Media Distraction in College Students

by

Zuowei Wang

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Education and Psychology)
in the University of Michigan
2015

Doctoral Committee:

Professor Kevin F. Miller, Co-Chair
Professor Priti R. Shah, Co-Chair
Professor Kai S. Cortina
Professor Frederick J. Morrison

Dedicated to my grandmother, Zhou Zhao Zhi (周兆芝，1941.9.12-2013.6.2)

Preface

"The digital revolution is far more significant than the invention of writing or even of printing. It offers the potential for humans to learn new ways of thinking and organizing social structures. Right now, we're evolving without much vision. But if we could boost our collective IQ [with computers and networks], maybe we could see where we're going." (Engelbart, 1997)

"The Net is, by design, an interruption system, a machine geared for dividing attention... Psychological research long ago proved what most of us know from experience: frequent interruptions scatter our thoughts, weaken our memory, and make us tense and anxious. The more complex the train of thought we're involved in, the greater the impairment the distractions cause." (Carr, 2011, pp. 131-132)

The rapid development of modern information technology has changed many aspects of the way students learn. To name a few of these changes: the usage of PowerPoint in college classrooms has replaced instruction on a traditional blackboard to a great extent (Szabo and Hastings, 2000), and students showed preference for this teaching method (Craig & Amernic, 2006). Lecture recording systems and online courses give students all over the world unprecedented access to learning opportunities (Eaton, 2004; Apperley et al., 2002). Learning management systems, which help instructors organize their course materials and students' assignments, are letting more students do their homework online (Bates & Sangra, 2011). Wikis and blogs enable real-time learning participation and collaboration from students (Wilen-Daugenti, 2009). In brief, learning today is becoming increasingly dependent on computers and the Internet.

Modern technology may benefit students in that it makes learning more convenient and appealing. However, technology also makes distractions and interruptions to learning more convenient and appealing. Computers and the Internet provide people with a wide variety of online activities. With a single click, people can get on Facebook, Twitter or YouTube where there are overwhelming numbers of emotionally gratifying posts and videos. The easy access to distractions on a computer has been noticed by online users, many of whom expressed the belief that "studying the same thing is much easier on paper than on the computer" (NathanielZhu, 2011). Both surveys and observational studies have shown that students spend much of their time in class or studying distracted by irrelevant media activities (Judd, 2013; Kraushaar & Novak, 2010; Rosen, Carrier and Cheever, 2013).

Two broadly opposed views of the impact of the internet on learning parallel the two quotes above. A pessimistic view holds that internet access is leading to a decline in essential studying skills. An optimistic view holds that as people gain more experience studying in an internet environment, they will develop the skills needed to manage studying in a connected world.

The pessimistic view is reflected in the best-selling book "The Shallows: what the Internet is doing to our brains" (Carr, 2011). Carr argues that the Internet is "by design, an interruption system, a machine geared for dividing attention". In the book, Carr provided a detailed analysis of how Internet has changed human cognition, especially for reading. He claims that many well educated people today have lost the interest, patience and even ability to read long articles after they have become used to reading online, with the result that reading becomes superficial.

According to Carr, information from the Internet has a nonlinear structure due to the large number of hyperlinks. Texts organized with hyperlinks impose an extra cognitive load on readers and thus result in more confusion, worse understanding and worse retention (Miall & Dobson, 2001; Niederhauser, Reynolds, Salmen & Skolmoski, 2000; Zhu, 1999). Hyperlinks require people to make constant decisions about what to read or not. This decision process consumes cognitive resources that would otherwise be available for deep processing of the reading materials. As a result, people's capacity to read long articles is challenged and their reading habit gradually changes.

The change in the habit of reading also alters how texts are written and distributed. Twitter, for example, limits its posts to 140 characters; the length of online articles published by news agencies such as the New York Times and the Washington Post has also greatly reduced compared to those previously published in the newspaper. These changes may in turn encourage superficial reading.

According to this pessimistic view, if one wants to stay focused in the digital era, the solution would be to stay away from the Internet when studying/working (Carr, 2011). This view has been put into educational practice. Many instructors banned laptop usage in the classroom and found this strategy effective in improving their teaching (e.g. Maxwell, 2007; Shirky, 2014).

The optimistic view, on the other hand, argues that people will adapt to this learning environment where their attention is constantly switched to something else. For one thing, our ancient ancestors were arguably good at attentional switching—they needed to constantly pay attention to slight changes in the environment for survival purposes, both in terms of hunting for food and avoiding danger, and this has been the case for tens of thousands of years until human beings mastered farming and stockbreeding. In contrast, large scale scholastic activities that require focused attention for an extended period only developed much more recently.

Research on brain plasticity also supports this optimistic view of internet usage on students. It is true that students might have difficulty processing non-linear (e.g. hyperlinked) content on the Internet (Niederhauser et al., 2000; Miall & Dobson, 2001; Zhu, 1999); however, it should also be noted that these studies were performed more than a decade ago when students did not have as much experience reading these contents as they do today. It is possible that current students have developed strategies to effectively deal with this new format of materials as they gain more experience. Indeed, more recent studies have shown that some students used better hyperlink selection strategies when reading hypertexts and the strategy selection was related to their self-regulation (Salmerón, Kintsch & Kintsch, 2010).

According to the optimistic view, human will eventually adapt to the Internet, just as what we have every time new technologies became available and our lives were changed. This could happen in at least two ways: first, we may gradually develop the cognitive capacity or strategies to efficiently process information online; second, intelligent computer programs may be developed to help us process information online. In addition, people have to adapt to this new environment. If, as Bill Gates (as cited in Green, 1999) has argued, "The Internet is becoming the town square for the global village of tomorrow," there may be no choice but to develop strategies that will allow students to harness this resource for learning.

While the pessimistic view is grounded in current observations of people's behavior when interacting with the Internet, the optimistic view acknowledges the necessity to embrace the digital era which in turn motivates the search for feasible solutions to help people adapt to the information explosion on the Internet. An 18 year old American college student was born in the year when Engelbart made the prediction quoted at the start of this chapter, and has grown up in a world where email and web access was available throughout their schooling. They thus constitute an important sample for looking at both the challenges that ubiquitous internet access pose to studying, and the extent to which students have evolved the ability to focus on learning in a world of constant distractions. Their peers in China have grown up in a different environment, with less access to the Internet and a different educational system. Thus comparing studying among these two groups of students may help us to identify the extent to which media distraction is a universal problem.

Contents

List of Tables

List of Figures

List of Appendices

Abstract

Recent development of media technology has greatly changed how students learn. Studying has become increasingly dependent on computer and the Internet, where students have easy access to a world of distractions. This dissertation consists of three studies that observed the amount of media usage during college students' study activities (Study 1) and investigated the effect of media distraction on their memory (Study 2), reading and quantitative reasoning (Study 3). Results showed that college students from both China and the USA spent a sizable amount of their study time on media activities; lab experiments showed that media activities negatively affected students' logical memory and reading comprehension, but did not affect performance on a quantitative reasoning task. In addition, the effect of media distraction on reading was negatively related to students' daily social media usage, suggesting that heavy social media users might have developed adaptations to media distractions. Current college students have grown up with social media websites, and many of them are constantly connected to smart devices. By studying the impact of these technological experiences on their learning and cognition, the dissertation identifies problems of student learning in this digital era, which in turn has implications for educational practices. It also contributes to understanding of the interaction between technological development and changes in human cognition.

Chapter 1. Literature review on media distractions in learning

1.1.The amount of media distractions in students' study activities

Rosen, Carrier and Cheever (2013) investigated the distractions that student encountered in their self-study activities. Students were asked to study 15 min meanwhile their behavior was observed. They found that on average students only focused on task for less than six minutes before they switched to something else—mostly distracted by technologies such as Facebook and texting. Judd (2013) analyzed 3372 sessions of students studying on computers and found that 70% of these sessions contained multitasking behavior. Over 50% of these sessions contained frequent multitasking. In contrast, students stayed focused in less than 10% of all these observed sessions. Kraushaar and Novak (2010) monitored students' laptop usage during lecture. They found that 42% of the time students were using their laptops doing non-course-related business.

1.2.What general effects does media multitasking have on learning?

A number of studies have investigated the relationship between students' media multitasking behavior and their learning. Specifically, researchers in these studies observed students' media multitasking behavior in lectures and self-study activities, and then examined the correlation between these activities and learning outcomes.

Hembrooke and Gay (2003) studied the effect of students' in-class computer usage on their learning outcomes. In the study, one group of students was allowed to use their computers in class whereas a comparable group was asked to close their laptops. After class, the two groups were given a test on the learning content. Results showed that students in the computer group had worse recall of the lecture. Similarly, other studies found that allowing students to use their laptops in class not only distracted the user, but also distracted fellow students (Fried, 2008; Sana, Weston and Cepeda, 2013). Moreover, a negative correlation was found between the amount of classroom laptop usage and understanding of the lecture, as well as overall course performance (Sana et al., 2013). A closer look at these activities confirmed that it was the amount of off-task activities that was negatively related to academic performance (Kraushaar and Novak, 2010; Ellis, Daniels and Jauregui, 2010). These studies suggest that students' media multitasking in the classroom may lead to learning distraction and reduces the efficiency of classroom instruction.

The effect of students' general computer usage outside of the classroom has also been examined. Wurst, Smarkola and Gaffney (2008) looked into how laptop usage affects students' achievement and learning satisfaction. As part of a larger project, they provided students with individual laptops hoping to facilitate more constructivist teaching activities. Unfortunately, results showed that the introduction of laptops to students in the experimental group did not elicit more constructivist learning activities. Neither did it improve students' GPA. In another study, Rosen et al. (2013) found that students' media multitasking behavior such as Facebook and texting was negatively related to their GPA. This negative correlation can partially be explained by the fact that multitasking might lower the efficiency of learning. Studies have shown that media multitasking slows down students' reading speed (excluding time spent on media; Bowman, Levine, Waite and Gendron, 2010; Fox, Rosen and Crawford, 2009).

To reveal the mechanism of the effect of media activity on learning performance, studies have investigated how media activity affect students' cognition in lab experiments. In one such study, Maas, Klöpper, Michel and Lohaus (2011) explored the short-term effect of media activities on students' memory performance. They asked college students (from Germany) to learn some Turkish vocabulary and then the students engaged in different kinds of media activities varying in arousal level. After media activities, students performed another task that evaluated their ability to concentrate, and then recalled the vocabulary they had learned. Results showed that higher arousal activities led to worse ability to concentrate, but the effect on memory performance was not significant.

However, this should not be interpreted as that students' memory was not affected by these media activities: firstly, because the authors did not include a control group where students did not engage in media activities, the results only suggest that the selected media activities did not differ in their effect on memory; secondly, it is also possible that students had remembered the Turkish vocabulary before they engaged in media activities and these media activities did not make them forget. Had the students engaged in media activities before (rather than after) they had learned the Turkish vocabulary, their memory might have been more negatively affected since the study showed that students' ability to concentrate was negatively affected by these media activities.

Indeed, the effect of media activities on memory consolidation was identified in another study, where researchers compared the effect of a light media game and that of a brief wakeful rest of the same length on senior adults' memory (Dewar, Alber, Butler, Cowan and Sala, 2013). In the study, subjects averaged 72.6 years old listened to a short story and then asked to recall it. After the recall, they either had a rest for 10 min, or played a media game for the same duration, after which they were given a surprise test to recall the story again. Results showed that subjects had better recall after a rest than a game. In other words, playing the media game after they remembered the story resulted in more forgetting compared to a rest.

In summary, media activities such as Facebook and texting lead to distractions in learning. Multitasking behavior and task switches induced by the digital technology during learning are negatively related to academic performance (Junco and Cotten, 2012). Lab experiments show that media activities negatively affect students' attention and memory.

1.3. What are the cognitive mechanisms that underlie these effects?

Media distractions are closely related to two well-studied topics in cognitive psychology: multitasking and task switching. When students are distracted by media activities during their study, they either multitask their study with media activities or switch between study and media activities. Thus knowledge on interference of multitasking and task switching will help understand how media distractions interfere with learning.

1.3.1. Multitasking interference explained by the EPIC model

Meyer and Kieras (1997) developed their EPIC cognitive framework (executive-process interactive control) in an effort to model human performance in multitasking situations. The EPIC model posits two components for human cognition: the memory stores, which consist of long-term memory, procedural memory and working memory, and the processing units, including visual, auditory and tactile perceptual processors. The memory stores also make the cognitive processor, which is "programmed with production rules stored in procedural memory". A production rule is a "if…then…"

condition-action pair that performs the action when the condition is satisfied. Thus interactions among the cognitive processor and different processing units serve the basis of human cognition. To be more specific, the different processing units collect and process information, which is then sent to the cognitive processor for processing, and finally it is sent back to the different processing units to carry out an action.

Within this cognitive framework, multitasking performance was explained with the following assumptions: the cognitive processor can process different production rules for different tasks simultaneously; however, the processing power of the different processing units (visual, auditory and tactile) is limited; executive cognitive processes thus coordinate the processing units for multitasking in such a way that "the tasks' production-rule sets do not try to use the same physical sensors". Based on these rules, computational models have been developed to simulate human beings' performance on a set of cognitive tasks, and the simulated response time on these tasks closely matched data obtained from human subjects, suggesting validity of the model.

The EPIC model, according to the authors, was the first "precise comprehensive framework" that incorporated previous discoveries in multitasking and it gave rise to a nice computational simulation for human multitasking performance. However, it should be noted that the construction of the model was based on basic abstract cognitive tasks in the laboratory and the reaction times modeled were around one second. It is not yet clear whether the same assumptions still hold in real life complex tasks such as college study activities.

1.3.2. Multitasking interference explained by the ACT-R model (resource competition)

Salvucci, Taatgen and Borst (2009) analyzed task interference in both multitasking and task switching by using the ACT-R theory (adaptive control of thoughts-rational, Anderson, 2007) and the “memory-for-goals” theory (Altmann and Trafton, 2002). The ACT-R theory posits that human cognition is achieved by the function of several cognitive modules: a declarative memory module that stores factual knowledge, a goal module that stores the current goal, a problem representation module that interprets the current situation into conditions of a problem, and a procedural module that applies different condition-action (if-then condition-action pairs) production rules. Due to human beings’ limited cognitive ability, each of these modules has been assumed to perform only one task at a time. Accordingly, for multitasking, interference may come from 1) two tasks retrieving declarative knowledge, such as facts and task instructions; 2) two tasks requiring different but complex problem representations; 3) two tasks requiring different processing procedures at the same time.

For task switching, interference could come from the goal module and the problem representation module. When switching to a new task, the goal and the problem representation for the current task will be cleared from the two modules, and the goal and problem representation for the new task will be retrieved from the declarative memory module. Since this retrieval takes time, this switch slows down the task performance. In addition, because information saved in the declarative module is subject to decay, a retrieval failure will increase the error rate in task switching. This hypothesis has been supported by experimental evidence showing that performance interference happened when two or more tasks required intermediate information storage (Borst, Taatgen and van Rijn, 2010).

In the context of media distractions in learning, this suggests if both the media activity and the learning activity require intermediate information storage, learning will be negatively affected by the media activity. Indeed, Lee, Lin and Robertson (2012) found that students' reading comprehension was not impaired by a background video, unless they were asked to remember the content of the video.

1.3.3. Cognitive fatigue hypothesis

Studies on multitasking and task switching suggest that media activity may interfere with learning because it competes for the cognitive resources needed for learning. From a slightly different perspective, media activities may also lead to cognitive fatigue so that students do not learn as well after spending their time on media activities. One interesting discovery about cognitive fatigue is its domain-specificity, i.e. studies have shown that engaging in a task that requires a particular cognitive process for some time will only lead to performance decline in another task that requires similar cognitive processing (Persson, Welsh, Jonides and Reuter-Lorenz, 2007). This suggests that the fatigue caused by media activities will impact those learning activities that require similar mental processes, but less so for other learning activities.

