Computers & Education 99 (2016) 81–93

Contents lists available at ScienceDirect

Computers & Education

journal homepage: www.elsevier.com/locate/compedu

Examining the influence of saliency of peer-induced distractions on direction of gaze and lecture recall

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A R T I C L E I N F O

Article history:
Received 5 October 2015
Received in revised form 13 April 2016
Accepted 16 April 2016
Available online 19 April 2016

Keywords:
Attention
Multitasking
Classroom
Learning

A B S T R A C T

In two experiments, we recorded participants' direction of gaze as they watched a lecture video while a nearby researcher (sitting in-view of the participant) either: (a) attentively watched the lecture video with their laptop turned off (no distraction), (b) read through a research article on their laptop (Low Saliency distraction), or (c) watched a soccer match on their laptop with muted volume (High Saliency distraction). After the lecture video, a test was given to gauge memory of lecture content. In Experiment 1, an analysis of direction of gaze revealed that participants were objectively more distracted with increasing levels of distractor saliency. However, no differences between saliency conditions were found in retention for lecture content. These results were replicated in Experiment 2, in which we administered a different repertoire of lecture-content questions. Findings are discussed in terms of the ability to strategically and opportunistically engage with lecture content, the availability of multiple cognitive-resource pools, and the varying impact that multitasking in the classroom might have on the user and nearby peers.

1. Introduction

Imagine you are a university or college student, sitting in a lecture-hall. Trying to attend to the lecture, you look around and notice that several of your peers have their laptops open. Not every one of those peers is engaging in lecture-related activities, such as taking notes. You notice several students checking their email, browsing Facebook, playing web-based games, or watching online-videos (perhaps an exciting soccer game). As you might imagine, students engaging in non-lecture related activities on their laptops might not only distract themselves from the ongoing lecture material, but may impair your learning as well. Indeed, scenarios such as this represent some of the challenges to attention that technology has brought into the classroom. As a result of these growing concerns, several studies have recently been devoted to better understand the impact that laptop-afforded multitasking might have on learning, both for the user (Barak, Lipson, & Lerman, 2006; Fried, 2008; Gaudreau, Miranda, & Gareau, 2014; Hembrooke & Gay, 2003; Junco, 2012; Ravizza, Hambrick, & Fenn, 2014; Risko, Buchanan, Medimorec, & Kingstone, 2013; Wood et al., 2012), and those around them (Sana, Weston, & Cepeda, 2013).

In terms of the impact on the user, there is growing evidence that laptop use and multitasking has a negative impact on learning, particularly when they are used for non-lecture related activities (Barak et al., 2006; Fried, 2008; Gaudreau et al., 2014; Hembrooke & Gay, 2003; Junco, 2012; Ravizza et al., 2014; Risko et al., 2013; Sana et al., 2013; Wood et al., 2012).

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http://dx.doi.org/10.1016/j.compedu.2016.04.006

For instance, Risko et al. (2013) had participants watch an hour-long lecture video while: (a) completing simple tasks on a laptop intended to mimic the sorts of typical activities engaged by students (e.g., posting Facebook messages or responding to emails), or (b) without engaging in secondary tasks. The results revealed that individuals who were required to multitask performed significantly worse on a subsequent retention test of the lecture content than their non-multitasking peers, a finding that has been demonstrated in several other studies as well (Gaudreau et al., 2014; Hembrooke & Gay, 2003; Ravizza et al., 2014; Sana et al., 2013; Wood et al., 2012).

In addition to distracting the user, laptop use and multitasking has been found to negatively affect the learning of nearby students. Indeed, Fried (2008) described "…laptop use by fellow students was the single most reported distractor … accounting for 64% of all responses" (pg. 911). These subjective reports of feelings of distraction by the laptop use of fellow students has been corroborated with experimental data. In a laboratory study, Sana et al. (2013) manipulated whether or not participants were in direct view of a peer engaging in multitasking on their laptop. Relative to those with a distraction-free view, participants who were in direct view of a multitasking peer scored significantly lower on a subsequent comprehension test.

One explanation that has been offered to account for the aforementioned findings is that lecture-unrelated activities afforded by laptops in the classroom coopt attentional resources of nearby peers, which would otherwise be devoted to lecture-related material (Sana et al., 2013). A widely held notion in psychological literature of human performance is that cognitive resources are limited to some degree (e.g., Kahneman, 1973). Cognitive Load Theory (e.g., Van Merrienboer & Sweller, 2005; see also Liu, Lin, Gao, & Kalyuga, 2015), for instance, suggests that information relevant to learning (i.e., intrinsic cognitive load), and information irrelevant to learning or learning distractions (i.e., extraneous cognitive load) both consume some proportion of total available cognitive resources. As noted by Van Merrienboer and Sweller (2005, p. 150), "[e]xtraneous cognitive load and intrinsic cognitive load are additive." For example, the more an individual works to ignore irrelevant information (e.g., distractions), the less cognitive resources they have to commit to the relevant to-be-learned material. Similarly, when to-be-learned material is complex and demands a greater commitment of processing resources, less cognitive resources are available to deal with distractions. Theories of learning such as Cognitive Load Theory thus emphasize processing limitations placed on individuals as a function of material complexity and extraneous distractions. Performance costs to learning are likely to occur when the individual does not have sufficient resources to deal with both intrinsic and extraneous cognitive loads.

