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Causes, effects, and practicalities of everyday multitasking

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A B S T R A C T

Everyday multitasking with electronic devices is common among all age groups, but the youngest generations of persons carry out the most everyday multitasking, especially in the form of media multitasking. Multitasking via technology in school settings or at home while studying is common for students. Both external factors (e.g., alerts from smartphones) and internal factors (e.g., thoughts about future online activities) influence multitasking prevalence. Although laboratory research has shown that performing concurrent tasks is subject to processing bottlenecks and to switch costs, real-life everyday multitasking is different from laboratory dual-task scenarios in several ways, including having more than two tasks involved, proceeding by interleaving tasks over extended periods of time, and allowing more flexibility in resource allocation and setting of priorities. Theoretically, everyday multitasking should be capable of achieving some processing efficiencies. Yet, empirical research shows that studying, doing homework, learning during lectures, learning from other sources, grades, and GPA likely are all negatively affected by concurrent multitasking with technology. Young people who frequently multitask compared with other young people may be poorer at ignoring irrelevant environmental information, but the effects of extreme multitasking on other cognitive outcomes are not clear-cut. There are strategies that people of all ages can use to minimize multitasking and reduce distractions when they are performing important tasks such as studying or doing homework.

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It's an hour before dinnertime at home, and a 6th-grader has an hour of math and language homework to do for school. The problem: He also wants to finish an "important" online game with his friends that they all started the night before. Can he do them both at the same time? Accurately?

By the calculations of Rideout, Foehr, and Roberts (2010), American 8- to 18-year-olds – dubbed Generation M for multitasking – are able to squeeze 10 hours and 45 minutes worth of media content into 7 and 1/2 hours of media use. The situation at home for youths has been described as media "saturation" through technology (Roberts, Foehr, & Rideout, 2005). In 2005, a nationally representative random-digit telephone dialing survey conducted in the United States found that one fifth of 0- to 2-year-olds and more than one third of 3- to 6-year-olds had televisions in their bedrooms. Other studies have shown that a significant number of children watched television, watched DVDs or videos, or used a computer on a daily basis (Vandewater et al., 2007). Among American teens, 78% own a cell phone and one in four go online mostly using the phone rather than a desktop or laptop computer (Madden, Lenhart, Duggan, Cortesi, & Gasser, 2013).

More recently, 8- to 18-year-old youths have been preoccupied with consuming modern media sources and, as a result, carry out extensive "media multitasking," according to the Kaiser Family Foundation which has collected extensive data on the prevalence of everyday multitasking in American youths (Rideout et al., 2010). However, children, teens and young adults all appear to do some kind of everyday multitasking. With respect to media consumption, there are so many sources of content available in a typical home that there exists a "media multitasking environment" for almost anyone (Brasel & Gips, 2011). Brasel and Gips asked younger and older adults to use a computer and to watch television at the same time, a multitasking situation that the authors dubbed "commonplace" in homes. Rather than focusing on one media source at a time, people switched between the media at an extreme rate of more than four switches per minute. The observation that modern technology users seem to have developed a need to switch between multiple sources of information has led some writers to suggest that some of us might be suffering from an AD/HD-like "iDisorder" (Rosen, Cheever, & Carrier, 2012).

It has been found that younger individuals are more likely than older individuals to do everyday multitasking. For instance, Carrier, Cheever, Rosen, Benitez, and Chang (2009) asked more than 1300 individuals from Southern California to fill out an everyday multitasking measure that asked about what technology-related tasks are combined for multitasking in a typical day at home. When they compared the extent of multitasking across age groups, the results were striking. On some typical task combinations seen across the generations, as seen in Table 1, there was only one task combination performed by 75% or more of the older adults (the Baby Boomer generation, born between 1946 and 1964). There were four such task combinations done by persons from Generation X (born between 1965 and 1979). And, six out of seven of the task combinations were performed by 75% or more of the young adults (the Net Generation, born in 1980 and later). Another item in the questionnaire asked individuals to estimate how many tasks they combine at one time when they multitask at home. The

Table 1
Proportions of each generation who combine selected tasks at home.

	Baby boomer (born 1946–1964)	Generation X (born 1965–1979)	Net generation (born 1980 and later)
Surf web and compute offline	.62	.75	.81
Email and text	.39	.63	.81
IM and music	.72	.69	.93
Telephone and TV	.77	.86	.85
Gaming and music	.60	.77	.79
Gaming and text	.43	.36	.57
Text and music	.69	.85	.92

Note. Data from Carrier et al. (2009), not included in original report. Baby Boomer generation: $n = 312$; Generation X: $n = 182$; Net Generation: $n = 825$. Proportions include only those participants who reported performing the individual tasks on a typical day.

Baby Boomers indicated that they multitasked a mean of 4.70 tasks, followed by the members of Generation X ($M = 5.41$) and the members of the Net Generation ($M = 5.90$). The rise in the number of tasks performed together from the oldest to the youngest generation was statistically significant.

Why people do everyday multitasking

Everyday multitasking occurs everywhere and anywhere, just like the computer-based technology with which it is associated. For students of all ages, technology is enmeshed in their school and home environments. Online worlds are as important a part of their lives as are physical locations (Rosen, 2007). A recent study by Rosen, Carrier, and Cheever (2013) showed how easily middle school, high school, and college students can be distracted while studying at home if they have technology present. Thirty-one middle school students, 124 high school students, and 108 college students were observed (all in Southern California) at home in their natural study environments while they studied for school. Minute-by-minute observations over a 15-minute period revealed that students had a difficult time focusing on their main task, averaging less than 6 minutes staying on task before switching to another task. Put another way, students stayed on task 65% of the time, for an estimated total of 10 minutes out of the 15-minute study period. Aside from getting up and walking around, switching to another task was most often associated with technological distractions, such as texting, Facebook use and watching TV. For all age groups, the amount of distracting technology available at the beginning of the study session predicted diminished on-task performance, and having the television on at least once during the study session significantly impacted study time.

