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Examining the Effects of Distractive Multitasking with Peripheral Computing in the Classroom

Jaime Eduardo Puente
Nova Southeastern University, jpuente777@outlook.com

Examining the Effects of Distractive Multitasking with Peripheral Computing in the Classroom

by

Jaime E. Puente

A dissertation submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy
in
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2017

We hereby certify that this dissertation, submitted by Jaime Puente, conforms to acceptable standards and is fully adequate in scope and quality to fulfill the dissertation requirements for the degree of Doctor of Philosophy.

Laurie P. Dringus, Ph.D. Chairperson of Dissertation Committee	Date
Steven R. Terrell, Ph.D. Dissertation Committee Member	Date
Martha M. Snyder, Ph.D. Dissertation Committee Member	Date

Approved:

Yong X. Tao, Ph.D., P.E., FASME Dean, College of Engineering and Computing	Date

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An Abstract of a Dissertation Submitted to Nova Southeastern University
in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

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Jaime E. Puente
March 2017

The growing use of information and communication technologies (ICTs) in college campuses has dramatically increased the potential for multitasking among students who have to juggle classes, school assignments, work, and recreational activities. These students believe that they have become more efficient by performing two or more tasks simultaneously. The use of technology, however, has changed the student's ability to focus and attend to what they need to learn. Research has shown that multitasking divides students' attention, which could have a negative impact on their cognition and learning**.**

The purpose of this study was to examine the effects of distractive multitasking on students' attention and academic performance in a classroom setting. Several studies in cognitive psychology have focused on individuals' divided attention between simultaneously occurring tasks. Such research has found that, because human attention and capacity to process information are selective and limited, a performance decrement often results when task performance requires divided attention.

Distractive tasks are defined as tasks or activities for which cognitive resources are used to process information that is not related to the course material. Multitasking is defined as the engagement in individual tasks that are performed in succession through a process of context switching. Using a non-experimental, correlational research design, the researcher examined the effects of distractive multitasking, with computer devices, during classroom lectures, on students' academic performance. This study used a monitoring system to capture data that reflected actual multitasking behaviors from students who used computers while attending real-time classroom lectures.

The findings showed that there was no statistically significant relationship between the frequency of distractive multitasking (predictor variable) and academic performance (criterion variable), as measured by the midterm and final evaluation scores. The results did not support the hypothesis that distractive computer-based multitasking could have a negative impact on academic performance.

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I dedicate this dissertation to the loves of my life, my wife Glenda, and our daughters Glenda Maria and Andrea Maria. Their love and encouragement were always there and for that, I am truly blessed. Thank you very much for your patience, support, and prayers during this long and challenging, but exciting academic journey.

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Chapter 1

Introduction

Background and Overview

Many universities have established laptop initiatives that provide one computer per student and teacher (Inan & Lowther, 2010; Penuel, 2006). While computer use in the classroom has significantly increased, few teachers have efficiently integrated computers and other peripheral computing devices, such as laptops, tablets and smartphones, as teaching tools to support instruction or learning activities. Weaver and Nilson (2005) noted there is a lack of substantial curriculum change in response to the presence of laptops in the classroom and this contributes to the difficulty in justifying the extensive use of peripheral computing in the classroom. Other researchers claim that educators are failing "digital natives" (often defined as those born after 1980) because they do not adapt instruction to their needs (Thompson, 2013). Additionally, some faculty members are banning laptop use in their classroom due to concerns that peripheral devices used during class meetings may create potential distractions for students that, in turn, have a negative impact on student learning (Baker, Lusk, & Neuhauser, 2012; Chanen, 2007; Fink, 2010; Kay & Lauricella, 2011; Meierdiercks, 2005; Yamamoto, 2007; Young, 2006). Whether laptops should be allowed in college classrooms continues to be debated among administration, faculty, and students (Gaudreau, Miranda, & Gareau, 2014; Groothuis, 2011; Loeffler, 2013; Quesada, 2012).

Lauricella and Kay (2010) found that 70% of students spent half their classroom time working on recreational activities, such as sending emails, instant messaging, playing games, and other non-academic activities while attending lectures. Kraushaar and Novak (2010) identified this behavior as distractive multitasking. They defined distractive multitasking as engaging in a group of tasks or activities in which cognitive resources are used to process information that is not directly related to the course material. In contrast, Kraushaar and Novak defined productive multitasking in a classroom setting as engagement in a group of tasks or activities that are directly related to completing a primary task associated with the course material.

According to Efaw, Hampton, Martinez, and Smith (2004), laptop use in the classroom has the potential to contribute to student learning through enabling an active approach to teaching and learning. Alvarez, Brown, and Nussbaum (2011) studied the potential of netbooks and tablet PCs for active learning in the classroom and found that these devices facilitated face-to-face collaborative learning. Laptop use also could have a negative impact on student attitudes and academic achievement by enabling distraction for students during lectures (Bellur, Nowak, & Hull, 2015; Bowman, Levine, Waite, & Gendron, 2010; Downs, Tran, McMenemy, & Abegaze, 2015; Ellis, Daniels, & Jauregui, 2010; Frein, Jones, & Gerow, 2013; Ravizza, Hambrick, & Fenn, 2014; Sana, Weston, & Cepeda, 2013; Wood et al., 2012). Grace-Martin and Gay (2001), in a seminal work on the topic of the impact of multitasking in the classroom, quantified browsing behavior (frequency and duration) of college students enrolled in two different courses, which they examined with students' academic performance. The researchers found that the more time students spent in browsing sessions, the lower their final grade. This finding is perhaps related to the prolonged inattention to the instructor.

Ellis et al. (2010) conducted an experiment involving 62 students who were randomly assigned to one of two groups: an experimental group whose members could send text messages via cell phone and a control group whose members could not text. Their findings indicated that the mean exam results of students who texted in class (*M* = 42.81, *SD* = 9.91) were significantly lower than that of students who did not text in class (*M* = 58.67, *SD* = 10.42). Ellis et al. found that, when computing devices were not used strictly for learning purposes in class, their use negatively affected the academic performance of business students.

Fried (2008) conducted a survey-based study in which students reported two main sources of distraction posed by laptop use in the classroom. One source of distraction was laptop use by fellow students and the other source of distraction was students had spent significant time during lectures using their laptops for activities unrelated to the course material. Fried found that students who bring laptops to class often engage in distractive multitasking.

Smartphones in the classroom are another source of distraction for students who use them to text, post on their social media platforms, watch YouTube, or play games. While research is just starting to focus on smartphones in the context of mobile learning (Chen & Yan, 2016; Heflin, Shewmaker, & Nguyen, 2017; Judd, 2013; Kuznekoff & Titsworth, 2013; Lepp, Barkley, & Karpinski, 2014), this type of distractive multitasking is not the focus of this study. Distractive multitasking is nothing new; students whispering, note passing, completing other class assignments, and even daydreaming during class predate multitasking as aided by technology. However, the pervasiveness and mobility of peripheral computing technologies encourage students to perform simultaneous tasks that include synchronous and asynchronous social computing and web browsing to the point that distraction leads to measurable decreases in memory or recall of lecture content (Hembrooke & Gay, 2003; Mokhtari, Delello, & Reichard, 2015).

Kraushaar and Novak (2010) examined the effects of different types of computer-based multitasking behaviors on learning outcomes in a classroom setting. They hypothesized that a higher frequency of multitasking would be correlated with lower academic performance. They defined distractive multitasking as tasks or activities in which cognitive resources are used to process information that is not directly related to the course material, and they quantified the impact of distractive multitasking (i.e., playing games, instant messaging, browsing unrelated websites, or checking email during class) on academic performance in a classroom setting.

The experimental course used in Kraushaar and Novak's (2010) study was a traditional lecture style class with content that included both declarative and procedural knowledge. Declarative knowledge concerns facts and events, and procedural knowledge concerns how to do things ("know-how") or how to perform a task (Berge & Hezewijk, 1999). Education involves a mix of declarative and procedural knowledge, found predominantly in theoretical and hands-on courses, respectively. Courses with varying mixes of declarative and procedural knowledge could yield different results in regard to the effects of distractive multitasking in the classroom.

Kraushaar and Novak (2010) found that students used their laptops to engage in activities other than those that support classroom learning. Specifically, (a) students opened an average of 65 tasks (active windows) per lecture, with 62% of these being categorized as distractive; and (b) non-course-related tasks were open and active on students' laptops 42% of the time. The authors found limited, mixed support for the hypothesis that a higher frequency of multitasking was correlated with lower academic performance.

Kraushaar and Novak's (2010) study is one of a few in the field that concerns multitasking behavior based on real-time information from a monitoring software tool that runs on students' laptops. Most of the literature is based on self-report surveys or anecdotal descriptions of multitasking, which may not provide an accurate or valid measure of the frequency or nature of distractive multitasking in a traditional lecture course, particularly because students may tend to under-report the frequency of distractive software usage (Fried, 2008).

Several studies in the fields of cognitive psychology and mediated learning have focused on the topic of divided attention between simultaneously occurring tasks in a learning environment (Baddeley, Lewis, Eldridge, & Thomson, 1984; Lee, Lin, & Robertson, 2012; Naveh-Benjamin, Craik, Perretta, & Tonev, 2000). The findings include the notion that, because human attention and capacity to process information are selective and limited, a performance decrement often results when task performance requires divided attention. Hembrooke and Gay (2003) focused on the simultaneous processing of two competing tasks, one task that involved the use of visual processing and the task that involved auditory processing. They found that "almost without exception performance on one or both tasks suffers a decrement as a direct result of having to perform the two tasks simultaneously" (p. 49).

Foerde, Knowlton, and Poldrack (2006) used functional magnetic resonance imaging (MRI) to examine brain activity as a means to study the effects of multitasking on learning. When examining the brain activity of the participants in a learning situation, a student can learn while multitasking, but that distraction lessens the student's efficiency level in learning material. Foerde et al. described that the brain learns in two different ways and in two separate areas. Declarative learning relies on the medial temporal lobe and concerns the learning of facts and events that can be recalled later and used with great flexibility (long-term memory). Habit learning relies on the striatum and concerns the acquisition of information based on behaviors that are repeated regularly and on behaviors that tend to occur subconsciously. Foerde et al. showed that declarative learning and habit learning appear to compete with each other, and, when dual-task learning occurs, habit learning seems to prevail over declarative learning. This result makes the acquisition of knowledge less efficient and less applicable to new situations.

Ophir, Nass, and Wagner (2009) found that there is an "illusion of competence," whereby heavy multitaskers perceive that they have absorbed much more of a lecture than they actually have. They found that self-described heavy media multitaskers (HMMs) performed worse on cognitive and memory tasks in the face of distractions than did people who said that they preferred to focus on single tasks (light media multitaskers; LMMs) when asked to focus attention on selective pieces. Their results also indicated that LMMs pay closest attention to information pertinent to their primary task. By contrast, HMMs are inclined to pay attention to a larger scope of information instead of focusing on a primary task. Ophir et al. concluded that such behaviors make HMMs less capable of filtering out interference from irrelevant stimuli and representations in memory.

In summary, computer usage in the classroom has been typically associated with poorer learning outcomes, poorer self-perception of learning, and students' reporting that they felt distracted by their own computers (Bellur et al., 2015; Downs et al., 2015; Fried, 2008; Sana et al., 2013; Wurst, Smarkola, & Gaffney, 2008). Additionally, many students believe that they can multitask with no serious impact on their academic performance, where there is empirical evidence that this is not the case. As teachers continue to integrate technology into their classroom, it is important to study why and how the multitasking associated with computer use may interfere with or serve as a distraction to learning.

Problem Statement and Goal

The wide availability of both computing devices and web content has led to an increase in students' computer-based multitasking during classroom lectures, but the effects of such multitasking on academic performance have not been adequately studied (Benbunan-Fich & Truman, 2009; Kirschner & Karpinski, 2010; Ravizza et al., 2014). This study involved an examination of the pervasive use of computing devices in the classroom and the extent that distractive multitasking with computers during instructional sessions has an impact on students' attention and academic performance.

The main goal of this study was to examine the effects of distractive multitasking on academic performance when university students used computers while attending real-time classroom lectures. This was accomplished by extending Kraushaar and Novak's (2010) research. The study used a methodology and data collection process similar to those of Kraushaar and Novak but with different types of participants, age groups, races/ethnicities, and locations. Additionally, the study used an experimental course with a mix of declarative and procedural knowledge, which is different from the mix used by Kraushaar and Novak.

For the purpose of this study, multitasking is defined as an individual's engagement in discrete tasks that are performed in succession (Dzubak, 2007). This engagement implies that there is necessarily some time spent switching between course-related and non-course related tasks (i.e., task-switching process). These non-course related tasks, also called distractive tasks, are defined as tasks or activities in which cognitive resources are used to process information that is not related to the course material (Kraushaar & Novak, 2010). Delbridge (2000) associates this task-switching process with an inherent cost (poorer learning and poorer performance) related to the amount of time required to complete the task, the errors made during completion, or both.

To achieve the goal for this study, the researcher identified and measured different instances of distractive multitasking engaged in by the students in the classroom. Typical examples of distractive multitasking were scenarios in which students engaged in surfing to find entertainment, emailing, online searching, Facebook, and other non-course-related activities. Multitasking behavior was conceptualized and measured in terms of the frequency of such multitasking. The researcher, using monitoring software, recorded the windows/page names for each software application running on the students' computers. These application windows were considered productive or distractive according to whether they were related to the course materials. The researcher measured the frequency of distractive multitasking by determining the number of distractive application windows that had the focus of a student during the lectures (active windows).