Both the resource competition hypothesis and the cognitive fatigue hypothesis suggest that media distractions will have a negative impact on learning if learning tasks require mental processes similar to those required by media activities. If this is true, we can expect that learning activities that require different types of cognitive processing (e.g. verbal vs. non-verbal) may be differently affected by media activities.

1.3.4. Evidence from neuroimaging data

A large number of neuroimaging studies have been performed to investigate the brain mechanisms of multitasking, most of which used basic sensory-motor tasks to accommodate the measurement constraint of the method. Few of these studies directly studied the brain mechanisms of multitasking in learning situations. This section summarizes one study that is relevant to multitasking in learning.

Foerde, Knowlton and Poldrack (2006) studied the effect of multitasking on learning by asking a group of students to study under two conditions: in one condition, students learned to predict weather by looking at some cues; in a second condition, students needed to learn the same prediction as well as keeping track of the number of high-pitched tones. After the learning phase, students were given two tests: one was to predict the weather based on the cues (implicit test) and the other was to identify which cue corresponded to which weather outcome (explicit test). Results showed that although students in the two conditions had no significant difference in the implicit test, the multitasking learning condition led to worse identification of the explicit cue-weather correspondence.

Interestingly, learning performance of the single task condition was correlated to brain activities in the hippocampus area, an area that is related to declarative knowledge learning, whereas learning performance in the multitasking condition was correlated to the striatum activation that is responsible for habit learning. The results suggest that habit learning will replace the declarative knowledge learning when the learner is engaged in a demanding multitasking task. Furthermore, learning that happens in a multitasking context may lead to less flexible knowledge acquisition that is unlikely to transfer to a new situation.

1.4.Is there evidence that people can become more effective at studying while multitasking with media?

This section will look at two related questions: 1) Are there systematic individual differences in the effects of multitasking on learning, and 2) Is there any evidence that people can learn to become better at incorporating media multitasking into their learning without suffering from interference?

In discussing the effect of multitasking on learning, it is necessary to consider individual differences to understand factors mediating this effect. For example, how much do people differ in the extent to which they multitask? Does multitasking equally affect learning in different students? Are people with more multitasking experience better at it? The identification of potential different sub-groups of multitaskers may help develop individualized learning strategies. By comparing these sub-groups, related cognitive functions can also be spotted, which provides guidance for potential intervention.

1.4.1. Individual difference in the frequency of multitasking

In an effort to identify heavy media multitaskers, Ophir et al. (2009) developed a MMI measure (media multitasking index) that included a comprehensive sample of people's activities with different media. Results showed that people's MMI value formed a normal distribution. Poposki and Oswald (2010) developed a multitasking preference inventory (MPI), which showed convergent and discriminant validity (as indicated by a confirmatory factor analysis and an α of 0.91). Further, subjects' scores on the MPI significantly predicted multitasking behavior in a simulation task where they spontaneously chose how many tasks to perform together. Results from these studies provide evidence of reliable individual difference in the amount of people's multitasking behavior.

1.4.2. Individual difference in coping with multitasking

Here "coping with multitasking" refers to students' performance in multitasking situations. This has to do, not with whether students choose to multitask or not, but with the effect that multitasking has on their study performance.

Konig, Buhner and Murling (2005) explored a series of potential factors that might affect multitasking performance, including attention, working memory, fluid intelligence, polychronicity (propensity to work on multiple things at a time) and extraversion. In their study, multitasking performance was assessed with a standardized test (Simultaneous capacity/Multi-tasking, SIMKAP) in which subjects needed to respond to specific stimuli (numbers, letters and figures), while simultaneously performing reasoning tasks and answering planning questions. Results showed that working memory, fluid intelligence and attention significantly predicted multitasking performance.

In a subsequent study, Buhner, Konig, Pick and Krumm (2006) investigated the working memory components that affected the speed and error rate in multitasking performance. Whereas multitasking speed was predicted by the coordination component of working memory, the error rate was related to the information storage component. Other studies have also found that a higher working memory capacity led to better coordination in the multitasking task, which resulted in superior overall performance (Hambrick, Oswald, Darowski, Rench and Brou, 2010).

To disentangle the relationship among intelligence, working memory and multitasking performance, Colom, Martinez, Shih and Santacreu (2010) performed a study where they tested subjects on these three measures. Both intelligence and working memory capacity correlated to multitasking performance; however, when these correlations were put together in a structural equation model, the effect of intelligence on multitasking performance disappeared, and working memory capacity remained as the only predictor. Thus working memory capacity is a more reliable predictor for multitasking performance.

Ie, Haller, Langer and Courvoisier (2012) studied the effect of mindful flexibility on college students' multitasking performance. Mindful flexibility is the "implicit awareness that a problem can be viewed from multiple perspectives", which can be reflected by a set of measures including trait mindfulness, intolerance of ambiguity, thinking style, complexity etc. In their study, after given a set of mindful flexibility tests, subjects were asked to write an essay and meanwhile respond to anagrams sent via an online chatting program by the experimenter. They found that students who had a higher mindful flexibility profile performed better in this simulation task.

To help select potential military personnel, Poposki, Oswald and Chen (2009) explored the non-cognitive factors that may affect multitasking performance. They recruited 152 college students and measured their extraversion, neuroticism, Type A Behavior Pattern (leading to stress-related symptoms), polychronicity and multitasking performance. Only neuroticism significantly predicted multitasking performance. To explain this prediction, the authors also tested students' state anxiety level during the task, and found that the state anxiety experienced during the multitasking test mediated the correlation between neuroticism and multitasking performance. Because state anxiety has been shown to reduce working memory capacity (e.g. Darke, 1988), this negative effect of state anxiety on multitasking performance could be a result of reduced working memory capacity. Thus the effect of non-cognitive factors on performance may operate through cognitive factors.

The other non-cognitive factors investigated by Poposki et al. (2009) did not show significant correlation to the multitasking performance, including extraversion and polychronicity, which is consistent with other studies showing extraversion and polychronicity had no effect on multitasking performance (Konig, Buhner and Murling, 2005).

In summary, people differ in the ability to cope with multitasking situations. Cognitive factors such as working memory capacity, fluid intelligence, attention regulation, and mindful flexibility are positively related to multitasking performance. Among these factors, working memory capacity seems to be the most robust predictor. Non-cognitive factors such as neuroticism, state anxiety are negatively related to multitasking performance, and it is likely that these non-cognitive factors operate through affecting subjects' working memory capacity.

1.4.3. Are heavy media multitaskers better at multitasking?

Oftentimes practice leads to improved performance. But in multitasking this is not always the case. Ophir et al. (2009) identified heavy media multitaskers based on scores on their MMI (media multitasking index) measure, and then compared their performance on a series of task-switching tests to those of light media multitaskers. They found that heavy media multitaskers performed worse on these task-switching tests where they were required to filter out interference caused by the switch. Because task-switching is essential to many multitasking situations where people switch among tasks before they finish each of the tasks, heavy media multitaskers' inferior performance on these task-switching tests indicates that they are not better multitaskers.

However, the results from Ophir et al. (2009) was not replicated by Minear, Brasher, McCurdy, Lewis and Younggren (2013), who used the same MMI and task-switching measures. Instead, Minear et al. (2013) found that heavy media multitaskers showed lower scores in fluid intelligence and they had higher scores in the self-reported measure of impulsivity.

The different results from these two studies could be a result of the difference in subjects. Subjects from Ophir et al. (2009) came from Stanford University whereas subjects from Minear et al. (2013) were recruited from College of Idaho. Because Stanford University is highly selective in its admission (6.6% for Stanford in 2012, and 92% for College of Idaho in 2010; data obtained from Google search using the key words "[university name] admission rate"), subjects from Stanford should be more homogeneous in their fluid intelligence then their Idaho peers, thus leading to the different results.

Cain and Mitroff (2011) also used the MMI measure to identify heavy vs. light media multitaskers. The two groups of subjects were tested on a singleton distractor task, in which they needed to identify a circle target and give a response to the symbol inside the circle. Distractors were presented together with the target. In half of the trials, subjects were told that color was a valid cue to identify the target because the target would not be red (the never condition); whereas in the other half, color was not a cue because sometimes the target can be red (the sometimes condition). Thus in the never condition, subjects should be able to take the advantage of the color cue by ignoring the stimulus with red color and provide a faster response. Results showed that light media multitaskers took more of this advantage compared to heavy media multitaskers: their response time in the *never* condition was significantly shorter than in the *sometimes* condition, but this did not happen to heavy media multitaskers. This discovery indicates that heavy media multitaskers failed to effectively use top-down processing to keep their attention from the distractors.

These results suggest that those who engage in more multitasking behavior actually performed worse in a number of cognitive tasks that required multitasking. They had difficulties in ignoring irrelevant stimuli and suppressing irrelevant responses after a task switch. However, it should be noted that all these studies are correlational so we cannot draw any causal conclusion based on these results. It is possible that the media multitasking experience harmed heavy media multitaskers' ability to focus their attention; the alternative is also possible that these people who had worse attention regulation skills tended to multitask more in their lives.

1.4.4. Evidence of becoming better at multitasking after training

A large number of studies have demonstrated that people' multitasking performance on particular tasks can be improved with training. Dux, Tombu, Harrison, Rogers and Tong (2009) trained a group of subjects using a dual task paradigm. In the task, subjects were presented with a visual stimulus together with an auditory stimulus and they needed to respond to the visual stimulus by pressing a button and respond to the auditory stimulus vocally. After 8 sessions of training (90 min each session), subjects' response became much faster both in the dual task and in the two subtasks when tested separately, and a larger response time decrease was found in the dual task, indicating reduced multitasking interference. They also measured subjects' brain activation change as a result of the training. Brain imaging data showed the reduced multitasking interference was not due to recruitment of different brain regions; instead, it corresponded to changes in the activation level of the related brain regions. These results indicate that the improvement in multitasking can result from more efficient information processing within the related brain areas.

Multitasking training can also be found in the large body of working memory training literature. As an example, Jaeggi, Buschkuehl, Jonides and Perrig (2008) used a dual-n-back task to improve subjects' working memory capacity. In a normal n-back task, one needs to give a response whenever the current stimulus is the same as the nth stimulus before it, forcing the subject to always remember the most recent (n+1) stimuli. The dual-n-back training task used by Jaeggi et al. (2008) required subjects to perform two n-back tasks together. In their task, subjects saw squares sequentially presented at eight different locations and meanwhile they listened to a list of eight different consonants from a headphone. The task required the subject to give a response whenever both the current square location and consonant were the same as the nth stimuli before them. The value of n started from 1 and became larger as the training progressed. Subjects' multitasking performance gradually improved over the course of 19 training sessions, and their working memory capacity was significantly improved as measured by a digit span task. Further, this improvement in working memory led to a transfer to intelligence improvement, as indicated by higher scores in the Bochumer Matrizen-Test (BOMAT). The results of this training study again demonstrated the close relationship among working memory, intelligence and the ability in multitasking (Konig et al., 2005; Colom et al., 2010).

The rationale of these multitasking training studies is to improve one's multitasking ability by practicing on these multitasking tasks. It has been assumed that human brains are plastic on the skills necessary for multitasking, and training can help the brain activate its potential on these skills. Indeed, studies have identified the brain changes as a result of multitasking training. For example, Maclin et al. (2011) found that after 20 hours of playing a video game subjects were able to divide more attention to a secondary oddball counting task. This attention reallocation was accompanied by electrophysiological signal changes in the brain (which was captured by ERP and EEG spectral analyses). In another study, Erickson et al. (2007) trained subjects in a dual-task where they responded to color and letter simultaneously using both hands. The authors found subjects' performance improvement was related to increased activation in the dorsolateral prefrontal cortex and decreased activation in other brain areas involved. These brain changes have been viewed as evidence for brain plasticity in multitasking.

As a summary of the literature on both sides, heavy multitaskers do not necessarily perform better in laboratory cognition tasks that require them to multitask; however, with proper training people can improve on specific tasks that requires multitasking. In the context of media distractions in learning, students who involve in more media activities may be less affected if their study is interrupted by these activities, and this hypothesis is tested in Study 3 of the dissertation.

1.5.Why do students multitask with media while studying?

The most obvious possibility is that students are not aware that mixing media consumption with studying interferes with study. Born in an age with computers and the Internet, students today have much more experience with the digital media. They are often called "digital natives" in contrast to older "digital immigrants" generation (Small, 2008). The fact that these digital natives have been multitasking on their computers as they grew up has led many people to believe that they are good at media multitasking. A recent review (Kirschner and van Merriënboer, 2013) describes this as a popular “urban legend” among students, despite evidence that media multitasking interferes with learning. This popular misbelief by students might contribute to excessive media multitasking behavior.

Although some students are aware that media multitasking threatens their learning efficiency, many do not seem able to resist the temptation of media multitasking. Wang and Tchernev (2012) studied this question from a need gratification perspective (“uses and gratifications” theory, Katz, Bulmler, & Gurevitch, 1973), assuming that media usage during learning “gratifies” four kinds of learner needs: emotional, cognitive, social and habitual. According to their model, it is these needs that drive multitasking behaviors. Carrying out the behaviors leads to gratification, which in turn changes the need. To investigate dynamic changes of needs and corresponding gratifications relating to the multitasking behavior, the researchers tracked students’ behavior, the motivation (need) behind the behavior and their satisfaction level (gratification) over 28 days. A dynamic panel analysis of the time series data showed that students’ media multitasking behavior was driven by their cognitive need, i.e. the need to seek for information. However, their multitasking behavior did not satisfy this cognitive need. Instead, it led to gratification of students’ emotional needs, i.e. feeling entertained by the media. In other words, although the original need leads to behavior which gratifies a different need, students did not realize this. As such, students’ original learning motivation is derailed toward another destination—entertainment. Over time, this need-gratification becomes a habit.

Other studies have identified several individual difference factors that are related with media multitasking behavior. People with a higher sensation-seeking profile tended to have more multitasking behavior with media (Jeong and Fishbein, 2007).

Similarly, people who show higher scores on impulsivity measures engage in more multitasking behaviors (Konig, Oberacher and Kleinmann, 2010). Heavy media multitaskers' cognitive control ability also differs from that of light media multitaskers. Ophir, Nass and Wagner (2009) measured different media multitaskers' cognition using a variety of cognitive control tasks. They found that heavy media multitaskers were more likely to respond to stimuli outside their current attentional focus: they had difficulties in ignoring the irrelevant information in the environment or in their short-term memory, and they showed worse ability in suppressing the irrelevant action response after a task switch. In brief, heavy multitaskers had a breadth-biased cognitive control; in other words, people who had a breadth-biased cognitive control system are more likely to multitask.

Environmental and situational factors also have an effect on people's multitasking behavior. Dabbish, Mark and González (2011) investigated self-interruption behavior at work place. They found that 1) open office seating led to an increase in self-interruption (compared to enclosed offices); 2) more self-interruptions happened earlier in the day; and 3) interruptions in the previous hour increased self-interruptions in the next hour. A fourth environmental factor that has been identified is work demand—a highly demanding task leads to more multitasking behavior, although this actually lowers efficiency (Konig et al., 2010).

In summary, a number of factors may contribute to students' media multitasking behavior during study, including a lack of awareness, impulsivity, cognitive bias, and the study/work environment.

1.6. Summary of literature review

Students' media multitasking is affected by both internal and external factors; the amount of media multitasking in study is negatively related to study achievement (i.e. lower GPA); cognitive studies of multitasking performance in lab conditions provides some preliminary explanations for understanding media multitasking in real life study situations; there is mixed evidence as to whether students can adapt to media multitasking as they have more experience with it.