The coopting of attentional resources by peers presumably leads students to spend more time looking at the content of their multitasking peers' laptops than if those peers were on-task. In other words, the distracting laptop might attract a nearby student's overt spatial attention. According to Cognitive Load Theory (Van Merrienboer & Sweller, 2005), multitasking peers may increase the extraneous cognitive load of surrounding individuals, and bring about costs to learning when those individuals have insufficient cognitive resources to devote both towards processing the relevant lecture material and to ignoring the irrelevant information on peers' laptops. One limitation of previous research, however, is that no objective measures of *in-the-moment* distraction (such as the direction of gaze of the putatively distracted student) have been obtained, leaving it unclear as to whether overt spatial attention is indeed coopted by the sorts of distracting information that may be afforded by laptops in the classroom. Furthermore, it remains to be explored how the different *types* of non-lecture related laptop activities by *peers* (e.g., watching videos or reading text on the screen) might influence one's level of distraction.

Here, we build on previous research addressing the impact of peer-induced distraction on lecture recall in several ways. In our experiments, participants sat in a teaching room and watched a previously recorded lecture video presented on a large television at the front of the room. Importantly, the researcher sat in front and slightly to the side of the participant with an open laptop. Our two novel innovations were: (1) monitoring participants' direction of gaze (using the webcam on the researcher's laptop), thereby obtaining an objective measure of the moment-to-moment focus of the participants' overt spatial attention; and (2) manipulating the *type* of information that was present on the researcher's laptop (which was within eye-shot of the participant), which allowed us to explore whether the degree of distraction by peer laptop use depends on the type of information the peer is viewing on the laptop. As in previous studies, we also tested participants on their retention of the lecture content at the end of the experimental session.

With regard to the type of information presented on the researcher' laptop, we included three conditions that varied in terms of the overall saliency of the information. In the first condition (Control), the researcher's laptop was open but the screen was turned off and the researcher attentively watched the lecture presented at the front of the room. In the second condition (Low Saliency), the researcher opened and read through a research article (i.e., mostly text) on their laptop during the middle portion of the lecture video. Finally, in the third condition (High Saliency), the researcher watched a video of a soccer game (while wearing earphones) during the middle portion of the lecture video. Given that motion is a salient visual cue (e.g., Abrams & Christ, 2003; Mahapatra, Winkler, & Yen, 2008), we assumed that the video of the soccer match was more visually salient than the static text of the research article. Of course, because there are other factors that might make the soccer match more salient than text (e.g., more colour in the soccer match) our goal was not to attribute any effects of our conditions to specific stimulus features, but to the overall general level of saliency. Aside from examining the influence of distraction saliency on peer attention, including these types of distractions allowed us to capture, in a general sense, the variety of typical distractions that may be present during an actual lecture (e.g., reading email, browsing Facebook, and watching online videos). This allowed us to examine whether different types of distracting information affected participants' objective level of in-the-moment distraction (here, the proportion of time spent looking at the researcher's laptop), as well as their retention of lecture content (obtained via a memory test at the end of the lecture video).

In accord with previous findings (Sana et al., 2013), we hypothesized that a laptop of a nearby peer engaging in non-lecture related activities (such as reading a research article or watching a soccer match) would be more distracting than a peer who was on-task (who did not use the laptop and watched the lecture video attentively). That is, participants in the *Low Saliency* and *High Saliency* distraction conditions will: (a) spend a greater proportion of time looking at the researcher's laptop screen than participants in the Control condition, and (b) perform worse on the subsequent retention test compared to participants in the control condition. We further hypothesized that playing a video of a soccer match (i.e., the *High Saliency* distraction) would elicit a significantly greater degree of distraction in our participants compared to reading a research article (i.e., the *Low Saliency* distraction condition). In terms of our dependent measures, we expected that participants in the High Saliency distraction condition would spend more time looking at the laptop and demonstrate poorer memory for the lecture content than the participants in the Low Saliency distraction conditions. These predictions were made based on the assumption that saliency of the distraction is a critical component in determining the effectiveness of that distraction, and that motion is an important and salient visual cue (Abrams & Christ, 2003; Mahapatra et al., 2008). Finally, we also asked participants about their feelings of distraction and their subjective feeling of the difficulty of recalling information for the memory test. Our expectation was that participants would report feeling most distracted and the greatest difficulty recalling information in the High Saliency condition, less so in the Low Saliency condition, and the least in the Control condition.

2. Experiment 1

2.1. Method

2.1.1. Participants

Participants were 65 undergraduate students (45 female, 20 male) from a Canadian university. Participation was voluntary and participants received partial course credit as compensation for their time. Participants were initially unaware they were being recorded during the lecture and were later asked to consent to have the recordings used for research purposes. Three participants were ultimately dropped from the sample due to their unwillingness to have their video recordings used or because it was too hard to assess where their gaze was directed, leaving a final sample of 62 participants available for analysis.

Of our 62 participants, 30 were from the Faculty of Arts, nine were from the Faculty of Science, eight were from Engineering, six were from Applied Health Sciences, five were from Mathematics, and one was from Environment (three did not give their Faculty). Approximately half (14) of the Arts students were majoring in Psychology, while other majors included Accounting (4), Anthropology (1), Business (5), Economics (1), Human Resource Management (1), Legal Studies (2), Liberal Studies (1), and Philosophy (1). Since the topic of our video lecture was history (the dark ages), it is important to note that there were no History majors in our sample.

