2
	Upper extremities pain	1
	None	30
Mobile Device	Eye fatigue	8
	Lower back pain	1
	Shoulder and neck pain	1
	Upper extremities pain	1
	None	31

Participants that used the desktop computer to complete the reading task indicated eye fatigue was caused by the glare from the monitor. Lower back pain, shoulder and neck pain, and upper extremities pain were experienced as a result of the participants' sitting posture and leaning forward to read the text from the monitor. Participants that used the mobile device to complete the reading task indicated eye fatigue was caused by the small screen size of the device. Lower back pain, shoulder and neck pain, and upper extremities pain were experienced as a result of the participants' sitting posture and the way they held the device in their hand(s) to read the passage.

Although more desktop computer users responded they experienced physical discomfort during the study than mobile devices users (12 desktop computer users compared to 11 mobile device users), mobile device users rated the NASA-TLX physical demand dimension higher than desktop computer users. Reasons for this may stem from physical features of the device, and type and length of the reading task. Despite the physical discomfort experienced by participants using both distance education modalities, 58 of the 84 participants responded they would use a mobile device for educational purposes, with 23 of those participants indicating they would read class material using the device.

Analysis of Reading Performance

Hypothesis 4

H_0: Increased levels of mental workload and the type of distance education modality engaged do not affect reading performance

Reading performance was composed of two measurements: reading mistakes and reading time. To determine whether modality and task load affected the amount of time participants needed to read the passage, a mixed effects ANOVA with two between subject factors (modality and task load) and one within subject factor (trials) was conducted. The dependent measure was elapsed time (in seconds). The ANOVA is shown in Table 12.

Table 12-Reading Time Analysis of Variance

Source	df	Mean Square	F	Sig.
Between-Subjects Effects				
Modality	1	74022.861	3.942	0.051
Load	2	65706.075	3.499	0.035*
Modality * Load	2	25953.456	1.382	0.257
Error	78	18779.495		
Within-Subjects Effects				
Trials	2	20478.099	15.712	0.000*
Trials * Modality	2	414.075	0.318	0.728
Trials * Load	4	618.23	0.474	0.755
Trials * Modality * Load	4	2564.421	1.968	0.102
Error (Trials)	156	1303.353		

The ANOVA showed a significant main effect for task load, $F(2, 78) = 3.499$, $p < 0.05$. Figure 15 plots the mean time required by participants to read the passage for the three levels of task load. The plot indicates the mean time needed for participants to read the passage increased as task load increased.

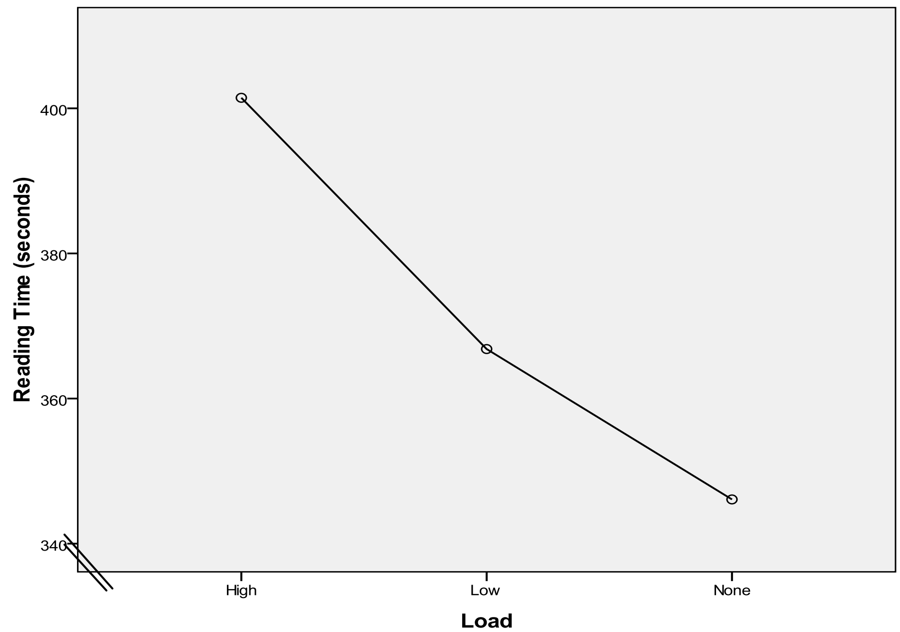

Figure 15-Plot of Mean Reading Time for Task Load Levels

Further analysis was performed using the Tukey HSD to conduct a pairwise comparison of task load levels. Table 13 reveals a significant difference for the amount of time required to read the passage between task load levels none and high across all trials.

Table 13-Reading Time Task Load Levels Pairwise Comparison

	(I) Load	(J) Load	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	High	Low	34.63	21.145	.236	-15.89	85.15
		None	55.36*	21.145	.028*	4.84	105.88
	Low	High	-34.63	21.145	.236	-85.15	15.89
		None	20.73	21.145	.592	-29.80	71.25
	None	High	-55.36*	21.145	.028*	-105.88	-4.84
		Low	-20.73	21.145	.592	-71.25	29.80

In addition, the ANOVA resulted in a significant effect for the trials, $F(2, 156) = 15.712$, $p < 0.05$. Figure 16 plots the mean time required by participants to read the passage across trials. The plot indicates the mean time needed for participants to read the passage decreased as trials increased.

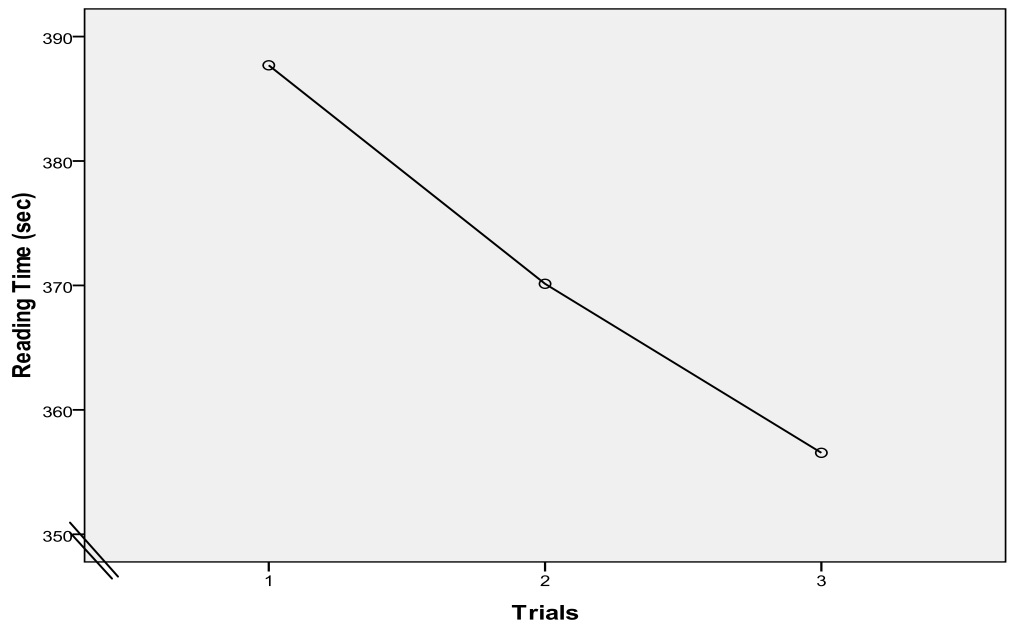

Figure 16-Plot of Mean Reading Time Across Trials

More time was needed by participants who read the passage and completed a secondary task. Reasons for this may stem from impingement of one task on the other and utilization of the same sensory channel for both tasks (Loewenthal, Chignell, & Hancock, 1985).

To evaluate the effect of modality and task load on the number of reading mistakes participants made while reading the passage, a mixed effects ANOVA was performed. There were two between subject factors (modality and task load) and one within subject factor (trials). The dependent measure was number of reading mistakes. The ANOVA is shown in Table 14.

Table 14-Reading Mistakes Analysis of Variance

Source	df	Mean Square	F	Sig.
Between-Subjects Effects				
Modality	1	4.321	0.076	0.783
Load	2	67.909	1.2	0.307
Modality * Load	2	72.583	1.283	0.283
Error	78	56.594		
Within-Subjects Effects				
Trials	2	86.016	13.69	0.000*
Trials * Modality	2	0.571	0.091	0.913
Trials * Load	4	2.546	0.405	0.805
Trials * Modality * Load	4	0.958	0.153	0.962
Error (Trials)	156	6.283		

The ANOVA resulted in only one significant effect for the trials, $F(2, 156) = 13.69$, $p < 0.05$. Figure 17 plots the mean number of mistakes made by participants while reading the passage for all trials. The plot indicates the mean number of mistakes made by participants decreased across trials as the number of trials increased. This decrease suggested despite the task load or distance education modality used, as participants continued reading the passage they became more comfortable with the task.