For college students in particular, research shows that everyday multitasking occurs in class, while studying, and while doing homework. Jacobsen and Forste (2011) asked American college students to complete online questionnaires that included time-use diaries of media use and other distracting tasks during learning times. They found that about two-thirds of the students reported using electronic media while in class, studying or doing homework. Ninety-one percent of American college students in a study by Tindell and Bohlander (2012) had sent or received a text message in their university class and 62% felt texting is acceptable in class if it does not disturb other students. Hammer et al. (2010) asked instructors and students from a technical college in Israel to complete questionnaires that asked about practices and beliefs regarding cell phone and laptop computer use during lectures. The results showed that students frequently use the devices for non-academic reasons. Junco and Cotten (2011) administered an online questionnaire to college students from four American universities that asked them to self-report their instant messaging (IM) use, their multitasking behaviors (while studying, while doing non-studying computer-based tasks, and while doing non-computer tasks), as well as other information. The authors found high rates of multitasking while IMing.

Perhaps the most obvious reason why students might be compelled to do so much everyday multitasking is because they think it helps them. Junco and Cotten (2011) found that there was a subset of students who engaged in intense multitasking despite the potential for negative effects. The belief that multitasking is beneficial could propel these students to continue multitasking and, Junco and Cotten surmised, could lead to a multitasking "habit" that cuts across domains. Or, college students might moderate their multitasking depending upon the situation. Judd and Kennedy (2011) installed tracking software on computers in a computer laboratory at a university in Australia to identify instances of students multitasking. The logs showed that multitasking was common but levels were not high and not consistent. Judd and Kennedy suggested that the reasons for computing could influence whether students multitask, i.e., students with a specific goal and sufficient motivation would be less likely to multitask than students with diffuse goals (such as catching up with friends). The authors also mention time constraints as influencing the decision to multitask: with limited time, there might be pressure to try to do more than one task at a time (Foehr, 2006; Levine, Waite, & Bowman, 2007; Mulder, de Poot, Verwij, Janssen, & Bijlsma, 2006). In another analysis of multitasking in Australian college students while carrying out self-directed studying, Judd (2013) found that multitasking – trying to perform tasks simultaneously – was common compared with focused study or to task switching.

According to Hammer et al. (2010), a "mobile culture" has invaded the college classroom, with students finding it legitimate to use laptops and cell phones for non-academic reasons in the classroom, and some behaving as if it is their right to be multitaskers during lectures. Among college students,

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Internet addiction also could play a role in everyday multitasking, causing some students to multitask more than the typical student. After all, excessive use of the Internet (and, hence, devices that access the Internet) is a typical feature of descriptions of Internet addiction (Block, 2008). Clayson and Haley (2012) administered questionnaires to students in college marketing classes in the U.S. The results showed that almost all of the students received text messages while in class and 86% of the students said that they had texted from within the classroom. Despite the fact that more than one-half of the students were taking a class in which texting was banned, 49% of the students said that they texted in class anyway. The most frequent reasons for texting in class were a desire to communicate, followed by concern about someone and boredom with the class.

American college students reported that they multitask when they are using computers and IMing because of time pressures, because of boredom while waiting for someone to respond to a communication, and, well, because they can (Baron, 2008). The latter reason becomes especially significant as it relates to the "affordances" provided by technological devices (Gibson, 1979; Norman, 1988). Contemporary computer-based gadgets let us, and in fact, encourage us to multitask. Operating systems on our laptop computers, the tabs system in Web browsers, and large screens on computer monitors afford multitasking. They let us run multiple programs or applications and keep several windows open simultaneously, sometimes related, sometimes not. In fact, one report of the Kaiser Family Foundation, after scrutinizing the self-reported devices with which American youth multitasked, dubbed the general-purpose computer (e.g., a laptop in the home) as the multitasking center of a youth's life (Foehr, 2006). Smartphones have icons that represent ways to connect with others and ways to gather information right on the main screen. Baron noted that college students use this to their advantage when socializing. They use the technology to "adjust the volume" of their communication stream. For instance, a student might use IM synchronously or asynchronously to control her level of interaction with another person. Being on the computer allows one to avoid the awkwardness that happens when one multitasks during a face-to-face communication.

Laboratory versus real-world multitasking

Multitasking is one of those terms that can be difficult to define. The traditional cognitive psychology laboratory study of "multitasking" would require that a participant perform two tasks simultaneously. Each task would have a clearly defined goal that is distinct from the other task. In many cases, the tasks would be simplified versions of basic cognitive tasks – so simple that it is rare that people make mistakes. Consider this task:

> If you hear a high-pitched tone, then press the key labeled "Hi." If you hear a low-pitched tone, then press the key labeled "Lo." Do this as fast as you can.

This task, a choice-reaction time task, can be performed in significantly less than a second. Surprisingly, simple tasks like these are liable to produce a kind of interference when performed simultaneously. A basic form of interference is indexed by the phenomenon known as the Psychological Refractory Period. This occurs when two choice-reaction time tasks are performed at the same time, even when the tasks are quite different in input and output modalities. The reaction time to one of the tasks is delayed because of the presence of the other task (Pashler, 1993, 1994; Pashler & Johnston, 1998; Pashler, Johnston, & Ruthruff, 2001; Welford, 1967).