2.1.2. Learning Environment

The lecture video was shown on a television that was 52 inches wide diagonally, and the participant sat approximately 5.2 m away from the television. While the participants watched the lecture video, a researcher sat with their laptop open and in direct view of the participant – approximately 1.9 m in front of, and on a diagonal to the participant (see Fig. 1). The researcher's laptop was used to both display distractions and record participants via the built-in webcam. To prevent

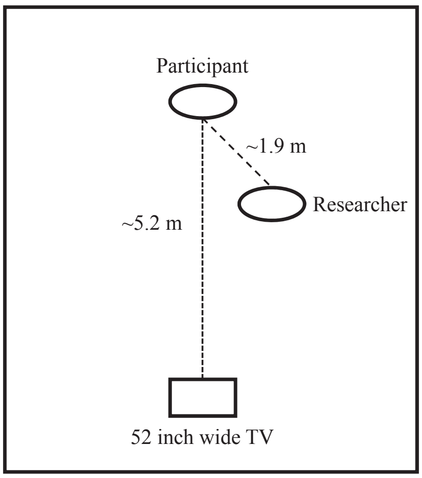

Fig. 1. A diagram depicting the rough layout of the Learning Environment. The lecture video was shown on a 52 inch wide television at the front of the room. Participants were seated approximately 5.2 m away from the television, and the researcher with their laptop sat approximately 1.9 m in front of and on the left-diagonal of the participant.

participants from becoming aware they were being recorded the activation light for the webcam was covered with black tape and webcam recording program was minimized.

2.1.3. Learning materials

All participants watched a 21-min video of a previously recorded and publicly-available lecture from the Open Yale courses module Classics Lecture 2 - The Dark Ages (http://oyc.yale.edu/classics/clcv-205/lecture-2). In the Low Saliency Distraction condition (described below), the researcher read a research article discussing interpersonal relationships and their relations to health outcomes (Schneider, Konijn, Righetti, & Rusbult, 2011). In the High Saliency Distraction condition, the researcher watched a soccer match from YouTube of a Barcelona versus Real Madrid match, available at: http://www.youtube.com/watch?v=f6XTk_C9PIQ.

2.1.4. Measures

Participants' directions of gaze were recorded via the built-in webcam on the researcher's laptop, using Photobooth Version 4.0.2 (288.5). Later, these recordings were examined by two blind coders assessing the direction of the participants' gaze throughout the lecture (see Results and Discussion).

The memory test consisted of sixteen multiple-choice questions (see Appendix A). Five questions came from the first 7 min, six from the critical middle 7 min, and five from the last 7 min of the lecture. At the end of the memory test participants were also asked to rate both how distracted they were by the researcher (on a 1–5 scale ranging from “Not at All” to “All of the Time”) and how difficult it was to recall the information presented in the lecture (on a 1–5 scale ranging from “Not at All” to “Very Difficult”).

Although not analyzed here, participants' media multitasking tendencies were assessed via the Media Use Questionnaire (Ophir, Nass, & Wagner, 2009). This questionnaire produces a Media Multitasking Index (MMI), reflecting the tendency to engage in multiple media sources concurrently in everyday life. The Media Use Questionnaire includes items such as: “On an average day, how many hours do you spend texting, instant messaging, or emailing?” and was included as a seemingly relevant means of introducing a time delay between the lecture and subsequent memory test, as it can take up to 10 min to complete. The time taken to complete the questionnaire was not recorded.

2.1.5. Procedure

While participants watched the 21-min lecture video, the researcher sat with their laptop open and in direct view of the participant. The first 7 min and last 7 min of each experimental session were the same across all conditions. Critically, during the middle 7 min period, the researcher engaged in one of three experimental manipulations using their laptop: (1) In the Control condition, the researcher simply continued watching the lecture and did not begin using the laptop; (2) In the Low Saliency Distraction condition, the researcher read a research article on their laptop; and (3) In the High Saliency Distraction condition, the researcher watched a soccer match on the laptop and listened to the commentary through earphones. During the final 7 min of the lecture video, the researcher always returned the laptop to its desktop screen and left it unused for the remainder of the lecture.

A memory test was completed after the lecture and after the aforementioned questionnaire (the MMI). The memory test consisted of sixteen multiple-choice questions (see Appendix A). Five questions came from the first 7 min, six from the critical middle 7 min, and five from the last 7 min of the lecture. At the end of the memory test participants were also asked to rate both how distracted they were by the and how difficult it was to recall the information presented in the. As well, though they were included for pilot purposes and are not analyzed here, two open-ended questions included at the very end of the test allowed participants to elaborate on why they found it difficult to recall the lecture and whether they find other students using laptops in class distracting. After the memory test participants were informed that they had been recorded during the lecture, and provided the option to allow the recording to be used for research purposes.

2.2. Results

The key outcomes evaluated for the present experiment were: (1) viewing time, (2) memory performance, and (3) self-reported feelings of distraction and difficulty recalling information.