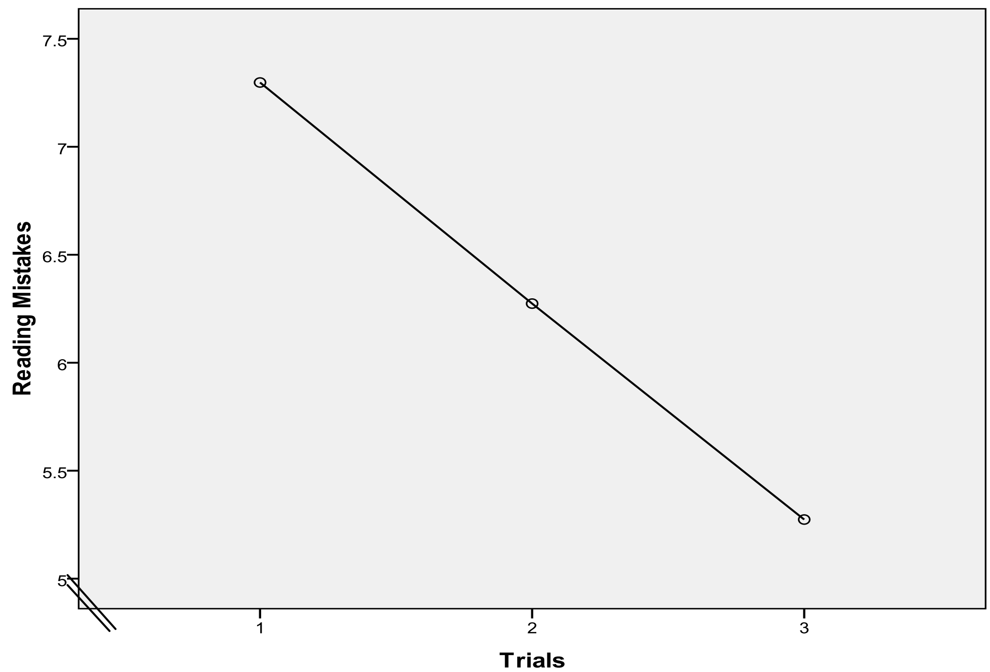

Figure 17-Plot of Mean Reading Mistakes Across Trials

Analysis of Learning Performance

Hypothesis 5

H_0: Increased levels of mental workload and the type of distance education modality engaged do not affect learning performance

Learning performance was composed of two measurements: achievement test scores and learning gain. To determine whether modality and task load affected participants' achievement test scores, a mixed effects ANOVA with two between subject factors (modality and task load) and one within subject factor (trials) was conducted. The dependent measure was test score. The ANOVA is shown in Table 15.

Table 15-Achievement Test Scores Analysis of Variance

Source	df	Mean Square	F	Sig.
Between-Subjects Effects				
Modality	1	11468.254	13.876	0.000*
Load	2	144.444	0.175	0.840
Modality * Load	2	1953.968	2.364	0.101
Error	78	826.496		
Within-Subjects Effects				
Trials	2	725.397	5.073	0.007*
Trials * Modality	2	77.778	0.544	0.582
Trials * Load	4	130.159	0.91	0.460
Trials * Modality * Load	4	292.063	2.043	0.091
Error (Trials)	156	142.979		

The ANOVA showed a significant main effect for modality, $F(1, 78) = 13.876$, $p < 0.05$. Figure 18 shows the mean achievement test score of participants for both distance education modalities. The plot illustrates the mean test score of participants was greater for those who used the desktop computer than the mobile device.

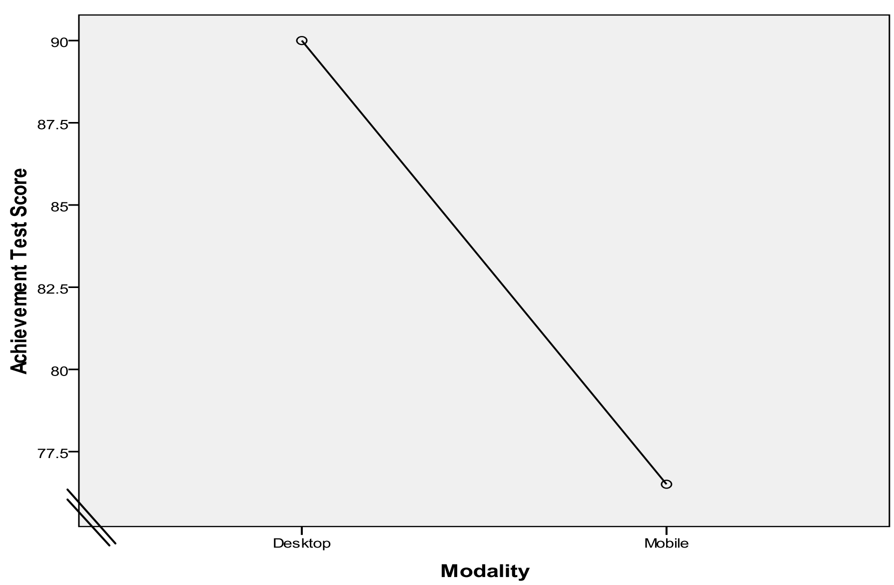

Figure 18-Plot of Mean Achievement Test Score for Both Modalities

The ANOVA also resulted in a significant effect for the trials, $F(2, 156) = 5.073$, $p < 0.05$. Figure 19 represents the mean achievement test scores of participants across the trials. The plot illustrates the mean achievement test score increased as trials increased.

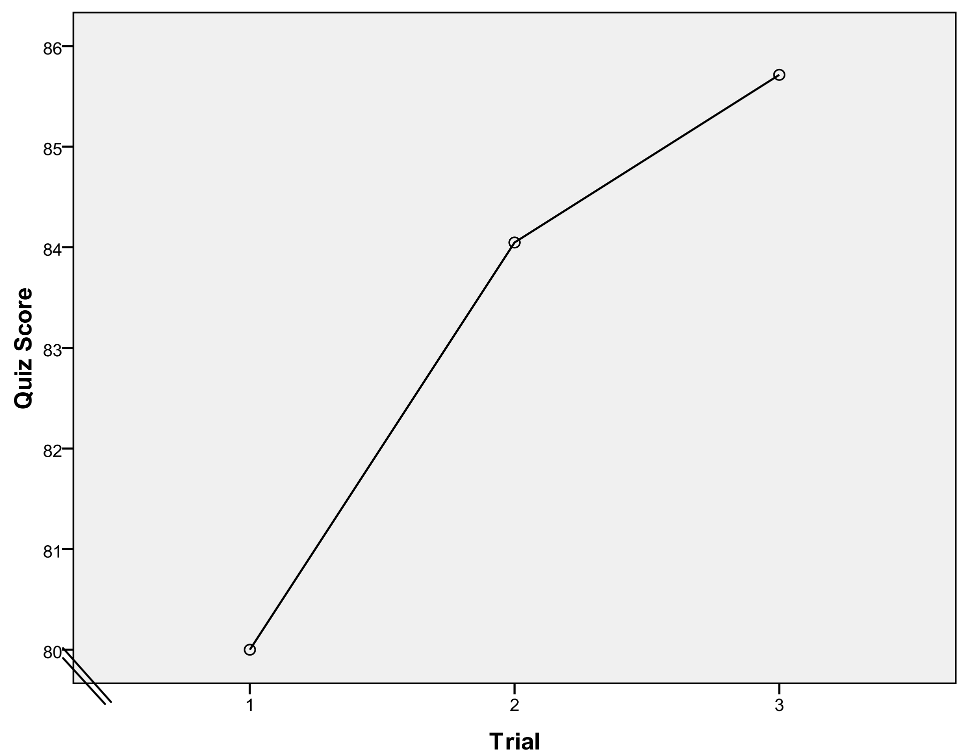

Figure 19-Plot of Mean Achievement Test Score Across Trials

Further analysis was conducted to examine participants' learning gain after reading the passage and taking the achievement test three times. Learning gain was defined as the difference between test scores of the first and third trials. To determine whether modality and task load affected participants' learning gain, a between subjects analysis of variance with two between subject factors (modality and task load) was conducted. The dependent measure was learning gain. The analysis is shown in Table 16.

Table 16-Learning Gain Analysis

Source	df	Mean Square	F	Sig.
Modality	1	304.762	.819	0.368
Load	2	400.000	1.075	0.346
Modality * Load	2	1161.905	3.122	0.050*
Error	78	372.161		

The analysis resulted in a significant effect for the interaction modality*load, $F(2, 78) = 3.122$, $p < 0.05$. Figure 20 shows the mean learning gain of participants for the interaction modality*task load. The plot indicates the mean learning gain for participants using the mobile device and exposed to the low level-task load experienced the highest learning gain.