Based on the frequency of the distractive multitasking, the researcher evaluated the impact of distractive multitasking behavior on academic performance. For the purpose of this study, academic performance was operationalized as the midterm and final evaluation scores.

Research Question and Hypothesis

The research question that guided this study is: “Is there a correlation between the frequency of distractive multitasking and academic performance (midterm and final evaluation scores)?” The study was built on hypotheses developed in previous research (Fried, 2008; Kraushaar & Novak, 2010; Mayer & Moreno, 2003; Wurst et al., 2008) that has shown that multitasking and the unstructured use of computers in the classroom can have a negative impact on academic performance. The hypothesis for this study, as drawn from Kraushaar and Novak (2010), which warrants further investigation is: “There will be a negative correlation between academic performance (midterm and final evaluation scores) and frequency of distractive multitasking.” In other words, more distraction from in-class multitasking using computers leads to lower academic achievement.

Constructs and Measures

The study includes a data analysis of student usage as reported by monitoring software installed on student computers. This real-time source of information helped the researcher to provide an accurate measure of the quantity and type of distractive multitasking and contributed to our understanding of the nature of computer use, distractions that occurred with its use, and the influence of distractions on learning (Fried, 2008; Kraushaar & Novak, 2010). Figure 1 presents the constructs and measures of the study.

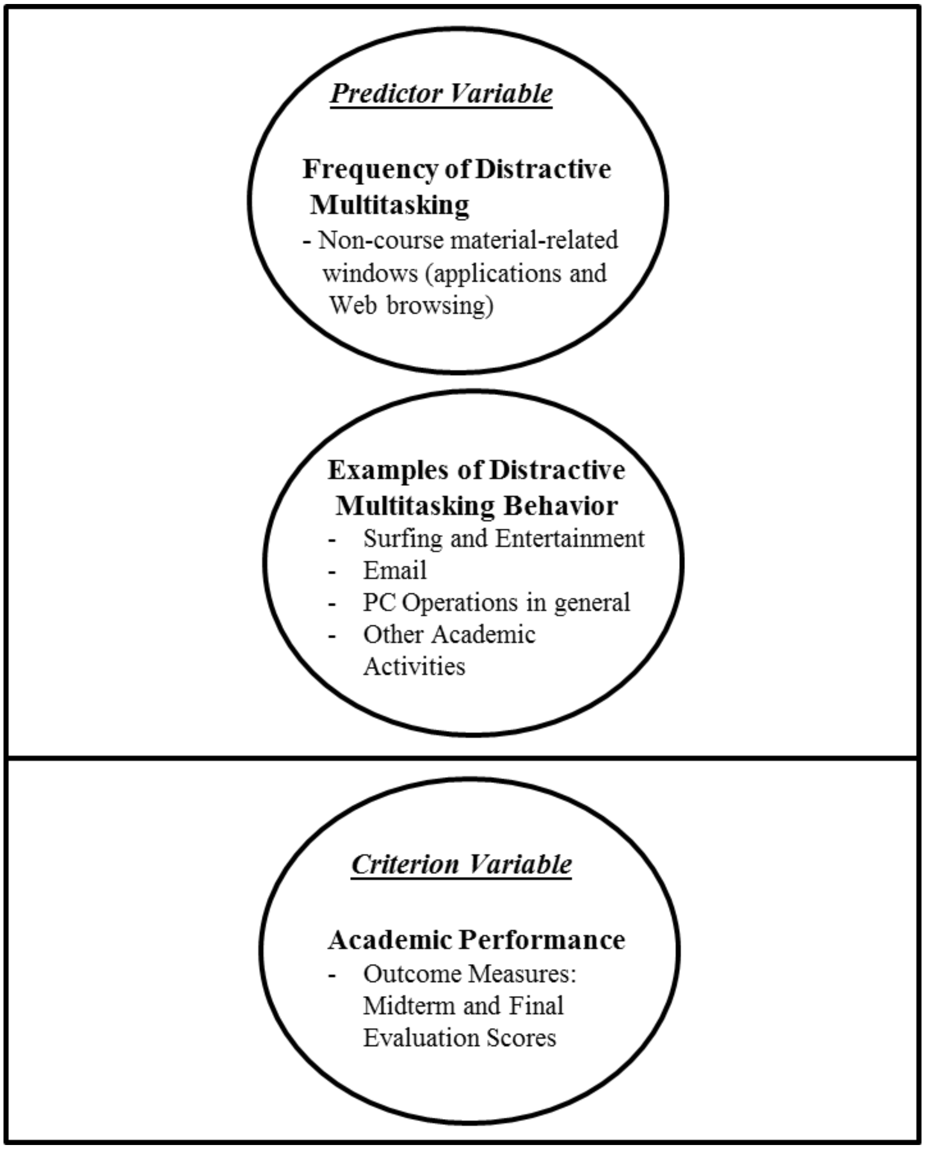


Figure 1. Study constructs and measures.

This study uses a correlational research design with the aim to examine the relationship and potential causality between two variables, which classifies the study as exploratory research. The predictor variable is frequency of distractive multitasking during class. This variable is the number of distractive windows as related to surfing and entertainment, email, PC operations in general (e.g., Windows Explorer, system software), and academic activities associated with other classes. The criterion variable is academic performance measured by the midterm and final evaluation scores.

Relevance and Significance

Taking notes while surfing the web, texting in class, and listening to a lecture while updating Facebook are becoming the norm in many classrooms. At present, there is limited research on multitasking using computers and other peripheral computing devices that examines its impact on educational outcomes (Junco & Cotton, 2011; Lepp et al., 2014; Ravizza et al., 2014). While multitasking has typically been seen as a useful skill, many studies have shown that there is a significant and measurable cognitive cost associated with frequent task switching (Naveh-Benjamin et al., 2000; Rubinstein, Meyer, & Evans, 2001; Sana et al., 2013). This cost is a significant decrease in performance, increase in time needed to complete tasks, and errors made during the completion of tasks when they are multitasked rather than completed sequentially. Bailey and Konstan (2006) found that interrupting a user's task at random moments results in decreased performance on the main task as well as increased feelings of frustration and anxiety. The cost of interrupting the execution of primary tasks was 3% to 27% more time needed to complete the tasks and the committing of twice the number of errors across tasks, compared to focusing on a single primary task.

The widely-publicized view of "digital natives" is that they are better learners and thinkers, as compared to individuals of prior generations, due to their early immersion in digital technology and multitasking during childhood and adolescence, when brain plasticity is high. Nevertheless, this early immersion is being increasingly viewed in a negative light (Judd, 2014; Thompson, 2013) and, as such, warrants further research. It would be useful to understand the extent to which this new generation of students may (or may not) be capable of deep learning and productive work while multitasking with computers in the classroom (Courage, Bakhtiar, Fitzpatrick, Kenny, & Brandeau, 2015; Rothbart & Posner, 2015). It also would be valuable to identify instructional strategies that can be adapted to their learning needs and that leverage their early immersion in digital technology (Thompson, 2013).

As stated in the authors' conclusions, several studies (Ellis et al., 2010; Foerde et al. 2006; Hembrooke & Gay, 2003; Mokhtari et al., 2015; Ophir et al., 2010; Sana et al., 2013) have shown evidence of the relevance and significance of the problem addressed in this study: (a) the potential negative impact of multitasking on learning due to the use of habit learning instead of declarative learning; (b) the adverse effect of multitasking on students' ability to learn complex new facts and concepts; and (c) the potential significant impact of multitasking on academic performance.

The need for this work is evidenced by the lack of research that warrants focus on distractive multitasking as related to the use of computers and other peripheral computing devices in a classroom setting (Iqbal, Grudin, & Horvitz, 2011). The study focused on student learning outcomes as students multitasking behaviors were monitored from laptop usage during instructional delivery (Fried, 2008; Kraushaar & Novak, 2010). Most previous research contains strong evidence that multitasking has a negative impact on memory encoding, which has implications for learning outcomes, but such research has not measured the specific impact of multitasking on learning (Judd & Kennedy, 2011; Ophir et al., 2009). Likewise, existing studies rely on self-reported perceptions of use or anecdotal descriptions of use, which may not necessarily reflect an actual multitasking scenario. Notably, students usually tend to underreport their multitasking activities.

Barriers and Issues

The effects of multitasking with computers and other peripheral computing in the classroom are difficult to understand. Kraushaar and Novak's (2010) study indicated that there was no statistically significant relationship between a higher frequency of multitasking and lower academic performance or between distractive multitasking duration and student performance. The duration of distractive multitasking was measured by the mean time that a distractive active window had the focus of and could easily be viewed by a student.

Previous research on the impact of multitasking on academic performance has encountered barriers, such as the potential for students to incorrectly self-report the distractive multitasking in which they are involved while attending a classroom lecture. Students usually tend to underreport the frequency of distractive multitasking. Thus, to develop a clear understanding of the nature of computer use and its influence on academic performance, Fried (2008) recommended using direct and real-time measures to complement the self-report methods.

Given that students who participated in the study knew that they were being monitored, a limitation of this exploratory study was the "novelty effect." The novelty effect occurs when individuals who participate in research respond to a novel situation differently in the context of the study than they would in the real world (Gravetter & Forzano, 2011). It is possible that some of the students who participated in the study had altered their multitasking behavior in some way, given that they knew that they were being monitored. This limitation exists in other exploratory studies (Judd, 2013; Judd & Kennedy, 2011; Kraushaar & Novak, 2010); however, researchers have found plenty of anecdotal evidence, e.g., inappropriate messages about classmates and/or instructors, that indicates that at least some students' behavior was not affected by their awareness of being monitored. These researchers thought that any bias that might have occurred would be in the under-reporting of distractive or inappropriate behavior. Research also has shown that, over time, as the novelty wears off, the behavioral response returns to a natural one.

The design of this study minimized the impact of the novelty effect. Specifically, the instructor of the course did not describe the exact nature of the research inquiry in any more detail than is ethically or legally necessary. The instructor of the course also informed the students that all the information to be collected would be anonymous and confidential, will be used only for research purposes, and would not have an impact on their final course grade. Thus, the researcher was presented only with de-identified research data that pertained only to the purpose of this study. Because students used institutional laboratory computers, not personal ones, they were not highly conscious of the monitoring software. The data collection process lasted for 10 weeks, and, in this regard, research has shown that the effect of the monitoring software on the participant's behavior decreases over time (Judd, 2013; Judd & Kennedy, 2011; Kraushaar & Novak, 2010).

Based on the above, the researcher does not anticipate that the novelty effect would threaten the external validity of this study. Additionally, the monitoring of student's computer usage provides a more reliable measure than do self-reports of multitasking behaviors, which may not reflect actual multitasking practices (Brasel & Gips, 2011; Fried, 2008).

Another limitation concerns the interpretation of results with respect to the effects of distractive multitasking with computers in the classroom. In this regard, Fried (2008) and Kraushaar and Novak (2010) noted that courses with varying mixes of declarative and procedural knowledge have the potential to produce different results. Courses with more declarative knowledge (theoretical) content might tend to encourage more distractive multitasking in the classroom compared with courses with more procedural knowledge (hands-on) content.

Assumptions, Limitations, and Delimitations

The researcher assumed that the participants in this study would frequently switch from task to task as a result of course-related activities and of interruptions caused by non-course-related activities. It should be noted that ongoing tasks take place with some degree of overlap in time. In other words, a student suspends an ongoing classroom-related task, either voluntarily or involuntarily, to switch attention to a non-classroom related task. As such, a certain task or tasks are set aside temporarily in favor of a new task or tasks.

The researcher used statistical analyses on the data, with the significance level set at .05. In this regard, it should be noted that one limitation of the study is its small sample size (64), as it involved students in only one course. A larger sample size would have had more statistical power and, thus, would have provided a greater opportunity to yield statistically significant results. Thus, the researcher recommends that this study be replicated with a larger sample.

A second limitation of this study is the novelty effect. As noted, the novelty effect occurs when research participants respond to a novel situation differently in the context of the study than they would in the real world (Gravetter & Forzano, 2011). The design of the study minimized the impact of the novelty effect.

A third limitation is that courses with varying mixes of declarative and procedural knowledge might have different results (Kraushaar & Novak, 2010). Courses with more declarative knowledge (theoretical) content might tend to encourage more distractive multitasking in the classroom, as compared with courses with more procedural knowledge (hands-on) content.

This study was delimited to a convenience sample available through a host university outside the United States. In this regard, a fourth limitation of this study is that the results cannot be generalized beyond the population from which the sample was collected. Further, the lack of random assignment to experimental and control groups has the potential to raise a threat to the internal validity of the study.

Definitions of Terms

Academic performance, for the purpose of this study, is operationalized as the midterm and final evaluation scores (Kraushaar & Novak, 2010).

Active window is an object that is currently displayed on the computer monitor and is considered to be "on top" and to have the focus of the student at any given time (Kraushaar & Novak, 2010).

Computer-based multitasking refers to multiple unrelated computer-based tasks performed concurrently (Benbunan-Fich et al., 2009).

Declarative knowledge is the type of knowledge that concerns facts and events (Berge & Hezewijk, 1999).

Digital natives are often defined as individuals born after 1980 (Thompson, 2013).

Distractive multitasking, for the purpose of this study, is the behavior of engaging in a group of tasks or activities in which cognitive resources are used to process information that is not directly related to the course material (Kraushaar & Novak, 2010).