To extend these discoveries, I will report results of three studies addressing the following questions: 1) the pervasiveness of media multitasking in college students in the U.S. and China (Study 1), 2) the effects of media activity on memory (Study 2), and 3) effects of media activity on higher-level cognition such as mathematical reasoning and reading comprehension, and whether students show adaptations to media multitasking when they study materials in these areas (Study 3). Because all these three studies require the measurement of media distractions, in the next section, I provide a methodology review for the measurement of media distractions.

Chapter 2. Methodology review for measuring media distractions

2.1.Self-report

Jeong and Fishbein (2007) explored the media and human factors that might have an effect on media multitasking behavior. To measure subjects' media multitasking behavior, they first ran a pilot study in which they investigated students' most frequent media multitasking activities. As a result, 13 activities were identified and subjects were asked to evaluate on a 4-point scale their frequency of performing each of these activities (along with other non-media activities), including six audio-based, four TV-based and three Internet-based activities. They found that all the three types of multitasking behavior were significantly related to students' score on a sensation seeking scale.

Ophir, Nass and Wagner (2009) studied the cognitive control in media multitaskers. Similarly to Jeong and Fishbein (2007), they developed a questionnaire that sampled 12 media activities, including "print media, television, computer-based video, music, audio, video or computer games, phone calls, instant messaging, text messaging, email, web and other computer based applications". Students were to estimate how many hours they spent on each of the medium per week (denoted as h). Besides, subjects also needed to estimate the frequency that they used any of the two media together with responses of "never", "a little of the time", "some of the time" or "most of the time". Thus for each medium, the frequency of it being used together with any of the other 11 media was obtained.

To quantify the results, the responses were assigned with numeric values: "never"=0, "a little of the time"=0.33, "some of the time"=0.67 and "most of the time"=1. For each medium i, the number of other media used together with it (m_i)

was calculated as the sum of these numeric frequencies. Then a media multitasking index (MMI) was calculated by the formula below, which is essentially the weighted average for the number of media used per hour.

$$\text{MMI} = \sum_{i=1}^{11} \frac{m_i \times h_i}{h_{total}}$$

Where h_i is the number of hours spent on medium i. Results showed that participants MMI scores showed an approximate normal distribution.

The questionnaire used by the study included a wide variety of media activities. Responses on these media activities were then used to derive the MMI measure, which provided a convenient estimation of the amount of people's media multitasking behavior. The MMI measure successfully distinguished different media multitaskers who showed varying levels of performance on a series of cognitive control tasks. Thus the self-report method can reliably reveal individual difference in the amount of students' media multitasking behavior.

Besides media multitasking, individual difference in the general preference for multitasking has also been studied. Poposki and Oswald (2010) explored the development of the Multitasking Preference Inventory (MPI). Responses from 192 undergraduate students on the MPI confirmed that it had both convergent and discriminant validity. Data collected from another 159 students further confirmed that MPI predicted enjoyment in a multitasking simulation as well as the number of tasks that the students chose to perform when given the opportunity to multitask. These results indicate that MPI is a valid measure for people's preference for multitasking and it is a strong predictor for people's multitasking behavior.

Self-report is a convenient method for researchers to obtain information about the amount of people's multitasking behavior. Studies that measured multitasking behavior using self-report indicate that people have different preference for multitasking and the amount of their multitasking behavior also varies. However, self-report has limitations in that it is difficult to measure the amount of people's multitasking behavior accurately and objectively. As reported by Nisbett and Wilson (1977), in self-report, subjects are not fully aware of the stimuli and their responses, and they do not base their response on true introspection. Indeed, Kraushaar and Novak (2010) found that students' self-report often under-estimated the time they actually spent in multitasking.

2.2.Computer monitoring programs

Specially designed computer monitoring programs can help researchers examine students' multitasking behavior on a computer with better accuracy. To investigate students' in class activities with their laptop, Kraushaar and Novak (2010) recruited a group of student volunteers who agreed to run a "spyware" monitoring program on their computers during lectures of a semester. The monitoring program recorded active program windows that a student interacted with. This allowed categorization of the students' activity: course related or not. Results showed that during the lecture students interacted with non-course related applications for 42% of the total computer usage time.

Judd and Kennedy (2011) used a custom-built monitoring system and recorded students' document and Internet activities in a university computer lab. The monitoring system was able to identify the user (from login information) and provide a timestamp when the active application on the computer was changed by the user.

The time-stamped files allowed inference of students' multitasking behavior. Specifically, the authors came up with three measures: the "repeated tasks measure" is the number of tasks that have been accessed more than five times in a session; the "simple multitasking measure" is the number of times the most used task has been accessed; and the "integrated multitasking measure" is an mathematically generated measure that considers the number of switches on each task and the time spent on each task. Using these measures, the authors found that undergraduate, male and international students multitasked more than their graduate, female and Australian domestic peers.

In a subsequent study, Judd (2013) used the same customized monitoring program but implemented a different multitasking coding system, where he first cut each session into 20 min overlapping segments and then classified each segment based on the active computer application in it, including little or no task switching, task switching with no multitasking and multitasking. An analysis of 3372 computer sessions showed that over 70% of the logged sessions contained multitasking behavior.

Computer activity logging program make it convenient to track students' multitasking behavior in a natural setting. However, the assumption that students' switched tasks when and only when the active computer application changed needs some deliberation. For example, a student could be searching information on the Internet while she writes, which is obviously a relevant study task; however, since there is a switch from the web browser to the word processing software, this activity would be counted as a task switch. In other situations, students' multitasking behavior such as texting or eating will not be captured by computer activities. Thus more sophisticated algorithms need be developed to make more accurate inferences about students' multitasking behavior based on the computer activities.

2.3.Human observation

Human observers can provide more intelligent coding of multitasking behavior. Rosen et al. (2013) recruited 128 student observers, who received training before they individually observed and coded other students' study behavior for 15 minutes. Each student observer performed the observation for 1-3 participants, resulting in a total of 263 valid observations. These participants came from different educational backgrounds, varying from middle school students to upper division university students. During the 15 min observation, observers filled out a minute-by-minute checklist of the learners' activity, including various media and study activities. They also counted the number of active computer windows at each minute, and the number of technology items in the study place.

From the observation data, the authors calculated on-task percentage, which was obtained by dividing the number of minutes that the learner was studying by 15 (the total observation time), and the number of on-task "runs", which is obtained by dividing the total study time by the number of off-task switches. The on-task runs reflect the participants' tendency to be distracted. Besides the observation data, participants also finished surveys asking them their study strategy, preference for task-switching, technology altitude, daily media usage, cell phone usage, social networking usage, school performance and reasons for task switching (qualitative data).

The comprehensive examination of these parameters facilitates the investigation of factors that affect students' multitasking behavior and it also reveals the academic consequences (school performance) of media multitasking. The recruitment of the large number of student observers allows observation in a natural learning situation thus the observed results had high external validity.

One critique of the above study is the potential “demand characteristics” the participants: during the observation participants could be altering their study behavior knowing that they were being observed. To eliminate the potential selection bias, other studies have used the random sampling method to measure subjects’ multitasking behavior. For example, Brante (2009) used an organizational sampling method to study teachers’ multitasking activities outside of the classroom. In the study, teachers were given an electronic watch or a hand-held computer that had been programmed to send out signals randomly to remind them of recording their current activities. Teachers’ multitasking behavior was then analyzed based on their logs of the activities. In line with this idea, students’ multitasking behavior can also be sampled in a similar way. For example, their smart phones could be used as the device to receive the random reminders to record the activities.

Perhaps a better way is to perform a natural observation of students’ multitasking behavior in public places where students usually study, such as libraries, computer labs, or even cafes. Although it would be difficult to obtain information other than the multitasking behavior, this natural observation can be quite informative before further research is carried out.

2.4.Eye tracking technology

Current eye tracking technology allows researchers to study the subtle eye fixation and movement patterns in various situations such as reading, driving and shopping. Applying eye tracking technology to the study of media multitasking in learning can help reveal more detailed information of media distraction.

Eye tracking technology can be classified into two categories based on the relative position of the eye tracker to participants' eyes. A stationary eye tracker tracks participants' eye fixations on a screen. For example, the Tobii T60 system includes a regular computer screen that can present experimental stimuli, along with an eye tracking device below the screen that detects the location and direction of pupils. After calibration, the eye tracker can calculate where on the screen the eyes are staring at (the fixation location).

A mobile eye tracker is different from a stationary eye tracker in that its relative location to the eyes stays the same during eye tracking. A mobile eye tracker is a device that can be put on subjects' head (thus a mobile eye tracker is also called "head-mounted" eye tracker). For example, the SMI Eye Tracking Glasses is a pair of glasses that has a scene camera facing the wearer's front and two eye cameras that are directed to the wearer's eyes. The two eye cameras capture the location and direction of pupils to calculate the position of the fixation, which is then mapped on to the scene video recorded by the scene camera. Thus the wearer's fixations can be shown in the scene video.

Stationary eye tracking systems can accurately identify students' multitasking behavior on the computer. Similar studies have been done in other research areas. For example, Ferreira et al. (2011) used a stationary eye tracker (Tobii T60) to study users' fixation pattern on different web based advertisements, and found that users looked more at the advertisements that contained negative emotional words. Similarly in a learning situation, a stationary eye tracker can help identify subtle behavioral patterns and capture micro multitasking activities that may be missed out by computer monitoring programs or human observation.

The mobile eye tracking system broadens the potential application because the scene camera can capture most of the visual field in front of the wearer. Thus students' fixations outside of the computer screen can also be recorded. One disadvantage of the mobile eye tracker, though, is the inconvenience during data analysis. Since the scene camera moves with the wearer's head, the ever-changing scene leads to moving areas of interest, and as a result manual coding of the recorded fixations is needed (before computer technology becomes capable of detecting objects in a moving scene, a.k.a. capacity for object permanence).

Compared to the other methods, eye tracking can provide the most detailed information on students' multitasking behavior. The data analysis programs provided by screen eye tracking systems are as convenient as that used in the computer monitoring programs. The data analysis for mobile eye tracking systems require some manual coding, but assistant programs that make the coding less time consuming are available (such as the BeGaze program developed by SMI).

As a summary, these different methods each have its own pros and cons, and selection of these methods depends on the research goals. The goal of Study 1 is to observe college students' media activities in their daily study activities in a natural setting, therefore human observation was implemented. The goal of Study 2 and Study 3 is to evaluate the effect of media activity on memory; accordingly, standardized experimental manipulation was applied and all subjects spent the same amount of time on media activities during learning activities. In addition, because Study 3 also evaluates the individual difference in reacting to media distractions, students' daily media usage was surveyed using self-report.

Chapter 3. Study 1: Observing college students study behavior in the USA and China

3.1.Pervasiveness of media distractions in college students

Section 1.1. has provided a review of prior studies on how much time college students spend on media activities during their study. One common feature of these studies is that students were aware of the measurement to some extent. In Rosen et al. (2013), observers made arrangements with students to come to their study places and performed one-on-one observations for 15 min. Judd (2013) used a less obtrusive design by installing computer monitoring programs in computer labs and students coming to the lab were informed that their computer activities were to be monitored. Similarly, Kraushaar and Novak (2010) installed monitoring programs on students' personal computers and collected log files from these students. Because students who participated in these studies were highly aware of the observation, they might have shown "demand characteristics" and the observed behavior might be different from what these students would normally do and thus threatens the validity of these results. Students might be more distracted than usual because the observation put extra stress on them; alternatively, they might be less distracted than usual feeling embarrassed of study distractions. Thus in the current study used an unobtrusive observation method to investigate the pervasiveness of media multitasking in students' real-life study activities.

Another limitation of these studies is that they focused on a highly homogeneous population. Almost all subjects from these studies came from the USA or other western developed societies. It remains unknown whether media distractions is a problem for western college students only, or it also happens in students from other cultural backgrounds.

The aim of Study 1 is to observe the amount of media activities among college students in China and the U.S. as they study in naturalistic settings. Examining media activities in a Chinese sample addresses the sampling bias commonly seen in psychological research. In the famous paper "The weirdest people in the world", Henrich, Heine and Norenzayan (2010) pointed out that psychological research published in world's top journals are usually based on samples taken from Western, Educated, Industrialized, Rich and Democratic (WEIRD) societies, and findings based on these samples often do not apply to other populations such as those in Asian countries.

In addition, examining students' media activities in China (in addition to USA) is also the best way to get a sense of the real-world prevalence of media multitasking, and the extent to which it might be a feature of American college student life as opposed to an issue that extends across cultural settings. Because college students study in a range of different settings, it can also allow us to see whether different study settings are associated with different patterns of media multitasking.

3.1.1. Differences in beliefs of education in the USA and China

Studies have compared differences in educational beliefs between China and the USA. For example, Li (2003) asked US and Chinese college students to generate terms related to "learning" in English and Chinese using free association. After validating the two lists, results showed that the US list contained many fewer terms related to "hard work, effort and persistence" compared to the Chinese list (3% vs. 20% respectively). This suggests that Chinese college students place a higher value on these concepts compared to their US peers.

Hard work and persistence has always been highly valued in by Chinese scholars. For over one thousand years, students in China studied hard to achieve personal advancement– study examinations had been used a single criterion for the selection of government officials of China until the early 1900s (Chen & Uttal, 1988). In studying for these examinations, students have believed that ability is malleable and it can be improved through efforts on gaining skills and knowledge (Chen & Uttal, 1988). If these beliefs still hold true for the contemporary college students in China, it is expected that their study should contain less entertainment such as media activities.

3.1.2. Factors related to media activities during study

As reviewed in Section 1, students partake in a large amount of media activities when they study (Rosen et al., 2013; Judd, 2013; Kraushaar & Novak, 2010). One obvious cause for media distraction is access to the Internet during study. In line with this logic, students who do not have immediate access to the Internet should show less media distraction compared to those who can get online with a click. Thus I hypothesize that students who are using computers in their study will spend less time on their study (more distracted) compared to other students who are not using computers.

Since countries differ in the penetration rate of computers and the Internet, students from countries that have a higher Internet usage rate are likely to spend more time online. A comparison of media activities during learning in populations that have different Internet penetration rates can also help us make inferences about the effect of internet accessibility on students' learning distractions. According to the World Bank (Figure 1), as of 2013 the Internet penetration rate in the two countries are 84.2% and 45.8% of the total population, respectively. In the current study, I compare media activities of college students from two countries: the USA and China. I hypothesize that fewer college students in China use computers in their self-study activity and they show less media distractions in learning. Certainly there are other differences between the two countries such as reviewed in Section 2.1.1; the current study aims to provide some preliminary results on the relation between internet access and media activities during learning. Longitudinal research within the same country that examines the relation between changes in internet penetration rate and changes in media distractions can provide more solid evidence to answer this question in the future.

As students have more experience with computers and the Internet, they may develop strategies that help them adapt to this new learning environment, so that studying on a computer becomes relatively less distracting. Based on the Internet penetration rate data from the World Bank, current US students on average have more years of experience with computers and the Internet compared to Chinese students (who were born around 1995), and US students are a more homogeneous sample in terms of internet usage. Thus I hypothesize that the difference in media distraction between students who are using computers in their study vs. students studying without computers should be smaller in students from the USA; in other words, I hypothesize there is an interaction between country and immediate computer access on the amount of media activities in students' study.

In addition, environmental factors such as noise level may also contribute to media distractions. The effect of noise on human performance has been well studied in cognitive psychology. A large body of literature has suggested that noise can impair human attention and thus hinder performance in a number of tasks varying from serial recall to spell check (Beaman, 2005). Noise may also lead to physiological changes when people engage in learning tasks. Linden (1987) found that subjects' blood pressure was higher when they performed mental arithmetic tasks with real life noise compared to no noise or white noise. Noise certainly increases arousal and may reduce students' resistance to distraction. I thus hypothesize that a noisier study environment will lead to more distractions in learning.

