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Univ Rennes, LP3C (Psychology of Cognition, Behavior & Communication Laboratory) - EA 1285, F-35000 Rennes, France

Author Note

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Corresponding author:

Eric Jamet
LP3C
Université Rennes 2 Haute Bretagne,1 place du recteur Henri Le Moal
35043 Rennes Cedex
France
Email: eric.jamet@univ-rennes2.fr

Abstract

University students often engage in multimedia (e.g., texting or social networks) and nonmultimedia (e.g., chatting with neighbors) off-task multitasking behaviors during courses. The aim of the present study was to describe these off-task multitasking behaviors and analyze their effects on learning performance in a real teaching session. More specifically, 187 students attended a cognitive psychology tutorial as usual, taking notes either on paper or on a laptop. In an effort to preserve the ecological setting, they were not informed of our research on multitasking. After 20 minutes, students had to report the number and duration of off-task multitasking behaviors they had engaged in and complete a learning questionnaire. Results showed that multimedia and nonmultimedia multitasking behaviors were frequent but also additive, especially among students who used a laptop. These behaviors had a negative impact on students' memorization of course content, although we found no significant effects on comprehension. Our study also showed that students who used a laptop had lower memory scores. A mediation analysis confirmed that this deleterious effect was partly attributable to multitasking. These results are discussed in terms of interference between off-task behaviors and the cognitive processes essential for learning.

Keywords: multitasking; real-course settings; learning; off-task behaviors

1 Introduction

It is now commonplace for university students to engage in off-task behaviors during lectures. Many studies have clearly shown that students multitask frequently-and in a variety of ways while they are supposed to be listening to their teacher. When Ragan, Jennings, Massey, and Doolittle (2014), for instance, combined in-class observation with survey methods, they found that students engaged in off-task computer activities (e.g., social media, web browsing) for nearly two-thirds of lesson time (see also Gaudreau, Miranda, & Gareau, 2014 for similar results). Phone use during classes is also very common. In their study, Tindell and Bohlander (2012) found that 95% of students brought their phones to class every day, 92% engaged in text messaging during lesson time, and 10% had done so at least once during an exam.

In this context, *multitasking* is defined "as divided attention and non-sequential task switching for ill-defined tasks as they are performed in learning situations" (Junco & Cotten, 2012, p. 505). These activities can be referred as *on-task* when they are relevant for the learning task, and *off-task* when they are not (see Wood & Zivcakova, 2015 for a review based in this distinction). *Multimedia multitasking* refers to activities involving the use of technology (Wood & Zivcakova, 2015). However, laptops and phones are not the only sources of distraction during lessons, and students have many opportunities for engaging in off-task activities that do not involve electronic devices (e.g. chatting with other students). Paradoxically, this more traditional nonmultimedia multitasking and its links to multimedia multitasking and learning outcomes have not yet been studied. The aim of the present study was to elucidate the effects of these different off-task multitasking activities on an immediate learning test in a real classroom context.

1.1 How can multitasking affect learning?

Although people commonly perform several tasks simultaneously in the course of their daily lives, research has shown that in many dual-task situations, performance suffers and more time is spent on each task (e.g. Pashler & Johnston, 1998 for a review). In the field of cognitive psychology, many theoretical models of multitasking performances emphasize that tasks drawing on different types of resources (i.e., perceptual, cognitive, or motor) can be simultaneously performed with little interference, but that bottlenecks can arise from the conflict caused when these tasks draw on the same resources, resulting in poorer performances (e.g. Meyer & Kieras, 1997; Salvucci & Taatgen, 2008; Wickens, 2002).

As far as learning complex multimedia material is concerned, several theories have underlined the potential cognitive overload generated by concurrent cognitive processes (e.g. Mayer, 2014; Sweller, Ayres, & Kalyuga, 2011). The cognitive theory of multimedia learning (CTML, e.g. Mayer, 2014) is based on the idea that meaningful learning, defined as a deep understanding of the material, occurs when learners actively engage in three generative processes: *selecting* the relevant incoming information; *organizing* this information into coherent cognitive representations; and *integrating* these representations with relevant prior knowledge. Mayer identifies three sources of cognitive load: 1) *essential processing* necessary for learning (selecting, organizing, and integrating); 2) *generative processing* arising from the motivation to learn, referring to learners' efforts to achieve a deeper understanding; and 3) *extraneous processing*, which is not necessary for learning, and is induced by the design of the document or the learning situation (e.g., presenting graphics and the corresponding speech in an asynchronous way in a multimedia document, or processing irrelevant words and pictures that are not directly related to the instructional objectives). To promote meaningful learning, the educational environment must minimize extraneous processing in order to avoid cognitive overload (Sweller et al., 2011), and facilitate essential processing in order to foster generative learning (Mayer, 2014). Off-task multitasking activities can be regarded as extraneous processing if they are performed during a learning task (e.g., during homework or a lecture). As suggested by CTML theory, this extraneous processing may hinder essential processing or generative learning, and affect learning outcomes or academic performance (see Wood & Zivcakova, 2015 for a review), especially for heavy media multitaskers who may have difficulties to filter out interference from irrelevant tasks (Ophir, Nass, & Wagner, 2009) and to focus on the task at hand (Shin, Webb, & Kemps, 2019)