2.2.1. Viewing time

Viewing time was assessed for the middle portion of the lecture in which our distraction manipulation took place. Two undergraduate research assistants, who were blind to the purpose of the study, assessed viewing time by watching videos of the participants collected via the camera on the researcher's laptop during the middle portion of the lecture. Overt gaze of the participants was coded as falling into one of three Regions of Interest: the distracting stimulus (‘Distraction’; i.e., the researcher's laptop), the lecture video (‘Lecture’), or other areas in the classroom (‘Other’). As the distraction was in the same location as the camera, when viewing the distraction the participants' gaze was directly toward the camera and this made the task of coding participants' gaze relatively easy. Gazes towards the camera were taken as looking at the distracting stimulus. Similarly, when participants were looking directly ahead (in the direction of the lecture video), this was classified as watching the lecture video. All other directions of gaze (e.g., to the right, towards the ceiling or floor) were counted as looking at ‘other’ areas. The two coders rated the total time the participants spent viewing each location – thereby obtaining a metric of the proportion of time spent viewing each Region of Interest (Distraction, Lecture, Other). This metric allowed us to determine whether participants' spatial attention was indeed coopted during the lecture by the distracting information presented on the researcher's laptop.

A series of correlations assessing the agreement between the two blind coders revealed that there was strong agreement for time spent viewing the Distraction, $r = 0.98$, the Lecture, $r = 0.96$, and Other locations, $r = 0.93$. The first coder's assessments were used for all analyses. The viewing time measure (proportion of viewing time in a given region) demonstrated a large degree of kurtosis and so was transformed to normality as follows: values were median-centered, then the cube-root of the absolute centered value was taken, and the sign of the centered value was reapplied (i.e., $\pm\text{abs}\,(x_{cent})^{1/3}$). Untransformed data, including skew and kurtosis, are provided in Table 1. The top row of Table 1 presents the overall proportion of time spent viewing each Region of Interest (Distraction, Lecture, Other). Table 1 also displays the proportion of time spent viewing each Region of Interest by Distractor Saliency condition (Control, Low Saliency, High Saliency). To show that our transformation greatly reduced the degree of kurtosis for viewing time, transformed skew and kurtosis indicators are also provided in Table 1, with transformed means for Region of Interest by Distractor Saliency depicted in Fig. 2.

It is important to first note that the proportions of time spent viewing each Region of Interest (Distraction, Lecture, Other) are ipsative, as differences in the amount of time that was not spent viewing the Distraction or Lecture necessarily determine the viewing time toward the Other locations (see Table 1 and Fig. 2A). This precluded us from including the Regions of Interest as a factor in a single analysis. As such we opted to analyze the data associated with each region separately, focusing primarily on the viewing time for the Distraction regions, as that was our main region of interest. However, for completeness we have also included analyses of viewing time for the Lecture video and 'Other' classification as well.

Given the ipsative nature of viewing time for each of the three Regions of Interest (Distraction, Lecture, and Other), three one-way analyses of variance (ANOVAs) were conducted to examine the between-participant effects of Distractor Saliency (Control, Low Saliency, High Saliency) on the proportion of time spent viewing each of the three Regions of Interest (Distraction, Lecture, Other). These analyses addressed the overall extent to which the distracting stimuli were effective at capturing overt spatial attention. For the Control condition, viewing time for the "Distraction" meant that the participant was looking in the direction of the researcher's laptop even though there was no distraction present. There were main effects of the Distractor Saliency on the proportion of time viewing the Distraction, $F(2,59) = 14.43$, $p < 0.001$, $\eta_p^2 = 0.33$ (see Fig. 2C) and the Lecture, $F(2,59) = 3.80$, $p = 0.028$, $\eta_p^2 = 0.11$ (see Fig. 2B). No effect of Distractor Saliency was identified for the Other locations, $F(2,59) = 0.564$, $p = 0.572$, $\eta_p^2 = 0.02$ (see Fig. 2D). Critically, these results indicate the relative allocation of overt spatial attention toward the Distraction (and Lecture) depended on the type of information (if any) being displayed on the researcher's laptop.

We next performed simple effects to decompose the impact of Distractor Saliency on viewing time for the Distraction and Lecture, separately. First, for time spent viewing the Distraction, Dunnett's *t*-tests (intended for multiple comparisons against a control group) were used to examine the differences between the Control and the two levels of Distractor Saliency, assessing the hypothesis that distracting information would lead to increased viewing of the researcher's laptop relative to the no distracting information. These tests revealed that compared to the Control group, there was a significant increase in viewing time for the High Saliency condition ($M_{diff} = 0.48$, $SE = 0.09$, $p < 0.001$), but not for the Low Saliency condition ($M_{diff} = 0.14$, $SE = 0.09$, $p = 0.108$). We also conducted a separate Tukey's HSD post-hoc analysis in order to examine potential differences

Table 1
Descriptive statistics for viewing time and memory performance measures in Experiment 1.