Alternatively, a second form of what might be called "multitasking" can be studied in the laboratory by asking people to perform two very simple tasks back-to-back, repeatedly. One of the key findings of research into this form of multitasking – called task switching – is that it is more difficult to switch to a new task than it is to repeat the same task. The difficulty is observed as a "switch cost," a delay in executing the new task compared with repeating the same task. Although small – on the order of hundreds of milliseconds – the cost is considered to be theoretically relevant to foundational theories of human cognition (Allport, Styles, & Hsieh, 1994; Rogers & Monsell, 1995). In the experimental literature, there also are cases where two tasks can be performed simultaneously without interference. There are two ways to think about this outcome. One is the possibility of "automaticity." With repeated performance, the mental processes required by a task might change such that they no longer rely on any cognitive functions that are used in another task and this would allow the automatic task

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to be paired with other tasks efficiently (Kirschner & Karpinski, 2010). Another possibility is that the two tasks do not use the same underlying mental processes or cognitive resources (Salvucci & Taatgen, 2010).

Real-life multitasking, i.e., everyday multitasking, might not resemble these laboratory forms of multitasking at all. Everyday multitasking, for instance in the workplace or the classroom, most likely contains elements of simultaneous cognitive processing (as studied in dual-task experiments), elements of task switching and elements of automaticity; however, in real life, multitasking might take a variety of forms, only sometimes resembling the classical dual-task experiment or the task-switching experiment. Task switching in real-life is more complex than in the laboratory, since people also seem to "interleave" two or more tasks by switching back and forth between the tasks prior to finishing any one task (Duggan, Johnson, & Sørli, 2013). There are often more than two tasks. In the study by Carrier et al. (2009), even the Baby Boomers were combining more than four tasks at home when doing everyday multitasking. In addition, everyday multitasking tasks usually are more complicated than laboratory tasks. For example, during weekly meetings in our laboratory, it has been observed that the student research assistants are simultaneously monitoring their cell phones, Facebooking, and surfing the Web, all while – presumably—listening to the featured speaker. Anecdotally, and not surprising to anyone who has observed everyday behavior, similar behavior is seen in restaurants, classrooms, boardrooms, stores and anywhere a smartphone can be used.

Additionally, there is considerably more flexibility in how a person chooses to allocate her resources during tasks, decides to allocate priority to tasks, and opts to begin, continue, and end tasks. In a study by Adler and Benbunan-Fich (2013), participants were given five real-life tasks to perform (the main task was a Sudoku puzzle), all arranged in a browser-like environment with each task on a separate tab. The participants were not given instructions as to how to organize their work; they were told only to complete the tasks. The researchers recorded when participants would switch to another tab to start work on another task. After asking the participants later why they switched tabs, it was discovered that participants who experienced negative feelings about the tasks (e.g., getting stuck on a task) were more likely to switch tasks during the study than participants who experienced positive feelings (e.g., curiosity). Based on their negative feelings, it appeared that some participants "self-interrupted" by starting or a switching to another task. Adler and Benbunan-Fich argued that peoples' decisions to switch from one task to another (and perhaps to even multitask at all) can be based on self-interruptions that are grounded in feelings related to progress on a task and the self-assessed prospect of goal attainment. Imagine a student in lecture who is beginning to fall further and further behind in understanding what the instructor is saying. Upon realizing this, the student's next thought, according to the research, is likely to be, *I wonder if anyone responded to my Facebook post. Let me check!* Of course, external interruptions exist as well and can direct our processing resources to engage in a new task (and therefore multitask) in addition to our current task. Media content from computer-based devices provides stimuli that grab our attention, such as the beep or vibration when a text message arrives (Armstrong, 2003). Technology itself has become more insistent from a sensory point of view, with beeps, reminders, follow-ups, alerts, etc. all customized to a specific person.

The effects of everyday multitasking upon learning

While there are clear limits on laboratory multitasking, it is theoretically possible that some forms and cases of everyday multitasking might actually improve one's efficiency. A recent theory of cognitive multitasking makes this explicit. Salvucci and Taatgen (2008) proposed an integrated theory of concurrent multitasking, Threaded Cognition, that proposes a serial procedural resource (i.e., performance limiting) that takes in and initiates requests to various processing resources (e.g., perceptual motor resources). There are no specialized executive processes and the theory allows for concurrent execution of tasks except when the serial procedural resource is required or when resources are occupied. The authors liken the serial process to the cook in a kitchen who can let some processes run independently (e.g., baking bread), but is required to be around when one process ends (e.g., prepare dough) and another needs to be initiated (e.g., put dough into the oven). Any theory of multitasking that allows processes to run independently of each other under some circumstances also naturally allows for the existence of "lag time." Lag time is time during the execution of a task when the limited

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resource (i.e., the cook) has nothing to do for that task so can be allocated to another task to get work done. The lag time present in real-life tasks might allow people in everyday settings to arrange their cognitive processing effectively across tasks (Kinzie, Whitaker, & Hofer, 2005). Another part of the theory is that with practice, execution of tasks depends less and less on declarative resources (knowledge) and more and more on procedural processes (i.e., production rules), leading to reduced interference between tasks. However, this change with practice is a slow process. So, the Generation M children who were found by Rideout et al. (2010) to squeeze almost 11 hours of media content into 7.5 hours of media use might actually be able to do it without loss of performance! Of course, this type of performance probably would require extremely judicious allocation of mental resources, planning, and arranging of physical and cognitive processes in order to maximize time savings by running some of the necessary processes in parallel, independently and in the background. Maybe these children have figured out how to do it, but more likely than not, if measured, their knowledge of the media content would not be as good as it would be if they had consumed the content from the media one at a time. Further, as will be discussed below, it seems unlikely that one could be successful at achieving such processing efficiencies when some of the tasks involved are active learning tasks.