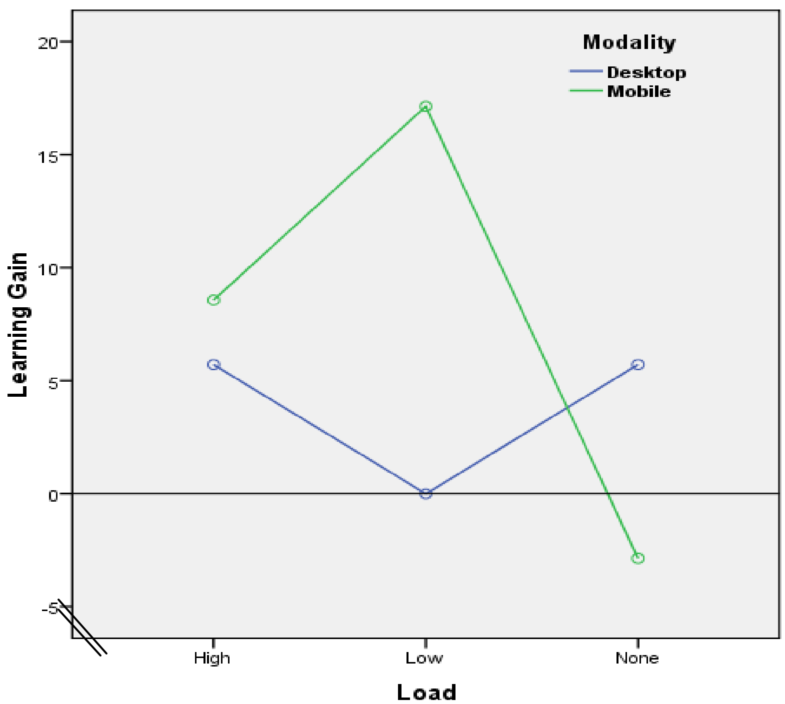

Figure 20-Plot of Mean Learning Gain for Modality*Load Interaction

There was statistical evidence to conclude increased levels of mental workload and the type of distance education modality engaged affected achievement test scores of participants. There was a significant effect for trials and modality. Achievement test scores of participants that used the mobile device were lower than those that used the desktop computer. Reasons hindering participants' ability to comprehend and retain the information read included physical features of the mobile device and task adaptability. Of the 42 participants that used the mobile device for the reading task, only 5 indicated the distance education modality affected their performance. Reasons included not being familiar with the device (despite only using the scroll button feature to scroll up and down the passage), "could not see the text clearly to remember what I was reading," and the "the words could have been bigger." Table 17 is a summary of the features participants indicated they use on their mobile devices. Despite participants using advance features on their mobile devices such as conducting mobile searches, sending and receiving e-mail and using mobile maps, the mobile device used during the experiment affected participants' achievement test scores.

Table 17-Features used on mobile device

Features used on mobile device	N (out of 84)	Percentage (%)	Rank Order
Send and receive text messages	80	95%	1
Send and receive e-mail	46	55%	3
Send and receive instant messages	28	33%	6
Send and receive pictures using the camera feature	59	70%	2
Have desktop instant messages forwarded to your phone	8	1%	9
Watch video or TV programs	14	17%	7
Use mobile search features for movie listings, weather, stock quotes, etc.	43	51%	4
Use mobile maps for driving directions	35	42%	5
None	4	5%	8

There was statistical evidence to conclude increased levels of mental workload and the type of distance education modality engaged affected learning gain of participants. There was a significant effect for the interaction modality*load. Participants that used the mobile device had a higher learning gain than those that used the desktop computer. Of the 42 participants that used the mobile device, 20 indicated completing the secondary task affected their performance. Reasons included “could not pay attention to the passage,” and “hard to comprehend and complete both tasks.” Five participants indicated the distance education modality affected their performance.

The experimental group with the most significant learning gain was mobile device-task load level low. Of the 14 participants in this experimental group, seven responded completing the secondary task affected their performance because it was distracting. Six participants responded reading the passage aloud affected their performance. Reasons included “use to silent reading,” “not paying attention to what I was reading because silent reading helps me focus,” and “I can read faster and clearer silently.” Only one participant responded the distance education modality affected his performance.

The lowest learning gain was mobile device-task load level none. Because a task load was not imposed on participants within this experimental group, they were able to focus completely on the primary task which was reading for comprehension. Of the 14 participants in this experimental group, three stated the distance education modality affected their performance citing physical features of the device as the root cause. The other 11 participants stated reading the passage aloud affected their performance with reasons such as “pressure to pronounce words,” “concerned about being scored and the researcher’s opinion of me,” and “not use to reading aloud.” One participant did reveal that reading the passage aloud reinforced the passage for him.

Summary of Research Questions

The proposed study sought to answer two research questions: 1) Does using mobile learning technologies with increased levels of mental workload introduce physical ergonomic discomfort, and affect physiological levels and perceptions of workload in study participants? and 2) Does using mobile learning technologies with increased levels of mental workload affect the performance of study participants? Potential answers to the two research questions are discussed below along with research implications and limitations of the study.

Summary of Question 1

Based on the results of Hypotheses 1, 2 and 3, mobile learning technologies with increased levels of mental workload introduced physical ergonomic discomfort and affected perceptions of mental workload in study participants. Physiological response was not affected by the increased levels of mental workload or mobile device used during the experiment.

Physical discomfort resulted from three factors: physical features of the mobile device, the actual reading task, and the duration of the reading task. The most recognized physical discomfort experienced by participants was eye fatigue from reading the passage from a small screen, and shoulder and neck pain caused by the participants’ posture in the chair and how they held the mobile device to read. Older participants expressed difficulty adjusting to the physical features of the device and being able to hold the device and scroll using the track ball. The task of reading the passage from the mobile device affect on physical discomfort and perceptions of mental workload may stem from users not wanting to engage in reading activities using a mobile device. Table 18 captures the educational activities participants indicated they would engage using their mobile device. The most popular responses were listening to a podcast of a lecture and sending messages to professors and classmates seeking information and asking and answering questions. Reading class material from a mobile device was not a top priority for students; it was ranked third.

Table 18-Mobile device uses for educational purposes

Features used on mobile device	N (out of 84)	Percentage (%)	Rank Order
Reading class material (lecture notes, slides, articles)	45	54%	3
Listening to a podcast of a lecture	62	74%	2
Send/Receive SMS to/from fellow students and professors	70	83%	1
Record and send video messages for digital story telling	24	29%	4

Although some participants responded using a mobile device for educational purposes would be beneficial in accessing course material on the go, participants did share their desire to read text that is not long. Reading text (particularly small text from a small screen) for an extended period of time would introduce physical ergonomic concerns and higher levels of perceived mental workload.

Summary of Question 2

Based on the results of Hypotheses 4 and 5, mobile learning technologies with increased levels of mental workload affected the reading and learning performance of participants. The amount of reading time required (participants that endured higher levels of task load required more time to read the passage), achievement test score results (mobile device users scored lower than desktop computer users), and learning gain (mobile device users had a higher learning gain than desktop computer users) were affected.

Discussion and Research Implications

The goal of the study was to investigate the notion that, despite the distance education modality used and increased levels of mental workload experienced, a difference in performance among research participants would not exist. Study results did not support this. The conceptual framework pictured in Figure 4 was used to examine if reading a passage with varying levels of task load from a distance education modality affected the physical discomfort, physiological response, perceived mental workload, and overall performance of participants. The research did reveal participants were affected by the distance education modality used and increased levels of mental workload. The results were unexpected for two reasons. First, despite advance features participants indicated they used on their mobile device (Table 17) and being more mobile and relying more on their mobile devices to connect with people and information, when it came to reading a passage from the device without using any other functions on the phone, performance suffered. Second, despite performance suffering, 58 (29 desktop computer users and 29 mobile device users) participants stated they would use a mobile device for educational purposes. Convenience and portability were top reasons offered. When asked what would prevent them from using a mobile device for educational purposes, 47 participants stated connectivity costs while 37 participants stated physical features of the device. Some participants expanded their responses to include examples of educational activities they would engage while using their mobile device: “not videos but reading passages without attachments,” “short quizzes, lecture notes, and e-mails but not long reading passages,” and “would not use for math; just for reading.” The comment “not being able to take notes while using the mobile device” is consistent with Rekkedal and Dye (2007). Researchers provided a keyboard to participants to help facilitate the problem. In Kukulska-Hulme (2007), screen size was identified as the biggest drawback to using PDAs for reading material.

Results of this study provided insight into capabilities and limitations of distance education students in their use of mobile devices for personal and educational purposes. When asked if using a mobile device for educational purposes would help students feel better connected with professors and fellow classmates, 61 participants stated yes. Twenty-three participants stated no, citing the following reasons: “I receive more information from the teacher in person,” “cannot see facial expressions using the mobile device,” “using a desktop computer or laptop would be the same,” and “I use a desktop computer a lot and I do not want to be accessible to classmates and professors 24/7.” Limitations identified should be further examined to aid in building successful m-learning environments so a difference in student performance is not present. It is not anticipated that students will be fully engaged with mobile devices as a replacement of the desktop computer in the immediate future however, because students desire the capability of accessing course material outside the traditional classroom or work environment and do so using their mobile devices, uncovering factors hindering student performance is pertinent. Below are suggestions to help facilitate closing the performance gap:

1. Using Activity Theory as the theoretical foundation, derive a formal definition of mobile learning theory that encompasses all factors and characteristics of each node of the activity system and understand the relationship between each. Aids in focusing on the entire activity system including the people, tools, and learning environment involved.
2. Mobile device producers partnering with distance education programs to design software, platform, and devices conducive for educational purposes and compatible with existing learning management systems.
3. Ergonomic assessment of m-learning activities to ensure they are not physically demanding or result in underload or overload of students.

Leveraging the second contradiction of Engeström's activity system, this study focused on the relationships between the subject, tool, and object. Activity Theory was used as the theoretical framework to examine an activity and identify areas of development (contradictions). Contradictions can be used to determine disruptions for changes and development of the system. Examining contradictions can help identify capabilities and limitations and their impact on the relationship between nodes. The relationship between the subject and object presented the contradiction between task and its affect on the subject. For this study the task of reading a passage with varying levels of task load affected participants' perceived mental workload. This suggested a performance-workload association (Burke, Szalma, Gilad, Duley, & Hancock, 2005; Yeh & Wickens, 1988). Performance decrements occurred because of competition for processing resources which lead to higher ratings of perceived mental workload from participants. The relationship between the subject and tool presented the contradiction between physical features of the mobile device and its affect on the participant. For this study the tool (mobile device) resulted in participants experiencing physical discomfort such as eye fatigue and shoulder and neck pain. The relationship between the three nodes affected reading and learning performance.