1.2 Survey-based studies of the effects of multitasking on learning

Many studies have demonstrated that multimedia multitasking practices have a negative impact on academic performance. In an exploratory survey, Kirschner and Karpinski (2010) demonstrated a negative relationship between Facebook use and academic performance. Similar results were obtained by (Jacobsen & Forste, 2011), when they evaluated how the use of electronic media (e.g., TV, games, instant messaging) by university students influenced their academic outcomes. For their part, Junco and Cotten (2011) found that college students made intensive use of instant messaging every day, and a large proportion of them reported that instant messaging had a detrimental effect on their schoolwork.

Several more specific studies focusing on multitasking during homework have shown that these behaviors are very frequent among students and are negatively correlated with their academic performance, as measured by Grade Point Average (GPA) scores (Junco & Cotten, 2012; Lau, 2017). A survey-based study analyzed the multitasking practices of 360 students during homework and in class (Bellur, Nowak, & Hull, 2015). Participants frequently multitasked during homework (e.g., 41% reported very frequent texting on their phones), as well as in class (e.g., 31% reported very frequent texting on their phones). Results showed that only multitasking in class was negatively associated with academic performances, as measured by GPA scores. The authors suggested that multitasking during homework is asynchronous (i.e., students alternate between off-task activities and working), whereas in class, off-task activities are synchronous with learning activities (listening, understanding, or taking notes). In view of the learning theories described above, we can assume that the negative effects of multitasking are exacerbated in the latter situation.

Other studies have focused on in-class multitasking. Gaudreau et al. (2014) conducted a large survey in which they asked more than a thousand students to report their in-class laptop use by evaluating how frequently they engaged in various behaviors (e.g., taking notes, sending e-mails, watching videos, searching for related or unrelated information on the web). Results indicated that laptop behaviors that were unrelated to school were negatively associated with both academic performance and satisfaction. The authors replicated these results in their second study, even after controlling for several potential variables (e.g., self-regulation failure, motivational deficit, or Internet addiction). Similar results were reported by Zhang (2015). This study also demonstrated that self-regulation behaviors are negatively associated with in-class laptop multitasking, which the author interpreted as reflecting a lack of self-regulation (see also Wei, Wang, & Klausner, 2012 for a similar proposition).

In another study (Kraushaar & Novak, 2010), a survey-based methodology was used conjointly with log recording data. About 40 students from an American university agreed to trigger spyware before each lecture to record their activity. Despite this, students had irrelevant windows that were active for 42% of the lecture time. The authors acknowledged that their results provided only limited support for the hypothesis that a higher frequency of multitasking is correlated with poorer academic performances, as significant correlations were only observed for one of the five subcategories of multitasking (i.e., instant messaging). One possible explanation put forward by the authors was that students who have frequently multitasked in class may lessen its impact by doing extra study before the exam, such that its impact can only be observed in an immediate in-class assessment. This kind of immediate assessment of learning outcomes has not so far been a feature of studies adopting a survey-based approach, but is used in experimental studies. More recently, using the same method of log-analysis, another study (Ravizza, Uitvlugt, & Fenn, 2016) has shown that non-academic Internet use was inversely related to class performance.

1.3 Experimental studies of multitasking effects on learning

The experimental studies described in this section adopted a comparative approach to assessing the effects of multitasking in simulated or real-life lectures. For example, in the study by Hembrooke and Gay (2003), these effects were investigated among students on a communication course. Half of them were allowed to open their laptops and use them as usual during a lecture, while the remaining half were asked to keep their laptops closed. Students in the open laptop condition performed significantly more poorly on immediate measures of memory for lecture content. The effects of in-class laptop use on student learning were also evaluated in a simulated lecture by Sana, Weston, and Cepeda (2013). Multitasking was induced by sending students questions that required online browsing to be answered. Results showed that multitasking had deleterious effects on the learning not only of those who engaged in them (Exp. 1), but also of those in the immediate vicinity who simply observed them (Exp. 2).

In several studies, students were asked to reply to text messages while viewing videotaped lectures (Kuznekoff & Titsworth, 2013; Rosen, Lim, Carrier, & Cheever, 2011). These two studies showed that frequently answering instant messages on a phone resulted in a decline in the recall of lecture content. By controlling the times at which they sent instant messages to students, Conard and Marsh (2014) were able to show that the interference effect mainly concerned items testing content that had been interrupted by the instant messaging. More recently, off-task messaging was also proved to have detrimental effects on memorization and notetaking during an academic presentation (Waite, Lindberg, Ernst, Bowman, & Levine, 2018).