When Carrier et al. (2009) examined the specific tasks that adults of all ages choose to combine during everyday multitasking, they found a high degree of agreement across generations (Baby Boomer vs. Generation X vs. Net Generation) as well as a high degree of agreement on which tasks are relatively easy or relatively difficult to combine when at home. Again, this is consistent with the idea of preexisting mental limitations that affect multitasking that do not change with age in adulthood or with extensive practice (Net Generation vs. other generations). Of course, these limitations are described by the theory of Threaded Cognition and embodied in the elements of theory described earlier: the serial procedural resource (e.g., the cook in the kitchen) and the various other mental resources that to some degree can be used in parallel with one another.

The theory of Threaded Cognition suggests that some multitasking will be successful (i.e., time saved without loss of accuracy) but in many cases it will not. A number of studies involving students demonstrate how the learning process is affected by everyday multitasking. An obvious precondition to learning is that one must become oriented toward the learning task. But, it is very easy for students to be distracted by their technological devices while studying. As the observational study of Rosen et al. (2013) showed, the greater the number of distracting technologies that a student has available in their study environment at the outset of studying, the less likely they are to stay on task while studying. While Rosen et al. did not measure the impact of this distraction on memory for the studied material, it is natural to assume that the time spent on the distracting event (e.g., watching TV) resulted in less learning of the target material. After orienting to the learning task, the active process of learning material must proceed. Apparently, this task cannot proceed unhindered when other technology-based tasks are occurring.

Doing schoolwork or homework also is affected by everyday multitasking. Correlational self-report data have shown this pattern. Junco and Cotten (2011) investigated how multitasking with IM affected students' academic performance. More specifically, they asked students to self-assess what impact IMing has on their homework (not specifically defined) and to report how much they multitask while IMing. The results showed that multitasking while IMing was predictive of IMing having a greater negative impact upon homework. Further, despite the majority of the sample believing that IMing was detrimental to schoolwork, they tended to multitask while IMing a great deal. The study by Adler and Benbunan-Fich (2013) mentioned earlier showed that a problem-solving task (in this case, a Sudoku puzzle) is interfered with by concurrent technology-based multitasking. In the case of solving this particular type of problem, accuracy in the task worsened as more switches were made to other computer-based tasks during the experimental time period. A brain imaging study conducted by Foerde, Knowlton, and Poldrack (2006) showed that performance on a task involving practicing and learning categorical information (a weather prediction task) was not affected by the simultaneous performance of a tone-counting task; however, the imaging results showed that the neural basis of the learned information changed from the hippocampus (the area devoted to declarative memory) to the striatum during distraction. Although not specifically done in the context of everyday multitasking, these findings suggest that homework or schoolwork performed in multitasking conditions might produce different types of learning than work performed alone. And finally, Rosen et al. (2013) found that preference for task

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switching during home study was one predictor of lower GPA among middle school, high school and college students.

Students frequently do everyday multitasking with technology during school and college lectures. Negative self-interruptions, as described earlier, are likely to be rampant. In a typical lecture, there probably are many times when the presentation becomes difficult to understand or when the material becomes uninteresting. The temptation to switch to another task with high emotional appeal (e.g., checking Facebook) is great. Further, if the student has left her cell phone on, even in "vibrate only" mode, there are going to be several external interruptions during the class period. In a texting study conducted by Rosen, Lim, Carrier, and Cheever (2011), the researchers attempted to send text messages to students on their own cell phones during a 30-minute college lecture. However, there were so many naturally occurring text messages sent and received by the participants during the class period – an average of nearly one and half texts in the 30 minutes – that these natural messages had to be accounted for in the analyses.

Qualitative data suggest that communication with other students during lecture via technology may be problematic for learning. Kinzie et al. (2005) distributed handheld computers to students to use as synchronous chat devices during lectures in a college course. Interviewing the students and instructors at a later point, the researchers found that the participants had trouble dividing their attention across the learning and chatting tasks. Experimental work supports this conclusion. Sending a text message during lecture does appear to interfere with learning. Ellis, Daniels, and Jauregui (2010) randomly assigned U.S. undergraduates to a lecture-only condition or a text-plus-lecture condition. In the lecture-only condition, students listened to a lecture about accounting principles and then took a quiz on the lecture material. The students in the text-plus-lecture condition also were required to send three texts to the instructor during the lecture, the timing of which was left to the students. The results showed a 27% reduction in memory for the lecture material when students had to text while learning. Sending and receiving text messages interfered with learning from a lecture in the study mentioned earlier by Rosen et al. (2011). One hundred and eighty five American undergraduates were randomly assigned to one of three groups that varied in how many text messages they were sent – and were asked to respond to – during a 30-minute videotaped lecture on life-span development. Students who were required to do a moderate amount of texting (8 to 15 texts sent and received) performed a little worse than low texters (0–7 texts) on a subsequent memory test (70% versus 72% correct) but the difference was not statistically significant. It was not until the amount of texting reached 16 or more texts that performance on the test was significantly worse than in the low texting group (65% versus 72% correct) reflecting the difference between a "C" and a "D" grade on the test. Finally, Kuznekoff and Titsworth (2013) found that American college students randomly assigned to do a lot of texting on their cellphones during a lecture (responding to 24 text messages in 12 minutes) remembered significantly less material from the lecture than students who did not text. However, students randomly assigned to do a light amount of texting (12 messages in 12 minutes) did not perform significantly worse when remembering the material.