Distractive tasks are tasks or activities in which cognitive resources are used to process information that is not related to the course material (Kraushaar & Novak, 2010).

Divided attention occurs when attention is divided between a primary task and a secondary task (Frein et al., 2013).

Frequency of multitasking is the number of times that a user shifts from one task to another during a computer session (Czerwinski, Horvitz, & Wilhite, 2004).

Interleaved approach refers to a multitasking approach by which the user suspends an ongoing task, either voluntarily or involuntarily, to switch attention to another task. As such, a certain task or tasks are set aside temporarily in favor of a new task or tasks (Adler & Benbunan-Fich, 2012).

Multitasking is an individual's engagement in discrete tasks that are performed in succession (Dzubak, 2007).

Novelty effect occurs when individuals who participate in research respond to a novel situation differently in the context of the study than they would in the real world (Gravetter & Forzano, 2011).

Open window is any window opened by a program that is running on the student's laptop (Kraushaar & Novak, 2010).

Parallel approach refers to two or more activities that are engaged in at the same time. Based on the limitations of human attention, however, this approach is impractical (Adler & Benbunan-Fich, 2012; Lang, 2001).

Procedural knowledge is type of knowledge that concerns how to do things ("know-how") or how to perform a task (Berge & Hezewijk, 1999).

Productive multitasking is the behavior of engaging in a group of tasks or activities that are directly related to the completion of a primary task associated with the course material (Kraushaar & Novak, 2010).

Sequential approach refers to an approach in which a user focuses entirely on one independent task that is started after completing the previous one. In this scenario, there are no multiple ongoing tasks, and, as such, this approach is not considered multitasking (Adler & Benbunan-Fich, 2012).

Task-switching process occurs when there is necessarily some time spent switching between tasks, during which information is selected and then attended to, processed, encoded, and finally stored (Chun, Golomb, & Turk-Browne, 2011).

Chapter Summary

This chapter presented the background to the study, the research problem, and the goal of the study. The research concern is the examination of the pervasive use of computing devices in the classroom and the extent to which distractive multitasking with computers during instructional sessions has an impact on students' attention and academic performance. The goal of the study was to provide an examination of the effects of distractive multitasking on academic performance when university students use computers while attending real-time classroom lectures. The research question that guided this study is, "To what extent does the frequency of distractive multitasking affect academic performance (midterm and final evaluation scores)?" The chapter also included a discussion of the relevance and significance of the study as well as the barriers and issues and the assumptions, limitations, and delimitations that affect this research. Finally, the key terms used throughout the study were defined.

Chapter 2

Review of the Literature

This chapter presents a review of the seminal and recent literature on media multitasking and its impact on cognitive processing and on learning outcomes in a classroom setting. This chapter is organized into five sections. The first contains the literature that establishes the background for this study, the second concerns the impact of multitasking on attention, the third focuses on how multitasking affects student outcomes, and the fourth section presents the research on the conceptualization and measurement of multitasking behavior. Finally, the fifth section concerns the gaps in the literature and how this study addresses them.

Background

The pervasive use of peripheral computing devices in college classrooms has resulted in a situation in which students have access, during class time, to real-time streaming data from social networking sites, (e.g., Facebook, Twitter, LinkedIn, Instagram); entertainment venues (e.g., YouTube); and news outlets (e.g., RSS feeds). The wide availability of both computing devices and web content has led to an increase in students' computer-based multitasking during classroom lectures, but the effects of such multitasking on academic performance have not been adequately studied (Benbunan-Fich & Truman, 2009; Junco & Cotton, 2011; Kirschner & Karpinski, 2010; Ravizza et al., 2014).

The study focused on the pervasive use of computer-based multitasking in the classroom (i.e., distraction caused by using a computing device in the classroom for non-course related activities) and sought to determine the extent that distractive multitasking during instructional sessions has an impact on students' attention and academic performance.

Several authors have attempted to conceptualize and measure multitasking behavior (Adler & Benbunan-Fich, 2012; Benbunan-Fich, Adler, & Mavlanova, 2011; Salvucci, Taatgen, & Borst, 2009). For the purpose of this study, multitasking is defined as an individual's engagement in multiple discrete tasks that are performed in succession (Dzubak, 2007). In the context of this study, this definition implies that a student spends some time performing a task related to the course and then switches to performing a non-course-related task for another period of time (i.e., task-switching process). As such, distractive multitasking occurs when a user switches attention from the main task, for example, paying attention to the lecture, to an unrelated computer-based secondary activity, such as engaging with friends using Facebook. Figure 2 illustrates typical multitasking student behavior in the classroom as envisioned in this study.

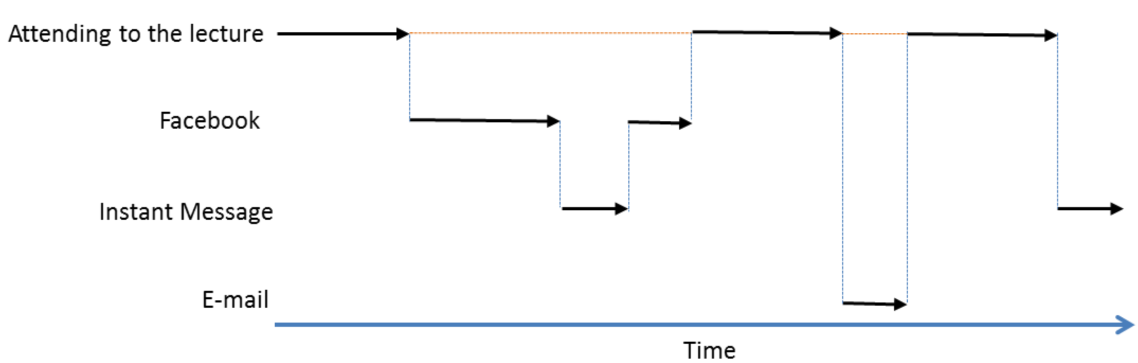


Figure 2. Typical multitasking student behavior in the classroom.

Figure 2 shows that multiple, ongoing tasks take place with some degree of overlap in time. Adler and Benbunan-Fich (2012) described this configuration of time overlap as the interleaved approach. In an interleaved approach, the user suspends an ongoing task, either voluntarily or involuntarily, to switch attention to another task. As such, a task or tasks are set aside temporarily in favor of a new task or tasks. Adler and Benbunan-Fich (2012) described other two approaches, sequential and parallel, based on the amount of overlap between tasks. In a sequential approach, a user focuses entirely on one independent task that is started after completing the previous one. In this scenario, there are no multiple ongoing tasks, and, as such, this approach is not considered multitasking. In a parallel approach, two or more activities are engaged in at the same time. Based on the limitations of human attention, however, this approach is impractical (Adler & Benbunan-Fich, 2012; Lang, 2001).

In these three approaches, originally defined by Bluedorn, Kaufman and Lane (1992), different amounts of time are spent on one task before switching to another, which results in a multitasking continuum (Salvucci et al., 2009). At one end are tasks that involve frequent switching, perhaps every second, and at the other end are tasks that involve long periods between task switches, perhaps minutes or hours, which can be considered a form of sequential multitasking. The interleaving approach can be positioned near in the middle of the multitasking continuum, closer to the frequent-switching end.

This study focused on the interleaved approach, which reflects a typical multitasking scenario in the classroom in which a student who moves his or her attention from instant messaging to the classroom lecture to Facebook to note-taking and then back again to the lecture. There is necessarily some time spent switching between tasks, during which information is selected and then attended to, processed, encoded, and finally stored.

Impact of Multitasking on Cognitive Processing

The cognitive psychology literature associates multitasking with the concepts of divided attention and task switching, which concern how humans attend to and process information (Chun, Golomb, & Turk-Browne, 2011). This reflects the fact that multitasking not only involves a change in tasks but also a change in the individual's attention and focus (Delbridge, 2000).

Delbridge (2000) associates task switching, which is a type of attention and focus switching (mental "juggling"), with an inherent cost related to either the amount of time required to complete the task or the errors made during completion, or both (Sana et al., 2013). Task switching, going from a primary to a secondary task, can be triggered by external signals and events. Additionally, a user also may switch among tasks in a self-guided manner (internal signals); for example, the student may start thinking about a friend and decide to go onto Facebook.

Several studies have been conducted to measure the cost or loss of time associated with task switching. Naveh-Benjamin et al. (2000) investigated the effect of divided attention on memory processes and memory outcomes and found "marked differences between the encoding and retrieval activities involved in processing the information created via multitasking" (p. 610). In particular, they found that the damaging effect of divided attention is much greater at encoding than at retrieval, which is related to the fact that different neural pathways are used during these separate processes.

To understand the effects of external interruptions on task switching and the process that occurs during task suspension and resumption, Iqbal and Horvitz (2007) conducted a field study over a two-week period at a private institution. In the study, the participants' performance of their normal computer activities (i.e., programming or content generation tasks) was the primary task. The external interruptions were the alerts generated by email and instant messaging applications. Iqbal and Horvitz found that computer users spent, on average, nearly 10 minutes on task switching, which means that 10 minutes was the time spent performing the primary task, when they received an alert of an incoming email or instant message. Depending on the type of interruption, they spent, on average, another 10 to 15 minutes performing a peripheral or secondary task before returning to the primary task. The researchers concluded that, over a two-week period, 27% of the cases of task interruptions resulted in more than two hours of time spent in another task or tasks until resumption of the primary task because users usually became involved in other multitasking activities after checking the incoming messages.

Bailey and Konstan (2006) measured the effects of interruption on task completion time and error rate as well as in regard to the affective dimensions of annoyance and anxiety. A total of 50 participants were randomly assigned to an experimental or control group. Participants performed primary tasks but experienced an application-initiated interruption that prompted them to perform peripheral tasks either between or during the execution of primary tasks. Participants in the experimental group were allowed to attend to a peripheral task whenever it appeared, whether or not the participant was executing a primary task at that time. Participants in the control group were instructed to complete a peripheral task only after the primary task was completed. The researchers' hypothesis was that presenting an interruption to a user only after the primary task was completed (boundary period) was less disruptive for the performance of the primary task, as compared to presenting an interruption while the user was still executing the primary task.

The results showed that interruptions during the execution of primary tasks had a negative impact on completion time and error rate for primary tasks. For example, the users in the experimental group required from 3% to 27% more time to complete the primary tasks and made twice the number of errors across tasks. Likewise, the results also indicated that the users in the experimental group experienced from 31% to 106% more annoyance and twice the increase in anxiety than did the users in the control group (Bailey & Konstan, 2006).

Foerde et al. (2006) used functional magnetic resonance imaging (MRI) to examine the effects of multitasking on the brain’s learning system. Although the researchers found that a student still can learn while multitasking, the active distractions involved in multitasking change how the student learns by making that learning less flexible and more specialized (not applicable to new situations), which results in information that cannot be retrieved as easily (less efficient). The results showed that multitasking shifts learning activity from the hippocampus, located in the medial temporal lobe, to the striatum. The hippocampus is associated with declarative memory (i.e., learning of facts and events), while the striatum is associated with procedural memory (i.e., learning of behaviors that tend to occur subconsciously). This shift makes the acquisition of knowledge less efficient, less applicable to new situations, and not conducive to deeper learning (Judd, 2013). In other words, when divided attention occurs, an individual will not learn as well if he or she had paid full attention. Specifically, distracted learning results in a superficial understanding of the studied material.

Iqbal et al. (2011) studied the effects of computer-based multitasking on attention among individuals attending colloquium-style presentations. Their goal was to understand why audience members choose to use computing devices despite the potential cost of multitasking (i.e., missing useful information). To this end, the researchers administered a questionnaire to speakers and their audiences.

Iqbal et al. (2011) found that both speakers and audience members felt that laptop use can enhance presentations, although audience members were more positive about this than were speakers. Both groups felt that laptops can enable listeners to multitask, but only audience members felt that smartphones could. Speakers felt that laptops and smartphones distract their users. The audience was more neutral in regard to their feelings that laptop and smartphones distract them. Notably, close to 50% of device users asserted that, despite missing some information while interacting with devices, the benefits of peripheral computing make such usage worthwhile. Audience members reported feeling that device usage could be disrespectful, but, surprisingly, the speakers themselves tended to disagree. Speakers also realized that the ability to use a laptop could induce busy people to attend the presentation. Related to this, most audience members had a negative reaction to the idea of turning off wireless access during presentations.

The attitudes and behaviors identified by Iqbal et al. (2011) led them to conclude that multitasking is likely to continue and to become increasingly acceptable. In this regard, they suggest that speakers should consider adjusting their presentations to account for audiences who divide their attention.

Impact of Multitasking on Academic Performance

Research has shown that students multitask with technology on a daily basis during class, work, and recreational activities (Fried 2008; Lauricella & Kay, 2010; Mokhtari et al., 2015). Many students claim to be able to multitask effectively; they do it often, and they believe that they do it well. However, despite these claims, several studies indicate that the human ability to multitask, or engage in simultaneous tasks, is limited (Fisch, 2000; Lang, 2001).