By expanding Kukulska-Hulme's (2002) research to examine cognitive and physical ergonomics influence on m-learning, the study fulfilled the research gap and investigated the impact distance education modality and task load have on an m-learning activity. The research contributed to the body of knowledge of how Activity Theory can be used to examine m-learning environments. From the Activity Theory perspective, the study's findings are significant to successful m-learning environments in the following ways:

1. Subject – identification of physical and cognitive limitations (discomfort and higher levels of mental workload) of users when engaging with a mobile device for educational purposes.
2. Tool – identification of physical features and limitations of the mobile device causing discomfort. This is beneficial to creators of mobile devices in enhancing physical features (for example presence of a scroll bar to identify length of material, a "home" key to get back to the top of a page) in order to be conducive for m-learning environments.
3. Object – identification of educational material and tasks distance education students can engage while using their mobile device. This is beneficial for practical reasons such as aiding in the creation and delivery format of educational content to be pushed to students.

The research outcomes are significant because they demonstrated despite the advance features and functions mobile device users have become accustomed to using, when using the devices for educational purposes, individual performance levels may suffer. The research confirms the need for continual examination of educational tasks fitting for mobile devices that take into account ergonomic factors and content delivery.

Limitations

Because of time constraints and a limited number of distance education students available to participate in the study, the study participation requirements were broaden to include all students and working professionals over the age of 25, not just current distance education students. The selected reading passage was not work or course related which might have affected participants' motivation to learn the material. The reading passage was sports related. One participant expressed his dislike for sports. A few others found the phrasing of the story to be "wordy" and the writing style of the author hard to follow. Motivation to learn the reading passage and perform well may have been different if participants read content that was work or course related that determined their success on a work or class assignment.

The experiment environment may have affected participants' performance. During the sessions, the researcher sat beside the participant for two reasons: First, the heart rate monitor used had a three feet range. Because the researcher wore the watch and the participant wore the heart rate monitor chest strap, the researcher had to sit close to ensure an accurate reading was obtained. Second, the researcher recorded reading mistakes made by the participant, and needed to be in the room with participants to record the mistakes. Instead, the experiment environment could have been set up differently to include: (a) a different heart rate monitor device with a greater range or different monitoring features, and (b) a video camera set up so the researcher could be outside the testing room but could still hear and record the reading mistakes.

A clicker or counting device was not used to assist participants with the secondary task. Although the secondary task consisted of imposing a mental task on participants while they read the passage, there was no way to ensure participants actually completed the task. Implementing a clicker or counting device would ensure participants actually attempted to complete the secondary task.

CHAPTER FIVE: CONCLUSION

The purpose of this research was to examine the physical, physiological, and perceived mental workload issues distance education students experienced while using m-learning technologies to access course material. The research addressed how these issues affected students' performance and perception of using mobile devices for educational purposes. The aim of the research was to determine whether despite increased levels of task load imposed on students using a mobile device for educational purposes, a difference would not exist in their performance. Participants read a passage using one of two distance education modalities, while experiencing one of three task load levels. Table 19 captures the results of the research questions and hypotheses posited for the study.

Table 19-Research Question and Hypotheses Summary

Research Question	Research Answer	Hypothesis	Accept/Reject H_0
Does using mobile learning technologies with increased levels of task load introduce physical ergonomic discomfort, and affect physiological levels and perceptions of mental workload in distance education students?	Mobile learning technologies with increased levels of mental workload introduced physical ergonomic discomfort and affect perceptions of workload in study participants	Increased levels of task load and the type of distance education modality engaged do not affect perceived mental workload	Reject
		Increased levels of task load and the type of distance education modality engaged do not affect physiological response (heart rate)	Accept
		Increased levels of task load and the type of distance education modality engaged do not increase physical discomfort	Reject
Do using mobile learning technologies with increased levels of task load affect the performance of distance education students?	Mobile learning technologies with increased levels of mental workload affected the performance of study participants	Increased levels of task load and the type of distance education modality engaged do not affect reading performance	Reject
		Increased levels of task load and the type of distance education modality engaged do not affect learning performance	Reject

Five hypotheses were tested to determine whether the distance education modality and task load affected participants' physical discomfort, subjective mental workload, physiological response, and performance (reading and learning). The results revealed there was statistical evidence to conclude increased levels of task load and the type of distance education modality engaged increased perceived mental workload levels of participants, physical discomfort, reading time and learning performance. Statistical evidence did not exist to conclude increased levels of mental workload and the type of distance education modality engaged increased physiological response or reading mistakes.

Future Research

During the interview session, subjects revealed activities they would engage while using their mobile device for educational purposes (Table 18). Future research could explore the effect engaging in those activities with a mobile device would have on students' performance, perceived mental workload, and satisfaction levels. Because the sample for this study was broadened to include any person over the age of 25, future research could limit the sample population to include only current distance education students over the age of 25 where the content used was course related (data could be taken across a semester). Using Activity Theory as the theoretical framework, future research can examine other contradictions illustrated in Figure 3 to analyze cognitive and physical ergonomic issues affecting m-learning environments (for example the primary contradiction would examine each node and identify cognitive and physical ergonomic factors imposed on m-learning environments).

The research taken from the adult student perspective will provide educators an understanding of the physical and cognitive issues students may face when using mobile devices in learning environments. The significance of extending Kukulska-Hulme's (2002) research was to examine ergonomic issues preventing subjects from maximizing the use of mobile devices in m-learning environments. Extending the study allowed the current study to not be focused on just usability, but the relationship between the user, mobile device, and educational task, and their affect on student performance. Understanding these relationships will aid in utilizing and creating successful m-learning environments in the future for distance education programs.

APPENDIX A: INFORMED CONSENT

<u>Project Title:</u> Physical Ergonomic and Mental Workload Factors of Mobile Learning Affecting Performance and Satisfaction Levels of Adult Professional Distance Learners: Student Perspective
<u>Investigator:</u> Rochelle Jones, Industrial Engineering Doctoral Student, UCF

Please read this consent document carefully before you decide to participate in this study. You must be 25 years of age or older to participate.

Research Purpose: The purpose of this research is to examine the physical, physiological, and task load issues distance education students experience while utilizing mobile learning technology to access course material that impact their performance and satisfaction. If you agree to participate in this research study, you will be one of approximately 80 subjects. This research project is part of a doctoral study.

Explanation of procedures: Subjects will be asked to read aloud a passage using a distance education modality (either a desktop computer or mobile device) while simultaneously completing a secondary task. Afterwards, subjects will be given a quiz and a questionnaire to complete rating perceived effort. During each trial, a heart monitor device will be used to obtain and measure subjects' heart rate. The monitor is being used for non-medical purposes. The researcher is trained in the use of this device and will administer the monitor for research purposes only. The participant will have the procedure explained and he/she will be told that this measure is for research purposes only and when complete it will not be given to a medical professional to review nor will they receive a copy. The measure will be immediately coded and separated from their name so it will not be possible to match the name with the consent form or the participant's identity.

Time required: 20 to 35 minutes per trial. Each subject will be asked to participate in 3 trials (all occurring on the same day).

Risks: There are no known risks associated with this experiment. You will not encounter any harmful or explicit material.

Benefits/Compensation: There are no direct benefits or compensation for participation.

Confidentiality: Your identity will be kept confidential. Your information (test instruments and demographic survey) will be assigned a code number and will be stored separately. When the study is completed and the data analyzed, all test instruments and questionnaires will be destroyed. Your name will not be used in any report.

Voluntary participation: Your participation is voluntary. There is no penalty for not participating. Subjects do not have to answer any question that he/she does not wish to answer when doing survey, interview or questionnaire research.

Right to withdraw from the study: You have the right to withdraw from the study at any time without consequence.

Whom to contact if you have questions about the study: Rochelle Jones, Doctoral Student, (407) 484-8118; Dr. Pamela McCauley-Bush, Faculty Advisor, Department of Industrial Engineering and Management Systems, (407) 823-6092. Questions or concerns about research participants' rights may be directed to the University of Central Florida Institutional Review Board Office at the University of Central Florida, Office of Research & Commercialization, 12201 Research Parkway, Suite 501, Orlando, FL 32826-3246. The phone number is 407-823-2901.