	Untransformed			Transformed	
	Mean (SE)	Skew (SE)	Kurtosis (SE)	Skew (SE)	Kurtosis (SE)
Proportion of viewing time					
Distraction	0.07 (0.16)	3.11 (0.30)	10.4 (0.60)	0.42 (0.30)	−1.19 (0.60)
Lecture	0.82 (0.32)	−1.88 (0.30)	2.53 (0.60)	−0.33 (0.30)	−1.47 (0.60)
Other	0.11 (0.02)	2.76 (0.30)	7.71 (0.60)	0.43 (0.30)	−1.23 (0.60)
Proportion of viewing time: distraction					
Control	0.02 (0.00)	1.36 (0.50)	0.84 (0.97)	1.17 (0.50)	−0.50 (0.97)
Low saliency	0.05 (0.01)	1.91 (0.50)	3.02 (0.97)	0.67 (0.50)	−1.23 (0.97)
High saliency	0.16 (0.04)	1.72 (0.51)	2.08 (0.99)	−0.59 (0.51)	0.06 (0.99)
Proportion of viewing time: lecture					
Control	0.90 (0.04)	−3.85 (0.50)	16.2 (0.97)	−0.90 (0.50)	−1.22 (0.97)
Low saliency	0.87 (0.03)	−1.48 (0.50)	1.71 (0.97)	−0.30 (0.50)	−1.51 (0.97)
High saliency	0.67 (0.08)	−0.76 (0.51)	−1.14 (0.99)	0.28 (0.51)	−1.12 (0.99)
Proportion of viewing time: other					
Control	0.01 (0.04)	1.40 (0.60)	0.71 (0.97)	0.83 (0.50)	−0.82 (0.97)
Low saliency	0.03 (0.02)	2.90 (0.50)	9.81 (0.97)	0.04 (0.50)	−1.85 (0.97)
High saliency	0.10 (0.05)	2.36 (0.51)	4.53 (0.99)	−0.32 (0.51)	−1.65 (0.99)
Memory test performance					
First segment	0.65 (0.03)	−0.65 (0.30)	−0.00 (0.60)		
Second segment	0.50 (0.03)	0.02 (0.30)	−0.64 (0.60)		
Third segment	0.61 (0.03)	−0.36 (0.30)	−0.58 (0.60)		

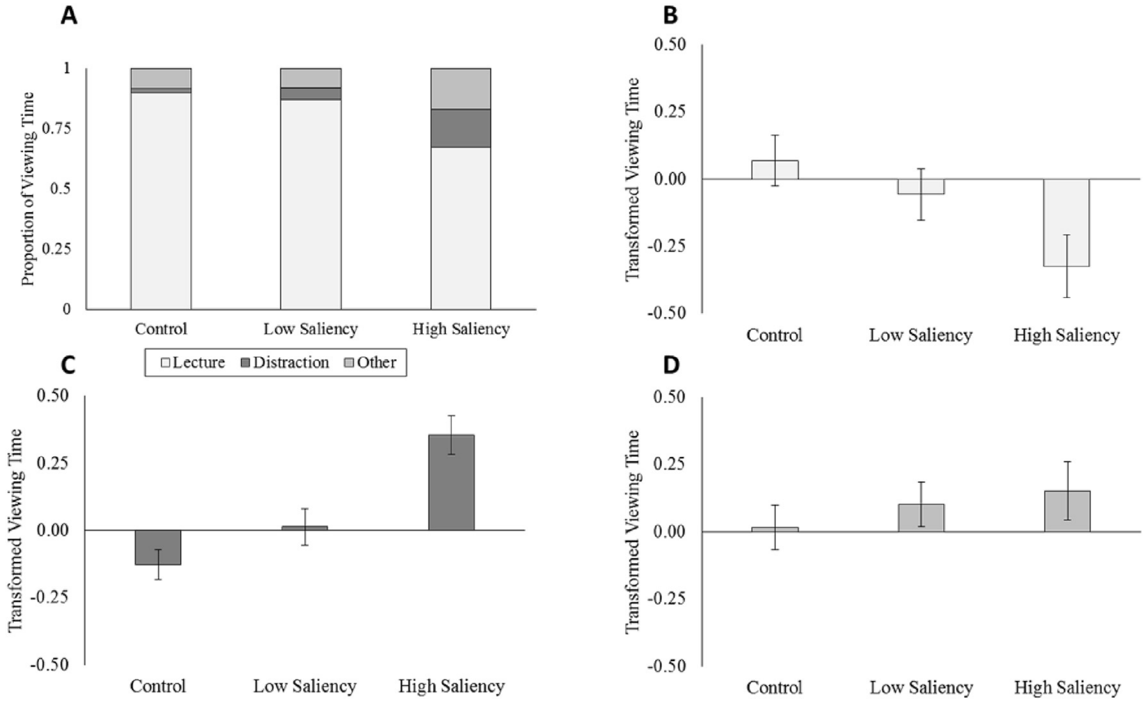

Fig. 2. The mean untransformed (Panel A) and median-centered transformed proportions of viewing time of the Lecture (Panel B), Distraction (Panel C), and Other locations (Panel D) for the three Distractor Saliency conditions (Control, Low Saliency, and High Saliency) in Experiment 1. Error bars denote one standard error of the mean.

between the two levels of distraction, assessing the hypothesis that the High Saliency distraction would have a greater impact on spatial attention than the Low Saliency distraction. High and Low Saliency differed significantly from one another in terms of Distractor viewing time ($M_{diff} = 0.34$, $SE = 0.09$, $p = 0.001$), with participants in the High Saliency condition viewing the researcher's laptop more than those in the Low Saliency condition.

An equivalent set of analyses was conducted on the proportion of time spent viewing the Lecture, again using Dunnett's *t*-tests to assess the hypothesis that distracting information would lead to decreased viewing of the lecture relative to the control. These tests revealed that relative to the Control condition there was a significant decrease in viewing time of the Lecture for the High Saliency condition ($M_{diff} = -0.39$, $SE = 0.15$, $p = 0.008$), but again not for the Low Saliency condition ($M_{diff} = -0.13$, $SE = 0.14$, $p = 0.302$). Furthermore, Tukey's HSD revealed High and Low Saliency to not significantly differ from each other in terms of viewing time of the Lecture ($M_{diff} = -0.27$, $SE = 0.15$, $p = 0.166$). Thus, while a more salient distraction did reduce attention to the Lecture, in addition to increasing attention to the Distraction itself, a less salient distraction showed little increase in attention to the Distraction.