Research also shows decreases in productivity and academic performance when multitasking occurs (Bellur et al., 2015; Downs et al., 2015; Ellis et al., 2010; Junco & Cotton, 2011; Ravizza et al., 2014); Rubinstein et al., 2001; Sana et al., 2013; Wood et al., 2012). Hembrooke and Gay (2003) explored the effects of using a computer to multitask in the learning environment. Forty-four students in an upper level Communications course participated in this study (22 males, 22 females). Half of students in this study were encouraged to use their laptops during class to supplement the teacher’s presentation by looking up background information (experimental group). These students were given the responsibility to monitor their own computing activities. The other group (22 students) heard the same lecture but was told to close their laptops during class (control group). Both groups of students were given a test right after the lecture.

Hembrooke and Gay (2003) found that, while the students who were encouraged to use their laptops explored lecture topics in detail, they also engaged in other forms of computing. They also found that students who had an open laptop during the class were more likely to multitask and performed significantly more poorly than did those who closed their laptop during the class session. The mean test score of the students who engaged in unrelated multitasking with their laptops was approximately 53 points out of a total score of 100 points, and, for those who kept their laptop closed, it was approximately 63 points. The results also indicated that students with open laptops remembered less lecture content than did those with closed laptops.

Junco and Cotten (2011) examined the impact of multitasking on educational outcomes among college students, using a web-based survey questionnaire provided to 4,491 students from four academic institutions. On the questionnaire, students were asked whether instant messaging interferes with the completion of their homework, and over half of the students responded that instant messaging had a detrimental effect on their schoolwork. They also found that students used instant messaging at high levels and that they multitasked while using instant messaging.

Ellis et al. (2010) also investigated the effects of multitasking on academic performance among undergraduate business students. The sample consisted of 62 students enrolled in the first accounting principles course. In their study, half of the business students were allowed to multitask in the form of texting during a class lecture, while half of the participants were not. The results indicated that students who texted in class scored lower on a traditional test of memory of the lecture's contents. The researchers concluded that multitasking during class is a distraction that is likely to result in lower academic performance.

Kraushaar and Novak (2010) examined the effects of different types of computer-based multitasking behaviors on learning outcomes in a classroom setting. They hypothesized that a higher frequency of multitasking would be correlated with lower academic performance. They defined distractive multitasking as tasks or activities in which cognitive resources are used to process information that is not directly related to the course material, and they quantified the impact of distractive multitasking (i.e., playing games, instant messaging, browsing unrelated websites, or checking email during class) on academic performance in a classroom setting. The authors found limited and mixed support for the hypothesis that a higher frequency of multitasking was correlated with lower academic performance.

Other researchers have examined the impact of social media on student grades. Kirschner and Karpinski (2010) found that Facebook users have lower academic performance and spend fewer hours per week studying than do nonusers. Junco (2012a) examined the frequency with which students multitask during class when using Facebook and text messaging, as opposed to other communication technologies, and examined the relationship between multitasking and academic performance. Junco concluded that using Facebook and texting during class were negatively related to overall semester grade point average (GPA). These findings are consistent with the cognitive science literature that shows that the attempt to pay attention to two tasks simultaneously has an inherent cost in regard to the amount of time required to complete the tasks or to the errors made during completion, or both (Delbridge, 2000; Sana et al., 2013). These findings also are congruent with the hypotheses of other studies that the use of laptops during class would result in poorer academic outcomes (Kraushaar & Novak, 2010; Sana et al., 2013; Wood et al., 2012).

Measuring Multitasking Behaviors

Multitasking behavior has been difficult to measure, partly because its definition varies in the literature (Adler & Benbunan-Fich, 2012). Nevertheless, several researchers have developed metrics for computer-based multitasking (Benbunan-Fich, Adler, & Mavlanova, 2009; Benbunan-Fich et al., 2011; Czerwinski et al., 2004; Kraushaar & Novak, 2010). These metrics provide the mechanisms to measure multitasking activity for studies that examine the impact of different multitasking patterns on attention and performance in general.

Benbunan-Fich et al. (2009) define computer-based multitasking as multiple unrelated computer-based tasks performed concurrently. They proposed a set of metrics for computer-based multitasking, using the three components identified by Burton-Jones and Straub (2006) to measure information technology (IT) usage, namely, user, task, and technology. The relevant metrics of multitasking (MT), proposed and discussed by Benbunan-Fich et al., are presented below. The subscripts indicate the metric's relation to the user (U), task (T) or computer technology (C).

1. MT_{UC} is a measure that combines user and computer technology. It is expressed as the number of active windows used during a computer session. A session, which has a beginning and an end, is the concept used to measure time instead of a standard unit of time, such as an hour. In the classroom context, it could be a

lecture session. Hence, the measure of multitasking from the perspective of the user and technology can be expressed as:

$\mathbf{MT_{UC} = \sum w_i}$, where w_i is a window from an application or a browser tab.

2. MT_{TC} is a measure of the interaction between the task and computer technology. It is expressed as the number of different software programs or applications required for each task and is derived by dividing the number of applications by the total number of tasks. The measure of multitasking focused on task and technology can be calculated by:

   $\mathbf{MT_{TC} = (\sum a_i) / (\sum t_j)}$, where $\sum a_i$ is the number of applications and $\sum t_j$ is the total number of tasks.

3. MT_{UT} is a measure that combines user and tasks. It is expressed as the percentage of overlapping tasks with respect to all tasks performed concurrently during the computer sessions. An overlapping task is defined as a task in which the start time occurs before the end time of a previously started task. MT_{UT} is a multitasking metric combining user and tasks and can be expressed as:

   $\mathbf{MT_{UT} = (\sum \theta t_i) / (\sum t_j)}$, where $\sum \theta t_i$ is the total number of overlapping tasks and $\sum t_j$ is the total number of tasks.

4. MT_{UTC} is a measure of multitasking that combines all three elements: user, task and technology. In a computer-based environment, task switching may have two contexts: one is a switch that takes place within the same task, and the other is a switch that takes place between different tasks. An example of a switch within the same tasks is a student's conducting research about a topic (single task). In such a case, he or she may be involved in two functional *subtasks*, namely,

conducting an online search (with a web-based search engine) and writing up the report (with a word processor). The MT_{UTC} metric is the ratio of between-task switches to all switches (sum of between-task switches and within-task switches). Benbunan-Fich et al. (2011) noted that this metric is new and has not been used in the research on multitasking. The MT_{UTC} metric can be expressed as:

$\mathbf{MT_{UTC} = (\sum S_b) / [(\sum S_b) + (\sum S_w)]}$, where $\sum S_b$ is the total number of between-task switches and $[(\sum S_b) + (\sum S_w)]$ is the total number of switches.

Kraushaar and Novak (2010) also proposed a set of metrics for computer-based multitasking (MT), and the first one of these metrics was used in this study:

1. The frequency of multitasking ($MT_{Frequency}$) can be measured by determining the mean number of active windows/tabs generated by the student during a lecture. In this regard, it is important to make a distinction between open windows/tabs and active windows/tabs. An open window/tab is any window/tab opened by a program running in the student's laptop, while an active window/tab is the window/tab that the user is actually using by switching to and from it. Every active window/tab should reflect an independent task set, and, thus, the number of windows/tabs is representative of task switching. The frequency of multitasking ($MT_{Frequency}$) can be expressed as:

   $\mathbf{MT_{Frequency}}$ **= n of Active Windows / N of Lecture Sessions**

2. The duration of multitasking ($MT_{Duration}$) can be measured by the total time in seconds of all active windows divided by the number of windows generated. Specifically, duration is the mean time that an active window has the focus of and

can be easily viewed by a student. The duration of multitasking ($MT_{Duration}$) can be expressed as:

$MT_{Duration}$ = Total Time Windows Active (in sec) / n of Windows Generated

This metric measures the maximum possible time that a student could be focusing on an active window, not the actual time. Without a mechanism to record eye movement, it is impossible to determine the actual time that a student spent focusing on an active window. Therefore, Kraushaar and Novak (2010) suggested that the duration of multitasking ($MT_{Duration}$) might not be a proxy measure for the actual duration of window focusing.

3. The ratio of distractive-to-productive multitasking (MT_{DPR}) can be measured by dividing the student's total number of distractive windows generated by the total number of productive windows generated during the semester lectures. The ratio of distractive-to-productive multitasking (MT_{DPR}) can be expressed as:

   MT_{DPR} = n of Distractive Windows / n of Productive Windows

Czerwinski et al. (2004) operationalized multitasking as the number of task switches. This metric is determined by counting the number of times that a user shifts from one task to the next during a computer session, which is equivalent to the multitasking metric used in this study. This switch-related measure, as well as those proposed by Benbunan-Fich et al. (2011) and Kraushaar and Novak (2010), is considered rich measures of multitasking because they combine elements of task, user and technology. This section presented a review of the different metrics that have been used to investigate the effects of computer-based multitasking behavior on performance in academic and professional environments.

Summary of Gaps in the Literature

Although the use of laptops and tablet PCs in the classroom has the potential, through enabling an active approach to teaching and learning, to contribute to student learning (Alvarez et al., 2011), their unstructured use can detract from classroom learning (Bowman et al., 2010; Junco & Cotton, 2012; Sana et al., 2013). At present, however, there is limited research on the effect of such multitasking on educational outcomes (Junco & Cotton, 2011; Kraushaar & Novak, 2010; Rosen, Carrier, & Cheever, 2013; Wood et al., 2012). Specifically, Kraushaar and Novak (2010) concluded that there was "limited and mixed support for the hypothesis that a higher frequency of multitasking is correlated with lower academic performance levels" (p. 249).

Wood et al. (2012) examined the impact of multitasking with different digital technologies when learning from real-time classroom lectures but only for immediate recall of information (20-minute lecture followed by a 15-minute quiz) in a controlled environment where participants were randomly assigned to one of seven multitasking conditions: four experimental conditions (using Facebook, MSN messaging, cell-phone texting, and email messaging) and three control conditions (natural use of technology, word processing only, and paper-and-pencil for note-taking). Interestingly, researchers found that only using Facebook and MSN messaging negatively affected learning.

Rosen et al. (2013) examined the impact of task switching on the ability to learn when students studied for 15 minutes in their homes. The research determined the frequency of switching from studying to another task, why they switched, and how this affected their academic performance. The tasks related to learning that researchers observed were reading a book, reading an appropriate website, writing on paper, and writing on the computer. The distracted tasks observed were spending time on Facebook, instant messaging, texting, watching television, listening to music, eating, and walking/stretching. One hypothesis for this study was that the use of social media and preference for multitasking would predict reduced academic performance. The results indicated that academic performance was negatively affected by using Facebook at least once during the study period. The negative impact of task switching preference on academic performance, however, was not validated.

Most of the studies on the effects of multitasking in the classroom setting have methodological issues related to their being based on self-report surveys or anecdotal descriptions, which may not provide an accurate or valid measure of the frequency or nature of distractive multitasking, particularly because students may tend to under-report the frequency of distractive software usage (Fried, 2008; Wood et al., 2012). To address this gap and to provide a more reliable measure of the association between distractive multitasking and academic performance, this study measured multitasking behavior based on real-time information from a monitoring software tool that ran on students' laptops (Judd, 2013; Kraushaar & Novak, 2010).

Some studies, such as those of Rosen et al. (2013), Wood et al. (2012), and Sana et al. (2013) have findings relevant to the current study but were limited to an examination of the impact of multitasking on immediate recall of information (i.e., immediate learning). These researchers did not examine the effects of multitasking on longer-term retention, as reflected in, for example, student grades. Wood et al. (2012) used different digital technologies (Facebook, MSN messaging, email, and cell-phone texting), but found that the use of only one, Facebook, was detrimental to academic performance. This study extended previous research by examining the effects of multitasking on academic performance in a classroom setting over the course of a semester.

The literature on multitasking has overwhelmingly focused on Caucasian student populations. For example, the samples used in two separate Facebook studies conducted at a 4-year public university in the northeastern United States contained only 2% and 7% Hispanic/Latino students (Junco, 2012a, 2012b; Junco & Cotton, 2012). The sample used in a third Facebook study, conducted at a large, public Midwestern university, contained only 2.3% Hispanic/Latino students (Kirshner & Karpinski, 2010). Thus, we did not know how Hispanic/Latino ethnicity affected the relationship between distractive multitasking and academic performance (Junco, 2012a, 2012b). This study extended the current body of literature on the relationship between distractive multitasking and academic performance to a Latin American undergraduate student sample.

Many studies have relied on grade point average as a single measure of academic performance, which is considered as a limitation (Rosen et al., 2013). To overcome this limitation, this study, instead, used midterm and final evaluation scores as the student academic performance data.

Finally, as educators continue to integrate technology into their classroom, they need to have a better understanding of how technology can lead to better classroom engagement. It is important to determine what kind of multitasking associated with computer use may interfere with learning in a classroom setting. This study provides such information, which can be used in future research that determines how computers might be used to maximize learning while, at the same time, minimizing distraction (Kraushaar & Novak, 2010).

Chapter Summary

Research in the areas of information processing and cognitive science have shown that the human brain has a limited capability to attend to multiple stimuli and to perform simultaneous tasks (Chun et al., 2011; Foerde et al., 2006; Mayer & Moreno, 2003; Rosen et al., 2013; Wood et al., 2012). Research on multitasking has shown that participants who divide their attention between two or more concurrent tasks ("dual task interference") may take longer to complete tasks and may make more errors than when the tasks are performed sequentially (Adler & Benbunan-Fich, 2012; Bailey & Konstan, 2006; Iqbal & Horvitz, 2007; Ophir et al., 2009). Secondary or distractive tasks may cause the primary task to go cognitively unattended due to a cognitive bottleneck. This results in weaker encoding of primary task information into short-term memory, which means that information will not be adequately transferred to long-term memory. Further, when switching back attention from the distractive task to the uncompleted primary task, additional cognitive resources and time are required to reorient the focus onto the primary task. This additional cognitive load leads to increases in tasks errors and times as well as annoyance and stress (Kraushaar & Novak, 2010).