When students were asked to answer instant messages while reading (Bowman, Levine, Waite, & Gendron, 2010), they took longer to read the passage even after the time taken to answer had been subtracted. However, no difference was found in comprehension (see Fox, Rosen, & Crawford, 2009 for similar results in a reading comprehension task). This result can be interpreted as a consequence of the task that was used. In a reading activity, students can switch sequentially between the instant messaging task and the reading task, whereas in the sort of videotaped learning task used in the two previous studies, the two tasks have to be performed concurrently. This interpretation is supported by the results of Pashler, Kang, and Ip (2013). In their first study, some students were asked to answer instant messages while reading and others not to do so. No interference effect was found on comprehension scores. Similar results were obtained when the information was presented in audio format and learners could pause to answer messages (Exp. 2). By contrast, comprehension scores were lower in a condition where the auditory information could not be paused (Exp. 3).More recently, Dindar and Akbulut (2016) distinguished between sequential and concurrent multitasking scenarios. In their sequential conditions, students had to switch between distractive videos and instructional videos, while in their concurrent conditions, they had to chat online while viewing instructional videos. Results showed that only concurrent multitasking interfered with learning outcomes. These results were recently replicated in more natural settings, a library room and a cafeteria (Örün & Akbulut, 2019, Exp. 1).

In a very comprehensive study (Wood et al., 2011), the effects of multitasking on learning in university lectures were assessed during three consecutive sessions in seven conditions: four digitally-based multitasking activities (texting using a cellphone, emailing, MSN Messaging, and Facebook) and three control groups (paper-and-pencil notetaking, notetaking with a word processor, and natural use of technology). Results indicated that participants in the Facebook and MSN conditions performed more poorly than those in the paper-and-pencil control. In the natural condition, almost half the participants used technology for every lecture, approximately one third used paper and pencil only, and the remaining students were inconsistent in their choices. Interestingly, only 57% of participants reported completely adhering to the instructions for technology use in their assigned condition across all three sessions. For example, some participants in the texting condition reported that they had sent emails and used the Internet for entertainment purposes during the task. Similarly, students in the paper-and-pencil control group texted on their phones. In total, only 23.5% of participants reported not using any technologies in any of the three sessions, but interestingly, results showed that these students outperformed those who engaged in multitasking activities on learning. In summary, although this study showed that 1) interference effects can be observed on learning in realtime classroom lectures and 2) technology use can influence these effects, 3) strict control of multitasking activities is difficult, as students naturally engage in various and concurrent activities of this type in natural settings.

1.4 Rationale for the present study

In summary, a wide range of studies have investigated multitasking and its effect on learning. These have used either survey-based methods or experimental comparisons between multitaskers and non-multitaskers. Both methodologies have benefits and drawbacks, and a mixed approach combining their particular strengths might be useful for expanding our understanding of multitasking effects on learning in natural settings.

As highlighted above, survey-based research has shown that off-task multitasking activities are extremely frequent among students attending lectures, and are negatively associated with academic performance (see May & Elder, 2018 for a recent review). However, these studies did not usually include direct assessments of learning performance, and all of them focused on multimedia multitasking. None of them jointly analyzed the effects of more traditional non-multimedia multitasking (e.g., reading a newspaper or doodling). Accordingly, the first aim of the present study was to evaluate these two kinds of off-task activities among college students attending real-life lectures.

Studies based on experimental comparisons have demonstrated negative effects of multitasking on learning, as assessed with immediate recall tests (e.g. Kuznekoff & Titsworth, 2013; Örün & Akbulut, 2019; Rosen et al., 2011; Sana et al., 2013). These evaluations are interesting because they 1) allow for a more precise evaluation of participants' retention of lesson content, and 2) are not influenced by post-class behaviors, unlike survey-based methods that used final exam performances as an indicator of learning (Kraushaar & Novak, 2010). However, in these studies, multitasking was usually imposed on students, which may have considerably influenced their results. In the present study, we adopted a mixed approach, in order to analyze natural multitasking behaviors but also, by interrupting the lecture, to immediately assess learning performances. This approach allowed us to avoid the effects of a posteriori behaviors, as well as to evaluate the effects of off-task multitasking activities on learning more accurately. With regard to the role of task timing in multitasking effects (Dindar & Akbulut, 2016; Örün & Akbulut, 2019; Pashler et al., 2013), we predicted that multitasking would have detrimental effects on learning outcomes (i.e., memorization and comprehension) because for this particular lecture, students would not be able to compensate for the effects of off-task activities with more learning time, in contrast to a reading-alone situation or homework (Hypothesis 1).