In the classroom lecture situation, the finding that texting interferes with learning is not consistent. However, there is evidence that other forms of communication, including social networking and IM, do impact memory for a lecture. Wood et al. (2012) examined the impact of technology use in the college classroom during lectures. Participants in their study – Canadian college students – were randomly assigned to one of several technology use or control conditions. For example, in one technology use condition, participants were required to use Facebook during three lectures. In other conditions, students were required to IM on a laptop computer, email on a laptop, or text on a mobile phone. The key control condition was a paper-and-pencil note-taking condition. The results showed that, compared with the key control condition, students in the Facebook and IM conditions performed significantly worse on memory tests for lecture material; however, texting and e-mailing did not result in worse performance. The authors speculated that texting did not interfere because it was not as distracting due to participants placing their phones away from themselves on the desktops, while e-mailing was not distracting because it did not automatically alert persons to incoming messages. Nonetheless, a post-hoc analysis combining all of the technology usage conditions together showed that students who used technology during lecture had lower memory scores than those who did not. Using a laptop computer during lecture, while allowing students the ability to take electronic

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versions of notes and to access course-relevant information during the class period, leads to multitasking and interferes with memory for the lecture. Unfortunately, the negative effect of laptop use spreads to nearby students, as well (Hembrooke & Gay, 2003; Sana, Weston, & Cepeda, 2013).

With unlimited study time, learning from a text might not be affected by a technological distraction (hence, multitasking). Bowman, Levine, Waite, and Gendron (2010) asked some American college students to comprehend a reading passage and others to perform reading comprehension while simultaneously responding to IM requests or right after IMing. Although reading times were slowed by the IM interruptions compared with the other two conditions, comprehension levels were not affected. The students in the simultaneous task condition apparently were able to switch away from reading comprehension to perform the IM task and then return again without ill effects on comprehension. When Bowman et al. analyzed the times taken to perform the individual and the combined tasks in detail, they found that the extra time spent reading in the simultaneous task condition was greater than the time required to do IMing alone. The authors surmised that this extra time could be due to an extra cost involved in switching between tasks, i.e., a switch cost. Part of that cost might have been due to a “resumption lag” with the participants having to go back and re-read sections of the text after IMing.

Learning is affected by performing a simultaneous learning task, even when the modes of presentation in the two tasks are different. When American undergraduate students were asked to simultaneously learn from a podcast and learn by reading an online article, memory for the information from the two sources declined compared with learning either source individually (Srivastava, 2013). Importantly, the authors administered several memory measures that varied in sensitivity, including a free recall measure (relatively less sensitive) and a recognition measure (relatively more sensitive). All memory measures were affected, suggesting a fairly catastrophic breakdown of learning with this type of media multitasking. The battering of the learning process by simultaneous media multitasking with another learning task was consistent with the results of a study done by Lee, Lin, and Robertson (2011). The setup in their study is reminiscent of what probably thousands of North American middle school, high school, and college students do every day. The participants, college students in the U.S., were asked either to read and learn some school-level information from print materials or to read for comprehension at the same time as learning from a videotape that contained information that also would be tested. Replace the videotape with YouTube videos and there is clear realism to this scenario. The analyses of the data showed significantly better reading comprehension in the read-only condition than in the multitasking condition.

Srivastava (2013) interpreted the results of the podcast/online article study using the limited capacity model of mediated message processing (LC4MP; Lang, 2000, 2006) in which encoding, storage and retrieval compete with each other for limited resources. Lee et al. (2011) suggested that two learning tasks compete for working memory and that this competition produces interference (Sweller, van Merriënboer, & Paas, 1998). But, the results can also be understood from the perspective of the theory of Threaded Cognition proposed by Salvucci and Taatgen (2008). Reading comprehension, at a minimum, involves parsing sentences, not to mention processes that allow a person to integrate new information with old information in memory. Parsing sentences places great demands upon declarative knowledge, access to which occurs serially in the theory’s conception. Therefore, just parsing two sentences simultaneously (e.g., from the podcast and the article) should be an extremely difficult task in a fixed period of time, let alone considering the organizational and memorial processes necessary for learning.

Practically speaking, it is irrelevant whether studying or learning is affected in the moment by everyday multitasking. What really matters to the typical student is the course grade. Earlier, several studies were described that demonstrated a widespread phenomenon of students using cell phones in the college classroom. Clayson and Haley (2012), reviewing the grades of students in a set of marketing classes in the U.S., found evidence that the academic “bottom line” for the student is affected by in-class multitasking. After gathering the points earned in the classes from the instructors, and comparing these to the students’ self-reports of the number of texts received in class, the researchers learned that grades were negatively impacted by receiving texts and, further, that this relationship held for all levels of GPA. Burak (2012) administered a questionnaire to 774 American college students assessing their multitasking and their grades. The analysis of the questionnaire data revealed that self-reported classroom multitasking was significantly associated with lower GPAs. Further, a regression analysis showed that the most important contributor to lower GPAs was texting (Burak, personal communication 2014). On the other hand, in their observational study of middle school, high school, and college students during a study session, Rosen et al. (2013) found limited connection between staying on task and overall GPA. All but one of the technologies observed to be used off-task during the study session failed to predict GPA. The one technology that did predict GPA was Facebook: accessing Facebook at least once during the study session significantly predicted a lower GPA. The logical connection between accessing Facebook during study and overall GPA is unclear and could take many forms. It was also found that Facebook use was the only immediate technology activity that significantly reduced on-task behavior (studying), hinting that GPA might be affected because Facebook use reduces academic study time.

Yet, other technology-based distractions did not appear to impact GPA, which suggests that there is something different about social media interactions and their mental distractions. One potential basis for the attractiveness of social media to a young person's focus of attention is the Fear Of Missing Out (FOMO), a phrase coined by MTV with respect to why youths and young adults keep checking their devices all of the time. The television station polled a large number of young people and found that the majority felt that "when I'm unplugged, I worry that I'm missing out on something" (Taylor, April 29, 2011). Rosen, Whaling, Rab, Carrier, and Cheever (2013), interested in studying links between technology use and psychiatric symptoms, measured people's anxiety about not being able to check their devices via a self-report measure. The authors found that younger generations report more anxiety than older generations, and that the majority in the younger generations check in very often (every hour, every 15 min or all the time) with their text messages, social networks, and cell phone calls. The researchers suggested that there is a causal link between anxiety about not checking in and the frequency of checking in. Indeed, Przybylski, Murayama, DeHaan, and Gladwell (2013), developed a measure of FOMO and found that young adults showed the highest levels of it and that FOMO was linked to seeking out social media.