2.2.2. Memory performance

Memory performance was evaluated using a test at the end of the lecture video to determine whether performance suffered as a result of the distraction. The memory test was divided into three approximately 7 min segments, corresponding to the first, middle, and last segments of the lecture, with the distraction occurring in the middle (second) segment. Average scores on the memory test for each Video Segment (First, Second, Third), collapsed across Distractor Saliency, are provided in Table 1 (bottom row). Fig. 3 shows the average scores on the memory test as a function of both Video Segment (First, Second, Third) and Distractor Saliency (Control, Low Saliency, High Saliency). There was no distraction in the first segment, and this allowed us to ensure we had equal baseline memory performance across the three conditions, as shown in Fig. 3. The second segment included material from the middle 7 min of the lecture, where the distraction manipulation occurred for the Low and High Saliency distraction conditions. The final segment corresponded to the remaining 7 min segment of the lecture, when the distraction was no longer present. Accordingly, the memory performance for the second segment, when the distraction occurred, is most critical for present purposes.

A mixed repeated-measured ANOVA was conducted to examine the between-subject effects of Distractor Saliency across the three Segments of the lecture video. Video Segment (First, Second, Third) was entered as the within-subject variable and Distractor Saliency (Control, Low Saliency, High Saliency) was entered as the between-subject variable. There was a main effect of Video Segment, $F(2,118) = 8.21$, $p < 0.001$, $\eta_p^2 = 0.13$, indicating a primary and recent effect for memory of lecture content (see Table 1, bottom row). However, there was no main effect of Distractor Saliency, $F(2,59) = 2.20$, $p = 0.119$,

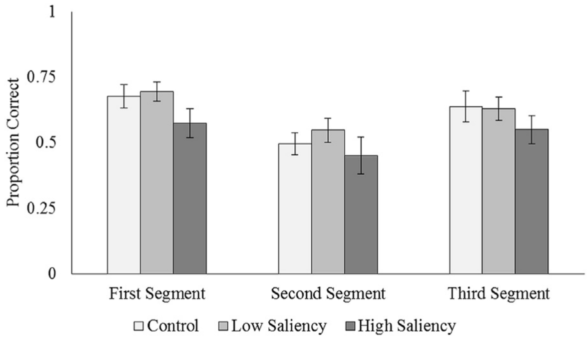

Fig. 3. The mean memory test performance in each Video Segment, for each distraction condition in Experiment 1. Error bars denote one standard error of the mean.

$\eta_p^2 = 0.07$, nor was there a Video Segment by Distractor Saliency interaction, $F(4,59) = 0.18$, $p = 0.95$, $\eta_p^2 = 0.01$ (see Fig. 3). Given that our main prediction was for effect to occur during the Second Segment of the lecture video, we further targeted the Second Segment and conducted a one-way ANOVA to examine the between-subject effects of Distractor Saliency (Control, Low Saliency, High Saliency). Again, however, there was no significant differences between the three conditions on memory performance for the Second Segment, $F(2,59) = 0.81$, $p = 0.448$, $\eta_p^2 = 0.01$ (Fig. 3). Thus, despite finding that the High Saliency distraction captured significantly greater spatial attention during the lecture, Distractor Saliency does not appear to necessarily bring with it costs to memory performance.

2.2.3. Self-reports

At the end of the memory test were two exploratory questions asking participants to report their subjective Level of Distraction by the researcher and Difficulty Remembering content of the lecture (see Table 2). Responses to each of these two questions were analyzed using two one-way ANOVAs comparing between-subject effects of Distractor Saliency (Control, Low Saliency, High Saliency). Level of Distraction was significantly different across conditions, $F(2,59) = 4.33$, $p = 0.018$, $\eta_p^2 = 0.13$, as was Difficulty Remembering, $F(2,59) = 3.39$, $p = 0.042$, $\eta_p^2 = 0.10$). These results indicate there were differences in how distracted the participants felt across the three conditions (control and two levels of distraction), and in how much difficulty they had remembering lecture material.

Simple effects analyses further decomposed these differences. Beginning with Level of Distraction (the degree to which participants were distracted by the laptop user), Dunnett's *t*-tests were used to compare the two distraction conditions against the control condition. These tests revealed that relative to the Control condition the High Saliency distraction was subjectively recognized as a significantly greater source of distraction ($M_{\text{diff}} = 0.89$, $SE = 0.32$, $p = 0.007$), while the Low Saliency distraction was nominally less effective but also a significant source of distraction ($M_{\text{diff}} = 0.71$, $SE = 0.32$, $p = 0.026$). Using a separate Tukey's HSD post-hoc test, the High and Low Saliency conditions were not found to significantly differ from one another ($M_{\text{diff}} = 0.17$, $SE = 0.32$, $p = 0.855$).

Similarly, follow-up Dunnett's *t*-tests on the participants' subjective reports of Difficulty Remembering lecture material also revealed that the High Saliency distraction made remembering subjectively more difficult ($M_{\text{diff}} = 0.75$, $SE = 0.31$, $p = 0.019$), while the Low Saliency distraction did not ($M_{\text{diff}} = 0.10$, $SE = 0.31$, $p = 0.539$), relative to the Control. A Tukey's HSD post-hoc analysis was again conducted comparing the High and Low Saliency conditions, revealing a non-significant difference ($M_{\text{diff}} = 0.65$, $SE = 0.31$, $p = 0.102$).