As most previous surveys assessed the effect of multimedia multitasking on learning, they focused on students who took notes on their laptop, but a large proportion of students only take notes on paper. Research has shown that using a laptop may have a detrimental effect on learning performance, and that students who use a laptop frequently engage in off-task activities (Fried, 2008; Hembrooke & Gay, 2003; Kraushaar & Novak, 2010; Ravizza et al., 2016). Furthermore, research on note-taking has shown that the medium used to take notes (laptop vs. longhand writing) influences the quantity of the notes taken (i.e., more notes recorded with laptops), but has mixed effects on learning (Bui, Myerson, & Hale, 2013; Luo, Kiewra, Flanigan, & Peteranetz, 2018; Mueller & Oppenheimer, 2014). However, to date, no study has assessed how using a laptop versus paper and pencil to take notes might influence off-task activities, with the exception of one study that used paper and pencil as a control condition (Wood et al., 2011) and imposed the mode of note-taking on students, potentially interfering with spontaneous behaviors. The third objective of the present study was therefore to analyze type of notetaking as a predictive factor for multitasking activities. Off-task multimedia multitasking activities could be performed by all the students on their phones, but we expected laptop users to be even more tempted than those who used paper and pencil to take notes (Hypothesis 2), and thus to perform more poorly on learning assessments (Hypothesis 3).

2 Method

2.1 Participants

The initial sample comprised 231 French undergraduates (first-year students, all belonging to the same year group of psychology majors). In order to preserve the naturalistic setting, students were only asked to sign an informed consent form when they started the test phase-that is, after the cognitive psychology tutorial (see second phase in Procedure section). None of them refused to take part in the study. A total of 44 students were excluded from the sample, either because they were repeating their year (i.e., had already attended the same course) or because they did not arrive on time for the start of the tutorial session. In the final sample (N = 187; 31 men and 156 women; mean age = 19.02 years, SD = 1.44), 90 students took notes on paper, while 97 used a laptop.

2.2 Material

The study took place during the first 20 minutes of a cognitive psychology tutorial session about phobias and cognitive-behavioral therapy. During this part of the tutorial, different contents on specific and social phobias were provided: (1) five PowerPoint slides describing specific and social phobias were displayed on a screen via a video projector, (2) a 7-minute video dealing specific phobia and particularly with bird and feather phobia was played using the same video projector, and (3) an excerpt from a book on a social phobia was read out by the teacher (no visual display for this material). This lecture consisted of the following sequence: three slides describing the four types of specific phobias, a 7-minute video illustrating a specific phobia (birds and feathers), two slides describing social phobias, and the reading aloud of a book excerpt providing an example of a social phobia. As this sequence was constructed so that each notion was first introduced then illustrated, it was impossible to counterbalance or randomize the order of presentation without hindering the understanding of the tutorial. At the end of the 20 minutes, participants were asked to fill in a four-part questionnaire handed out by the teacher:

a) Personal data: age, sex, way of taking notes (paper, laptop);

b) Personal interest in psychology, cognitive psychology and phobias: three items rated on 10-point Likert scales ranging from *Very low* to *Very high*;

c) Engagement in two kinds of multitasking: (1) multimedia multitasking, referring to off-task activities involving the use of technologies (e.g., social media such as Instagram, Twitter, Snapchat, Facebook and others, messaging using a mailbox, SMS and instant messaging, Internet searches and other digital activities like playing games and watching videos); and (2) non-multimedia multitasking, referring to off-task activities performed without using electronic devices (e.g., reading a newspaper, chatting with other students, doodling, and other nondigital activities). Participants had to rate the frequency and total duration of each activity: no time, less than 1 minute, 1-5 minutes, 5-10 minutes, 10-15 minutes, or 15-20 minutes. They also had to indicate when each activity took place (during slides, video or text) and which device was used (mobile phone, laptop, tablet, etc.) to perform it. Additional information about multimedia multitasking activities was collected regarding social media (consulting and posting), messaging (sending or receiving) and Internet searches (related to course content or not);

d) Learning outcomes, assessed with a questionnaire including memorization and comprehension items relating to the content of the course. Memorization was evaluated with nine memory questions (e.g., "What is the name of the four main types of specific phobias?") that were scored by awarding 1 point for each correct answer, with a maximum total score of 12. In order to provide the correct responses to the memory questions, participants had to recall information supplied in the video for three questions, the reading aloud for two questions, and the slides for four questions. The items probed information that was only given in one format.

Comprehension was assessed with three new case studies presented in 5-line texts. (e.g., “Trevor has a great fear of falling, he is terrified of climbing up scaffolding, a building or a steeple. He is currently a builder and that’s a real problem, as height is part of his job. What type of phobia does Trevor have? Be as precise as possible”). The aim was to evaluate the students’ ability to apply knowledge from the tutorial to diagnose the phobias being described. In order to provide the correct responses to the case studies, participants had to transfer knowledge from all the parts of the lecture, as the answer was never explicitly provided.[1]

2.3 Procedure

The experiment took place during eight cognitive psychology tutorial sessions (each composed of small groups of 35 students on average), each lasting 2 hours. Those lectures all took place during the same week, as part of the regular course schedule. Three different teachers (one professor and two teaching assistants) were involved in this study. To ensure that the instructional content was exactly the same for all the participants, the three teachers used a preprinted text that they followed during all the sessions. Teacher identity was also included as a controlled variable in statistical analyses to control for possible differences.