The long-term effects of everyday multitasking

Beyond the immediate academic impact of everyday multitasking, the extent of multitasking in the population, especially among young persons, makes one wonder about the long-term effects of attempting to do too much at the same time. Until very recently, this question had not been pursued by traditional research into multitasking (i.e., cognitive psychology research). While it is clear that people are multitasking more than ever in their everyday lives, what is not clear is whether people have been getting better or worse at it. A number of social critics and researchers have suggested a range of potential positive and negative effects of extensive everyday multitasking with devices (e.g., Small & Vorgan, 2009) but there is not much solid empirical evidence available to evaluate the claims. Some people have raised the possibility that youth who multitask a lot could get better than the average person at multitasking or other attentional skills (e.g., Foehr, 2006). One might wonder whether all of the multitasking "practice" that people are getting has made them effective multitaskers or even "supertaskers" (Watson & Strayer, 2010). Other people (e.g., Carr, 2011) have argued that the kind of rapid attention shifting that is involved in multitasking with devices could lead to an inability to focus and a perpetually shallow level of processing of information. In the proposed concept of Continuous Partial Attention by Stone (2007), technology-induced multitasking for extended periods of time leads to reduced depth of processing, increased stress and anxiety, and a reduction in creative and problem-solving performance.

College-aged students, being the most studied age bracket when it comes to multitasking, have provided most of the data over several decades upon which theories of multitasking and attention have been formed. Coincidentally, contemporary college students also represent some of the most avid multitaskers when it comes to use of technological devices. It would be not unexpected to see that current research into dual-task performance and other forms of multitasking find that college students are able to combine two or more cognitive tasks efficiently. But, this is not the case. Laboratory research into concurrent task performance shows that although with certain tasks people can diminish the time costs associated with multitasking (Dux et al., 2009), data continue to show the existence of stubborn mental limitations when people (i.e., college students) try to multitask. So, based on basic laboratory research, all of this everyday practice does not seem to be resulting in major improvements in general multitasking skills for college-aged persons compared with earlier generations of students.

Several researchers have carried out correlational studies, looking for differences in multitasking skills between people who multitask a lot in everyday life and those who do not multitask much. Keep in mind that the correlational nature of these studies means that it is not possible to know if everyday multitasking causes cognitive changes or if cognitive differences lead to extensive everyday multitasking. There have been studies comparing persons with different multitasking habits on laboratory-based multitasking performance. Ophir, Nass, and Wagner (2009) administered a media use questionnaire to 262 American university students in which students estimated their weekly use of 12 different media forms, plus estimated the simultaneous use of each form with the other forms. The estimates were used to create a media multitasking index (MMI) for each student. A High Media Multitaskers group (HMMs) and a Low Media Multitaskers (LMM) group were created based on the MMIs. Ophir et al. (2009) gave participants a task-switching measure to assess this form of multitasking skill. Participants performed either a letter classification task (vowel or consonant) or a number classification task (even or odd). The tasks occurred successively or alternately.

Their results revealed that HMMs had significantly higher switch costs than the LMMs. Ophir et al. attributed the switch cost disadvantage to the inability of the HMMs to filter out irrelevant task information in memory (described below). In contrast, a follow-up study by Minear, Brasher, McCurdy, Lewis, and Younggren (2013), using an almost identical procedure with 221 American college students (aged 18–25 years old), failed to find a task-switching deficit for HMMs compared with LMMs. While overall the two groups experienced a significant "switch cost," they did not differ statistically in the size of the cost. A recent study by Alzahabi and Becker (2013) has taken the research by Ophir et al. one step further. The researchers compared low and high media multitaskers on measures of task switching and dual-task performance (trying to do two things at exactly the same time). Participants were asked to respond as quickly as possible to either a number (by classifying it as even or odd) or a letter (by classifying it as a consonant or a vowel). In the dual-task situation, participants were asked to complete both classifications at the same time; in the task-switching situation, participants performed the same classification repeatedly with occasionally switches between the types of classification. The study results showed that there was an advantage for high media multitaskers in task switching but not in dual-task performance. So, the evidence for improved task switching is very inconsistent, and there was not laboratory evidence for improved dual-task performance.

Some of this research also has examined everyday multitasking and its effects on the ability to ignore irrelevant information. Ophir et al. (2009) tested the ability to ignore environmental distractors (i.e., selective attention). The authors gave two tests that required filtering out stimuli that were irrelevant to the task. Both measures showed that the HMMs were significantly worse than the LMMs. In an interesting reinterpretation of these results, Lin (2009) proposed that HMMs were dividing their attention across the focal targets and the distractor material despite being told to focus on only the key information. Further, Lin argued that this was a potentially important skill to have in the modern media-heavy age: to be able to perform a primary task while also superficially sampling distracting information for other useful stimuli.

Ophir et al. (2009) also tested whether HMMs would have a more difficult time than LMMs in ignoring extra information in working memory. The tests used were the "2-Back" and "3-Back" tests. In these measures, participants are given the challenging task of remembering a target letter for a few seconds while other letters appear on the computer screen. The task is challenging because each other letter that appears is also a target to be remembered. In the 2-Back test, the participant has to decide if the current letter is one that appeared two letters ago; in the 3-Back test, the participant has to decide if the current letter is one that appeared three letters ago. The results showed that HMMs had a more difficult time in these tasks than the LMMs. In contrast, however, Minear et al. (2013) gave American college students a different task designed to measure difficulty in dealing with irrelevant information in working memory (the Recent Probes Item Recognition Task) and found no performance differences between HMMs and LMMs.