Researchers have begun to examine how students multitask in the classroom and how their multitasking affects their ability to learn and their overall educational outcomes (Fried, 2008; Junco & Cotton, 2011; Kraushaar & Novak, 2010; Wood et al., 2012). In a classroom setting, students tend to switch back and forth between academic and non-academic tasks. These non-academic tasks, which are generally performed on a laptop, include engaging with social networks and playing games and can lead to poorer academic performance (Junco, 2012a, 2012b; Junco & Cotton, 2012; Kirschner &

Karpinski, 2010; Wood et al., 2012). Although recent studies have reported negative impacts of computer-based multitasking on academic performance, to date, there is no consensus on the effects of technology use on academic performance.

The literature presents a variety of activity-based metrics for measuring computer-based multitasking behaviors (Benbunan-Fich et al., 2009, 2011; Czerwinski et al., 2004; Kraushaar & Novak, 2010). This study operationalized and measured computer-based multitasking by determining the frequency of distractive multitasking ($MT_{Frequency}$) through the mean value of active windows/tabs generated by a student during *n* lectures for all the instances of distracted multitasking behavior identified in this study. This activity-based metric combines two components (user and technology) of the three identified by Burton-Jones and Straub (2006), and the methodology is discussed in detail in the following chapter.

Chapter 3

Methodology

Study Design

This study uses a correlational research design with the aim to examine the relationship and potential causality between two variables, which classifies it as exploratory research (Gay, Mills, & Airasian, 2011). The predictor variable is frequency of distractive multitasking during class. Kraushaar and Novak (2010) defined distractive multitasking during class as students engaging in a group of tasks or activities in which cognitive resources are used to process information that is not directly related to the course material. For the purpose of this study, frequency of distractive multitasking is the average number of distractive windows as related to surfing and entertainment, email, PC operations in general (e.g., Windows Explorer, system software), and academic activities associated with other classes. The criterion variable is academic performance, as measured by the midterm and final evaluation scores.

This study concerns the effects of distractive multitasking, via a single-information technology platform (a computer device) and in a specific period of time, on learning outcomes in a classroom setting. The research determined the relationship between aspects of distractive multitasking and academic performance. Prior research has indicated that laptop use in the classroom is associated with multitasking and distraction (Fried, 2008; Kraushaar & Novak, 2010; Mokhtari et al., 2015). These, in turn, lead to decreased understanding of course material, which has a negative impact on academic performance. The research on the relationship between distractive multitasking, based on computer use in the classroom, and decrements in learning, however, comes primarily from self-reports and online surveys. Therefore, this study used a monitoring system to capture data that reflected actual multitasking behaviors from students who used computers while attending real-time classroom lectures. This study extends Kraushaar and Novak's (2010) research on this relationship by quantifying the impact of computer-based multitasking on learning.

Participants and Setting

The projected 64 study participants were undergraduate Latin American students enrolled in the Department of Computer Science in the School of Engineering at the Instituto Tecnológico Autónomo de México (ITAM), a private university located in Mexico City that is one of the nation's leading institutions of higher education. The participants were obtained through convenience sampling of the computer science students registered in a freshman-level required course during the winter 2015 semester. The course was titled Computational Tools and Algorithms (COM 16301). College students were chosen as participants for this study due to their strong usage of social technologies and their potential to multitask in the classroom (Kirschner & Karpinski, 2010).

In this course, the students had the opportunity to learn about and use computational tools for modeling as a means to assess and solve problems in various areas of engineering through structured reasoning, application of basic notion of mathematics, analysis of information, and the use of computer systems. The coursework occurred in the context of an innovative entrepreneurship project that used information and communication technologies. Due to the correlational nature of this study, all students participated in the same activity, i.e., used computers to perform their academic activities during the lecture, and were not divided into control and experimental groups. The use of a control group would not contribute to the addressing of the hypothesis.

Students in the class used lab desktop computers provided by the School of Engineering, connected via a wired network, which allowed them to work individually, in groups of two to three to review the materials to be submitted to the instructor and to develop tasks for a group project to be presented at the end of the semester. If they wished, students also could bring their own laptops to class to be used instead of the ones provided by the school. However, this was not encouraged.

Students participated in discussions with the instructor and learned to use various software tools that allow them to solve engineering problems similar to the ones that they will find in their professional careers. Students learned how to use computational tools, such as the computer algebra system Maple, MS Excel/Solver/VBA-Macros, and programming of algorithms using Visual Basic, to model and solve engineering problems. The working method is based on the instructor’s posing interesting problems, which are address through four key stages: (a) understanding the problem, (b) designing the solution for the problem, (c) implementing the solution with the aid of the computer, and (d) validating the solution and results.

Through the course’s inclusion of various computational tools for engineering tasks, students learned to identify and apply basic concepts of modeling, simulation and evaluation in various areas of engineering, including innovation and entrepreneurship, simulation systems, project evaluation, project planning, control and management, market analysis, modeling of business processes and strategy definition. The course was taught in a traditional lab style classroom that included a computer and projection system connected to a large-screen display and met twice a week for an hour-and-a-half over an 18-week semester.

In the first part of the lecture, the instructor explained the theoretical concepts, and, to demonstrate these concepts, directed the students to use the computational tools to access procedural knowledge to complement the lecture. In the second part, the students worked individually and in groups with their computers on specific tasks through examples, exercises, and problems, which were presented to students as work to be performed during the class and outside the class as homework. The students downloaded a file with the instructions for the task, which they did on their computers during the class and later at home. These instructions included, for example, references to video materials that provided demonstrations of the software tools (e.g., MS Excel, Maple, Visual Basic); samples of algorithms for modeling as a means to simulate, assess, and solve engineering problems; and links to educational materials on the Web to support their individual and group tasks. The task, which needed to be completed before the next lecture, involved computational tools that enabled the students to apply the material learned during the class.

Student performance data included a midterm and a final exam score. Both exams were traditional in-class examinations that consisted of theoretical questions and problems that needed to be resolved using the computational tools learned during the semester. The researcher expected that these evaluation scores would be very much affected by distractive multitasking in the classroom, based on the fact that both evaluations concerned activities performed in the classroom. The researcher did not take into account any score that related to activities performed outside the classroom (e.g., homework, projects). The researcher correlated separately the midterm exam score and the final exam score with the frequency of distractive multitasking measured during the classes before each exam.

Research Question and Hypothesis

The following research question was addressed in this study: "Is there a correlation between the frequency of distractive multitasking and academic performance (midterm and final evaluation scores)?"

The frequency of multitasking ($MT_{Frequency}$) was measured by the mean value of active windows/tabs generated by a student during *n* lectures for all the subcategories of distractive multitasking behavior: surfing and entertainment, email, PC operations in general (e.g., Windows Explorer, system software), and academic activities associated with other classes. In this regard, it is important to make a distinction between open windows/tabs and active windows/tabs. An open window/tab is any window/tab opened by a program running on the student's computer, while an active window/tab is the object that is currently displayed on the computer monitor and is considered to be "on top" and to have the focus of the student at any given time. The active window is the one currently awaiting or receiving mouse and keyboard input. Every active window/tab reflects an independent task set, and, thus, the number of windows/tabs is representative of task switching. The formula that was used is as follows:

$$\mathbf{MT_{Frequency} = Mean\ of\ active\ windows\ during\ N\ lecture\ sessions}$$

To answer the research question, the researcher correlated separately the midterm evaluation score and the final evaluation score with the frequency of distractive multitasking ($MT_{Frequency}$) of the students. This study used Pearson correlation coefficients (r) to determine the relationship between the frequency of distractive multitasking and academic performance.

This study builds on hypotheses developed in previous research (Fried, 2008; Kraushaar & Novak, 2010; Mayer & Moreno, 2003; Wurst et al., 2008) that has shown that multitasking and the unstructured use of computers in the classroom can have a negative impact on academic performance. The hypothesis for this study was: "There will be a negative correlation between academic performance (midterm and final evaluation scores) and frequency of distractive multitasking" (Kraushaar & Novak, 2010).

Procedures

Because the researcher did not interact directly with the study participants and was presented only with data that were completely de-identified, the researcher did not need Institutional Review Board approval to conduct the study. The only person who interacted with the students was the instructor of the course, who presented the de-identified data to the researcher.

The instructor of the course also informed the students that all the information to be collected will be anonymous and confidential, would be used only for research purposes, and would not have an impact on their final course grade. Related to this, the researcher was presented only with data that pertain to the purpose of this study.

A computer science professor from the Instituto Tecnológico Autónomo de México (ITAM) was recruited to cooperate with the researcher in conducting this study. This professor helped the researcher to select the appropriate instructor and course for this study. The professor also coordinated the logistics, e.g., found computers for students, obtained IT support for installing the data logger in the machines, coordinated with his teaching assistant to ensure that the monitoring system was fully operational during the class, retrieved the multitasking data files from the students' computers, and stored them in a shared folder in the cloud for later analysis by the researcher. Permission for the professor and students to participate in this study was sought from the school authorities.

The selected instructor taught the computer science course chosen as appropriate for this study, and this course served as the test bed course for this study. The course needed to meet the following criteria: (a) be taught in a traditional lecture-style classroom; (b) meet once a week for a total of 3 hours per week over an 18-week semester; (c) require that students use computers in the classroom to enable participation in lectures and to complete assignments; and (d) have student participation in the study be voluntary (Kraushaar & Novak, 2010).

Permission for the instructor and students of the selected course to participate in the proposed study was sought. Appendix A includes a permission letter from the Chair of the Department of Computer Science at Instituto Tecnológico Autónomo de México (ITAM), which allows the cooperating instructor and the researcher to conduct the study at this school. During the first week of the term, the cooperating instructor explained to the students the purpose of the study, how the monitoring software works, the kind of information that will be collected, the benefits of participating in the study, and how the information from the study will be used. To minimize the impact of the novelty effect, the cooperating professor did not describe the exact nature of the research inquiry in any more detail than is ethically or legally necessary.

Students were told about the methods to be used to assure their anonymity and to protect their data. Student user names were replaced by a 4-digit code, and students were assured that their data will be used only in aggregate form for purposes of the research and that no personal identification of the students will be made available.

Given that students who participated in the study knew that they were being monitored, a limitation of this exploratory study is the "novelty effect." The design of this study minimized the impact of the novelty effect by including the strategy described in the Barriers and Issues section in Chapter 1. Prior research has shown that the use of monitoring software addresses the problems of students' underreporting multitasking that occurs in self-report surveys and provides a more accurate measure of the quantity and nature of distractive multitasking in the classroom (Fried, 2008).

Multitasking behavior data and academic performance data (midterm and final evaluation scores) were collected for each study participant. Finally, multitasking data was analyzed quantitatively using the appropriate statistical tools (Kraushaar & Novak, 2010).

Data Collection

Students who decided to participate in the study were assigned computers in the lab that had the monitoring software tool installed on them. Those students used the same computer for the entire semester. All machines were assigned an identification number.

The researcher, through the cooperating instructor, monitored the students' multitasking behaviors throughout a limited period of time during the academic semester and quantified their multitasking activity in terms of frequency of multitasking during class.

Multitasking behavior data were collected based on actual information directly from a monitoring software tool that ran on students' computers. Academic performance data were collected for each study participant from the cooperating instructor's academic records system. Student performance data consisted of midterm and final evaluation scores.

Data Analysis

Data analysis focused on the predictor variable, which was the frequency of distractive multitasking during class. This multitasking metric is objective and computer-centric. It is objective because it is based on actual usage patterns and is computer-centric because this study considers computer-based multitasking with only a single device (computer). Quantitative measures of the frequency of multitasking were collected during 10 weeks of the academic semester, and these were based on actual student usage as reported by activity-monitoring software installed on students' computers.

During the measurement process, each active window was classified as either productive or distractive. Active windows that were related to the course material were classified as productive, while active windows not related to the course material were classified as distractive. The distractive windows were further subdivided into four subcategories: surfing and entertainment (e.g., non-course-related web-surfing, online searching, Facebook, games), email (e.g., web-based email applications, Gmail, Outlook), PC operations in general (e.g., Windows Explorer, system software), and academic activities associated with other classes (Kraushaar & Novak, 2010).

The researcher then correlated the aggregated value of the distracting multitasking behaviors of the students for all the distracting multitasking subcategories with their academic performance (midterm and final evaluation scores). The results of these correlations determined the effects of distractive multitasking on learning performance in the classroom.

Statistical Analysis

In this study the researcher collected quantitative data as a means to address the research question. A quantitative data analysis, using Pearson correlation coefficients (r), was conducted to identify the relationship between the multitasking construct (frequency of distractive multitasking), including all four of the distracting multitasking subcategories, and the students' academic performance (midterm and final evaluation scores). To determine the effect of distractive multitasking on academic performance, the researcher also conducted a two-tailed test of significance of the correlation, using a significance level of $p \leq 0.05$.

Materials and Apparatus

The materials and apparatus that were needed for this study included the following:

- The Activity Monitor™ package, which is software for monitoring the multitasking activity of students and is available from SoftActivity. This software allowed remote computer monitoring and keylogger recording in real time as well as allowed the researcher to view and record Internet activity and trace all programs started and run by the students.