The overarching goal of the current study is to investigate the amount of media multitasking/switching during learning in college students from two different populations. Compared to previous studies, the current study 1) is performed at representative study places that college students often go to, 2) compares students' media distractions from different countries, i.e. USA and China, 3) evaluates environmental factors such as noise level, time of the day and contextual factors such as studying alone or with friends, wearing earphones or not etc.

Hypothesis 1: consistent with prior research, students in both countries spent a sizable amount of their study time on media activities;

Hypothesis 2: environmental factors such as the noise level of study places are negatively related to study time in both countries.

Hypothesis 3: using computers in study is related to less study time.

Hypothesis 4: fewer students in China use computers in their study and they spent longer time on their study.

Hypothesis 5: the effect of immediate computer access on study time differs in the two countries.

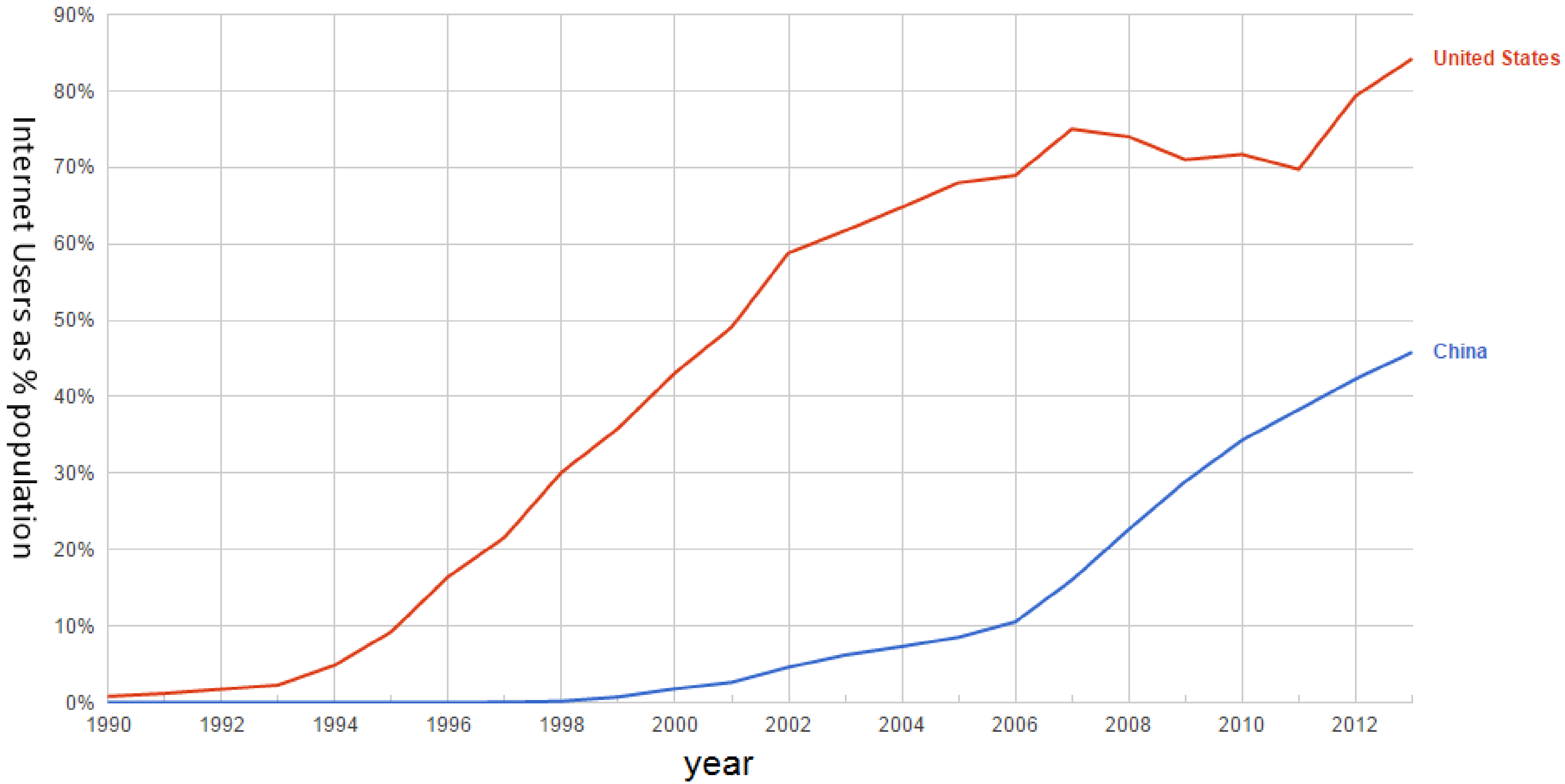


Figure 1. Changes in percentage of internet users in the USA and China, 1990-2013 (World Bank, 2013)

3.2. Observation method for the current study

The four methods for measuring distractions as reviewed in Section 2 require different levels of human effort and they can be used to focus on different scopes of media activities during learning. Self-report is the easiest method to obtain students' media usage information, and this method is implemented in Study 3.

However, self-report is also the least accurate, especially in terms of the details of media usage. For example, it would be difficult for students to estimate how many minutes they spend on a particular website. In such situations, computer monitoring programs will be helpful. However, this method is also limited in that it does not record students' other activities off the computer. When students are distracted by their smart phone, computer monitoring programs will not be able to capture that.

Human observation, although requiring more effort on researcher's side, allows the most detailed documentation of students' media activities in their learning. In Rosen et al. (2013), student's study behavior was observed and coded by trained research assistants who sat behind the student. This allowed comprehensive investigation of learning distractions that included not only from the computer but also from other sources such as cellphone or music player. Yet the fact that the student being observed was aware of the observation may lead to artifacts in the results.

In Study 1, I adopted the observation paradigm used in Rosen et al. (2013) but performed the observation on anonymous students who studied in public places without informing them of the observation. This unobtrusive method allowed us to investigate students' study distractions in the natural setting.

This method does have its limitations. Due to the unobtrusive nature, we do not know students' goals and priorities during the observation. It is possible that students intentionally spend time on media activities during the observation, and this is calculated as distractions to their study with the current method. However, two observational manipulations are implemented to minimize this possibility: first, the observation is performed at popular study places; second, the observation only includes students who are studying at the beginning of the observation; third, the duration of observation is short (10 min for each student) and an intentional goal switch from study to entertainment is not very likely, unless a large number of students only intend to study a few minutes at a time.

3.3.Methods

3.3.1. Study places

The current observational study was performed in the USA and China. The US sample was taken on the Central Campus of the University of Michigan, Ann Arbor. The Chinese sample was taken from Beijing Normal University (BNU). For the selection of study places, I asked seven undergraduate students from Michigan and 10 undergraduate students from BNU to name three study places that they often went to. We then rated the noise level of these study places on a five point scale after discussion. To make sure the rating of noise level was consistent in both countries, four of the seven US students went to the BNU campus and rated the noise level of the study places there.

3.3.2. Observation sheet

A data recording sheet was designed to facilitate observation (Figure 2). For each subject, observers provide background information for the observation, including the location and noise level, date and time, gender of the subject, and whether the subject was 1) studying alone or with friends, 2) using Mac, PC or tablet, 3) eating or drinking during the observation, 4) listening to music, or wearing ear phones. Subjects' study behavior was recorded on a 4 by 2 table with eight different kinds of activities (Figure 2). In the observation, observers could quickly record an activity by writing in the corresponding cell.

Figure 2. Data observation sheet used in Study 1.

Observer: _______________ Location (and noise level, 1-5): _________________

Date: _________________ Time: _______________________

M F (circle one)

Study on computer	Study without computer
Social media	Phone
Games/Movies	Email
Talking	Other

Context: Alone With Friends Can't tell

Devices: Mac Windows Tablet

Other: Eating Drinking Listening to Music

3.3.3. Observation procedures

Seven students from Michigan and 10 students from BNU were recruited from a research method classes from both universities to perform the observation. They received training before the formal observation. The training was first provided for the seven US students. They rotated to be 1) acting students who sat in the lab and studied for 10 minutes, and 2) apprentice observers who observed and recorded acting students' study behavior. After each observation session, observers and students discussed the recorded activities until they reached agreement. They then went to the selected study places in pairs or trios to observe anonymous students' study behavior, after which they compared and discussed their observation until reaching agreement.

The 10 Chinese students were trained following similar procedures. Four of the seven US students also assisted in the training to make sure observers from both countries were following the same observation procedure.

In the formal observation, each observer was assigned two or three selected study places to perform the observation. The observation happened "in secret" (unobtrusively): after observers arrived at their assigned places, they first randomly selected a student who was currently studying to observe, then they found a seat where they could have a clear view of the student's study behavior; after they were seated, they pulled out their own study materials and pretended to study, meanwhile they prepared the study observation sheet and a timer (cellphone or watch) before they started the observation.

Students may go the library or other settings for purposes other than to study. A downside of our unobtrusive observations is that we couldn't ask the students what they were intending to do. Thus we only picked students to observe who were studying at the time of selection.

Each selected student was observed for 10 minutes. At the beginning of each minute, the student's current behavior was recorded on the recording sheet by the observer putting a number in the corresponding cell (Figure 2). The number, which varied from 0 to 9, represented the order of the observation. For example, if a student was on social media website at the 5th observation, then the observer would put the number "4" under the cell "social media". Multitasking was recorded by putting the same number to multiple cells. During the observation, the observer also filled out the background information (e.g. gender of the student, devices the student was using etc.).

3.4. Results

3.4.1. US Data

One hundred and eight students (45 male) who studied in 9 study locations on the Michigan central campus were observed. The study places included libraries, study rooms in the dormitory, student cafeterias, study areas in university buildings, etc.

During the observation, 39% of the subjects ate or drank something; 60% were studying alone, 39% were studying with friends, and the remaining 1% could not be decided with certainty; 7% were studying without a computer, 74% using Mac, and 19% using Windows computers (the remaining 7% did not have a computer visible during the observation); 35% were wearing earphones during their study.

Students who used their computer during the observation studied slightly less time (*M*=6.2 min, SD=3.1 min) compared to those who did not use computer (*M*=6.6 min, *SD*=3.8 min), but this difference did not reach statistical difference, *t*(104)=.356, *p*=.722, due to the small sample of students who did not use computers (*n*=8).

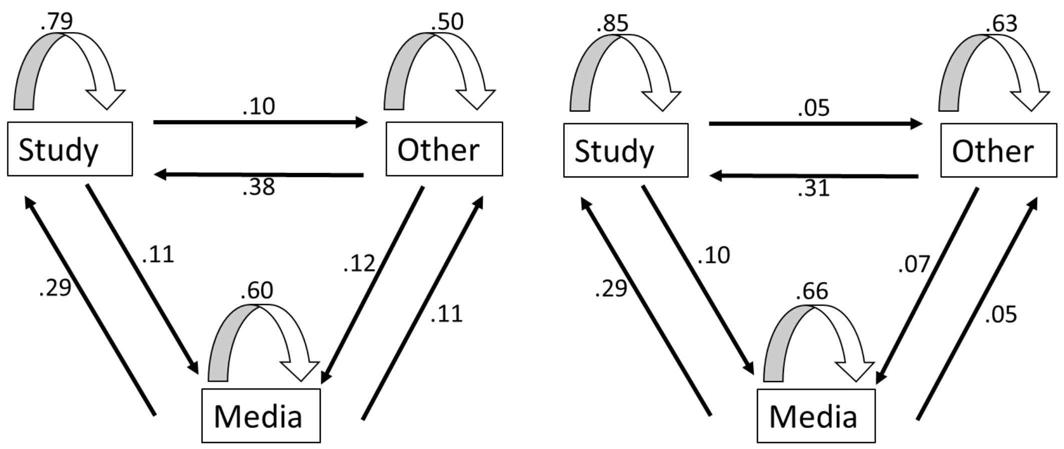
Table 1 shows the average time US students spent on different activities. Because I focus on media activities during study, the eight activities are divided into three categories: study (study on computer, study without computer), distracted (social media, phone, games/movies), and others (talking, email and other). For the US students who were initially studying, , they spent 6.2 minutes studying, 2.2 minutes on media activities and 1.8 minutes on other activities of the 10 minute observational period.

The level of distraction was positively related to the noise level of the study place, *r*(108)=.306, *p*=.001. Time spent on study was negatively related to noise level, *r*(108)=-.194, *p*=.044. Those who studied with friends spent less time studying (*M*=5.3 min, *SD*=3.0 min) compared to those who studied alone (*M*=6.8 min, *SD*=3.2 min), *t*(105)=2.37, *p*=.020.

The number of task switches from study behavior to other activities were calculated for each student observed. Within the 10 min observation, US students on average switched from study to other activities 1.8 times (SD=0.9). On average they engaged in study activities for 4.4 min (SD=3.3 min) before they switched to something else.

A Markov Chain analysis was performed to reflect features of task switches. The probability of switching from one activity to other activities was calculated for each of the three categories of activities (Figure 3). In Figure 3, arrows represent a switch from one task to another task in the next minute (or a task itself, meaning no switch); the numbers next to these arrows represent the probability of corresponding switches. From Figure 3 (left), it is clear that students' main activity was study: because the observation only included students who were initially studying, the chain of activities in Figure 3 always started from "Study". After one minute, students had 79% chance of keeping studying, 11% of switching to media activities and 10% to other activities. After two minutes, students had a (0.79)^2 + 0.79*0.11*0.29 + 0.79*0.10*0.38 = 68 % chance of still studying. In line with this calculation, after infinite number of minutes, students will reach a "stable state" where the probability of engaging in each activities stays the same, that is: study-61%, media-21%, other-18%.

Figure 3. Probability of switches among tasks (left—USA; right--China)



3.4.2. China Data

A total of 169 students from the BNU campus were observed (52 male). The study places included libraries, classrooms, student cafeterias etc. Twenty three percent of the students ate or drank during the observation; 53% studied without a computer, 4% using Mac, and 42% using Windows computers. 69% of these students were studying alone, and 25% were studying with friends, and the rest 6% students couldn't be decided with certainty. Twenty three percent were wearing earphones.

Compared to the US sample, fewer students used computers in their study. Students who used computers spent less time (*M*=7.1 min, *SD*=2.9 min) studying compared to students who did not use computers (*M*=7.9 min, *SD*=2.6 min), $t(197)=1.82$, $p=.035$ (one tail test).

Table 1 also shows the average time Chinese students spent on different activities. They spent 7.5 out of 10 minutes on their study, 1.6 minutes on media activities, and 1.1 minutes on other activities.

Table 1. Average time (min) spent on different activities (SD in parentheses) in the two countries.

	China	USA
Study on computer	3.27(4.02)	4.57(3.34)
Study without computer	4.28(4.27)	1.59(2.78)
Social media	0.59(1.66)	0.87(1.17)
Phone	0.88(1.81)	0.96(1.61)
Games/Movies	0.15(0.87)	0.33(1.59)
Email	0.08(0.56)	0.34(0.89)
Talking	0.61(1.76)	0.90(1.65)
Other	0.37(1.41)	0.61(1.24)

For these BNU students, the noise level also negatively predicted the amount of time spent on study, $r(169) = -.183$, $p=.018$. But the correlation between media distraction and noise level was not significant, $r(169)=.082$, $p=.288$. Students who studied with friends spent less time studying ($M=6.6$, $SD=2.8$) compared to those who studied alone ($M=7.8$, $SD=3.0$), $t(156)=2.30$, $p=.023$.