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[1] Reliability for these learning outcomes measures was moderate, with an internal consistency of $\alpha = .60$ for memory and $\alpha = .62$ for comprehension, a little below the usual threshold of .70. This was not entirely unexpected in this context, given the limited number of questions that could be asked on the content of a short tutorial session, and the fact that the questions assessed different contents covered in the session and thus were not entirely interchangeable. This limited reliability could only decrease the relations with other variables and thus lead to underestimating the effects of multitasking on learning outcomes.

The first phase was designed to be as close to ecological conditions as possible. The participants took their places as usual in their classroom for their tutorial in cognitive psychology, unaware of the present study. The teacher introduced them to the subject of the tutorial: phobias and cognitive-behavioral therapy. During the first 20 minutes, he presented the five slides and the 7-minute video, and read out the book excerpt. At the end of these 20 minutes, the teacher interrupted the tutorial in order to ask the students to answer our questionnaire.

In the second phase, each student received the four-part questionnaire: (1) consent form and personal data, (2) personal interest in psychology, cognitive psychology, and phobias, (3) multitasking activities during the tutorial, and (4) learning outcomes (knowledge of the content provided during the first 20 minutes). A few additional items were used to check that the students met the inclusion criteria: arriving on time for the beginning of the tutorial, and following the course for the first time. Participants had 20 minutes to answer this questionnaire. All responses were collected anonymously. After this second phase, the course resumed normally.

2.4 Data processing

Answers to the multitasking part of the questionnaire were processed to yield four pieces of information for each multitasking activity: (1) Did the student engage in this particular activity during the tutorial? (2) How many times did he or she engage in this activity? (3) What was the total duration of this activity? (4) When exactly (during the slideshow, while watching the video, or while the teacher was reading the book) did this activity take place? Total duration was scored by assigning numerical values to answers on a 5-point Likert scale ranging from 1 (*Less than 1 minute*) to 5 (*15-20 minutes*). For multimedia multitasking, scores for social media (checking and posting), messaging (sending or receiving) and Internet searches (related to the course content or not) were summed to yield a single series of scores per activity. Finally, each participant's scores were summed to create three multitasking indices: total number of different activities they engaged in; total number of times they engaged in multitasking; and combined duration of all the multitasking activities.

For learning outcomes, we created two learning performance scores: a memory score, corresponding to the sum of correct answers to the nine memorization items, and a comprehension score, corresponding to the sum of correct answers for the three case studies.

3 Results

The sample size was $N = 187$. Because the three multitasking indices were positively skewed, all inferential tests were performed using bootstrapping (20.000 resamples; inference based on bias-corrected and accelerated confidence intervals; analyses performed using SPSS v20). These three indices were highly correlated (all Spearman's rank correlation coefficients ρs > .80, all ps < .001), confirming that the three ways of indexing the amount of multitasking provided converging information. For simplicity, the three scores were thus summarized with a single multitasking index for analysis (average of the three scores after standardization; analyzing the three scores separately yielded similar results).

3.1 Objective 1: Describing multitasking practices

Altogether, 91% of students ($n = 170$) reported engaging in at least one multitasking activity during the session. Students performed a median of 2 different multitasking activities (median absolute deviation, MAD = 1, range = 0–8). Taking all the multitasking activities together, students engaged in a median of 5 multitasking behaviors (MAD = 4, range = 0–68).

Given that the answer "I engaged in this activity for 15-20 minutes" scored 5 points, and the sampled section of the session lasted just 20 minutes, the summed duration of multitasking was very high, with a median of 4 (MAD = 3, range = 0–26). These high levels of multitasking, observed during a session about the cognitive approach to phobias, contrasted with the fact that students reported being interested in cognitive psychology in general (median = 7 on a 10-point Likert scale) and in the topic of phobias in particular (median = 8).

Insert Table 1 about here

Descriptive statistics for all multitasking activities are displayed in Table 1. Most of the students engaged in multimedia multitasking and/or non-multimedia multitasking. The most frequent multitasking activity was chatting with one's neighbors, followed by receiving and sending text messages and using Facebook. Most students who communicated via text messages both received and sent messages. The same was true for students who communicated via online instant messaging. By contrast, most students who used Facebook simply browsed publications, rather than writing publications of their own. The same was true for the other social media and for communicating via e-mails. The small fraction of students who engaged in other types of multitasking reported very diverse activities, including "doing coursework for another class", "looking through the window", "listening to music", and "sleeping".

Results were similar for both multimedia and non-multimedia multitasking (both ps $< .001$). By contrast, interest in the course topic did not influence multitasking: as indicated by a regression analysis (on the whole sample, total *N* = 187; controlling for identity of the teacher), there was no relation between the multitasking index and either interest in psychology (β = -.04, 95% CI [-.34, .53], *p* = .221), in cognitive psychology (β = -.02, 95% CI [-.17, .14], *p* = .814), or in phobias (β = -.03, 95% CI [-.19, .13], *p* = .704). Again, results were similar for both multimedia and non-multimedia multitasking.