- The hardware consisted of the lab desktop computers provided by the School of Engineering at the Instituto Tecnológico Autónomo de México (ITAM).

Resource Requirements

The resources required to conduct this research were as follows:

- Access to activity monitor software was crucial to the successful completion of the research. This software is difficult to develop, and commercial versions are expensive. Its cost is estimated at $1,050 for a 50-computer educational license. The company SoftActivity graciously facilitated access to the activity monitor software tool at no cost for this study. The researcher acknowledges the support of the company SoftActivity to this research.
- Statistical tools are a major component of analyzing the data. Two statistical packages were evaluated for their applicability to the study: SPSS and Microsoft Excel with statistical functions. Microsoft Excel software was used to conduct the statistical analyses required in this study.

Chapter Summary

This chapter presented the methodology that was used in this non-experimental, correlational study. The chapter began with an overview of the study design, which was followed by a discussion of the selection of the participants and the setting. Then the research question and hypothesis, including how they were addressed, were presented, followed by a description of the step-by-step procedures that were used in the study, including the procedures and testing environment. The chapter concluded with a discussion of how the data were collected and statistically analyzed. Specifically, Pearson correlation coefficients were used to show the relationship between the criterion and predictor variables.

Chapter 4

Results

This chapter presents the results of the analysis of the effects of distractive multitasking, related to computer work, on students' attention and academic performance and is organized into four sections. The first section contains the data generation, collection, and analysis and includes a detailed presentation of how the researcher (a) obtained and collected the data, (b) quantified the frequency of distractive multitasking during class, and (c) determined the correlation between distractive multitasking and academic performance. The second provides the results for both distractive multitasking and correlation. The third section presents qualitative observations made by the researcher, based on his attending two weeks of classes during the study, and the fourth includes the results in regard to how multitasking affects student outcomes and whether the study hypothesis was supported.

Data Generation, Collection, and Analysis

For the purpose of this study, a convenience sample of 53 undergraduate students enrolled in the Department of Computer Science in the School of Engineering at the Instituto Tecnológico Autónomo de México (ITAM), a private university located in Mexico City and one of the nation's leading institutions of higher education, was utilized. The original sample contained 64 students, but nine students were removed from the study and the data of two had missing responses, bringing the sample down to 53. Specifically, seven students decided not to participate in the study and signed the appropriate form to indicate this decision, and two students did not sign the form, and, thus, it was assumed that they did not want to participate in the study. As noted, two other students had missing responses, as seen in the data-cleaning process performed to improve data quality, and, thus, their data were removed. The remaining 53 students signed the appropriate form, indicating their consent to participate.

A non-experimental, correlational design was used to examine the relationship between distractive multitasking activity on students' attention and academic performance in a classroom setting. Because this study examines the relationship and potential causality between two variables, it can be considered exploratory research (Gay et al., 2011). The research question that guided the study was, "Is there a correlation between the frequency of distractive multitasking and academic performance (midterm and final evaluation scores)?" The predictor variable was frequency of distractive multitasking during class, while the criterion variable was academic performance, as measured by the midterm and final evaluation scores.

For the purpose of this study, the frequency of distractive multitasking during class is the average number of distractive windows as related to four specific distractive categories: surfing and entertainment (e.g., non-course-related web-surfing, online searching, Facebook, games), email (e.g., web-based email applications, Gmail, Outlook), PC operations in general (e.g., Windows Explorer, system software), and academic activities associated with other classes. The greater the generation of these active windows, the higher the frequency of distractive multitasking.

The $MT_{Frequency}$ formula is used to measure the frequency of distractive multitasking behavior. Specifically, $MT_{Frequency}$ is the total number of active distractive windows generated by the student divided by the number of lectures scrutinized by the monitoring system (Kraushaar & Novak, 2010). The formula is as follows:

$MT_{Frequency}$ = Mean of active windows during N lecture sessions

Students with higher $MT_{Frequency}$ engaged in more frequent multitasking during the lectures than did students with lower $MT_{Frequency}$. The researcher calculated each student's $MT_{Frequency}$ for the distractive multitasking category, which included all four subcategories of distractive activity: surfing and entertainment, email, PC operations in general, and academic activities associated with other classes.

The researcher independently examined the relationship between distractive multitasking activity on students' attention and academic performance for two sets of class sessions during the semester and, as such, collected multitasking data for these two sets of class sessions. The first set of class sessions occurred right before the mid-term exam and consisted of four weeks of classes (Period A). The second set of class sessions occurred right before the final exam and consisted of six weeks of classes (Period B; Figure 3).

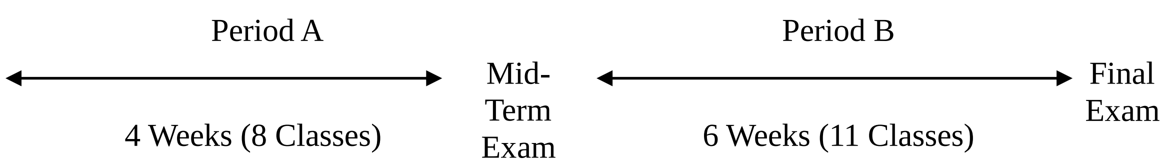


Figure 3. Time periods for study of multitasking.

To quantify the frequency of distractive multitasking, the researcher analyzed each active window, using the image of the screen shot stored in the log file of the monitoring system to determine whether it corresponded to a productive or distractive task. This was a screen shot of what the student was focusing on at that precise moment or the one currently waiting for and/or receiving mouse and keyboard input. Appendix C shows examples of screen shots that illustrate both a productive and distractive task. The analysis of each screen shot was a detailed and time-demanding task, as it involved quantifying multitasking data for 53 students collected over 10 weeks and 19 lectures in total, which meant about 1,000 data blocks per student per lecture. The researcher, along with two students hired to assist with the data coding, analyzed the screen shots.

To minimize the coder's subjective interpretation of the screen shot and to maintain intra-coder reliability (stability), the researcher ensured that the same coder analyzed the data, in this case, the screen shots, in the same manner during the coding process by providing the coder with the instructions seen in the student multitasking activity rubric included in Table 1. In a similar fashion, to achieve reliable coding among multiple coders and to maintain inter-coder reliability (reproducibility or investigator triangulation), the researcher ensured that different coders analyzed the same data (screen shots) in a consistent manner (Lazar, Feng, & Hochheiser, 2010). The researcher used data triangulation for four weeks of classes out of the total 10 weeks used to conduct the study. Two weeks corresponded to Period A and the other two weeks to Period B. The inter-coder reliability was acceptable, as the percentage agreement was 81%.

As seen in the rubric information in Table 1, an active window denoted a productive task if it was related to the course material; otherwise, it denoted a distractive task. If the active window denoted a distractive task, the researcher additionally had to identify to which of the four subcategories of distractive activity (surfing and entertainment, email, PC operations in general, and other academic activities associated with other classes) the distractive task belonged.

Table 1

Student Multitasking Activity Rubric Information

Multitasking Category	Application Examples
Productive: Course material-related windows	MAPLE, Excel, course portal-related windows (tasks or activities that are directly related to a primary computing task associated with the course material)
Distractive: Non-course material-related windows	Tasks or activities for which cognitive resources are used to process information that is not directly related to the course material
Surfing and entertainment	Non-course-related web-surfing, online searching, Facebook, games, and so forth
Email	Web-based email applications (Gmail, Hotmail)
PC Operations	Windows Explorer, control panel, command prompt, locating and/or downloading files, file management, tuning the computer for better performance
Other academic activities	Academic work for other courses

The total number of active windows for both multitasking categories, productive and distractive, was determined for each student and for each lecture during the two sets of class sessions, Period A (four weeks) and Period B (six weeks). The number of active windows for the distractive multitasking category per student and lecture was classified into one of the four subcategories of distractive multitasking (surfing and entertainment, email, PC operations in general, and academic activities associated with other classes). The total number of active windows for both multitasking categories, productive and distractive, represents the number of times that the student shifted from one task to the next during the corresponding class session.

As noted, $MT_{Frequency}$ for the distractive multitasking category was obtained by dividing the total number of active distractive windows generated by the student during Period A or Period B by the number of lectures that are scrutinized by the monitoring system during each time period. The researcher calculated, for each student, the average number of active windows during *n* lecture sessions ($MT_{Frequency}$) for the overall productive multitasking and overall distractive multitasking category, which encompassed all four subcategories of computing distractive tasks and for each one of the subcategories of distractive multitasking.

It is important to note that only the frequency of overall distractive multitasking was used for calculating the correlation with academic performance. The mean (Average function) and standard deviation (STDEV.P function) calculations were performed using Excel. A sample of this descriptive data is presented in Appendix B.

This study used Pearson correlation coefficients (*r*) to determine the relationship between the frequency of distractive multitasking and academic performance at the .05 level (95% confidence level). The researcher used Excel as the statistical tool to automate this part of the calculation process. The correlation variables are presented in Table 2. The significance of the relationship was assessed after the Pearson coefficient (*r*) was obtained.

Table 2

Correlation Variables

Period A (8 Class Sessions)		Period B (11 Class Sessions)	
Predictor Variable	Criterion Variable	Predictor Variable	Criterion Variable
$MT_{Frequency}1$	Mid-term Exam-1	$MT_{Frequency}1$	Final Exam-1
$MT_{Frequency}2$	Mid-term Exam-2	$MT_{Frequency}2$	Final Exam-2
…	…	…	…
$MT_{Frequency}n$	Mid-term Exam-n	$MT_{Frequency}n$	Final Exam-n
…	…	…	…
$MT_{Frequency}53$	Mid-Term Exam-53	$MT_{Frequency}53$	Final Exam-53

Note. A sequence of rows for the rest of the students is indicated by ". . ."

Frequency of Multitasking and Correlation Results

Table 3 presents the results of a descriptive analysis of the frequency of multitasking behavior ($MT_{Frequency}$) by multitasking category for the first set of class sessions, Period A, which occurred before the midterm exam and lasted four weeks (Kraushaar & Novak, 2010).

Table 3

Analysis of $MT_{Frequency}$ by Software Multitasking Category (Period A)

Multitasking Category	Mean $MT_{Frequency}$	$MT_{Frequency}$ Std. Dev.	Minimum $MT_{Frequency}$	Maximum $MT_{Frequency}$
Overall (Productive + Distractive)	71.3	27.8	16	175
Productive	48.7	21.8	3	152
Distractive	22.6	10.9	3	59.6
Surfing and entertainment	4.1	4.2	0	19.4
Email	1.7	2.8	0	14.1
PC operations	14.1	5.3	3	27.7
Other academic activities	2.7	5.1	0	26

Students generated 71.3 active windows, in total, for productive and distractive multitasking per lecture on average. On average, however, students generated fewer distractive windows (22.6) per lecture than productive windows (48.7). Only 32% of the total active windows can be categorized as distractive. The distractive multitasking category is further classified into surfing and entertainment, email, PC operations, and other academic activities categories, for which the means of the frequency of distractive multitasking ($MT_{Frequency}$) were 4.1, 1.7, 14.1, and 2.7 active windows per lecture, on average, respectively (Kraushaar & Novak, 2010).

There was one student who generated as many as 175 active windows in total for productive and distractive multitasking per lecture. This means that this student shifted 175 times from one task to another during a specific lecture, denoting a high degree of multitasking. On the other end of the spectrum, there was a student who generated only 16 active windows per lecture.

There also was divergence in the frequency of productive and distractive multitasking ($MT_{Frequency}$). One student generated as many 152 productive active windows per lecture, while another generated only three productive active windows per lecture. In a similar fashion, one student had a frequency of distractive multitasking ($MT_{Frequency}$) of 59.6 active windows per lecture, while another had a frequency of distractive multitasking ($MT_{Frequency}$) of only three active windows per lecture.

Table 4 presents the results of a descriptive analysis of the frequency of multitasking behavior ($MT_{Frequency}$) by multitasking category for the second set of class sessions, Period B, which occurred before the final exam and lasted six weeks (Kraushaar & Novak, 2010).

Table 4

Analysis of $MT_{Frequency}$ by Software Multitasking Category (Period B)

Multitasking Category	Mean $MT_{Frequency}$	$MT_{Frequency}$ Std. Dev.	Minimum $MT_{Frequency}$	Maximum $MT_{Frequency}$
Overall	115.8	33.5	62.8	215
Productive	85.2	24.2	40.7	179
Distractive	30.6	14.3	12.8	80.3
Surfing and entertainment	7.2	9.3	0.1	54.8
Email	2.9	4.5	0	27.2
PC operations	17.8	6.7	7	35
Other academic activities	2.7	2.2	0	9.9

Students generated 115.8 active windows, in total, for productive and distractive multitasking per lecture, on average. On average, however, students generated fewer distractive windows (30.6) per lecture than productive windows (85.2). Only 26% of the total active windows can be categorized as distractive, a lower percentage than occurred during Period A. The distractive multitasking category is further classified into surfing and entertainment, email, PC operations, and other academic activities categories, for which the mean frequency of distractive multitasking ($MT_{Frequency}$) incurred by the students were 7.2, 2.9, 17.8, and 2.7 active windows per lecture on average, respectively (Kraushaar & Novak, 2010).

One student generated as many as 215 active windows in total for productive and distractive multitasking per lecture. This means that this student shifted 215 times from one task to another during a specific lecture, denoting a high degree of multitasking. However, another student generated only 62.8 active windows per lecture.