For every 10 min, BNU students on average had 1.7 task switches (SD=0.8) from study to other activities; they on averaged studied 5.5 min (SD=3.4) before switched to do something else. Figure 3 provides a summary of the probability of all possible switches during one minute. For these students in China, their stable state of the three activities is: study-66%, media-22%, other-12%.

3.4.3. Cross country comparison

In the 10 min observation, students from China spent longer time on their study (M=7.6 min, SD=2.9 min) compared to US students (M=6.2 min, SD=3.2 min), $t(275)=3.72$, $p<.001$. They also spent slightly less time on media activities (M=1.6 min, SD=2.4 min) than US students (M=2.2 min, SD=2.8 min), $t(275)=-1.73$, $p=.085$.

Students from the two countries did not differ in the number of task switches in their study, $t(256)=-1.039$, $p=.30$; however, they did differ in how long they kept studying before switched to something else: $t(247)=2.589$, $p<.001$: students in China (M=5.5 min) studied about 1 min longer compared to students in US (M=4.4 min) before they switched tasks.

Students from the two countries showed different patterns of distraction throughout the day. A marginally significant interaction between time of the day and country was found, $F(8, 259)=1.928$, $p=.056$. Simple effects comparison showed that around 12 pm, 4 pm and 6 pm US students spent less time on study tasks.

On average, the selected study places in Michigan seemed to have a higher noise level compared to BNU, $t(275)=3.26$, $p<.001$. On a five point scale (5 being the most noisy), the average noise level of the selected Michigan study places was 2.72 ($SD=1.55$), compared to 2.19 ($SD=1.17$) in BNU.

I also analyzed the relation between listening to music (operationalized by wearing earphones) and the level of distraction. Overall, music has a significant effect on the level of distraction, $F(1,272)=5.30$, $p=.022$ even after controlling for environmental noise level.

3.5.Discussion for Study 1

Results from this observation study confirmed that American and Chinese college students engaged in a large amount of media activities during their study (Hypothesis 1). Compared to previous observational studies of college students' study media distractions (e.g. Rosen et al., 2013), the current study used unobtrusive observation so that students' study activities were observed in a natural setting. Results showed that students were more distracted than had been observed from previous studies: Rosen et al. (2013) found that students on average studied 6 min before switching to media activities; in contrast, the current study showed that college students only studied 4.4 min (US sample) or 5.5 min (Chinese Sample) in one sitting. Although there may be other differences in the samples and settings, it seems likely that students would stay more focused on their study when knowing that they are observed.

Because the observation did not survey students' goals, questions arise about whether it is indeed an observation of students' study activities, and whether the observed media activities should be treated as distraction to students' study. While these concerns are valid, several manipulations were implemented in the current study to minimize this problem. First, the observation was performed at study places where the most common activity was to study, and the observation only focused on students who were studying at the beginning of observation. In addition, because each observation only lasted for 10 min, it is unlikely that the observation included a planned switch from study to entertainment—if a large number of planned switches had happened in the observation, then that would suggest that students had become used to constant task switch during their study; in other words, they were habitually distracted. Second, the Markov Chain transition probability analysis (Figure 3) confirmed that the most common activity was indeed study, and only in about 10% of the time did students switch from study to media activities within one minute; in addition, once they were engaging in media activities they have a high probability of going back to their study (about 30%) within a minute (50% within 2 min, 65% within 3 min).

The noise level of study places predicted study time in both countries—noisy study places were related to less time devoted to study (Hypothesis 2). This result extends our current understanding of the relation between noise and learning: it not only impairs performance in the learning task (e.g. Beaman, 2005), but also reduces task engagement and increases distraction. In both countries there were students who worn earphones in their study. This did not seem to have helped them to stay focused in a noisy study environment—even after controlling for environmental noise level, those who had their earphones on tended to be more distracted. However, because students chose where to study, it is also likely that students who were more focused on studying might avoid noisy places to study.

Using computers is related to less time devoted to study in China but not in the USA. Hypothesis 3 is thus partially confirmed. Because the current US sample only had a very limited number of cases where students did not bring a computer (*n*=8), it is possible that the difference between students with or without computers cannot reach statistical significance due to the small sample size. For the same reason, Hypothesis 5 (the effect of immediate computer access on the amount of media activities differ in the two countries) cannot be reliably estimated based on the current data.

Students from China spent less time on study-irrelevant media activities compared to students from the USA. Some possible explanations, as discovered in this study, could be 1) the study places in China had a lower noise level—in both countries, the noise level of the study environment is negatively related to the time devoted to study; 2) fewer students from China brought their computers when they were studying (Hypothesis 4). This cross cultural comparison suggests that the level of media distractions is correlated with how much students rely on their computers in their study.

In addition, students' productivity seems to differ by the time of the day, and this difference varies by country. Based on currently available data, US students seemed to be less productive at noon and in the late afternoon (4 pm and 6 pm, potentially, before and after dinner).

In summary, college students in the USA and China alike spent a sizable amount of their study time engaged in media activities. Media consumption seems to be a universal problem that happens across different cultural settings. Meanwhile, differences do exist between different student populations. Fewer college students in China used computers during the observation and they showed less distraction.

The unobtrusive observation used in the current study provides a glimpse of college students' study behavior in the most natural setting. Meanwhile, because of the unobtrusiveness, a lack of control prevents us from understanding how these distractions affect student learning. In Study 2 & 3, the effect of media distractions is studied in controlled lab experiments.

Chapter 4. Study 2: Effects of media distractions on memory

Study 1 suggests that media consumption is a significant factor in college students' study activities, but it does not tell us how it affected their learning. Because learning involves complicated cognitive processes including cognitive factors such as memory and attention, and non-cognitive factors such as emotion and motivation, the effects of media activities on learning can be explored from these multiple facets. In the current dissertation, I focus on the cognitive factors. In Study 2, I study the effect of media distractions on students' logical memory. In Study 3, I study the effect of media activities on higher level learning, looking at students' reading comprehension and mathematical reasoning.

4.1.Factors affecting memory performance

Prior studies have generally suggested that memory is fragile and memory performance can be negatively affected by a number of factors (Castel, Balota, & McCabe, 2009; Einstein, Smith, McDaniel, & Shaw, 1997; Kuo, Liu & Chan, 2012; Stevens, Kaplan, Ponds, Diederiks, & Jolles, 1999; Winch, 1912a; Winch, 1912b). Two factors, background task and fatigue, are particularly relevant to investigation of the effect of media activities in learning. Because college students constantly interrupt their study with media activities (as shown in Study 1), media activities may consume their cognitive resources as a "background" task in their study and this may also lead to cognitive fatigue.

Background tasks that are performed along with a memory task can negatively impact memory performance. In Einstein et al. (1997), young (averaged 19 years old) and old adults (averaged 73 years old) were asked to remember specific words presented in a sequence and respond to these words when they saw them showing up later in the sequence. They found that both age groups' performance was significantly impaired when they were asked to perform a background task in which they needed to respond to a predetermined number presented aurally. In particular, the impairment was most pronounced when the background task required processing during the encoding phase of words they were to remember. This result suggests that in real life situations, if students engage in media activities in their study, then thoughts about these activities may become a "background" task that impairs their ability to remember new materials.

Cognitive fatigue that results from media activities may also negatively affect students' memory performance. The effect of fatigue on students' ability to remember new materials has been studied since early last century. In Winch (1912a, 1912b), school aged pupils were asked to remember consonant letters by either reading a list or listening to their teacher. Results showed that students performed slightly better (about 2%) if the tests were given in the morning compared to the afternoon. Because the only difference was the time of the day, the author attributed this effect to students' cognitive fatigue and concluded that cognitive fatigue negatively affected students' memory.

In a more recent study, the effect of cognitive fatigue on memory encoding was investigated (Klaassen, Evers, De Groot, Veltman & Jolles, 2011). In this study, young (25-35) and mid-aged (50-60) adults worked on a word classification task before a recognition task for these words in one of the two conditions: in the fatigue condition, subjects performed the classification and recognition task after 1.5 h of a cognitively demanding task; in the baseline condition, they performed the task after 1.5 h of a low demand task. Their brain activation during encoding of successfully recognized words were analyzed. Results showed that both age groups had reduced activation of brain areas that were related to memory encoding. However, no significant differences on memory performance were detected between the two conditions, suggesting the two tasks that varied in cognitive demands had similar effect on memory encoding.

Although few studies have directly studied how media activities affect memory, one study by Dewar et al. (2012) showed that a brief wakeful rest after subjects had remembered a short story resulted in less forgetting of the story compared to a media game of the same duration. In other words, playing a media game after one has remembered a story may result in more forgetting compared to having a rest. However, because subjects in this study were a small group (n=14) of senior adults (on average 73 years old) who were not familiar with media games, it is possible that the game is particularly cognitively taxing for these subjects. It remains unknown whether media game also affects younger population such as college students. Examining the effect of media game (activities) on college students' learning is important given that their study activities are constantly interrupted by media activities, as shown in Study 1. If media game also negatively affects college students' memory consolidation, the practical implication for them is that they should not engage in media activities immediately after they have learned some materials.

Another question that could potentially be answered by the experiment in Dewar et al. (2012) is the effect of media game on the formation of new memory, although this effect was not tested/reported in the paper. As reported in Maas et al. (2011), engaging in media activities resulted in worse ability to concentrate. Thus students' ability to remember new materials will likely decrease after playing media games.

In addition, it remains unclear how media activity differ from other activities in terms of its effect on learning. For example, after students have memorized the learning materials, what will happen to their memory if they go on to work on some math problems? Will the math work lead to more forgetting than the media activity? This question has practical significance because students often use media activities as a break, hoping that media activities will refresh their brain so that they can learn better after the media activities. But is it true? Do media activities give students a refreshing study break?

Hypothesis 1: engaging in media activities before learning will lead to less learning compared to having a rest.

Hypothesis 2: media activities following learning will lead to more forgetting compared to a rest.

Hypothesis 3: media activities following learning will lead to more forgetting compared to other learning activities.

4.2.Method

4.2.1. Participants

Participants were recruited from the University of Michigan Introduction to Psychology subject pool. Sixty-two participants completed the study and earned one hour's credit to fulfill their course requirement.

4.2.2. Memory task

The logical memory test (Story B and Story C) from Wechsler Memory Scale IV (WMS, Adult Battery) was used in the current study. In the task, participants listened to recorded stories, after which they were asked to recall the story. Their performance was scored based on the elements that were correctly recalled. Each story has 25 elements, so the recall score for each story ranges from 0 to 25.

4.2.3. Media activity

The popular game “Spot the difference” was selected as the media activity in this study. This game has been used in prior studies investigating the effect of media activity on memory (Dewar et al., 2012). In the game, participants saw two almost identical pictures on the screen and they needed to find the five differences between the two pictures. One reason for using this task is that it does not require heavy semantic processing so that any effect on semantic memory is unlikely to be due to semantic interference.

4.2.4. Learning activity

The effect of media activity on memory was measured in comparison not only to rest, but also to another learning activity. By comparing the effect of media activity and the effect of other learning activity on students’ memory, students’ popular belief that media activities can help them refresh their brain is tested. In the current study, a simple math task was used as the learning activity. In the math task, students were asked to perform mental calculation by adding two three-digit numbers together and selecting the correct answer from two options.

4.2.5. Procedure

The design of the current study was inspired by the procedure used in Dewar et al. (2012). Thirty-two participants completed the rest and game experiment. After signing the consent form, they listened to the first story (either Story B or Story C from WMS) and performed an immediate recall of the story, after which they either had a rest of 15 min or played the "Spot the Difference" game for 10 min and then rested for 5 min; then they listened to the second story and performed an immediate recall of the story, which was followed by the 10 min game and 5 min rest or the 15 min rest. Finally, they were asked to recall the two stories (a surprise recall). There were two counterbalanced manipulations between participants, one was the order of the two stories, and the other was the order of the game/rest. Figure 4 is a demonstration of the procedure.

Another 30 participants completed the rest and math experiment. This experiment followed the same procedure with that of the rest and game experiment. The only difference was to replace the media game with 3-digit mental addition problems on the computer.

Figure 4. Illustration of procedures in Study 2 (game vs. rest experiment).

4.3.Results

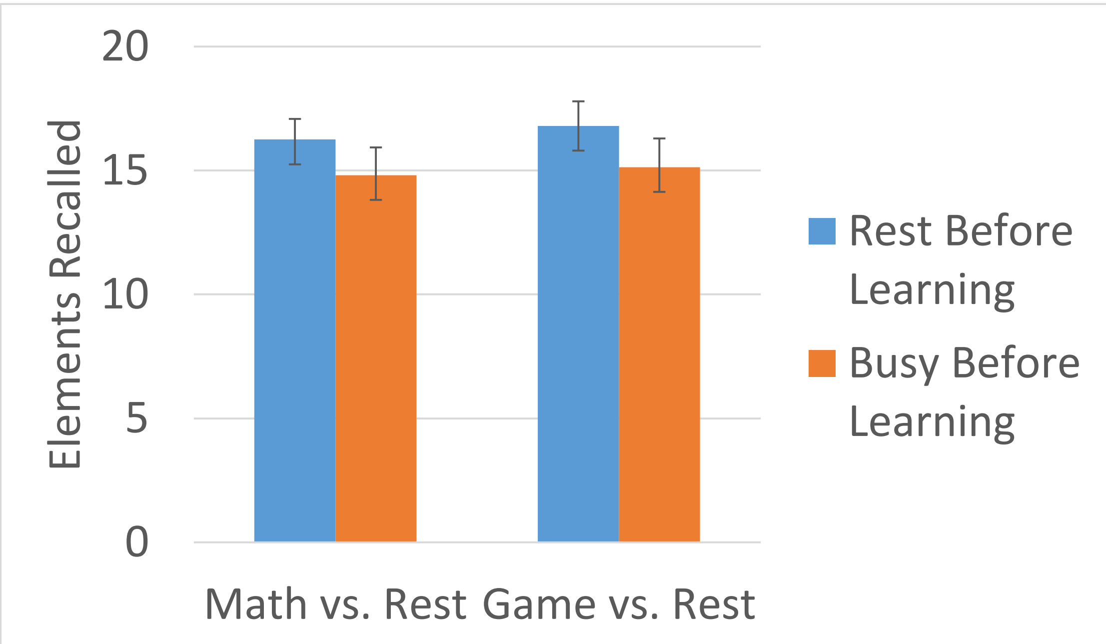
4.3.1. Effect of media/math activity on new learning

A two by two ANOVA was conducted on the performance of the immediate recall of the second story. The two independent variables were: cognitive load before listening to the second story (10 min activity and 5 min rest, or 15 min rest) and the activity (math or game). This analysis shows the effect of media activities on memory encoding.

A significant main effect of cognitive load before listening to the story was found, $F(1,58)=183.5$, $p=.047$. Post hoc analysis shows that solving math problems or playing media game before the story resulted in fewer elements remembered in the immediate recall ($M=15.0$, $SD=4.4$) compared to having a rest of the same length before learning ($M=16.5$, $SD=3.5$).

The effect of activity (math or game) was not significant, $F(1, 58)=14.4$, $p=.164$. The interaction between cognitive load before learning and the activity (math or game) is not significant, $F(1,58)=.012$, $p=.912$. These results are summarized in Figure 5.

Figure 5. Effect of pre-learning activity on new learning



4.3.2. Effect of media/math activity on memory consolidation

Memory consolidation can be reflected by the score difference between immediate recall and that of delayed recall, in other words, the amount of forgetting over the delay. The first comparison was made within each experiment: the amount of forgetting was compared between the story followed by a rest and the story followed by media/math activities. This difference shows the effect of media/math activity on memory consolidation relative to that of a pure rest.