3.2 Objective 2: Effects of multitasking on learning performance

Students displayed moderate learning performance for the contents of the course, with no floor or ceiling effects (memory questions: *M* = 8.27, *SD* = 2.99, range = 1–15; comprehension questions: *M* = 1.76, *SD* = 0.76, range = 0–3). The difference in learning performance between multitaskers (*n* = 170) and non-multitaskers (*n* = 17) was not assessed, owing to the large imbalance in group sizes. Instead, we used a regression analysis to test the relation between the multitasking index and learning performance (*N* = 187), controlling for teacher identity (represented by dummy-coded variables) and for interest in psychology, cognitive psychology and phobias. There was a significant negative relation between multitasking and memory scores, so that a high level of multitasking was associated with lower recall performance (β = -.16, 95% CI [-.29, -.04], *p* = .028). By contrast, comprehension scores were not related to multitasking (β = -.01, 95% CI [-.17, .13], *p* = .866). It is noteworthy that ways of taking notes did not moderate the effect of multitasking on memory scores (β = .00, 95% CI [-.46, .50], *p* = .985), suggesting that the deleterious effect of multitasking was similar whether students took notes on a laptop or not.

3.3 Objective 3: Effect of ways of taking notes on multitasking and learning outcomes

The final set of analyses investigated the relation between ways of taking notes, multitasking and learning performance. (Group sizes were $n = 97$ for laptop note-taking and $n = 90$ for longhand note-taking; ways of taking notes was dummy-coded for analysis as 0=by hand, +1=with a laptop.) Ways of taking notes influenced multitasking behaviors: students engaged in significantly more multitasking when taking notes on a laptop ($\beta = .20$, 95% CI [.04, .35], $p = .009$), controlling for teacher identity and interest. This only held true for multimedia multitasking: although students who took notes on a laptop demonstrated more multimedia multitasking ($\beta = .24$, 95% CI [.10, .39], $p = .002$), ways of taking notes had no effect on non-multimedia multitasking ($\beta = -.04$, 95% CI [-.18, .11], $p = .581$). In other words, laptop note-taking elicited more multimedia multitasking, but not less non-multimedia multitasking.

Students who took notes on a laptop had lower memory scores ($\beta = -.16$, 95% CI [-.32, .02], $p = .025$), congruent with the literature and with the higher level of multitasking observed in these students (though the association of a significant *p*-value and a beta bootstrapped confidence interval including zero indicates an effect of limited magnitude). Comprehension scores were again unaffected ($\beta = .01$, 95% CI [-.16, .19], $p = .902$). Interestingly, a mediation analysis (bootstrapped mediation based on the process macro for SPSS; Preacher & Hayes, 2008) indicated that the deleterious effect of laptop note-taking on memory performance was significantly mediated by the increased level of multitasking (indirect effect = -.03, standard error = .02, 95% CI [-.08, -.01], although the indirect effect through multitasking was small. The remaining effect of ways of taking notes on memory performance, when controlling for multitasking, was significant at the trend level (direct effect = -.14, standard error = .07, 95% CI [-.28, .01], $p = .065$), suggesting partial mediation.

4 Discussion

The first objective of this study was to describe multitasking practices during a real-life course with near-real-time reporting by students. As in other studies with delayed reporting of behaviors (e.g. Bellur et al., 2015; Fried, 2008; Gaudreau et al., 2014; Kirschner & Karpinski, 2010; Lau, 2017; Tindell & Bohlander, 2012; Zhang, 2015) or objectives measures (Kraushaar & Novak, 2010; Ravizza et al., 2016), our results clearly demonstrated that students engage extremely frequently in off-task multitasking. We found that 73% of students in our sample engaged in multimedia multitasking activities during the first 20 minutes of the tutorial session: text messaging was the most common, about a third of them used Facebook and other social media were used by less than 15% of our sample. However, it should be borne in mind that students could engage in a number of multitasking behaviors simultaneously. Non-multimedia multitasking activities were therefore also very frequent in our sample (66% of students). For example, 60% of students declared that they had chatted with their neighbors. This is an interesting result, as this type of non-multimedia multitasking activity has never previously, to our knowledge, been considered in research on multitasking. It may not be without consequences for learning, as many studies in the field of working memory have shown that irrelevant speech and articulatory suppression have deleterious effects on memory tasks (e.g. Neath, Farley, & Surprenant, 2003). As highlighted earlier, these high levels of multitasking also contrasted with the fact that students reported being interested in the topic of the course.