Minear et al. (2013), in order to further assess attentional skills in multitaskers, gave American college students a task designed to measure alerting, orienting, and executive attention using the Attention

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Network Task from Fan, McCandliss, Sommer, Raz, and Posner (2002). This task results in three measures – alerting, orienting and executive attention – based on one popular model of the human attention system (Posner & Boies, 1971; Posner & Petersen, 1990). Alerting is defined as becoming and staying attentive toward the environment. Orienting is allocating attention to a specific stimulus. Executive attention is necessary to deploy resources in order to deal with multiple attentional cues. However, in the data from Minear et al., these tasks showed no performance differences between HMMs and LMMs. Minear et al. stated at least two possible differences between their study and the study by Ophir et al. that could explain the conflicting outcomes. One possibility was that the participants in the two studies employed different attentional strategies in carrying out the tasks. The participants, college students, came from very different types of colleges. Another possibility was that the two groups of participants might have varied in how much prior success they had in everyday multitasking.

Other cognitive processes also have been assessed for associations with everyday multitasking. Minear et al. (2013) compared their HMMs and LMMs on a measure of working memory borrowed from Conway et al. (2005), finding no significant difference. The authors also compared the two groups on a measure of fluid intelligence using Raven's standard Progressive Matrices (RPM; Raven, 1998). Here, there was a difference between the groups: HMMs performed significantly lower than the LMMs. However, in a careful analysis of the reaction times to individual items on the RPM, in conjunction with their finding that HMMs showed higher levels of impulsivity than the LMMs, the authors argued that the differences in fluid intelligence probably were due to HMMs giving up sooner on RPM items than the LMMs.

Coping with the negative effects of everyday multitasking

There are a few interesting results to consider when addressing the question of how people should deal with the potentially negative effects of everyday multitasking. One is a finding in the previously described texting-in-the-classroom study by Rosen et al. (2011). The researchers compared three randomly assigned groups of students (No/Low Texting, Medium Texting, High Texting) on their performance in a classroom lecture learning task. In that study, despite finding that the High Texting group learned less from a concurrent lecture than a Low/No Texting group, further analyses showed that the amount of interference due to texting was related to how quickly a student responded to a text. Although students were instructed to respond to the experimenters' text messages, many chose to delay their responses, and, further, students also received messages from friends and family to which they could choose when they wanted to respond, if at all. The analysis showed that participants who waited a few minutes to respond to a text message did substantially better on the learning task than those who responded more rapidly. Although this was a post-hoc analysis of the data that merits further experimental investigation, there is very little other empirical evidence available that can tell us how people should deal with the negative effects of everyday multitasking.

If it is true that the students in the study by Rosen et al. (2011) were strategically delaying their response to a text message to avoid interference with learning, then this option represents one of several possible choices that people, especially students, can make when using digital devices in learning situations. Rosen, Carrier, and Cheever (2010), noting the ubiquity of smartphones and the associated amount of time that people use them, referred to smartphones and other portable computer devices as Wireless Mobile Devices (or WMDs, a play on the phrase Weapons of Mass Destruction). In the classroom, clearly, optimal learning and focusing on the lecturer should be associated with minimizing the distractions from WMDs. If the teacher has not already required it, students have the option of completely turning off their cell phones, or partially doing so by turning off the ringers and/or turning off the vibrate mode. Putting the cell phone away into a backpack or purse might be even more helpful in reducing how much stimulation reaches the student during lecture. Based on the idea that technological devices grab our attention through the sensory stimuli that they provide, then minimizing that stimulation should reduce our distractions in learning environments. When studying, students increasingly appear to be using electronic devices to read and absorb material. Pressure from educational institutions to switch away from paper textbooks and toward electronic texts has contributed to this trend in behavior.

Reading and learning from electronic devices offer their own options for students who want to make learning-enhancing adjustments to their study sessions. For WMDs and laptops and home desktop computers, this means turning off the music or turning down the volume of the music. Students also

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have the options of closing extra windows on the devices – assuming that windows contain applications that are potentially distracting such as Facebook as found by Rosen et al. (2013) in their observations of students studying – and de-cluttering their reading experience by using a reader application or program that eliminates distracting banners, navigation bars or extraneous Internet links (e.g., using the "Reader" button in the Safari Web browser). Other ways to "turn down the volume," although this time with respect to the amount of concurrent communication happening during studying (Baron, 2008), include turning off social media applications such as Facebook or deactivating phone alerts from them.

The reader surely can think of many more options that are available to people trying to learn from electronic devices. Some types of students seem to be more at risk for distraction during this type of learning than other students. Research in education has found that students with low prior knowledge of a topic (perhaps due to disorientation in a busy learning environment), students with experience in online environments (perhaps due to ease of processing irrelevant information), and students with computer familiarity (perhaps due to the gradual development of shallow browsing strategies with computer experience) are less likely than other students to learn when studying online (Kushnir, 2009; Müller-Kalthoff & Möller, 2006; Wecker, Kohnle, & Fischer, 2007).

As Rosen et al. (2011) pointed out, making strategic decisions about technology usage that benefit learning is a form of metacognition. Metacognition, which literally means thinking about thinking, could include self-judgments of learning abilities, knowledge of one's own learning styles and self-estimated knowledge and skill levels. When asked whether they can name all U.S. presidents to date in chronological order, most college students immediately "metacognitively" know that they cannot do it. Metacognition applied to learning also might be applied to learning that involves digital devices. Here are some examples: noticing one's anxiety caused by separation from digital devices, knowing when to stop texting in class or during a meeting and knowing when to put away or look away from the laptop during lecture.