2.3. Discussion

In Experiment 1 we investigated whether the type of information on a nearby peer's laptop influenced the allocation of overt spatial attention during a lecture video, and whether these differences were accompanied by changes in memory performance. As predicted, salient distractions appeared to capture overt spatial attention. Increasing the saliency of lecture-unrelated information on a nearby peer's laptop meant that the participant spent more time attending to the distracting information and less attending to the lecture video. However, these differences in overt spatial attention were not mirrored in memory performance, as participants performed equally well on the memory test despite the type of distraction on the researcher's laptop. Additionally, after the lecture video we also asked participants to report on their subjective feelings of distraction and level of difficulty recalling content. Indeed, consistent with differences in the allocation of spatial attention, participants reported feeling more distracted and having more trouble remember lecture content when they received the High Saliency distraction. These findings are particularly interesting, as the more objective memory test failed to demonstrate any such differences. It seems, then, that participants receiving the High Saliency distraction were actually able to perform comparably to other participants, including those in the Control condition, despite reporting greater feelings of distraction and difficulty remembering the material.

Table 2
Descriptive statistics for self-report and memory test measures in Experiment 1 and 2.

	Measure	Control	Low saliency	High saliency
		Mean (SE)	Mean (SE)	Mean (SE)
Experiment 1	Level of distraction	1.71 (0.21)	2.43 (0.22)	2.60 (0.25)
	Difficulty remembering	3.00 (0.20)	3.10 (0.21)	3.75 (0.26)
Experiment 2	Memory: recognition	0.54 (0.04)	0.54 (0.05)	0.49 (0.04)
	Memory: recollection	0.45 (0.06)	0.51 (0.06)	0.39 (0.05)
	DSS: Mind wandering	36.9 (2.21)	36.9 (2.22)	38.8 (2.03)

One possible explanation for the similarity in memory performance across our conditions is that our memory test questions were not sensitive enough to detect differences in memory performance across conditions. Perhaps questions testing recall, rather than recognition (which were utilized in Experiment 1), may be better suited to identify effects of distractor saliency on memory performance. Thus, before speculating on the reasons why participants were able to maintain equivalent performance across conditions despite being differently distracted (both behaviourally and subjectively) across conditions, we first thought it prudent to (a) replicate our findings from Experiment 1, and (b) employ a different set of memory test items. This was accomplished in Experiment 2.

3. Experiment 2

3.1. Introduction

In Experiment 2 we sought to replicate and extend our findings from Experiment 1, making several modifications to the methodology used in Experiment 1. First, to potentially increase the sensitivity of our memory test, we included both multiple choice and fill-in-the-blank memory test questions at the end of the study. Second, we also used a longer excerpt from the lecture, which increased the duration of the distraction from 7 to 10 min. The time delay between the end of the lecture and start of the test was also increased. Finally, as an extension to our findings from Experiment 1, we added a new outcome measure – task-unrelated mind wandering (or daydreaming) – to better assess participants' ability to attend to the lecture.

3.2. Method

3.2.1. Participants

To increase the likelihood of detecting differences across conditions (particularly in memory performance), the sample size in Experiment 2 was increased to 81 university undergraduate students (23 female, 58 male)[1,2]. Participation was voluntary and participants received partial course credit. Results for two males and seven females were dropped from the final analysis due to either their unwillingness to have their video recordings used or because it was too hard to assess where their gaze was directed.

3.2.2. Learning Environment

The Learning environment was identical to that of Experiment 1.

3.2.3. Learning materials

The lecture viewed was identical to the lecture in Experiment 1, except that it was now watched for half an hour, instead of 21 min.

3.2.4. Measures

Participants were recorded via the built-in webcam on the researcher's laptop, as in Experiment 1.

A revised memory test was administered, consisting of 18 multiple-choice (recognition) questions and 18 fill in the blank (recall) questions (See Appendix C). Twelve questions came from the first 10 min, 12 from the middle 10 min and 12 from the last 10 min of the lecture. This allowed assessment of learning before the distraction, during the distraction, and when the distraction was no longer present. Two fill in the blank questions (questions 27 and 36) were dropped from analysis, as less than 10% of participants answered them correctly. A printing error for some participants also resulted in dropping question 6, as it was unclear where the blanks were that the participants needed to fill in. Notably, none of these questions assessed memory for content delivered during the critical distraction period.

[1] We aimed to increase our sample size by 50% to roughly 90 participants, however, stopped short due to limitations of the available participant pool.

[2] Although we reported more detailed demographic information for our participants in Experiment 1, we did not have this same information recorded for our participants in Experiment 2. However, participants were drawn from the same participant-pool, so it is reasonable to assume that demographic information of participants in Experiment 2 is similar to that of participants in Experiment 1.