The next comparison was made between the two experiments, i.e. the amount of forgetting was compared between the stories followed by the media game to those followed by mental addition. This comparison shows whether playing media game can serve as a refreshing break in comparison to other learning activities (e.g. math).

In the game and rest experiment, the amount of forgetting caused by playing the media game (M=2.27, SD=1.82) was significantly higher than that caused by rest (M=.37, SD=1.32), $t(29)$=5.375, p<.001. In contrast, in the math and rest experiment, the forgetting caused by solving math problems (M=1.40, SD=2.21) was similar to that caused by rest (M=1.34, SD=1.80), $t(31)$=.127, p=.90. Between-experiment comparison showed that media activity led to more forgetting compared to math activity, $t(60)$=1.69, p=.09.

4.4. Discussion for Study 2

Playing a media game before remembering a story results in less learning as reflected by immediate recall tests, and the effect is similar to that of working on some mental addition problems before learning. This result replicates prior studies on the effect of cognitive fatigue on memory encoding. For example, Winch (1912a, 1912b) reported that students' ability to remember letters was worse in the afternoon, after they had studied for the whole morning; intensive cognitive tasks also reduced brain activations in areas that are related to memory encoding (Klaassen et al., 2011). Thus one possible explanation for the effect found in this study may be that students' cognitive resources were consumed by the media game or the mental calculation task and their ability to encode memory materials suffered. In contrast, a wakeful rest before students remembered the materials resulted in better learning.

It is true that the effect of media game or math (compared to rest) on memory encoding is small and the difference only reached significance when data from the game and the math experiments were combined. However, it should be noted that the media game lasted only 10 min, and it was followed by a 5 min rest due to the repeated measures design. Had the subjects spent longer time on this media game, the negative effect on their memory may be larger.

Playing a media game after one has remembered the materials leads to more forgetting compared to having a rest. Dewar et al. (2012) found that a media game following a memory task led to worse recall of the materials in old adults; this study replicated this result with the college student population, suggesting that media games also affect college students' memory performance despite that they are more familiar with these games.

Interestingly, the forgetting caused by media activities is even larger than that caused by working on some demanding math problems of the same duration. The practical implication of this finding is that if students decide to use media activities as a brief study break, they may as well learn something new (e.g. working on some math problems), which is actually more “refreshing” than media activities.

One unexpected effect was the difference between the rest conditions in the two experiments. The rest condition in the “game” experiment resulted in less forgetting compared to that in the “math” experiment. Although the current data cannot provide any clarification for this effect, some speculations can be made based on the design of the two experiments. It is possible that students’ anticipations of the two experiments affected the effectiveness of rest. Students might have experienced more anxiety during the rest in the math experiment than the game experiment, and this anxiety could negatively affect their memory. Another explanation could be that the effects of math and game differ in their half-life: although the media game had a stronger effect on memory, this effect quickly faded out and thus did not affect the rest; in contrast, the effect of media game may be milder, but it also lasted longer and carried over to the rest condition, making the rest less effect than that in the game experiment. In future research, a between-subject design where each subject only experiences one of the three conditions (game, rest or math) can provide evidence to help clarify these speculations.

In summary, this study playing a media game is not a refreshing break for memory tasks, both in terms of memory formation and memory consolidation.

Chapter 5. Study 3: effects of media activity on reading comprehension, quantitative reasoning and evidence of adaption

5.1.Effect of media activities on different learning tasks

Study 1 shows that college students' study activities involve constant switch between study and media activities. The current study investigates the effect of media activities on the performance of subsequent learning. Because learning tasks vary in their nature and may require different kinds of cognitive processing, the effect of media activities on learning performance may vary as a function of the cognitive requirements of different study tasks. In the current study, I choose two distinct study tasks, reading comprehension and mathematics reasoning to evaluate how media activities before performing these tasks affected the performance on these tasks.

The two study tasks were taken from GRE (Graduate Record Examination) practice book (ETS, 2012). The reading comprehension task was part of the verbal reasoning sub-test, and the mathematics reasoning task came from the quantitative reasoning sub-test. According to ETS, the two sub-tests were designed to measure different content areas: the verbal reasoning test measures students' ability to "analyze and draw conclusions from discourse…select important points [from an article]…summarize text; understand the structure of a text…" in contrast, the quantitative reasoning sub-text measures students' ability to "solve problems using mathematical models; apply basic skills and elementary concepts of arithmetic, algebra, geometry and data interpretation" (ETS, 2015). From these descriptions, it is clear that the verbal reasoning task requires more verbal processing than the quantitative reasoning task.

The two learning tasks in the current study are also differently related to the logical memory task used in Study 2, in which students needed to remember stories and recall these stories. The reading comprehension task, which requires students to “understand the meaning of individual words and sentences; understand the meaning of paragraphs and larger bodies of text; summarize a passage; understand the structure of a text in terms of how the parts relate to one another; analyzing a text and reaching conclusions about it…” (ETS, 2015), is closely related to the logical memory task used in Study 2 in that both require memorizing and understanding verbal information. In addition, both tasks also require interpretation of verbal information since in the logical memory task students can use reasoning to recall what have happened in the story that they have heard. In contrast, the quantitative reasoning problems provide information by using graphs and math formulas and thus do not require direct processing of verbal information.

Study 2 shows that media activities such as a light media game lead to worse performance in the logical memory task. In specific, one discovery was that playing media game for 10 min before listening to a story resulted in slightly worse immediate recall of the story than having a rest of the same duration. Because logical memory plays an important role in reading comprehension, it is expected that if students engage in media activities before they perform a reading task, their reading may be negatively affected. However, if they perform a quantitative reasoning task after media activities, the effect remains unknown. It is possible that quantitative reasoning will not be affected because of the weak relation between this task and the ability to remember stories; alternatively, it may be negatively affected by media activities through a different mechanism other than verbal logical memory. Thus the first question addressed in the current study is whether media activities differently affect performance on learning tasks that belong to different content areas.

5.2. Effect of media activities on students who vary in daily social media usage

As reviewed in Section 1.4, there is mixed evidence concerning whether heavy media usages can react better to media distractions in their study. On one hand, Ophir et al. (2009) found that heavy media multitaskers performed worse in a number of laboratory tasks that required multitasking, and heavy media users were found to have difficulties to use top-down processing to divert their attention from irrelevant information (Cain & Mitroff, 2011). However, some of these results could not be replicated in different populations (e.g. Ophir et al., 2009; Minear et al., 2013). On the other hand, cognitive training research has consistently found that people's performance in multitasking situations can be improved with proper training (Dux et al., 2009; Jaeggi et al., 2008; Konig et al., 2005; Colom et al., 2010).

These mixed results make different predictions for whether college students can become better at dealing with media distractions in their study. Specifically, as students have more experience using social media, is the distracting effect of these activities on their study decreasing? This question is important for students and educators: if students are adapting to these activities during their study behavior, then educators should focus on helping students developing better time management skills; if, however, the distracting effect of these media activities stay the same as students have more experience using them, then in addition to time management skills, students should also improve their multitasking ability in order to navigate in this increasingly distracting digital era. As a starting point to investigate this question, this study addresses the question whether the effect of media distraction differs in students who vary in social media usage.

Hypothesis 1: media activities will negatively affect reading performance;

Hypothesis 2: media activities will affect math reasoning performance to a different extent compared to reading;

Hypothesis 3: how much students are affected by media distractions is dependent on their daily media usage.

5.3.Methods

5.3.1. Participants

Subjects were recruited from the University of Michigan Introduction to Psychology Subject Pool. Eighty-nine participated in the reading experiment; 54 in the mathematical reasoning experiment (See Table 2a&b for details about sample size).

5.3.2. Learning tasks

To explore whether the effect of media distractions is general across different learning activities, two distinct learning tasks were selected in the current study: reading comprehension (reading) and quantitative reasoning (math). Both of these tasks were obtained from the GRE practice book published by the Educational Testing Service (ETS). Each task contained two tests. In the reading comprehension test, subjects read two passages and answer some choice questions. In the quantitative reasoning task, subjects compare the magnitude of two quantities by solving math problems.

5.3.3. Media activities and manipulation of media distraction

To recreate media distractions in the lab, a range of media activities were used in the experiment. Media distraction was manipulated by asking subjects engage in some media activities before they performed the learning task. These media activities included: playing a media game ("Spot the difference" as used in Study 2), playing with their cellphone, getting on Facebook, Twitter or other social media websites, watching videos on YouTube. They were asked to engage in these activities at their choice for 10 minutes.

5.3.4. Daily media usage, GPA, study strategies and multitasking preferences

Students' media experience was measured by a questionnaire asking them to estimate the number of hours they spent on different media activities on an average day (Appendix A). In the analysis, the time spent on different social media websites were summed up as a measure of social media usage; the total time spent on all the media activities were also calculated. At the end of the questionnaire, they were asked to report their GPA.

Students' study strategies was evaluated using the questionnaire designed by Duncan and McKeachie (2005; Appendix B).

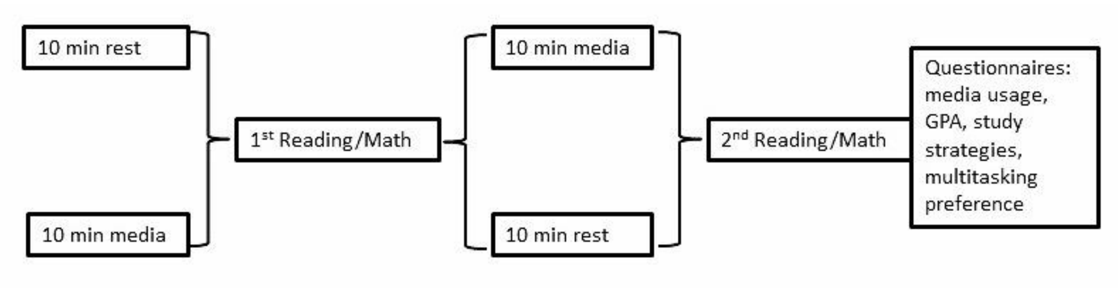
Students' multitasking preferences was assessed with the Multitasking Preference Inventory (Poposki and Oswald, 2010; Appendix C).

5.3.5. Procedures

Two experiments were performed to investigate the effect of media activities on two different learning tasks: reading comprehension or quantitative reasoning. The procedures for both experiments are the same, with the only difference being the learning tasks.

After subjects signed the consent form, they were randomly assigned to one of the two procedures as depicted in Figure 6. Half of the subjects had a 10 min rest, and worked on the first reading comprehension (or quantitative reasoning) task, and then they engaged in media activities for 10 min before working on the second reading comprehension (quantitative reasoning) task. In both learning tasks, subjects were encouraged to provide accurate answers without worrying about the time it took, although their response time was recorded. Finally, they completed the questionnaires described in 4.3.4.

Figure 6. Procedures for Study 3.



5.4.Results

5.4.1. Descriptive Analysis

Results for descriptive analysis are provided in Table 2. The two experiments (reading vs. math) are reported separately.

Table 2a. Summary of students' response (performance data and questionnaire responses) in the Reading Experiment

Item	Mean	SD	Sample Size
GPA	3.42	0.42	73
Reading % Answers Correct (after rest)	53%	24%	89
Reading Task Completion Time (after rest)	392 s	108 s	89
Reading % Answers Correct (after media)	51%	24%	89
Reading Task Completion Time (after media)	409 s	118 s	89
Study Strategies Questionnaire *	51	9	89
Multitasking Preference Questionnaire **	36	10	89
Daily Social Media Usage	3.1 h	3.2 h	89

*Score range for this questionnaire is 12~84, with high score indicating better study strategies; same for math experiment.

**Score range for this questionnaire is 14~70, with high scoring indicating a preference for multitasking.

Table 2b. Summary of students' response (performance data and questionnaire responses) in the Math Experiment

Item	Mean	SD	Sample Size
GPA	3.42	0.35	53
Math % Answers Correct (after rest)	68%	18%	54
Math Task Completion Time (after rest)	241 s	90 s	54
Math % Answers Correct (after media)	67%	21%	54
Math Task Completion Time (after media)	242 s	80 s	54
Study Strategies Questionnaire	53	10	54
Multitasking Preference Questionnaire	37	12	54
Daily Social Media Usage	2.4 h	1.9 h	54

5.4.2. Factors related to GPA

Students' social media usage was negatively related to their GPA, $r(124) = -.201$, $p = .024$; their total media usage was also negatively related to their GPA, $r(124) = -.252$, $p = .004$. Their study strategies was positively related to their GPA, $r(124) = .161$, $p = .072$.

The correlation between students' multitasking preference and their GPA was not significant, $p > .10$.

GPA did not predict reading performance, nor math performance. All p's > .10.

5.4.3. Effects of media activities on reading

After subjects spent 10 min on media activities, their reading became slower than if they had a 10 min rest, $t(101) = -1.78$, $p = .078$ (two-tail). Accuracy was not affected, $t(101) = .58$, $p = .56$.

5.4.4. Whose reading were more affected by media activities?

The time difference between reading performed after rest vs. media activities was negatively related to one's social media usage, $r(100) = -.243$, $p = .015$. Social media usage was not related to students' baseline reading performance (performance after a rest), both in terms of accuracy and time, p's > .10.

Because some subjects read faster after engaging in media activities, their media usage was compared to those who read slower after media activities. Results showed that those who reader faster after media activities had more social media usage, $t(98) = 2.14$, $p = .035$.

Other factors, such as GPA, study strategies, multitasking preferences were not related to the effect of media activities on reading, all p's > .10.

5.4.5. Effects of media activities on math reasoning

After media activities, students' math reasoning performance did not differ from that after a rest, both in terms of accuracy and speed (Table 2). All p's > .10.

5.5. Discussion for Study 3

5.5.1. Effect of media activities on different learning activities

The current study explored the effect of media activities on subsequent higher level learning activities. Results showed that brief media activities such as Facebook, Twitter, YouTube or other cellphone activities negatively affected college students' reading speed. After 10 min of media activities, students needed longer time to finish the reading task.

This finding is consistent with results of Study 2. Study 2 shows that media activities (such as a media game) negatively affect students' memory encoding and consolidation. In the reading comprehension task used in Study 3, students needed to remember and integrate information provided in the texts and then try to answer reading comprehension questions, a process that demands memory encoding and consolidation. Because media activities negatively impacted their memory efficiency, they needed more time to read the texts and figure out answers to questions.

The current study did not find effect of media activities on math reasoning performance. According to Table 2b, this is not due to floor or ceiling effect. This suggests that the effect of media activities varies in different learning contexts. This concurs with the task interference literature on human performance. From a resources competition perspective (Salvucci et al., 2009; Borst et al., 2010), this suggests that the cognitive resources that students' recruit during media activities do not compete with those required by the math reasoning task. Similarly, from a cognitive fatigue perspective (Persson et al., 2007), this suggests that the "cognitive fatigue" caused by media activities prior to learning activities is domain specific.

In practice, students may selectively use media activities as a study break depending on what kind of learning activities they are working on. For example, if their study activity involves a lot of reading, or requires them to memorize new information, then media activities may not serve a good study break for them; on the other hand, if their learning activity resembles the math reasoning task used in Study 3, they might be able to enjoy some media activities during a break without worrying about the potential negative effect on their learning. Future studies should systematically investigate the interaction between different kinds of media activities and learning activities to provide scientific guidance for students so they can be more mindful about using media activities in their study.

5.5.2. Long term usage of media activities in learning and adaption

Study 3 surveyed students' daily social media usage. They on average spent about 3 hours a day on social media, and for some (1 SD above the mean) it is about 6 hours. For these heavy users, they may accumulate 10,000 hours of social media usage within 4-5 years. In the famous book "Outliers: The story of success", Gladwell (2008) reported his discovery that 10,000 hours of deliberate practice was essential for individuals to develop skills in a given domain in order to become an exceptional expert. In the domain of social media usage, will students become "experts" in using social media in their study?