The second objective of this study was to evaluate the effects of multitasking on learning performance. The results validated our first hypothesis, by demonstrating that multitasking has a deleterious effect on an immediate memory test. This is an original result, as studies generally focus on delayed evaluation (e.g., academic performance; see above) or, when using immediate evaluation, are not conducted in naturalistic conditions (e.g. Conard & Marsh, 2014; Kuznekoff & Titsworth, 2013; Pashler et al., 2013; Rosen et al., 2011; Sana et al., 2013; Wood et al., 2011). The only exception is a recent study (Wammes et al., 2019) in which students were asked to indicate whether or not they were multimedia multitasking when a signal was presented on a slide in the course (Study 1) or via an application on their personal computer (Study 2) during several months of lectures. In both these studies, multimedia multitasking was associated with negative learning outcomes evaluated with in-class quiz scores, as in our study.

Furthermore, in all these studies and contrary to ours, students were informed that a learning evaluation would be carried out after the lecture, which may have influenced their learning strategies. Our study yielded results that complement this field of research by showing that, in natural settings (i.e., a real-life tutorial session with students not warned of the impending evaluation), the level of off-task multitasking clearly has a negative impact on memorization.

Regarding comprehension, contrary to our hypothesis, we failed to find any significant correlation between the level of multitasking activities and comprehension scores. We had assumed that because multitasking activities can hinder essential processing and generative learning (Mayer, 2014), they would have negative effects on deep learning, as assessed by comprehension scores. This was not the case, as all correlations between comprehension scores and multitasking indices were very low. Given that the study design was geared more toward learning than comprehension, one possible explanation is the lack of sensitivity of our comprehension measure. This variable included only three questions and only five kinds of phobias as possible answers. Dispersion was also low, with most participants answering either one or two questions correctly. It is therefore likely that this variable lacked the discriminating power to pick up a negative effect of multitasking.

It is nonetheless possible that multitasking has a deleterious effect on memorization but not on comprehension. In Sana et al. (2013)'s simulated classroom study, multitasking effects were observed on factual questions, but also on complex questions that required the application of knowledge. However, in a recent study in which students were assigned to a texting or nontexting condition (Waite et al., 2018), negative effects of texting were observed for multiple-choice questions testing factual information, but not for essays that required more elaborated processes. As texting also affected the quality of the notes taken, the authors suggested that the students were distracted by texting and, consequently, never encoded in memory some of the information provided in the course. High-order representations based on the summarization of this information, albeit incomplete, and its integration with pre-existing knowledge in long-term memory may be less affected. This explanation is also compatible with our results and with CTML (e.g. Mayer, 2014). In other words, off-task multitasking activities may affect the processes of selecting and encoding incoming detailed information that were evaluated by the memorization test in our study. Conversely, there may be little or no impairment of the processing (organizing and integrating) of more general information needed to successfully perform tasks such as our three case studies assessing comprehension. Further studies featuring more specific assessments of memorization and comprehension are needed to resolve this issue.

Our third objective was to analyze the effect of ways of taking notes on multitasking and learning outcomes. Several studies have already demonstrated that students who use a laptop frequently engage in off-task activities. For example, the amount of laptop use in the classroom was negatively correlated with several measures of learning in Fried's study (2008). In another study (Hembrooke & Gay, 2003), students who were asked to keep their laptops closed during a lecture performed better on a surprise quiz than those who were encouraged to use them. Our study sheds further light on these results, by showing that laptop users (about 50% of the students in our sample) engaged in more off-task multimedia behaviors than longhand note-takers. Laptop users were presumably more tempted by off-task activities in this computer environment than students who only had their phones. Interestingly, laptop users did not compensate for the higher level of multimedia activity by engaging in fewer non-multimedia behaviors (e.g., chatting with their neighbors). As a consequence, students who used a laptop during this real-life tutorial session engaged in more off-task activities than longhand note-takers (thus validating our second hypothesis) and scored a little lower on memorization of course content. Importantly, the effect of ways of taking notes on learning performance was partly mediated by multitasking: in other words, subjects who took notes on a computer recalled less content from the course inasmuch as they engaged in more multitasking. Although the effect size for the mediation was small, this confirms that the deleterious effect of computer note-taking is partly attributable to multitasking, which is an original contribution to the literature.

Our study had several limitations. First, although our sample was recruited over several sessions of the same tutorial for different students, it was still the same course on the same topic. This may have influenced our results, given that students reported being quite interested in the lecture and given that students who report being more interested in the topic have been shown to be less likely to media multitask during lectures (e.g. Wammes et al., 2019). Second, the current design in natural settings did not allow us to consider several contextual factors (e.g., time of day or day in the week, teacher's pace, or type of course) that may influence multitasking activities. This was also the case for many individual factors, such as level of self-regulation (Wei et al., 2012; Zhang, 2015) or reliance on technology (e.g. Terry, Mishra, & Roseth, 2016). In the same way, the current study could not control for prior knowledge because 1) for the participants, no test of cognitive psychology knowledge had ever been performed, as the study took place a few weeks after the beginning of their first year of study, and 2) conducting such a test at the beginning of the course would have been perceived as highly unusual and could have influenced upcoming behaviors. Future studies could be conducted to assess the influence of prior knowledge level, or more generally of overall academic performance, on multitasking activities.