There also was divergence in the frequency for productive and distractive multitasking ($MT_{Frequency)}$. One student generated as many 179 productive active windows per lecture, while another generated only 40.7 productive active windows per lecture. In a similar fashion, one student had a frequency of distractive multitasking ($MT_{Frequency)}$ of 80.3 active windows per lecture, while another student had a frequency of only 12.8 active windows per lecture.

The Pearson correlation coefficients (*r*) between the frequency of distractive multitasking ($MT_{Frequency}$) and academic performance at the midterm exam (Period A) was r = -0.123, while that at the final exam (Period B) was r = 0.015. Neither correlation was significant.

The results did not support the hypothesis, "There will be a negative correlation between academic performance (midterm and final evaluation scores) and frequency of distractive multitasking." In other words, the hypothesis that more distraction from in-class multitasking, using a computer, leads to lower academic achievement was not supported.

Observations of Class Sessions

Although the design of this study does not include a formal collection of qualitative data, the researcher engaged in some qualitative observations when attending class sessions during two weeks of the semester. The course, Computational Tools and Algorithms, was taught in a traditional lab-style classroom that included desktop computers, connected via a wired network, and met twice a week for an hour-and-a-half over an 18-week semester. The classroom also included a computer for the instructor and a projection system connected to a large-screen display.

All students had access to a shared folder in the course portal from which they downloaded the course material for each lecture. In the first part of the lecture, the instructor reviewed the previous lecture and explained the theoretical concepts (declarative knowledge) for the current lecture. To show how to apply these concepts, the instructor directed the students to use the computational tools to obtain procedural knowledge to complement the theoretical part of the lecture.

In the second part of the lecture, the students worked individually or in groups with their computers on specific tasks, such as exercises and problems (procedural knowledge), which were presented to students as work to be performed during the class and as homework outside the class. During the second part of the lecture, the instructor chose randomly at least one student to go to the front of the class and to use the instructor's computer to solve a sample problem, showing the results in the projection screen. The rest of the students continued to work simultaneously on the same problem on their assigned lab computer.

The class was interactive; the instructor walked around the classroom most of the time, asking questions to the students and vice versa. The course also was hands-on, and, as such, the students had to be attentive to the instructor and follow the problem resolution by their peers who were in front of the class.

To keep track of the data collected from each machine for a specific student, the instructor asked the students to always use the same machine throughout the semester. The researcher saw the instructor's enforcing the use of the same machine when a student wanted to switch computers to sit next to a friend. This helped to maintain the veracity of the data.

The instructor commented to the researcher that the course included a lot of content for the semester and, thus, needed to be taught at a fast pace, which demanded a high degree of attention from students so that they did not lag behind. The researcher also noted that some students did not do homework from class to class, as indicated by their not knowing how to use Excel functions, which were taught in previous classes.

The researcher observed the students' multitasking with their cellular phones, but this type of multitasking was not measured, as this study considered only lab computer-based multitasking. The instructor continued to encourage the students to work individually on the problem, using their assigned lab computer, and not just to copy the solution that was being developed by a classmate and displayed on the big screen.

The researcher also observed that, when students arrived late to the class, they struggled to catch up, given the fast pace of the class. This was indicative of the need to pay continuous attention to the instructor.

Results in the Context of the Research Question and the Hypothesis

This section presents the results as related to the research question and hypothesis. The research question that guided this study is, "Is there a correlation between the frequency of distractive multitasking and academic performance (midterm and final evaluation scores)?" The study was built on hypotheses developed in previous research (Fried, 2008; Kraushaar & Novak, 2010; Mayer & Moreno, 2003; Wurst et al., 2008) that shows that multitasking and the unstructured use of computers in the classroom can have a negative impact on academic performance. The hypothesis for this study, as drawn from Kraushaar and Novak, is, "There will be a negative correlation between academic performance (midterm and final evaluation scores) and frequency of distractive multitasking." In other words, more distraction from in-class multitasking, using computers, leads to lower academic achievement.

The quantitative findings in the study showed that there was no statistically significant relationship between the frequency of distractive multitasking (predictor variable) and academic performance (criterion variable), as measured by the midterm and final evaluation scores for both of the time periods (Period A: $r = -.123$, $p > .05$; Period B: $r = .15$, $p > .05$). The findings suggest that distractive multitasking did not interfere with academic activities under the specific conditions of the classroom setting established for this exploratory study.

Chapter Summary

The results of the analysis of distractive multitasking and its effect on students' attention and academic performance were presented in this chapter. Notably, the researcher tested intra-coder and inter-coder reliability to ensure the validity of research findings.

To address the research question and hypothesis, the researcher needed to quantify the frequency of distractive multitasking by identifying and counting the active distractive windows generated by each student for each set of class sessions and dividing this number by the number of lectures scrutinized by the monitoring system. The result is the mean number of distractive windows generated by each student during each set of class sessions (Period A and Period B) as well as the frequency of distractive multitasking for Periods A and B. Pearson correlation coefficients (r) were used to measure the relationship between the frequency of distractive multitasking ($MT_{Frequency}$) and academic performance (midterm and final exams) at the $\alpha = .05$ level for the distractive software category.

The quantitative findings showed that there was no statistically significant relationship between the frequency of distractive multitasking (predictor variable) and academic performance (criterion variable) measured by the midterm and final evaluation scores. The following chapter provides a discussion of results as related to the literature, the implications of research, and limitations and future directions.

Chapter 5

Conclusions, Implications, Recommendations, and Summary

This chapter is organized into four main sections. The first section presents the conclusions of the study based on the results related to the effects of distractive computer-based multitasking on students' attention and academic performance in a classroom setting as well as provides an explanation of how the goal of the study was achieved and its strengths, weaknesses, and limitations. The second section provides the implications of the study's findings as well as the contribution of the study to our understanding of the impact of multitasking on learning. The third section contains recommendations for further research and professional practice. Finally, the fourth section presents a summary of the study, including the problem statement and goal, research question and hypothesis, methodology, key findings, implications, and recommendations.

Conclusions

Goal of the Study and Results

Research has shown the negative impacts of distractive multitasking on academic performance (Bowman et al., 2010; Ellis et al., 2010; Sana et al., 2013; Wood et al., 2012). Thus, the main goal of this study was to examine the effects of distractive multitasking on academic performance when university students used computers while attending real-time classroom lectures. This was accomplished by extending Kraushaar and Novak's (2010) research on the effects of distractive computer-based multitasking, via a single-information technology platform (a computer device) and in a specific period of time, on learning outcomes in a classroom setting.

To examine the goal, the researcher identified and measured different instances of distractive multitasking engaged in by the students in the classroom. Typical scenarios of distractive multitasking involved students' engaging in surfing to find entertainment, emailing, online searching, and other non-course-related activities. Multitasking behavior was conceptualized and measured in terms of the frequency of such multitasking. The researcher, using monitoring software, recorded the windows/page names for each software application that was running on the students' computers. These application windows were considered productive or distractive according to whether they were related to the course materials. The frequency of distractive multitasking was measured by determining the average number of distractive application windows that had the focus of a student during the lectures (active windows). Based on the frequency of the distractive multitasking, the researcher evaluated the impact of distractive multitasking behavior on academic performance. For the purpose of this study, academic performance was operationalized as the midterm and final evaluation scores.

The study was built on previous research (Fried, 2008; Kraushaar & Novak, 2010; Mayer & Moreno, 2003; Wurst et al., 2008) that has shown that multitasking and the unstructured use of computers in the classroom can have a negative impact on academic performance. The hypothesis for this study, as drawn from Kraushaar and Novak (2010), is: "There will be a negative correlation between academic performance (midterm and final evaluation scores) and frequency of distractive multitasking." In other words, more distraction from in-class multitasking using computers leads to lower academic achievement.

The results did not support the hypothesis that distractive computer-based multitasking can have a negative impact on academic performance. Specifically, the results show that, under the conditions of this study, students generated less distractive multitasking than productive multitasking. As such, they did not become as distracted as was hypothesized. Further, students who multitasked frequently during the lecture lessened the negative performance impact of distractive multitasking by engaging more frequently with tasks associated with the course material (productive multitasking). Productive multitasking might have acted as "good multitasking," compensating for the negative impact of distractive multitasking ("bad multitasking"). The smaller percentage of distractive windows seen in the study results may be due to the fact that the course included a lot of content for the semester, which, thus, needed to be taught at a relatively fast pace. This demanded a high degree of attention from students so that they did not fall behind.

The course was highly interactive, and the instructor frequently walked around the classroom, posing questions to the students and observing how much progress they were making. This instructor's teaching practice discouraged students from engaging in distractive computer-based multitasking, and, thus, they would tend to generate fewer distractive windows. Finally, students may have studied outside of class before each exam, which would have compensated for any potential negative performance impact of distractive multitasking.

Strengths, Weaknesses, and Limitations of the Study

Most of the studies on the effects of multitasking in the classroom setting have methodological issues related to their being based on self-report surveys or anecdotal descriptions, which may not provide an accurate or valid measure of the frequency or nature of distractive multitasking, particularly because students may tend to underreport the frequency of distractive software usage (Fried, 2008; Wood et al., 2012). Thus, a strength of this study is that it provided a more reliable measure of the association between distractive multitasking and academic performance through its being situated within an authentic, formal learning setting (classroom) and measuring multitasking behavior based on real-time information from a monitoring software tool that ran on students' computers.

In addition, many studies have relied on GPA as a single measure of academic performance, which does not reflect the performance in the class whose material is being studied. The current study used midterm and final evaluation scores as the student academic performance data, which also can be considered one of the study's strengths. A final strength of this study is its measurement of multitasking behavior on a longer-term basis, over the course of a semester, and not only during a few lectures or over a short period of time.

This study also had several limitations. One limitation concerns its small sample size (53 participants) and the use of a convenience sample that included students in only one course. A larger sample size, which includes students in more than one course, would have had more statistical power and, thus, would have provided a greater opportunity to yield statistically significant results.

A second limitation concerns the novelty effect, which occurs when research participants respond to a novel situation differently in the context of a study than they would in the real world (Gravetter & Forzano, 2011). It is possible that some of the students who participated in the proposed study had altered their multitasking behavior in some way, given that they knew that they were being monitored. Research also has shown that, over time, as the novelty wears off, the behavioral response returns to a natural one. Nevertheless, the design of the study minimized the impact of the novelty effect, as the measurements were taken over the course of a semester.

A third limitation is that the role of smartphones and other digital devices (e.g., tablets) in distractive multitasking was not considered, as this study was limited to a single source of computer-based multitasking (a computer). A final limitation of this study is that it was correlational, and, as such, no causality regarding the effects of distractive computer-based multitasking on academic performance can be inferred.

Implications of the Study

The course used in this study was hands-on and interactive, requiring students to be very attentive to the instructor's explanation of the theoretical concepts (declarative knowledge) and to the resolution of the practical problems discussed in class (procedural knowledge), for which the computer was an essential tool for learning. This implies that courses with more procedural knowledge content might encourage less distractive computer-based multitasking during the lecture when the computer is an essential instrument for acquiring that procedural knowledge.

Students who multitask frequently during the lecture lessen the negative performance impact potentially caused by distractive multitasking by engaging more frequently with tasks associated with the course material (productive multitasking). This implies, as noted earlier, that productive multitasking might act as “good multitasking,” compensating for the negative impact of distractive multitasking (“bad multitasking”).

Recommendations

Recommendations for Further Research

Based on the results and limitations of this study, several recommendations for further research can be made. This study was limited to a single source of computer-based multitasking (a computer device). Thus, the impact of multitasking on learning, using other technology platforms (e.g., smartphones, tablets), is needed.

In addition, the study sample was small and limited to students in one course. Further research should use a larger sample to ensure greater statistical power for subsequent analysis as well as a more diverse sample, in terms of race/ethnicity, gender, income, and academic institution, to increase the generalizability of the findings.

This study treated multitasking and the use of technologies mainly as distracting tasks. Thus, further research could examine the effect of the use of technologies for tasks related to the course material (productive tasks) on learning and how they affect the overall multitasking context when both distractive and productive tasks are present.

Considering that courses with a different mix of declarative and procedural knowledge might produce different results, it would be useful to future researchers to consider courses with a variety of mixes to learn more how this affects distractive multitasking on learning. Finally, as noted, it may be that students who multitask frequently during the lecture can compensate for the potential negative performance impact by studying outside of class. Future researchers could investigate this by including quizzes after each lecture (i.e., immediate learning) to determine the in-the-moment impact of distractive multitasking.

Recommendations for Professional Practice

Based on the results of this study, recommendations for professional practice can be made. Research on the performance consequences of computer-based multitasking can be used to inform educators, practitioners, and policymakers in regard to optimal management of computer use in the classroom. Nevertheless, in courses for which technology is not necessary for learning, educators may want to discourage laptop or smartphone use in the classroom.

Summary of the Study

There is limited research on the impact of multitasking, using computers and other peripheral computing devices, on educational outcomes (Iqbal et al., 2011; Junco & Cotton, 2011). Existing studies rely on self-reported perceptions or anecdotal descriptions of use, which may not reflect an actual multitasking scenario, and students usually tend to underreport their multitasking activities (Fried, 2008).

The main goal of this study was to examine the effects of distractive multitasking on academic performance when university students used computers during classroom lectures. To this end, a methodology and data collection process similar to that of Kraushaar and Novak (2010) was applied, but with different types of participants, age groups, races/ethnicities, and locations. The study used an experimental course with a mix of declarative and procedural knowledge, which is different from the mix used by Kraushaar and Novak.