- ☐ I have read the procedure described above
- ☐ I am 25 years old or older
- ☐ I voluntarily agree to participate in the procedure and can receive a copy of this description upon request

______________________________	______________________________	__________
Signature of Subject	Subject Name (please print)	Date

APPENDIX B: MOBILE DEVICE SPECIFICATIONS

Features Available	• Wireless e-mail • Organizer • Browser • Phone • BlackBerry® Maps • Media player • Corporate data access • SMS • MMS • GPS
Size and Weight	• 4.49"/114mm (Length) • 2.60"/66mm (Width) • 0.55"/14mm (Depth) • 4.6 oz/132g (Weight)
Data Input/Navigation	• Trackball • QWERTY (Keyboard) • Keyboard backlighting
Voice Input/Output	• Stereo headset capable • Headset jack • Integrated earpiece/ microphone • Built-in speakerphone • Headset, hands-free and serial port profiles supported (Bluetooth® technology) • M4, T4
Display	• Font size (user selectable) • Color display • Backlighting • Light sensing screen
Notification	• Polyphonic/MIDI ringtones • MP3 ringtones • Vibrate mode • LED indicator
Approximate Battery Life	• Standby time: up to 16 days, Talk time: up to 300 minutes (GSM/GPRS) • Standby time: up to 9 days, Talk time: up to 220 minutes (CDMA)
Memory	• Expandable memory – support for microSD card • 64 MB (Flash memory)
Modem	• RIM® wireless modem • Tethered modem capability
E-mail Integrations	• Works with BlackBerry® Enterprise Server for Microsoft® Exchange

	• Works with BlackBerry® Enterprise Server for IBM® Lotus® Domino® • Works with BlackBerry® Enterprise Server for Novell® GroupWise® • Integrates with an existing enterprise e-mail account • Integrates with optional new device account
Accessories Included	• USB cable • Wall charger
Device Security	• Password protection and keyboard lock • Support for AES or Triple DES encryption when integrated with BlackBerry® Enterprise Server • FIPS 140-2 Validated (FIPS validation) • Optional support for S/MIME
Wireless Network	• Dual-band 900/1800 Mhz GSM/GPRS networks • Dual-band 800/1900 MHz CDMA2000 1X Ev-DO networks

APPENDIX C: SUBJECT QUESTIONNAIRE

Project Title: Physical Ergonomic and Mental Workload Factors of Mobile Learning Affecting Performance and Satisfaction Levels of Adult Professional Distance Learners: Student Perspective
Investigator: Rochelle Jones

Age: ____________ Gender (circle one): Male Female

Profession: __________________________

Do you own a mobile device? (circle one): Yes No

Make and model of your mobile device: ____

How long have you had your mobile device? (select one)

< 3 months 3 – 6 months 6 -12 months 12 – 24 months > 2 years

Rate your mobile device usage: (select one)

Heavy Above Average Average Below Average Barely

Which features have you used on your mobile device? (circle all that apply):

Send and receive text messages	Send and receive instant messages
Send and receive e-mail	Have desktop instant messages forwarded to your phone
Watch video or TV programs	Use mobile search features for movie listings, weather, stock quotes, etc.
Send and receive pictures using the camera feature	Use mobile maps for driving directions

Have you ever used your mobile device to access course material? (circle one): Yes No

How satisfied are you with you mobile device? (select one):

Very Satisfied Somewhat Satisfied Neutral Somewhat Dissatisfied Very Dissatisfied

Do you own a desktop computer? (circle one): Yes No

Do you own a laptop? (circle one): Yes No

Do you use the Internet on your desktop computer or laptop? (circle one): Yes No

In general, how familiar with computers would you say you are? (select one)

Very Familiar	Fairly Familiar	Neutral	Slightly Familiar	Not at all

How many times in a typical week do you send e-mail? (select one)

Zero	1 – 5	6 – 10	11 – 15	16 – 20	21+

How many times in a typical week do you access the World Wide Web? (select one)

Zero	1 – 5	6 – 10	11 – 15	16 – 20	21+

How long have you been using a personal computer?

< 1 year	1 – 2 years	2 – 5 years	5 – 10 years	> 10 years

How many Web-based training classes have you taken? (select one)

0	1	2	3 or more

How many college (academic) courses have you taken in which there was some use made of the Internet and/or the World Wide Web? (select one)

0	1	2	3 or more

What is your ethnicity? (select one)

White / Caucasian	Hispanic	Black/African American	Asian American/Pacific Islander	American Indian	Other ___________

Test Subject # ______________________

APPENDIX D: READING PASSAGE

They Might Be Giants

by Dave Barry

OK, fans. Time for Great Moments in Sports. The situation is this: The Giants are playing a team whose name we did not catch in the hotly contested Little League Ages 6 and 7 Division, and the bases are loaded. The bases are always loaded in this particular Division for several reasons.

First off, the coach pitches the ball to his own players. This is because throwing is not the strong suit of the players in the Ages 6 and 7 Division. They have no idea, when they let go of the ball, where it's headed. They just haul off and wing it, really try to hurl that baby without getting bogged down in a lot of picky technical details such as whether or not there is now, or has ever been, another player in the area where the ball is likely to land. Generally there is not, which is good, because another major area of weakness, in the Ages 6 and 7 Division, is catching the ball.

Until I became a parent, I thought children just naturally knew how to catch a ball, that catching was an instinctive biological reflex that all children are born with, like knowing how to operate a remote control or getting high fevers in distant airports. But it turns out that if you toss a ball to a child, the ball will just bonk off the child's body and fall to the ground. So you have to coach the child. I go out in the yard with my son, and I give him helpful tips such as: "Catch the ball!" And: "Don't just let the ball bonk off your body!" Thanks to this coaching effort, my son, like most of the players on the Giants, has advanced his game to the point where, just before the ball bonks off his body, he winces.

So fielding is also not the strong suit of the Giants. They stand around the field, chattering to each other, watching airplanes, picking their noses, thinking about dinosaurs, etc. Meanwhile on the pitchers' mound, the coach of the opposing team tries to throw the ball just right so that it will bounce off the bat of one of his players, because hitting is another major area of weakness in the Ages 6 and 7 Division.

The real athletic drama begins once the opposing coach succeeds in bouncing the ball off the bat of one of his players, thus putting the ball into play and causing the fielders to swing into action. It reminds me of those table-hockey games, where you have a bunch of little men that you activate with knobs and levers, except that the way you activate the Giants is, you yell excitedly in an effort to notify them that the ball is headed their way. Because otherwise they'd probably never notice it.

"Robby!" I'll yell if the ball goes near my son. "The ball!" Thus activated, Robby goes on Full Red Alert, looking around frantically until he locates the ball, which he picks up and — eager to be relieved of the responsibility — hurls in some random direction. Then, depending on where the ball is headed, some other parent will try to activate his child, and the ball will be hurled again and again, pinball-style, around the field, before ultimately bonking off the body of the first baseman. Of course at this point the batter has been standing on the base for some time. Fortunately, in this league, he is required to stop there; otherwise, he could easily make it to Japan.

This is why the bases are always loaded, which is what leads us to today's Sports Moment. Standing on third base is James Palmieri, who is only 5, but who plays for the Giants anyway because his older brother, T.J., is on the team. James got on base via an exciting play: He failed to actually, technically, hit the ball, but the Giants' wily coach, Wayne Argo, employed a classic bit of baseball strategy. "Let's let James get on base," he said. And the other team agreed, because at this point the Giants were losing the hotly contested game by roughly 143 — 57.

So here it is: James is standing on third, for the first time in his entire life, thinking about dinosaurs, and next to him, ready to activate, is his mom, Carmen. And now Coach Wayne is throwing the pitch. It is a good pitch, bouncing directly off the bat. Bedlam erupts as parents on both teams try to activate their players, but none is shouting with more enthusiasm than Carmen. "Run, James!" she yells, from maybe a foot away. "Run!"
James, startled, looks up, and you can almost see the thought forming in his mind: I'm supposed to run. And now he is running, and Carmen is running next to him, cheering him on, the two of them chugging toward the plate, only 15 feet to go, James about to score his first run ever. Then suddenly, incredibly, due to a semi-random hurl somewhere out in the field, there appears of all things: the ball. And — this is a nightmare — an opposing player actually catches it, and touches home plate and little James is OUT.

Two things happen: One, Carmen stops. She says a bad word. A mom to the core. Two, James, oblivious, keeps running. Chugs right on home, touches the plate smiling and wanders off, happy as a clam. You can have your Willie Mays catch and your Bill Mazeroski home run. For me, the ultimate mental picture is James and Carmen at that moment: the Thrill of Victory, the Agony of Defeat. A Great Moment in Sports.

APPENDIX E: NASA-TLX ASSESSMENT TOOL

NASA-TLX Mental Workload Rankings

INSTRUCTIONS: For each of the pairs listed below, circle the scale title that represents the more important contributor to workload in the task you just performed.

Mental Demand	or	Physical Demand
Temporal Demand	or	Mental Demand
Performance	or	Mental Demand
Effort	or	Mental Demand
Frustration	or	Mental Demand
Temporal Demand	or	Physical Demand
Performance	or	Physical Demand
Effort	or	Physical Demand
Frustration	or	Physical Demand
Temporal Demand	or	Performance
Temporal Demand	or	Frustration
Temporal Demand	or	Effort
Performance	or	Frustration
Performance	or	Effort
Frustration	or	Effort

NASA-TLX Mental Workload Rating Scale

INSTRUCTIONS: Please place an “X” along each scale at the point that best represents the magnitude of each factor in the task you just performed.

<u>Mental Demand</u>: How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc)? Was the mission easy or demanding, simple or complex, exacting or forgiving?

Low High

<u>Physical Demand</u>: How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the mission easy or demanding, slow or brisk, slack or strenuous, restful or laborious?

Low High

<u>Temporal Demand</u>: How much time pressure did you feel due to the rate or pace at which the mission occurred? Was the pace slow and leisurely or rapid and frantic?

Low High

<u>Performance</u>: How successful do you think you were in accomplishing the goals of the mission? How satisfied were you with your performance in accomplishing these goals?

Low High

<u>Effort</u>: How hard did you have to work (mentally and physically) to accomplish your level of performance?

Low High

<u>Frustration</u>: How discouraged, stressed, irritated, and annoyed versus gratified, relaxed, content, and complacent did you feel during your mission?

Low High

APPENDIX F: NASA-TLX AND SECONDARY TASK LOAD ANALYSIS

APPENDIX F presents the statistical procedures (descriptive analysis, mixed effects ANOVA, and pairwise comparisons) performed and analysis of the other five dimensions of the NASA-TLX and the secondary task participants completed.