This form of "digital metacognition" can be applied to the workplace, too. Selecting a primary task to perform and focus on might work better if the employee has learned, through instruction or through reflection, some strategies to do so. As with the student trying to learn more effectively, these primary tasks take place on and off of digital devices and there would be a range of options available to workers to maximize performance and minimize distractions. The theory of Threaded Cognition and the concept of automaticity also provide knowledge that can be put to good use in the workplace. Some multitasking – the pure form of multitasking that involves parallel processing of two separate tasks – might be possible under the right conditions. Noting when two tasks *can* proceed together and when they cannot gives insight to the worker as to what choices should be made to maximize performance. In general, well-rehearsed tasks should have reduced dependence on serial resources and so should be less likely to interfere with a primary task.

Ie, Haller, Langer, and Courvoisier (2012) tried improving media multitasking in a different way. Coming from the perspective of "mindfulness," the authors trained participants (adults from age 18 to 50) in an attempt to induce a form of temporary mental flexibility that would encourage "creation of novel distinctions and flexibility." The training exercises also reinforced the notion of the "permeability of categories." An example exercise to raise mindfulness was to provide three positive and three negative explanations for the person's actions in the ambiguous scenario, "Jonathan took $5000 from the teller." The logic of the training was to improve multitasking performance by enhancing mindful flexibility. The participants next performed media multitasking in the form of doing a word processing task while simultaneously performing an anagram task through a chat program. The results did not confirm expectations, as the mindfulness training did not significantly alter multitasking performance; however, it was learned that one's prior level of mindfulness (trait mindfulness) predicted multitasking performance, with those high in trait mindfulness performing better than those participants low in trait mindfulness. The authors interpret this finding as suggesting that people who are implicitly or explicitly aware of multiple perspectives on a scenario are better at media multitasking than other individuals and raise the possibility that fostering trait mindfulness might be a way to enhance people's technology-based multitasking skills.

Summary and conclusions

Everyday multitasking is prevalent in contemporary society, especially among youth who engage extensively in media multitasking. One of the important venues for understanding everyday multitasking

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is in the classroom. During periods of life – particularly middle school, high school, and college – when learning requires long spans of focused attention for studying texts and listening to lectures, electronic devices are providing platforms for losing focus via media multitasking. Several possible contributors to the multitasking associated with devices are a need to get more done in a fixed period of time, a desire to communicate with others, addiction to the Internet or to the cell phone, a wish to switch away from a boring task to a more interesting one, and the Fear Of Missing Out (Block, 2008; Clayson & Haley, 2012; Judd & Kennedy, 2011; Taylor, April 29, 2011). In addition, the devices themselves – and the programs and applications that they provide – can draw in our attention via beeps and vibrations and the built-in capability to open new windows and multiple, simultaneous applications.

Research in the laboratory has investigated the root causes of interference between tasks during multitasking, uncovering important limitations in human information processing that include a seemingly fixed serial processor involved in even the simplest of tasks and a performance cost that is incurred when people rapidly switch between tasks (Allport et al., 1994; Pashler, 1993, 1994; Pashler & Johnston, 1998; Pashler et al., 2001; Rogers & Monsell, 1995; Welford, 1967). However, real-life multitasking is more complex and more flexible than laboratory multitasking in several ways, so it is unclear how much these basic attentional limits in processing will affect a person in the real world. More elaborate theories of multitasking, such as the theory of Threaded Cognition (Salvucci & Taatgen, 2008), provide an approximation of what happens when people perform everyday multitasking and might be used to predict when everyday multitasking will help and when it will interfere with completing task goals in a timely manner.

Learning, perhaps the most important task in which a middle school, high school, or college student must engage, can be affected by everyday multitasking in several ways. The act of orienting to the learning task can be compromised simply by the presence of electronic gadgets as shown in Rosen et al. (2013). Doing homework can be affected by doing electronic tasks at the same time (Adler & Benbunan-Fich, 2013; Junco & Cotten, 2011). The use of communication devices brought into the classroom may interfere with learning lecture material (Ellis et al., 2010; Kinzie et al., 2005; Kuznekoff & Titsworth, 2013; Rosen et al., 2011). With unlimited study time, distraction by gadgets might not interfere with the knowledge gained from a learning task, but the time required to learn the material could be greater and constant distraction can increase stress and anxiety (Bowman et al., 2010). Trying to learn information from two separate media sources simultaneously appears to be detrimental for learning (Lee et al., 2011; Srivastava, 2013).

Using devices in the classroom might affect the academic bottom line – the grade (Burak, 2012; Clayson & Haley, 2012) – although using devices outside the classroom during study time has a less clear impact on grades. The long-term effects of everyday multitasking are not readily apparent. Young people who form the Net Generation – who also happen to be the most avid multitaskers – do not appear to be getting any better at multitasking than prior generations and seem to be bound by the same mental limitations as other individuals. However, a few potential differences between heavy media multitaskers (HMMs) and light media multitaskers (LMMs) have emerged. HMMs appear to be less able than LMMs to avoid the influence of irrelevant environmental distractors (Ophir et al., 2009).

From a practical standpoint, everyday multitasking seems well entrenched in contemporary life even in critical information-rich venues like the classroom and the workplace. However, the possible negative effects of multitasking with our WMDs give rise to the challenge of finding effective ways to control our learning and our work performance in a highly distractible world. Simple choices, like a student in a lecture deciding to delay a response to an incoming text message until the teacher has finished making her point, might contribute to improved efficiency with everyday multitasking. Many other simple choices are available to learners and to workers as they struggle to stay on task when the primary task is an important one. These deliberate behaviors for handling one's school and work domains can be understood as a form of metacognition – digital metacognition – that might be teachable or might result from critical self-reflection of one's prior learning and working experiences. Of course, digital metacognition might rest on the individual's insight into the fact that multiple devices impede learning. To the degree that students believe that they can multitask effectively, they may have to be educated and persuaded to adopt these strategies.

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