Third, our three multitasking indices (estimated number of activities, estimated number of behaviors for each activity, and estimated total duration of these behaviors) relied on post-task self-declared behaviors, as is the case in many survey-based studies. However, although we acknowledge that these indices could be deemed unreliable in a delayed survey, participants in our study responded to the questionnaire just a few minutes after the behaviors had occurred. Moreover, our results showed that these three indices provided highly convergent evidence (all $\rho s > .80$) of multitasking in the classroom. One interesting approach for future studies would be to combine this kind of immediate self-report and immediate learning assessment with log-analysis methods (e.g. Ravizza et al., 2016), or observational techniques or methods such as video recording, to analyze their convergent validity. These qualitative methods (e.g. interviews, observation, video-stimulated recall) have been used recently by Deng (2020) in a self-study context, but with a small sample. In a real course, the challenge would be to preserve the naturalistic setting as far as possible, to avoid influencing participants' multitasking behaviors.

Lastly, although we clearly distinguished off and on-task multitasking activities, it would be interesting in future studies to compare self-interruptions and externally induced interruptions (Adler & Benbunan-Fich, 2013; Katidioti, Borst, van Vugt, & Taatgen, 2016). In our study, writing a message or initiating a chat with a neighbor can be considered as self-interruptions, whereas receiving an email notification or answering an oral request from another student are externally induced interruptions. In the tutorial situation analyzed in this study, self-generated interruptions, including on-task chatting, are concurrent with the course content as students cannot interrupt the course of the tutorial. This allowed us to predict that all types of multitasking would have detrimental effects on learning. In reading-alone or homework situations, self-generated interruptions appear to be very frequent (Calderwood, Ackerman, & Conklin, 2014), and may have less impact on performance. It would be interesting in future studies to compare the proportion of self-generated and external interruptions in homework and course situations, as well as their effects on task performance, and the possible influence of the individual factors mentioned above on these two types of interruptions.

Our results also have practical consequences regarding the efficiency of students' learning. Although it could be argued that the negative effects we observed on immediate learning could be compensated for by more homework, as previously highlighted, this would only be true if the quality of the personal notes needed to do so was not impacted by multitasking activities.

Furthermore, our results question current strategies for curbing off-task behaviors in the classroom. A recent study showed that making students aware of multitasking effects with regular text messages was not sufficient to change their behaviors (Terry et al., 2016). Although other strategies exist (see Flanigan & Kiewra, 2018; Parry & le Roux, 2019 for recent reviews), there has so far been too little research assessing their effects, given the increasing evidence of negative effects of off-task multitasking on learning efficiency.

5. Conclusion

Taken together, our results confirm the conclusions of experimental studies about multitasking, but in a natural setting. Our study shows that in a tutorial session where students cannot control the pace of information, 1) even when students express high interest in the topic, off-task multitasking activities are extremely frequent, 2) students who use a laptop are more likely to engage in these off-task activities, and 3) these activities have deleterious effects on course content memorization, partly contributing to the detrimental impact of laptop note-taking on performance.

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Table 1

Descriptive Statistics for All Multitasking Activities

Multitasking activity	% students	Number		Duration	
		M (*SD*)	Range	*M* (*SD*)	Range
Multimedia multitasking	73%				
Text messages	57%	7.04 (8.91)	1–40	3.34 (1.93)	1–10
Facebook	30%	2.02 (1.88)	1–10	2.00 (0.91)	1–5
Snapchat	16%	2.21 (2.61)	1–14	1.96 (1.10)	1–4
Twitter	13%	1.92 (1.41)	1–5	2.21 (1.22)	1–6
Instant messaging	13%	6.48 (11.30)	1–45	2.39 (1.85)	1–8
E-mails	12%	2.09 (2.18)	1–8	1.68 (0.95)	1–4
Instagram	8%	1.21 (0.43)	1–2	1.57 (0.65)	1–3
Internet browsing	7%	1.62 (1.19)	1–5	2.43 (0.85)	1–4
Other apps	5%	1.00 (0.00)	1–1	1.50 (1.07)	1–4
Games (computer)	3%	1.60 (0.89)	1–3	2.60 (0.89)	2–4
Other social networks	2%	1.67 (1.15)	1–3	2.33 (0.58)	2–3
Non-multimedia multitasking	66%				
Chatting	60%	2.86 (2.11)	1–10	2.04 (0.84)	1–4
Doodling	10%	1.80 (1.37)	1–5	2.38 (1.45)	1–5
Other multitasking	7%	2.09 (1.58)	1–5	2.50 (1.24)	1–5
Games (on paper)	1%	1.50 (0.71)	1–2	2.50 (0.71)	2–3

Note. % students = percentage of students who reported that they had engaged in this activity; Number = number of times the students engaged in this activity; Duration = reported duration of the activity. Number and duration were only computed for students who reported engaging in the activity.