This question was answered by examining the relation between students' media usage and how much they were affected by media activities in their learning. In the reading experiment, it was found that students' time to answer reading comprehension questions became longer after media activities compared to that after a rest (within subject design). The time difference for task completion between the reading task performed after media activities and that after rest was used as a measure of the effect of media activities on reading efficiency. This measure was negatively related to students' daily social media usage. In other words, students who had more daily social media usage was less affected by media activities in the reading experiment. This suggests that heavy social media users might have become more used to social media activities when they were studying.

This result differs from Ophir et al. (2009) that found that heavy media multitaskers were worse at resolving task interference as a result of task switching. Three factors may account for this difference. First, subjects in Ophir et al. (2009) were highly homogeneous (college students from the highly selective Stanford University), and studies performed in a more diverse student population failed to replicate their results (Minear et al., 2013). Second, the tasks used in Ophir et al. (2009) were only remotely related to real life situations when students switch between media activities and study activities. Thus these results do not have high external validity and say little about whether heavy media users react better when their learning activities are interrupted by media usage. Third, the Ophir study used a between subject design so the correlation between media usage and performance in task switching situations may be confounded by individual differences in cognitive ability; in contrast, the current study used a within-subject design and compared the same students' performance in different situations. This provided a purer estimate of how well each individual reacted to media activities after controlling for individual difference, and how this is related to their daily usage of social media.

It should be pointed out that the current study, like Ophir et al. (2009), is a correlational study so it remains unclear whether experience using social media reduces the interruptive effect of these activities on learning, or students who find social media not disruptive to their learning are more likely to engage in more social media activities. However, the result, although correlational, does have implications for educational practice: it shows that those who use more social media are not necessarily worse in reacting to these activities in their study. Thus educational intervention should not only focus on how to help heavy media users recover from media distractions in learning; instead, intervention should also focus on how to help students better manage their study time so that they can devote more time on their study as opposed to on social media.

Chapter 6. General discussion

Computers and the Internet have become integral to college students' life. Based on the current observation at representative study places on university campuses, almost all students in a developed country sample (University of Michigan) and more than half of the students in developing country sample (Beijing Normal University) used computers during a randomly selected 10 min period of their study. With a longer observation window, the number of students using computers in their study should only be larger.

Students who used their computers in their study on average spent more time distracted and less time on task. This is supported by evidence both from cross country comparison and comparison within the Chinese sample (the US sample was too biased to make a reliable comparison, with too few students not using a computer). This suggests that the spread of computer and the Internet in higher education is related to more technological distractions in student learning.

Technological distractions has yielded interesting learning habits among the observed college students. Firstly, they only utilized 60% - 75% of their study time, with the rest of the time mostly on media activities; secondly, students' study activities were constantly interrupted—about 2 interruptions per 10 min, and they on average could only stay focused on their study for 4-5 min before switching to something else.

The effect of these study interruptions caused by media activities was evaluated in controlled lab experiments. Students' memory, as measured by a logical memory test, was affected by media distractions in two ways. If students engage in media activities before they remember something new, they tend to remember less (encoding interference); if they engage in media activities after they have remembered something, they tend to forget more (consolidation interference)—both in comparison to having a rest of the same length.

The mechanism of the two types of interference needs to be investigated in future research. In Study 2, a graph comparison media game was used as the media activity. For encoding interference, the effect of media activity is similar to that of mental addition. For consolidation interference, however, mental addition task resulted less interference compared to media activity. Neuroimaging data such as fMRI or ERP may help understand the shared and unique factors in media activity and math calculation that lead to these results. Identifying these factors will shed light on targeted intervention to reduce the effect of media distractions on learning.

The negative effect of media activities on logical memory was also found in higher level learning activities such as reading. After 10 min media activities commonly seen among college students (social media websites, videos, cellphone usage etc.), college students became slower in understanding reading materials, reflected by longer time to answer reading comprehension questions. Because reading requires one to remember and process logical information in texts, the observed effect of media activities on reading performance can partially be attributed to interference to logical memory.

Reading is a common activity in college students' study activities. In order to go through college education, they at least need to read 1) textbooks and lecture notes/slides to learn new materials; 2) prompts for homework and exams; 3) information from various sources for writing etc. Because of the ubiquity of reading in college education, and because of the habitual media distractions in college students' study, the negative effect of media activities on reading supported Carr's (2011) observation and deserves attention from researchers as well as teachers and educational practitioners. Future research should further investigate how media activities in reading affect students' understanding.

Media activities do not affect all kinds of learning activities equally. In contrast to reading, Study 3 failed to find any effect on students' math reasoning. This result is consistent with cognitive fatigue research showing that cognitive fatigue is domain specific (Persson et al., 2007), which means fatigue on one cognitive task will only transfer to another task that requires similar cognitive processing. In line with this logic, because media activities (Facebook, Twitter, YouTube and cellphone texting etc.) contain a lot of reading, engaging in these activities will interfere with the reading task that follows; in contrast, because the math reasoning task used in Study 3 involved little verbal processing, performance on this task was not affected.

Finally, there is evidence showing that college students might have developed some adaptation to media distractions in their study. First, in the reading experiment, the effect of media activities on subsequent reading was smaller in students who had more daily social media usage. Second, the effect of using computers (on the amount of media distractions) is smaller in the US, where college students have longer experience using computers and the Internet, than China (World Bank, 2013).

Chapter 7. Limitations and future directions

The current research focuses on two aspects: 1) observing media distractions in college students and 2) examining the effect of these distractions on their learning. The goal is to understand how recent technological developments impact college students so as to provide meaningful guidance for improving educational practice in this context. To achieve this goal, research on both aspects should be extended. In addition, future research should also focus on developing ways of helping students adapt to the learning environments that is increasingly dependent on computers and the Internet.

Observation of media distractions. Study 1 used unobtrusive observation to investigate media distractions in college students. As pointed out earlier in Section 3.7, one limitation of this method is the negligence of students' intentions. Because the observed students might have intentionally changed their goals from study to media entertainment during the 10-minute-long observation, it may be unfair to "accuse" them of being distracted. However, results from Study 2 and Study 3 show that these media activities during study negatively affected students' learning performance in a number of study tasks. By outcome, the observed students in Study 1 were very likely to have been distracted as well.

It should be noted that currently only two universities from two countries were selected for the observation. This is a very small sample and results may be biased. Thus one important task for future research is to replicate the observation in broader student populations, which may include more diverse universities from the two countries, as well as students from other countries. Study 1 has provided detailed instructions for performing the observation, and the observation table (Figure 2) is available for use for researchers interested in replicating the observation in a different sample.

Another limitation concerns the accuracy of observation. Although we provided extensive training for observers and observation from different observers showed high convergence during and after the training, the unobtrusive design prevented a close look at the activities students engaged in. In order to have a more accurate investigation, a combination of different observation methods (such as informed observation, computer monitoring and eye tracking as reviewed in Section 2.2) should be applied in future research and results obtained from these methods should be cross-validated.

Effects of media distractions on learning. Study 2 & 3 provide a snapshot of the effect of media activities on student learning. Results from these studies have generated some interesting questions to be answered by future research. For example, what are the effects of media distractions on the memory of materials of different nature (e.g. non-verbal materials)? Are there differences between voluntary media distractions (students switch to something else with no apparent external distractors) vs. involuntary media distractions (computers/cellphones send out notifications that catch students' attention)? For voluntary media distractions, are there factors that can predict the occurrence of these distractions? In other words, when do students "decide" to switch to some media activities when they are studying? Do they switch to media activities after finishing a small step in their study task, or when they encounter a difficulty in problem solving? How do media distractions affect other study activities such as writing? How do media activities affect students' emotion (e.g. perseverance) and cognition (e.g. working memory)?

Study 3 provides some preliminary evidence of students' adaptation to media distractions during reading. Because of the correlational design we cannot make any causal inferences about the relation between social media usage and the magnitude of interruption to reading: it is possible that those who "happen" to use more social media have become more efficient at processing media information, it is also possible that those who find social media distracting choose to avoid these activities—interestingly both suggest some extent of adaptation. In future research, longitudinal data that reflect developmental changes related to media usage can provide more convincing evidence to test this adaptation hypothesis.

Exploring strategies to deal with media distractions. The ultimate goal of studying media distractions in college students is to come up with ways to help them deal with these distractions. Currently we do not yet know what would be the best way to reduce media distractions in students' study activities, and many people hold pessimistic views about students' computer and internet usage. Carr (2011) criticizes the internet as "an interruption system", and many teachers ban internet usage in class and have found this effective in helping students stay focused on their learning (e.g. Maxwell, 2007; Shirky, 2014). This strategy, although appears to be working, is not the optimal solution in the long term. As an ancient Chinese idiom goes, this is a typical example of "refusing to eat for fear of choking (因噎废食)". Computers and the Internet have become integral to our lives, and once students leave school and enter workforce, they will have to work with these technologies. If the education system fails to prepare them for this, the productivity of the whole society will likely suffer.

We have to embrace the changes brought about by the development of media technology. Efforts from two directions may help students adapt to this new study environment. The first is to improve students' capacity to navigate in the distracting learning environment. Trainings that improve students' attention regulation, working memory capacity and study strategies that reduce distractions in real life situations need to be developed and tested. The development of such programs will be inspired by research on the effects of media distractions on learning, and individual differences in dealing with media distractions (Jeong & Fihbein, 2007; Koig et al., 2010; Ophir et al., 2009).

In one training program, Levy, Wobbrock, Kaszniak and Ostergren (2011) provided meditation and relaxation training for office workers and compared their computer multitasking performance before and after the training. The multitasking performance was evaluated in a natural office, where workers performed a set of specially designed office routines (schedule a meeting, writing a memo etc.). In the training, subjects were assigned to one of three groups: one group received meditation training that focused on the voluntary control of attention focus, one group received relaxation training where they practiced body and mind relaxation, and a third control group who did not receive any intervention. Results showed that the mediation training group reported lower stress level during multitasking and they had better memory about the tasks. Further, Levy, Wobbrock, Kaszniak and Ostergren (2012) found that people in the meditation group showed less task switch and stayed on each task longer. The authors argued that the reduced task switches was a result of better attention management—workers in the meditation group were able to "notice interruptions without necessarily relinquishing (their) current task". Future research can evaluate the effect of similar training programs on students' media multitasking behavior during their study activities.

The other direction is to make renovations to the current learning environments. One reason college students are constantly distracted by media activities during their study may be that they find these activities much more appealing compared to their study activities. By introducing recent technology to the creation of new learning environments, students may be attracted to learning and thus reduce media distractions. For example, natural language processing and speech processing can lead to systems that can be used to evaluate students' learning in real time and provide timely feedback for them; eye tracking may be used to predict and identify media distractions, based on which computer programs can be developed to help students manage their study activities.

Chapter 8. Conclusion

Media distraction abounds in college students' study activities. It consumes students' study time and changes their study habit. Media activities during learning negatively affect students' logical memory, and slow down students' reading speed. With more experience with media activities, students seem to have developed some adaption to these activities during learning -- heavy media users are less affected by media distractions in controlled lab environments. To help students deal with these distractions, future research should focus on teaching students strategies to navigate in the distracting online learning environment. At the same time, by taking advantage of digital technology, innovations to current learning environment may also help students stay focused in the digital era.

Appendix A. Daily media usage (including GPA) questionnaire.

Please indicate how many hours you spend on these activities on an average day; please write down your response to the left of each item.

________ 1. Watching computer video (e.g. Youtube, online television episodes etc.)

________ 2. Listening to music

________ 3. Non-music audio

________ 4. Video/computer games

________ 5. Telephone and mobile phone voice calls

________ 6. Instant messaging

________ 7. Text messaging

________ 8. Email

________ 9. Facebook posting (status, photos etc.)

________ 10. Facebook browsing (others' posts, photos, etc.)

________ 11. Twitter posting

________ 12. Twitter browsing

________ 13. Other social media websites

________ 14. Web surfing (other)

Your current GPA (all the information is anonymous): ____________

Appendix B. Study strategies questionnaire (Duncan & McKeachie, 2005).

On a scale of 1-7, with 1=”not at all true of me”, 7=”very true of me”, rate these items and write down your response to the left of the items.

________1. During class time I often miss important points because I’m thinking of other things.

________2. When reading for a course, I make up questions to help focus my reading.

________3. When I become confused about something I’m reading for a class, I go back and try to figure it out.

________4. If course readings are difficult to understand, I change the way I read the material.

________5. Before I study new course materials thoroughly, I often skim it to see how it is organized.

________6. I ask myself questions to make sure I understand the material I have been studying in a class.

________7. I try to change the way I study in order to fit the course requirements and the instructor’s teaching style.

________8. I often find that I have been reading for a class but don’t know what it was all about.

________9. I try to think through a topic and decide what I am supposed to learn from it rather than just reading it over when studying for a course.

________10. When studying for a course I try to determine which concepts I don’t understand well.

________11. When I study for a class, I set goals for myself in order to direct my activities in each study period.

________12. If I get confused taking notes in class, I make sure I sort it out afterwards.

Appendix C. Multitasking Preference Inventory (Poposki & Oswald, 2010).

On a scale of 1-5, with 1=”not at all true of me”, 5=”very true of me”, rate these items and write down your response to the left of the items.

________1. I prefer to work on several projects in a day, rather than completing one project and then switching to another.

________2. I would like to work in a job where I was constantly shifting from one task to another, like a receptionist or an air traffic controller.

________3. I lose interest in what I am doing if I have to focus on the same task for long periods of time, without thinking about or doing something else.

________4. When doing a number of assignments, I like to switch back and forth between them rather than do one at a time.

________5. I like to finish one task completely before focusing on anything else.

________6. It makes me uncomfortable when I am not able to finish one task completely before focusing on another task.

________7. I am much more engaged in what I am doing if I am able to switch between several different tasks.

________8. I do not like having to shift my attention between multiple tasks.

________9. I would rather switch back and forth between several projects than concentrate my efforts on just one.

________10. I would prefer to work in an environment where I can finish one task before starting the next.

________11. I don’t like when I have to stop in the middle of a task to work on something else.

________12. When I have a task to complete, I like to break it up by switching to other tasks intermittently.

________13. I have a “one-track” mind.

________14. I prefer not to be interrupted when working on a task.

References

Altmann, E. M., & Trafton, J. G. (2002). Memory for goals: An activation-based model. *Cognitive science, 26*(1), 39-83.

Anderson, J. R. (2007). *How can the human mind occur in the physical universe?* : Oxford University Press.

Apperley, M., Jansen, S., Jeffries, A., Masoodian, M., McLeod, L., Paine, L., . . . Voyle, T. (2002). Lecture capture using large interactive display systems. *International Conference on Computers in Education, Vols I and Ii, Proceedings*, 143-147.

Bates, A. T., & Sangra, A. (2011). *Managing technology in higher education: Strategies for transforming teaching and learning*: Jossey-Bass.

Beaman, C. P. (2005). Auditory distraction from low-intensity noise: a review of the consequences for learning and workplace environments. Applied Cognitive Psychology, 19(8), 1041-1064.

Borst, J. P., Taatgen, N. A., & van Rijn, H. (2010). The problem state: a cognitive bottleneck in multitasking. *Journal of Experimental Psychology: Learning, memory, and cognition, 36*(2), 363.

Bowman, L. L., Levine, L. E., Waite, B. M., & Gendron, M. (2010). Can students really multitask? An experimental study of instant messaging while reading. *Computers & Education, 54*(4), 927-931.