Mental Demand

To determine if modality and task load affected participants' perceived mental demand, a mixed effects ANOVA with two between subject factors (modality and task load) and one within subject factor (trials) was conducted. The dependent measure was the NASA-TLX mental demand rating. The ANOVA is shown in Table 20.

Table 20-NASA-TLX Mental Demand Rating Analysis of Variance

Source	df	Mean Square	F	Sig.
Between-Subjects Effects				
Modality	1	4250.893	3.282	0.074
Load	2	24564.250	18.965	0.000*
Modality * Load	2	1399.155	1.080	0.345
Error	78	1295.230		
Within-Subjects Effects				
Trials	2	737.726	6.391	0.002*
Trials * Modality	2	345.679	2.995	0.053
Trials * Load	4	186.030	1.612	0.174
Trials * Modality * Load	4	140.030	1.213	0.307
Error (Trials)	156	115.425		

The ANOVA resulted in a significant effect for task load, $F(1, 78) = 18.965$, $p < 0.05$. Figure 21 illustrates the mean mental demand rating of participants for each task load level. The plot indicates the mean mental demand rating was significantly lower for task load level none than task load levels high and low.

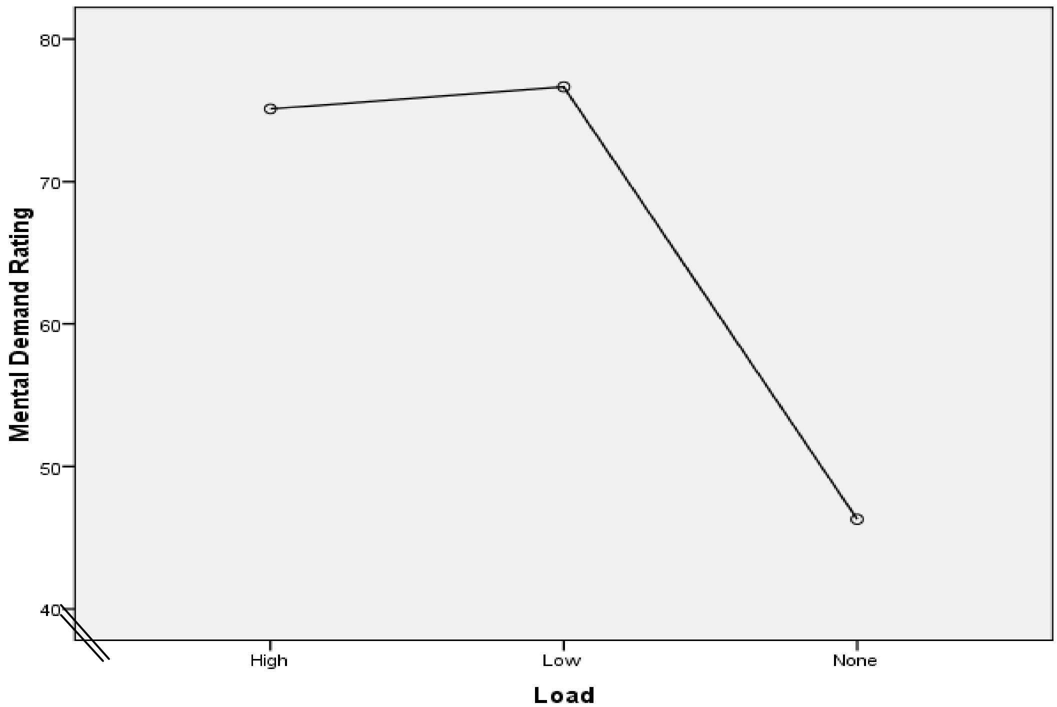

Figure 21-Plot of Mean Mental Demand Rating for Task Load Levels

The ANOVA also resulted in a significant effect for the trials, $F(2, 156) = 6.391$, $p < 0.05$. Figure 22 depicts the mean mental demand rating of participants across the trials. The plot indicates the mean mental demand rating decreased as the number of trials increased indicating participants' perceived mental demand of completing the task decreased over time.

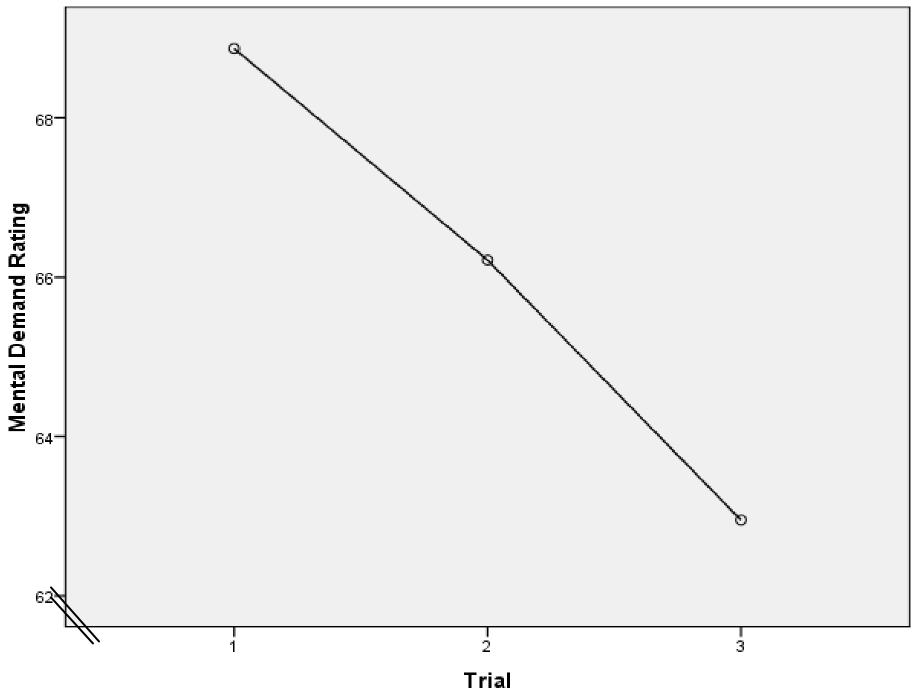

Figure 22-Plot of Mean Mental Demand Rating Across Trials

Temporal Demand

To determine if modality and task load affected participants' perceived temporal demand, a mixed effects ANOVA with two between subject factors (modality and task load) and one within subject factor (trials) was conducted. The dependent measure was the NASA-TLX temporal demand rating. The ANOVA is shown in Table 21 which resulted in no significant effects.

Table 21-NASA-TLX Temporal Demand Rating Analysis of Variance

Source	df	Mean Square	F	Sig.
		Between-Subjects Effects		
Modality	1	843.337	0.516	0.475
Load	2	509.635	0.312	0.733
Modality * Load	2	146.778	0.09	0.914
Error	78	1634.458		
		Within-Subjects Effects		
Trials	2	447.647	2.321	0.102
Trials * Modality	2	83.718	0.434	0.649
Trials * Load	4	81.623	0.423	0.792
Trials * Modality * Load	4	212.087	1.099	0.359
Error (Trials)	156	192.904		

Performance

To determine if modality and task load affected participants' perceived performance, a mixed effects ANOVA with two between subject factors (modality and task load) and one within subject factor (trials) was conducted. The dependent measure was the NASA-TLX performance rating. The ANOVA is shown in Table 22.

Table 22-NASA-TLX Performance Rating Analysis of Variance

Source	df	Mean Square	F	Sig.
		Between-Subjects Effects		
Modality	1	1152.861	1.068	0.305
Load	2	5341.218	4.947	0.009*
Modality * Load	2	5780.171	5.354	0.007*
Error	78	1079.632		
		Within-Subjects Effects		
Trials	2	114.528	0.725	0.486
Trials * Modality	2	28.028	0.177	0.838
Trials * Load	4	33.069	0.209	0.933
Trials * Modality * Load	4	377.998	2.391	0.053
Error (Trials)	156	158.077		

The ANOVA resulted in a significant effect for task load, $F(1, 78) = 4.947$, $p < 0.05$. Figure 23 shows the mean performance rating of participants for each task load level. The plot indicates the mean performance rating was significantly lower for task load level high than task load level low and none indicating participants imposed with task load level high, believed their performance was negatively affected.

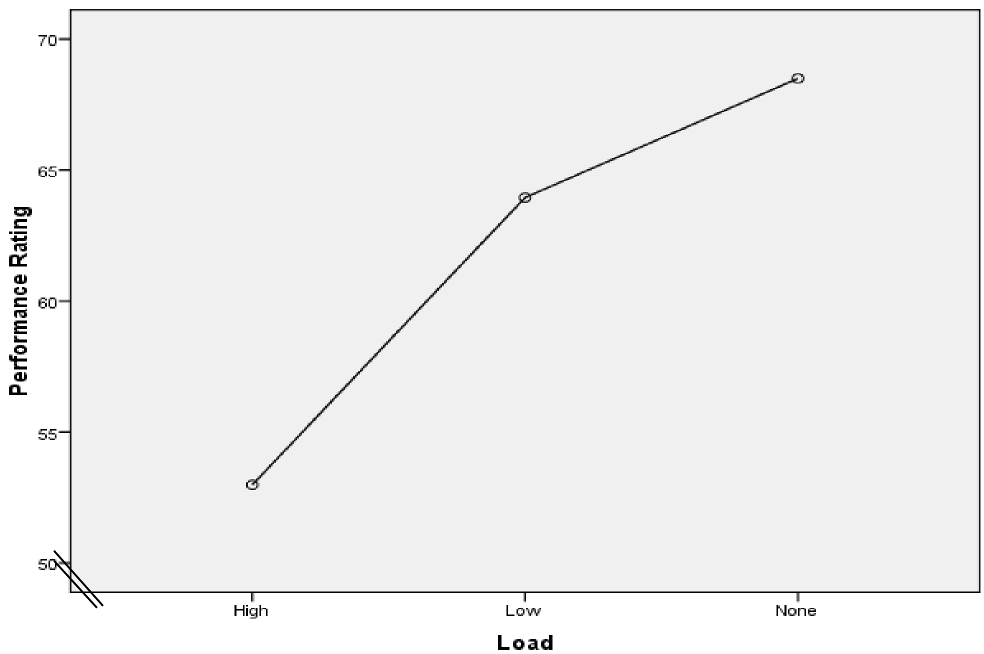

Figure 23-Plot of Mean Performance Rating for Task Load Levels

The analysis also resulted in a significant effect for the interaction modality*load, $F(2, 78) = 5.354$, $p < 0.05$. Figure 24 illustrates the mean performance rating of participants for the interaction modality*task load. The plot indicates the mean performance rating of participants using the desktop computer and experiencing no load was higher than the other experimental groups suggesting participants in this group were satisfied with their performance. It is interesting to note that participants that used the mobile device and experienced low and high levels of task load rated their satisfaction with their performance higher than desktop computer users that experienced high and low levels of task load.