The researcher identified and measured different instances of distractive multitasking engaged in by the students in the classroom. Typical scenarios of distractive multitasking involved students' engaging in surfing to find entertainment, emailing, online searching, and other non-course-related activities. Multitasking behavior was conceptualized and measured in terms of the frequency of such multitasking. The researcher, using monitoring software, recorded the windows/page names for each software application that was running on the students' computers. These application windows were considered productive or distractive according to whether they were related to the course materials. The researcher measured the frequency of distractive multitasking by determining the average number of distractive application windows that had the focus of a student during the lectures (active windows). Based on the frequency of the distractive multitasking, the researcher evaluated the impact of distractive multitasking behavior on academic performance. For the purpose of this study, academic performance was operationalized as the midterm and final evaluation scores.

The research question that guided this study is: "Is there a correlation between the frequency of distractive multitasking and academic performance (midterm and final evaluation scores)?" and the hypothesis, as drawn from Kraushaar and Novak (2010), is: "There will be a negative correlation between academic performance (midterm and final evaluation scores) and frequency of distractive multitasking."

For this study, a convenience sample of 53 undergraduate students enrolled in the Department of Computer Science in the School of Engineering at the Instituto Tecnológico Autónomo de México (ITAM), a private university located in Mexico City and one of the nation's leading institutions of higher education, was utilized. The course was taught in a traditional lab-style classroom that included a computer and projection system connected to a large-screen display, and students met twice a week for an hour-and-a-half over an 18-week semester. Students in the class used lab desktop computers provided by the school, connected via a wired network, which allowed them to work in groups of two to three to review the materials to be submitted to the instructor and to develop tasks for a group project to be presented at the end of the semester.

This study used a correlational research design with the aim to examine the relationship and potential causality between two variables, which classifies the study as exploratory research. The predictor variable is frequency of distractive multitasking during class. For the purpose of this study, the frequency of distractive multitasking during class is the average number of distractive windows as related to four specific distractive categories: surfing and entertainment (e.g., non-course-related web-surfing, online searching, Facebook, games), email (e.g., web-based email applications, Gmail, Outlook), PC operations in general (e.g., Windows Explorer, system software), and academic activities associated with other classes. The criterion variable is academic performance measured by the midterm and final evaluation scores. This study used a monitoring system to capture data that reflected actual multitasking behaviors from students who used computers while attending real-time classroom lectures.

The researcher independently examined the relationship between distractive multitasking activity on students' attention and academic performance for two sets of class sessions during the semester and, as such, collected multitasking data for these two sets of class sessions. The first set of class sessions occurred right before the mid-term exam and consisted of four weeks of classes. The second set of class sessions occurred right before the final exam and consisted of six weeks of classes.

Pearson correlation coefficients were generated to determine the relationship between the frequency of distractive multitasking and academic performance but found no statistically significant relationship. As such, the results did not support the hypothesis that distractive computer-based multitasking can have a negative impact on academic performance. Specifically, the results show that, in this study, an average student generates less distractive multitasking than productive multitasking and, thus, did not become as distracted as was hypothesized.

The results can be understood in view of certain considerations. The course used for this exploratory research was hands-on and interactive, requiring students to be very attentive to the instructor's explanation of theoretical concepts (declarative knowledge) and the resolution of the practical problems discussed in class (procedural knowledge) for which the computer was an essential tool for learning. In addition, due to the large course content, it had to be taught at a relatively fast pace, which demanded a high degree of attention from the students so that they did not fall behind. Further, the instructor's practice of walking around the class and interacting with the students discouraged them from getting distracted. Finally, students may have studied outside of class before each exam, which would have compensated for any potential negative performance impact of distractive multitasking.

The results suggest that students who multitask frequently during the lecture lessen the negative performance impact potentially caused by the distractive multitasking by engaging more frequently with tasks associated to the course material (productive multitasking). It appears that productive multitasking acts as “good multitasking,” compensating for the negative impact of distractive multitasking (“bad multitasking”). This highlights the importance of the mix of declarative and procedural knowledge in the course as related to the effects of multitasking. Courses with different mixes of declarative and procedural knowledge might produce different results in terms of the impact of distractive multitasking on learning (Kraushaar & Novak, 2010).

Recommendations for further research and for professional practice were made. Future researchers should (a) consider on the impact of multitasking on learning, using other technology platforms (e.g., smartphones, tablets); (b) use a larger sample to ensure greater statistical power for subsequent analysis as well as a more diverse sample, in terms of race/ethnicity, gender, income, and academic institution, to increase the generalizability of the findings; (c) explore the effect of the use of technologies for tasks related to the course material (productive tasks) on learning and how they affect the overall multitasking context when both distractive and productive tasks are present; (d) examine the effect of experimental courses with a variety of mixes of declarative and procedural knowledge to learn more how this affects distractive multitasking on learning; and (e) include quizzes after each lecture (i.e., immediate learning) to determine the in-the-moment impact of distractive multitasking.

Regarding professional practice, it was recommended that (a) research on the performance consequences of computer-based multitasking be used to inform educators, practitioners, and policymakers in regard to optimal management of computer use in the classroom; and (b) for courses for which technology is not necessary for learning, laptop or smartphone use in the classroom be discouraged.

Appendix A

Research Study Approval Letter

INSTITUTO TECNOLOGICO AUTONOMO DE MEXICO

Fundado en 1946.

Mexico City, January 12th. 2015

Mr. Jaime Puente
PhD Candidate
Nova Southeastern University
Fort Lauderdale, USA

Dear Jaime Puente

This is to confirm that in the context of your doctoral thesis dissertation titled "Examining the Effects of Distractive Multitasking with Peripheral Computing in the Classroom", I have authorized professor Angelica Sulvarán Velázquez to anonymously survey the students in her course COM16301 "Computational Tools and Algorithms" to gather information about multitasking in the personal computers during lecture time.

Students will be invited to participate voluntarily and knowingly in the experimentation. Data will be gathered anonymously and there will be no implications on the students' performance in the course.

The data gathered by means of a software monitoring tool will be at your disposal for your thesis work.

Sincerely,

Dr. Víctor Manuel González y González
Professor and Head of the Department of Computing Science
Instituto Tecnológico Autónomo de México

RIO HONDO No. 1 COL. PROGRESO TIZAPAN C.P. 01080 MEXICO, D.F. TEL.: 5628-4000

Appendix B

Partial Worksheet to Illustrate Calculation of $MT_{Frequency}$

Period A

			Week 3		Week 4		Week 5		Week 6				
Student Name	Machine No.	Multitasking Category	Feb 24	Feb 26	Mar 3	Mar 5	Mar 10	Mar 12	Mar 17	Mar 19	MT Frequency	STDEVP	Midterm Exam
Student X	33	Overall	43	61	73	75	77	147	185	230	111.38	63.20	65.00
		Productive	14	40	26	37	51	50	160	137	64.38	50.20	
		Distractive	29	21	47	38	26	97	25	93	47.00	28.77	
		Surfing and entertainment	3	2	6	3	3	19	2	3	5.13	5.37	
		Email	7	10	20	22	13	18	8	15	14.13	5.23	
		PC operations	5	7	21	9	10	16	15	32	14.38	8.28	
		Other academic activities	14	2	0	4	0	44	0	43	13.38	17.92	

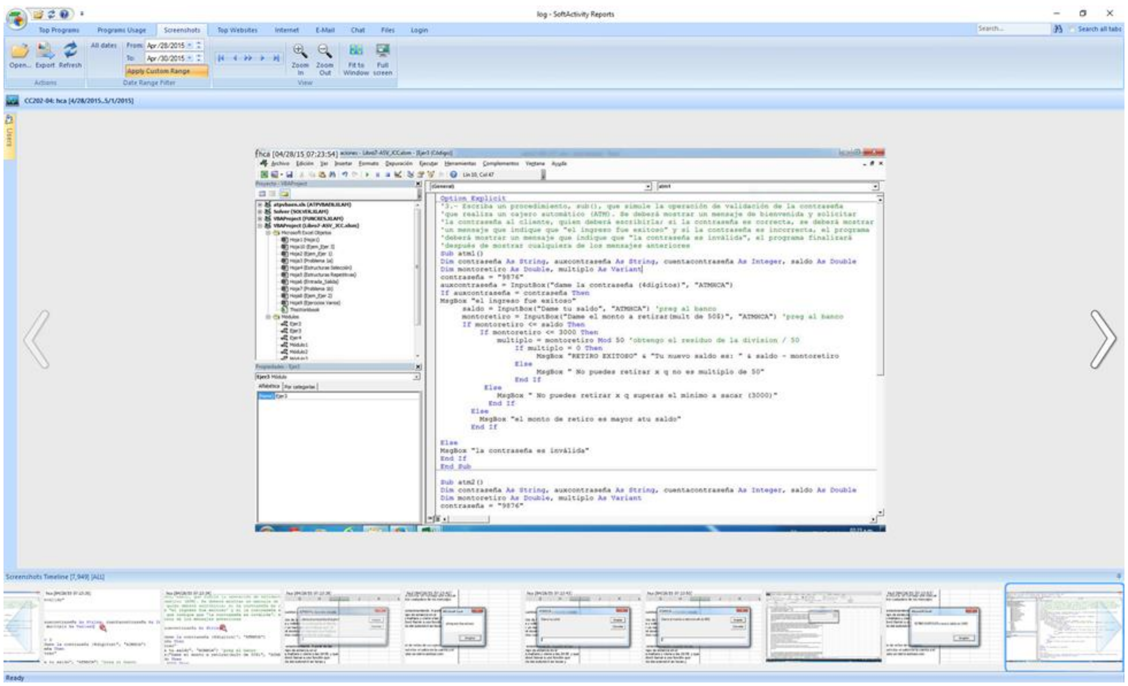
Period B

			Week 8		Week 9		Week 10		Week 11		Week 12	Week 13				
Student Name	Machine No.	Multitasking Category	Apr 7	Apr 9	Apr 14	Apr 16	Apr 21	Apr 23	Apr 28	Apr 30	May 7	May 12	May 14	MT Frequency	STDEVP	Final Exam
Student X	33	Overall	173	185	131	216	189	145	238	239	283	304	230	212.09	51.42	87.00
		Productive	104	109	67	140	96	79	205	168	180	129	173	131.82	42.99	
		Distractive	69	76	64	76	93	66	33	71	103	175	57	80.27	34.57	
		Surfing and entertainment	13	13	0	16	30	14	9	32	38	85	18	24.36	21.86	
		Email	21	40	22	19	30	31	9	16	49	49	13	27.18	13.24	
		PC operations	22	21	17	16	10	6	15	23	16	35	26	18.82	7.52	
		Other academic activities	13	2	25	25	23	15	0	0	0	6	0	9.91	10.15	

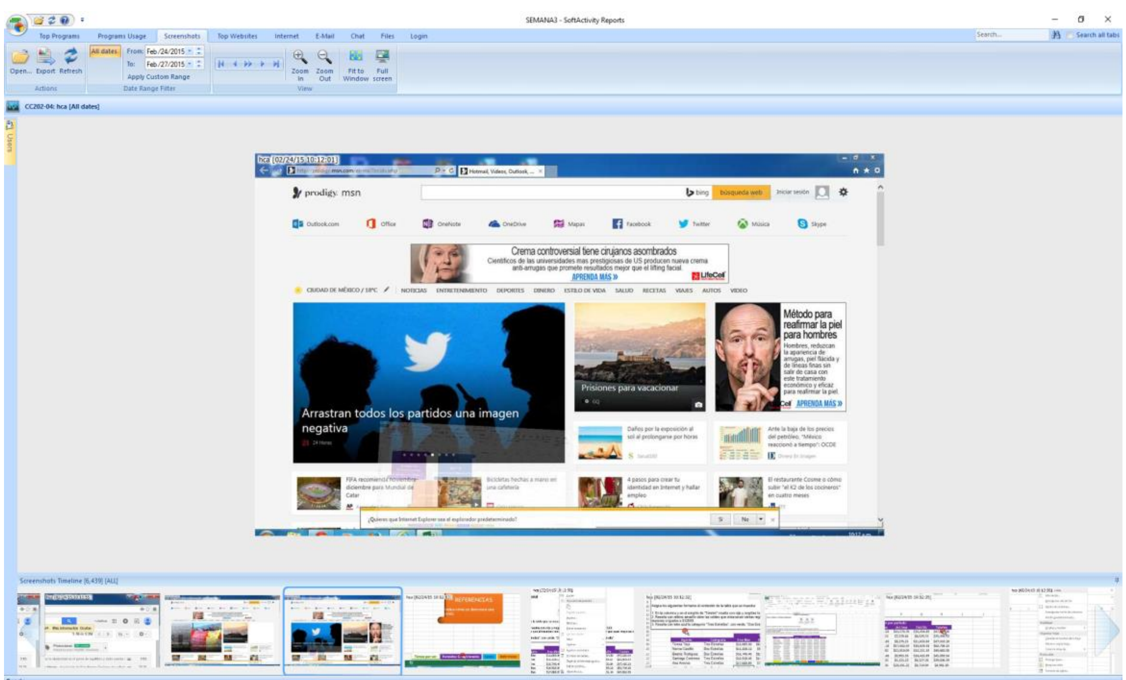
Appendix C

Examples of Screen Shots Stored in the Log File of the Monitoring System

Productive Task



DistractiveTask



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