Brante, G. (2009). Multitasking and synchronous work: Complexities in teacher work. *Teaching and Teacher Education, 25*(3), 430-436.

Bugeja, M. J. (2007). Distractions in the wireless classroom. *Chronicle of Higher Education, 53*(21), C1-C4.

Bühner, M., König, C. J., Pick, M., & Krumm, S. (2006). Working memory dimensions as differential predictors of the speed and error aspect of multitasking performance. *Human Performance, 19*(3), 253-275.

Cain, M. S., & Mitroff, S. R. (2011). Distractor filtering in media multitaskers. *Perception-London, 40*(10), 1183.

Carr, N. (2011). *The shallows: What the Internet is doing to our brains*. WW Norton & Company.

Castel, A. D., Balota, D. A., & McCabe, D. P. (2009). Memory efficiency and the strategic control of attention at encoding: Impairments of value-directed remembering in Alzheimer's disease. *Neuropsychology*, *23*(3), 297-306.

Chen, C., & Uttal, D. H. (1988). Cultural values, parents' beliefs, and children's achievement in the United States and China. *Human Development*, *31*(6), 351-358.

Colom, R., Martínez-Molina, A., Shih, P. C., & Santacreu, J. (2010). Intelligence, working memory, and multitasking performance. *Intelligence, 38*(6), 543-551.

Craig, R. J., & Amernic, J. H. (2006). PowerPoint presentation technology and the dynamics of teaching. *Innovative Higher Education, 31*(3), 147-160.

Croxall, B. (July 8, 2010). Six ways to avoid letting your computer distract you, from http://chronicle.com/blogs/profhacker/6-ways-to-avoid-letting-your-computer-distract-you/25356

Dabbish, L., Mark, G., & González, V. M. (2011). *Why do i keep interrupting myself?: environment, habit and self-interruption.* Paper presented at the Proceedings of the SIGCHI Conference on Human Factors in Computing Systems.

Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of verbal learning and verbal behavior, 19*(4), 450-466.

Darke, S. (1988). Anxiety and working memory capacity. *Cognition and emotion, 2*(2), 145-154.

Dewar, M., Alber, J., Butler, C., Cowan, N., & Della Sala, S. (2012). Brief wakeful resting boosts new memories over the long term. *Psychological science*, 0956797612441220.

Dewar, M., Alber, J., Cowan, N., & Della Sala, S. (2014). Boosting Long-Term Memory via Wakeful Rest: Intentional Rehearsal Is Not Necessary, Consolidation Is Sufficient. *PloS one*, *9*(10), e109542.

Duncan, T. G., & McKeachie, W. J. (2005). The making of the motivated strategies for learning questionnaire. *Educational Psychologist, 40*(2), 117-128.

Dux, P. E., Tombu, M. N., Harrison, S., Rogers, B. P., Tong, F., & Marois, R. (2009). Training improves multitasking performance by increasing the speed of information processing in human prefrontal cortex. *Neuron, 63*(1), 127-138.

Einstein, G. O., Smith, R. E., McDaniel, M. A., & Shaw, P. (1997). Aging and prospective memory: the influence of increased task demands at encoding and retrieval. *Psychology and aging, 12*(3), 479-488.

Ellis, Y., Daniels, B., & Jauregui, A. (2010). The effect of multitasking on the grade performance of business students. *Research in Higher Education Journal, 8*, 1-10.

Engelbart, D. (1997). In “Voices from the Frontier.” Businessweek, 1997-6-22, retrieved 2015-06-25 from http://www.bloomberg.com/bw/stories/1997-06-22/voices-from-the-frontier

Erickson, K. I., Colcombe, S. J., Wadhwa, R., Bherer, L., Peterson, M. S., Scalf, P. E., . . . Kramer, A. F. (2007). Training-induced functional activation changes in dual-task processing: an FMRI study. *Cerebral Cortex, 17*(1), 192-204.

ETS. (2012). *Practice book for the paper-based GRE revised general test*. Retrieved from https://www.ets.org/s/gre/pdf/practice_book_GRE_pb_revised_general_test.pdf

ETS. (2015). *GRE test content and structure*. Retrieved from http://www.ets.org/gre/revised_general/about/content

ETS. (2015). *Reading comprehension questions: Introduction*. Retrieved from https://www.ets.org/gre/revised_general/prepare/verbal_reasoning/reading_comprehension

Foerde, K., Knowlton, B. J., & Poldrack, R. A. (2006). Modulation of competing memory systems by distraction. *Proceedings of the National Academy of Sciences, 103*(31), 11778-11783.

Fox, A. B., Rosen, J., & Crawford, M. (2009). Distractions, distractions: does instant messaging affect college students' performance on a concurrent reading comprehension task? *CyberPsychology & Behavior, 12*(1), 51-53.

Fried, C. B. (2008). In-class laptop use and its effects on student learning. *Computers & Education, 50*(3), 906-914.

Gladwell, M. (2008). *Outliers: The story of success*. Hachette UK.

González, V. M., & Mark, G. (2004). *Constant, constant, multi-tasking craziness: managing multiple working spheres.* Paper presented at the Proceedings of the SIGCHI conference on Human factors in computing systems.

Green, D. L. (2007). *I-Quote: Brilliance and Banter from the Internet Age*. Globe Pequot.

Hambrick, D. Z., Oswald, F. L., Darowski, E. S., Rench, T. A., & Brou, R. (2010). Predictors of multitasking performance in a synthetic work paradigm. *Applied Cognitive Psychology, 24*(8), 1149-1167.

Hembrooke, H., & Gay, G. (2003). The laptop and the lecture: The effects of multitasking in learning environments. *Journal of Computing in Higher Education, 15*(1), 46-64.

Ie, A., Haller, C. S., Langer, E. J., & Courvoisier, D. S. (2012). Mindful multitasking: The relationship between mindful flexibility and media multitasking. *Computers in Human Behavior, 28*(4), 1526-1532.

Jaeggi, S. M., Buschkuehl, M., Jonides, J., & Perrig, W. J. (2008). Improving fluid intelligence with training on working memory. [Article]. *Proceedings of the National Academy of Sciences of the United States of America, 105*(19), 6829-6833. doi: 10.1073/pnas.0801268105

Jeong, S. H., & Fishbein, M. (2007). Predictors of multitasking with media: Media factors and audience factors. [Article]. *Media Psychology, 10*(3), 364-384. doi: 10.1080/15213260701532948

Judd, T. (2013). Making sense of multitasking: Key behaviours. *Computers & Education*, *63*, 358-367. doi: 10.1016/j.compedu.2012.12.017

Junco, R., & Cotten, S. R. (2012). No A 4 U: The relationship between multitasking and academic performance. *Computers & Education*, *59*(2), 505-514.

Katz, E., Blumler, J. G., & Gurevitch, M. (1973). Uses and gratifications research. *The Public Opinion Quarterly, 37*(4), 509-523.

Kirschner, P. A., & van Merriënboer, J. J. (2013). Do Learners Really Know Best? Urban Legends in Education. *Educational Psychologist*(ahead-of-print).

Klaassen, E., Evers, E., De Groot, R. H. M., Veltman, D., & Jolles, J. (2011, September). Episodic memory encoding in middle age: effects of ageing and cognitive fatigue on brain activation. Poster presented at the Annual meeting for the international society for neuroimaging in psychiatry, Heidelberg, Germany.

Konig, C. J., Buhner, M., & Murling, G. (2005). Working memory, fluid intelligence, and attention are predictors of multitasking performance, but polychronicity and extraversion are not. [Article]. *Human Performance, 18*(3), 243-266. doi: 10.1207/s15327043hup1803_3

Konig, C. J., Oberacher, L., & Kleinmann, M. (2010). Personal and Situational Determinants of Multitasking at Work. [Article]. *Journal of Personnel Psychology, 9*(2), 99-103. doi: 10.1027/1866-5888/a000008

Kraushaar, J. M., & Novak, D. C. (2010). Examining the Affects of Student Multitasking with Laptops during the Lecture. *Journal of Information Systems Education*, *21*(2), 11.

Kuo, M. C., Liu, K. P., & Chan, C. C. (2012). Factors involved in memory encoding and their implications for the memory performance of older adults and people with mild cognitive impairment. *World Journal of Neuroscience, 2,* 103-112.

Lee, J., Lin, L., & Robertson, T. (2012). The impact of media multitasking on learning. *Learning, Media and Technology, 37*(1), 94-104.

Levy, D. M., Wobbrock, J. O., Kaszniak, A. W., & Ostergren, M. (2011). *Initial results from a study of the effects of meditation on multitasking performance.* Paper presented at the CHI'11 Extended Abstracts on Human Factors in Computing Systems.

Levy, D. M., Wobbrock, J. O., Kaszniak, A. W., & Ostergren, M. (2012). *The effects of mindfulness meditation training on multitasking in a high-stress information environment.* Paper presented at the Proceedings of the 2012 Graphics Interace Conference.

Li, J. (2003). US and Chinese cultural beliefs about learning. *Journal of Educational Psychology*, *95*(2), 258-267.

Linden, W. (1987). Effect of noise distraction during mental arithmetic on phasic cardiovascular activity. Psychophysiology, 24(3), 328-333.

Lutz, A., Slagter, H. A., Dunne, J. D., & Davidson, R. J. (2008). Attention regulation and monitoring in meditation. *Trends in cognitive sciences, 12*(4), 163-169.

Maass, A., Klöpper, K. M., Michel, F., & Lohaus, A. (2011). Does media use have a short-term impact on cognitive performance? A study of television viewing and video gaming. *Journal Of Media Psychology: Theories, Methods, And Applications*, *23*(2), 65.

Maclin, E. L., Mathewson, K. E., Low, K. A., Boot, W. R., Kramer, A. F., Fabiani, M., & Gratton, G. (2011). Learning to multitask: Effects of video game practice on electrophysiological indices of attention and resource allocation.*Psychophysiology, 48*(9), 1173-1183.

Maxwell, N. G. (2007). From Facebook to Folsom Prison Blues: How banning laptops in the classroom made me a better law school teacher. *Richmond Journal of Law and Technology*, *14*(2).

Meyer, D. E., & Kieras, D. E. (1997). A computational theory of executive cognitive processes and multiple-task performance: Part I. Basic mechanisms. *Psychological review, 104*(1), 3.

Miall, D. S., & Dobson, T. (2006). Reading hypertext and the experience of literature. *Journal of Digital Information*, *2*(1).

Minear, M., Brasher, F., McCurdy, M., Lewis, J., & Younggren, A. (2013). Working memory, fluid intelligence, and impulsiveness in heavy media multitaskers. *Psychonomic bulletin & review*, 1-8.

Miyake, A., & Shah, P. (1999). *Models of working memory: Mechanisms of active maintenance and executive control*: Cambridge University Press.

NathanielZhu. (2011) Retrieved August 13, 2013, from http://hubpages.com/forum/topic/78717

Niederhauser, D. S., Reynolds, R. E., Salmen, D. J., & Skolmoski, P. (2000). The influence of cognitive load on learning from hypertext. *Journal of educational computing research*, *23*(3), 237-255.

Ophir, E., Nass, C., & Wagner, A. D. (2009). Cognitive control in media multitaskers. *Proceedings of the National Academy of Sciences, 106*(37), 15583-15587.

Passolunghi, M. C., & Siegel, L. S. (2001). Short-term memory, working memory, and inhibitory control in children with difficulties in arithmetic problem solving. *Journal of experimental child psychology, 80*(1), 44-57.

Perfetti, C. A., & Goldman, S. R. (1976). Discourse memory and reading comprehension skill. *Journal of Verbal Learning and Verbal Behavior*, *15*(1), 33-42.

Persson, J., Welsh, K. M., Jonides, J., & Reuter-Lorenz, P. A. (2007). Cognitive fatigue of executive processes: Interaction between interference resolution tasks. *Neuropsychologia, 45*(7), 1571-1579.

Poposki, E. M., & Oswald, F. L. (2010). The Multitasking Preference Inventory: Toward an Improved Measure of Individual Differences in Polychronicity. [Article]. *Human Performance, 23*(3), 247-264. doi: 10.1080/08959285.2010.487843

Poposki, E. M., Oswald, F. L., & Chen, H. T. (2009). Neuroticism negatively affects multitasking performance through state anxiety: DTIC Document.

Rosen, L. D., Mark Carrier, L., & Cheever, N. A. (2013). Facebook and texting made me do it: Media-induced task-switching while studying. *Computers in Human Behavior, 29*(3), 948-958.

Salmerón, L., Kintsch, W., & Kintsch, E. (2010). Self-regulation and link selection strategies in hypertext. *Discourse Processes*, *47*(3), 175-211.

Salvucci, D. D., Taatgen, N. A., & Borst, J. P. (2009). Toward a Unified Theory of the Multitasking Continuum: From Concurrent Performance to Task Switching, Interruption, and Resumption. [Proceedings Paper]. *Chi2009: Proceedings of the 27th Annual Chi Conference on Human Factors in Computing Systems, Vols 1-4*, 1819-1828.

Sana, F., Weston, T., & Cepeda, N. J. (2013). Laptop multitasking hinders classroom learning for both users and nearby peers. [Article]. *Computers & Education, 62*, 24-31. doi: 10.1016/j.compedu.2012.10.003

Schunk, D. H., & Zimmerman, B. J. (2003). Self-regulation and learning. *Handbook of psychology*.

C Shirky. (2014, Sep 8). Why I just asked my students to put their laptops away. Retrieved from https://medium.com/@cshirky/why-i-just-asked-my-students-to-put-their-laptops-away-7f5f7c50f368

Small, G. W., & Vorgan, G. (2008). *IBrain*: Harper Collins.

Stevens, F. C., Kaplan, C. D., Ponds, R. W., Diederiks, J. P., & Jolles, J. (1999). How ageing and social factors affect memory. *Age and ageing*, *28*(4), 379-384.

Szabo, A., & Hastings, N. (2000). Using IT in the undergraduate classroom: should we replace the blackboard with PowerPoint? *Computers & Education, 35*(3), 175-187.

Wang, Z., & Tchernev, J. M. (2012). The “myth” of media multitasking: Reciprocal dynamics of media multitasking, personal needs, and gratifications. *Journal of Communication, 62*(3), 493-513.

Wilen-Daugenti, T. (2009). *Technology and learning environments in higher education*. New York: Peter Lang Publishing, Inc.

Winch, W. H. (1912a). Mental fatigue in day school children as measured by immediate memory: Part I. *Journal of educational Psychology*, *3*(1), 18.

Winch, W. H. (1912b). Mental fatigue in day school children as measured by immediate memory. Part II. *Journal of Educational Psychology, 3*(2), 75.

Winters, F. I., Greene, J. A., & Costich, C. M. (2008). Self-regulation of learning within computer-based learning environments: A critical analysis. *Educational Psychology Review, 20*(4), 429-444.

World Bank (2015) Internet users as percentage of population. Retrieved March 27, 2015 from https://www.google.com/publicdata/explore?ds=d5bncppjof8f9_&met_y=it_net_user_p2&idim=country:CHN:IND:USA&hl=en&dl=en#!ctype=l&strail=false&bcs=d&nselm=h&met_y=it_net_user_p2&scale_y=lin&ind_y=false&rdim=region&idim=country:CHN:USA&ifdim=region&hl=en_US&dl=en&ind=false

Wurst, C., Smarkola, C., & Gaffney, M. A. (2008). Ubiquitous laptop usage in higher education: Effects on student achievement, student satisfaction, and constructivist measures in honors and traditional classrooms. *Computers & Education*, *51*(4), 1766-1783.

Zhu, E. (1999). Hypermedia Interface Design: The Effects of Number of Links and Granularity of Nodes. *Journal of Educational Multimedia and Hypermedia*,*8*(3), 331-358.