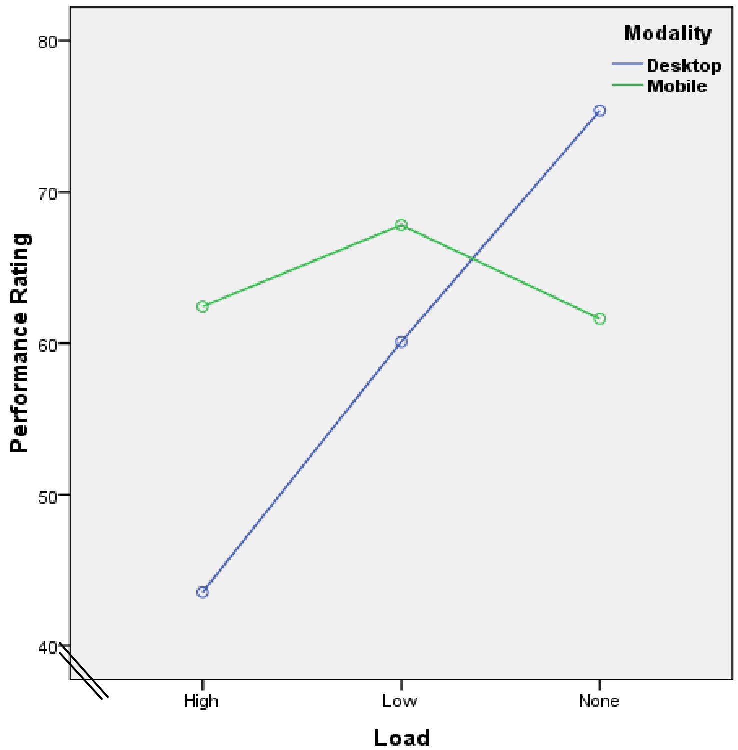

Figure 24-Plot of Mean Performance Rating for Modality*Load Interaction

<u>Effort</u>

To determine if modality and task load affected participants' perceived effort needed to complete the task, a mixed effects ANOVA with two between subject factors (modality and task load) and one within subject factor (trials) was conducted. The dependent measure was the NASA-TLX effort rating. The ANOVA is shown in Table 23.

Table 23-NASA-TLX Effort Rating Analysis of Variance

Source	df	Mean Square	F	Sig.
Between-Subjects Effects				
Modality	1	6945.75	5.473	0.022*
Load	2	14424.206	11.366	0.000*
Modality * Load	2	646.429	0.509	0.603
Error	78	1269.077		
Within-Subjects Effects				
Trials	2	947.171	4.829	0.009*
Trials * Modality	2	54.25	0.277	0.759
Trials * Load	4	211.052	1.076	0.370
Trials * Modality * Load	4	295	1.504	0.204
Error (Trials)	156	196.16		

The ANOVA resulted in a significant effect for modality, $F(1, 78) = 5.473$, $p < 0.05$. Figure 25 displays the mean effort rating of participants for both distance education modalities. The plot suggests the mean effort rating of participants was greater for those who used the mobile device than the desktop computer. This implies mobile device users perceived accomplishing their level of performance required more effort than desktop computer users.

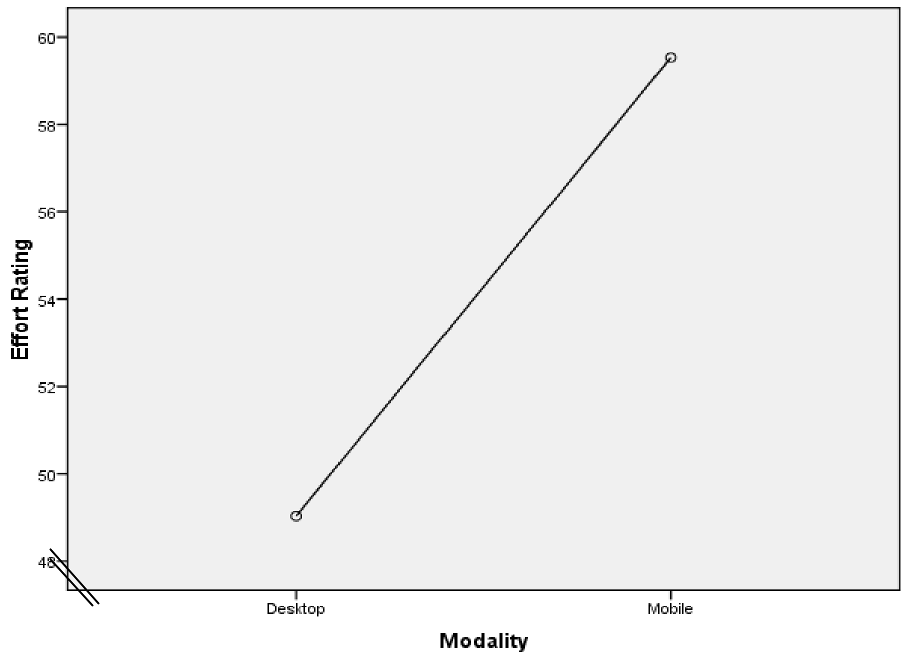

Figure 25-Plot of Mean Effort Rating for Both Modalities

The ANOVA also resulted in a significant effect for task load, $F(1, 78) = 11.366$, $p < 0.05$. Figure 26 shows the mean effort rating of participants for each task load level. The plot indicates the mean effort rating was significantly lower for task load level none than task load levels high and low indicating participants imposed with no task load level perceived the amount of effort needed to complete the task as small.

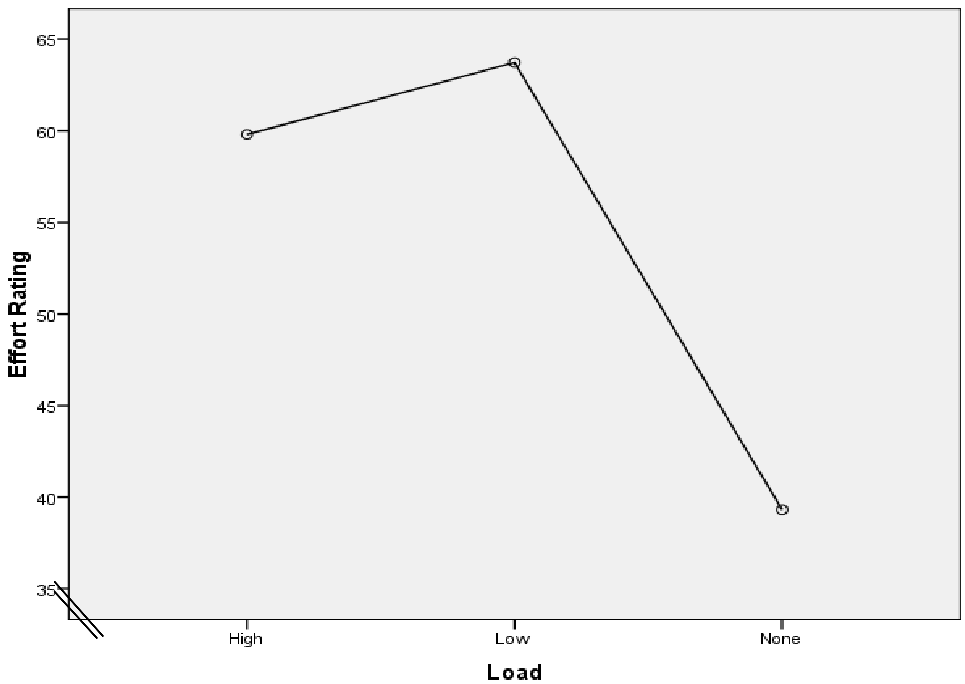

Figure 26-Plot of Mean Effort Rating for Task Load Levels

The ANOVA also resulted in a significant effect for the trials, $F (2, 156) = 4.829$, $p < 0.05$. Figure 27 depicts the mean effort rating of participants across the trials. The plot indicates the mean effort rating decreased as the number of trials increased indicating participants' perception of the amount of effort needed to complete the task decreased over time.

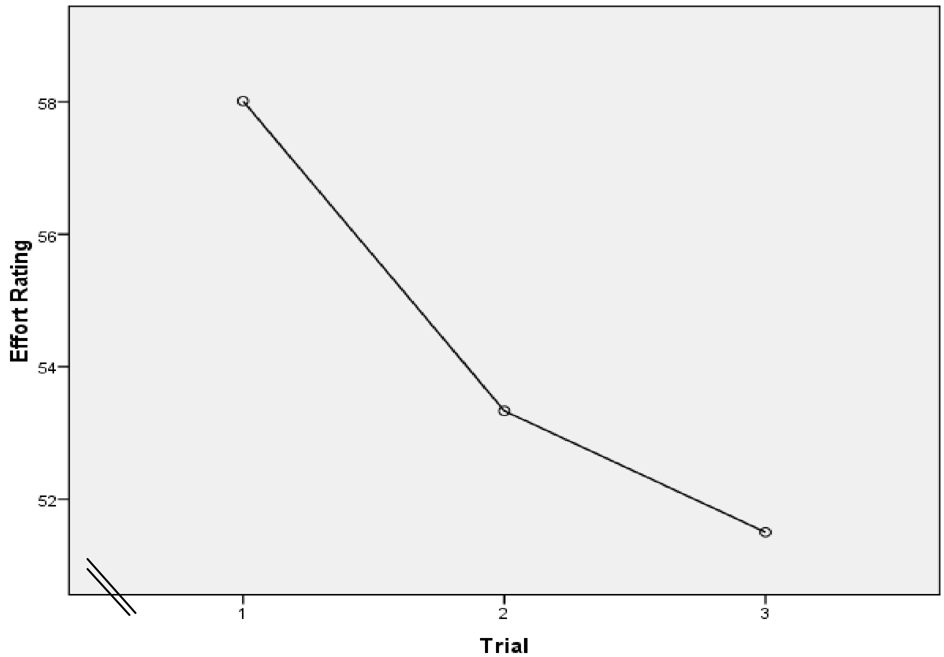

Figure 27-Plot of Mean Effort Rating Across Trials

Frustration

To determine if modality and task load affected participants' perceived frustration in completing the task, a mixed effects ANOVA with two between subject factors (modality and task load) and one within subject factor (trials) was conducted. The dependent measure was the NASA-TLX frustration rating. The ANOVA is shown in Table 24.

Table 24-NASA-TLX Frustration Rating Analysis of Variance

Source	df	Mean Square	F	Sig.
Between-Subjects Effects				
Modality	1	1754.861	.899	0.346
Load	2	10409.921	5.333	0.007*
Modality * Load	2	1210.302	.620	0.541
Error	78	1952.050		
Within-Subjects Effects				
Trials	2	105.444	0.455	0.635
Trials * Modality	2	667.444	2.878	0.059
Trials * Load	4	118.319	0.51	0.728
Trials * Modality * Load	4	238.296	1.028	0.395
Error (Trials)	156	231.896		

The ANOVA resulted in a significant effect for task load, $F(1, 78) = 5.333$, $p < 0.05$. Figure 28 shows the mean frustration rating of participants for each task load level. The plot indicates the mean frustration rating was significantly lower for task load level none than task load levels high and low indicating participants imposed with no task load level were less frustrated with the task than those imposed with a task load level.

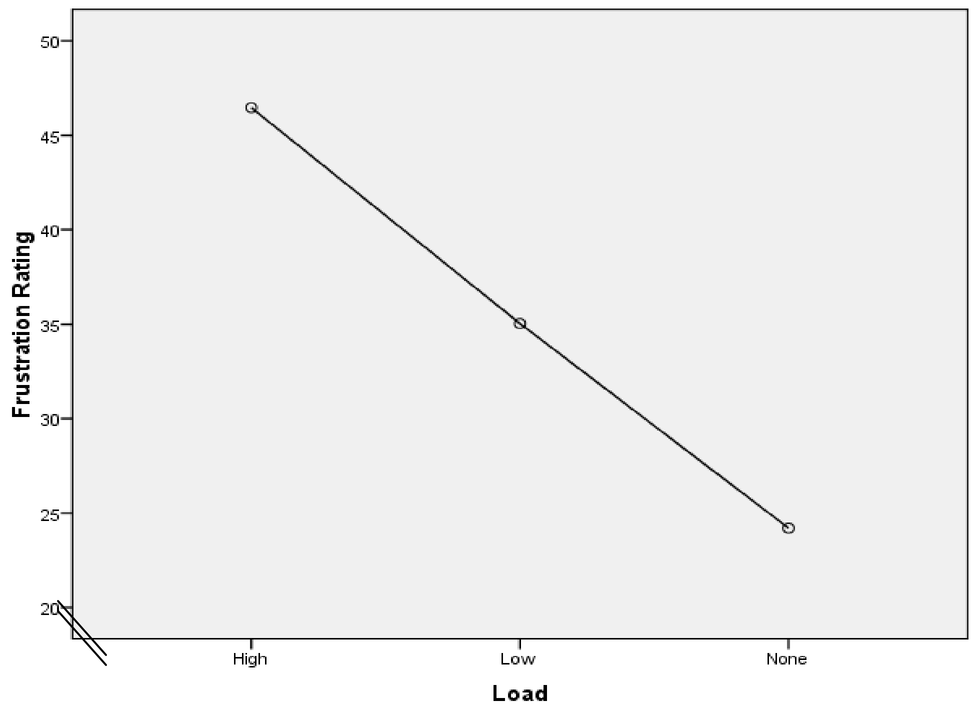

Figure 28-Plot of Mean Frustration Rating for Task Load Levels

Secondary Task Analysis – Task Load Level Low

There were three levels of task load imposed on participants: none (baseline), low and high. The low level task load consisted of participants counting the number of times they saw the word “ball(s)” while reading the passage aloud. To determine if modality affected participants’ performance completing the secondary task for task load level low, a mixed effects ANOVA with one between subject factors (modality) and one within subject factor (trials) was conducted. The dependent measure was the count of the number of times participants indicated they saw the word “ball(s).” The ANOVA is shown in Table 25 which resulted in no significant effects.

Table 25-Secondary Task: Task Load Level Low Analysis of Variance

Source	df	Mean Square	F	Sig.
Between-Subjects Effects				
Modality	1	2.012	0.039	0.844
Error	26	51.162		
Within-Subjects Effects				
Trials	2	1.107	0.183	0.833
Trials * Modality	2	3.298	0.546	0.582
Error (Trials)	52	6.036		

Secondary Task Analysis – Task Load Level Low

The high level task load involved participants counting the number of times they saw the letter "h" while reading the passage aloud. To determine if modality affected participants' performance completing the secondary task for task load level high, a mixed effects ANOVA with one between subject factors (modality) and one within subject factor (trials) was conducted. The dependent measure was the count of the number of times participants indicated they saw the letter "h." The ANOVA is shown in Table 26 which resulted in no significant effects.

Table 26-Secondary Task: Task Load Level High Analysis of Variance

Source	df	Mean Square	F	Sig.
Between-Subjects Effects				
Modality	1	6205.762	0.291	0.594
Error	26	21341.892		
Within-Subjects Effects				
Trials	2	5675.512	1.656	0.201
Trials * Modality	2	1191.083	0.348	0.708
Error (Trials)	52	3426.977		

APPENDIX G: INSTITUTIONAL REVIEW BORAD APPROVAL LETTER

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901, 407-882-2012 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Notice of Expedited Initial Review and Approval

From : **UCF Institutional Review Board**
FWA00000351, Exp. 6/24/11, IRB00001138

To : **Rochelle R. Jones**

Date : **August 04, 2008**

IRB Number: **SBE-08-05748**

Study Title: **Physical Ergonomic and Mental Workload Factors of Mobile Learning Affecting Performance and Satisfaction Levels of Adult Professional Distance Learners: Student Perspective**

Dear Researcher:

Your research protocol noted above was approved by **expedited** review by the UCF IRB Vice-chair on 8/1/2008. **The expiration date is 7/31/2009.** Your study was determined to be minimal risk for human subjects and expeditable per federal regulations, 45 CFR 46.110. The category for which this study qualifies as expeditable research is as follows:

> 7. Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

The IRB has approved a **consent procedure which requires participants to sign consent forms.** Use of the approved, stamped consent document(s) is required. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Subjects or their representatives must receive a copy of the consent form(s).

All data, which may include signed consent form documents, must be retained in a locked file cabinet for a minimum of three years (six if HIPAA applies) past the completion of this research. Any links to the identification of participants should be maintained on a password-protected computer if electronic information is used. Additional requirements may be imposed by your funding agency, your department, or other entities. Access to data is limited to authorized individuals listed as key study personnel.

To continue this research beyond the expiration date, a Continuing Review Form must be submitted 2 – 4 weeks prior to the expiration date. Advise the IRB if you receive a subpoena for the release of this information, or if a breach of confidentiality occurs. Also report any unanticipated problems or serious adverse events (within 5 working days). Do not make changes to the protocol methodology or consent form before obtaining IRB approval. Changes can be submitted for IRB review using the Addendum/Modification Request Form. An Addendum/Modification Request Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at http://iris.research.ucf.edu .

Failure to provide a continuing review report could lead to study suspension, a loss of funding and/or publication possibilities, or reporting of noncompliance to sponsors or funding agencies. The IRB maintains the authority under 45 CFR 46.110(e) to observe or have a third party observe the consent process and the research.

On behalf of Tracy Dietz, Ph.D., UCF IRB Chair, this letter is signed by:

Signature applied by Joanne Muratori on 08/04/2008 11:11:46 AM EDT

Joanne Muratori

IRB Coordinator

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