Participants also completed a number of newly-added questionnaires. The most critical of these questionnaires was the daydreaming subscale of the Dundee Stress Scale (DSS; Matthews et al., 1999), which measures the amount of time spent engaged in thoughts not relevant to the task at hand, and includes items such as "I thought about how much time I had left". The DSS is scored using a 5-point scale affixed at (1) Never and (5) Very often. This measure allowed us to assess mind wandering at the state level during the lecture, which may have been affected by the distraction. The remaining questionnaires were again included as a seemingly relevant way to introduce an additional time delay between the lecture and the memory test. They included an assessment of mind wandering at the trait level, using the Deliberate Mind Wandering Questionnaire (MW-D; Carriere, Seli, & Smilek, 2013) and the Spontaneous Mind Wandering Questionnaire (MW-S; Carriere et al., 2013), as well as an initial version of the trait-level Voluntary Media Multitasking Questionnaire (unpublished and currently under development; see Appendix B), and two trait-level attention measures: the Mindful Attention Awareness Scale-Lapses Only (MAAS-LO; Carriere, Cheyne, & Smilek, 2008), and the Attention Related Cognitive Errors Scale (ARCES; Carriere et al., 2008). Due to our small sample size, we did not perform any analyses of the trait-level questionnaires, which were included for piloting and time delay purposes only. Accordingly, we report only the results for the DSS questionnaire, a state-level measure of mind wandering which could offer additional insight on the mental state of our participants during the lecture.

3.2.5. Procedure

The procedure was identical to that of Experiment 1. The only notable differences were the change in lecture duration time, which questionnaires were provided after the lecture, and the questions on the memory test (which now included both recollection and recall items). Now, the critical middle segment when the three conditions (Low and High Saliency distractions, and Control) were presented comprised the middle 10 min of the lecture (from 10 to 20 min) instead of the middle 7 min of the lecture (previously from 7 to 14 min). The two distraction condition materials were identical to Experiment 1, with the exception that the soccer match was played for 3 min longer than before (equating to the additional 3 min added to each lecture segment).

After watching the lecture video, participants completed the newly-added questionnaires, including the DSS, MW-D, MW-S, Voluntary Media Multitasking Questionnaire, MAAS-LO and ARCES. Following completion of the questionnaires, the revised memory test was administered.

3.3. Results

Three main outcomes were evaluated for the present study: (1) the participants' viewing time of the Distraction, the Lecture, and the 'Other' locations in the classroom; (2) memory performance using the revised test; and (3) state mind wandering (assessed retrospectively), to see if the saliency of distraction influenced the overall amount of mind wandering during the lecture.

3.3.1. Viewing time

As in Experiment 1, two blind coders assessed and coded gaze from the video recordings during the middle portion of the lecture. Strong positive correlations between coders were found for time spent viewing the Distraction, $r = 0.93$, time spent viewing the Lecture, $r = 0.95$, and time spent viewing Other locations, $r = 0.96$. As in Experiment 1, the first coder's assessments were used for all analyses. Also as in Experiment 1, viewing time demonstrated a large degree of kurtosis, and was therefore transformed to normality using the same formula used during the analysis of the data from Experiment 1. Untransformed means, skew, and kurtosis are provided in Table 3, along with post-transformation skew and kurtosis. Transformed means are depicted in Fig. 4.

The viewing time data were analyzed using three one-way ANOVAs to examine the between-participant effects of Distractor Saliency (Control, Low Saliency, High Saliency) on the time spent viewing each of the three Regions of Interest (Distraction, Lecture, Other). Replicating our findings from Experiment 1, there were main effects of Distractor Saliency on the proportion of time viewing the Distraction, $F(2,78) = 9.13$, $p < 0.001$, $\eta_p^2 = 0.19$ (see Fig. 4C) and the Lecture, $F(2,78) = 7.77$, $p = 0.001$, $\eta_p^2 = 0.17$ (see Fig. 4B), but no effect of Distractor Saliency on time spent viewing the Other locations, $F(2,78) = 1.41$, $p = 0.251$, $\eta_p^2 = 0.04$ (see Fig. 4D). As in Experiment 1, these data indicate the relative allocation of overt spatial attention toward the distraction depended on the type of (or lack thereof) distraction information being displayed.

The two main effects of viewing time for the Distraction and Lecture were further analyzed by comparing each of the levels of distractor saliency for the two locations, separately. First, for time spent viewing the Distraction, Dunnet's *t*-tests revealed that, relative to the Control condition, there was a significant increase in viewing time for the High Saliency condition ($M_{diff} = 0.42$, $SE = 0.10$, $p < 0.001$), but not for the Low Saliency condition ($M_{diff} = 0.15$, $SE = 0.10$, $p = 0.103$), relative to the Control. A separate Tukey's HSD post-hoc test also showed the High and Low Saliency distractions differed significantly from one another in terms of the time spent viewing the distraction ($M_{diff} = 0.27$, $SE = 0.10$, $p = 0.026$), with participants in the High saliency condition viewing the researcher's laptop more than those in the Low Saliency condition. These differences in the proportions of viewing time of the Distraction all closely replicated those of Experiment 1.

Equivalent analyses were next conducted on the proportions of time spent viewing the Lecture. Dunnett's *t*-tests revealed a significant decrease in time spent viewing the Lecture for the High Saliency condition ($M_{diff} = -0.48$, $SE = 0.12$, $p < 0.001$), but not for the Low Saliency condition ($M_{diff} = -0.17$, $SE = 0.13$, $p = 0.154$), relative to the Control. Additionally, a Tukey's HSD

Table 3
Descriptive statistics for viewing time and memory performance measures in Experiment 2.

	Untransformed			Transformed	
	Mean (SE)	Skew (SE)	Kurtosis (SE)	Skew (SE)	Kurtosis (SE)
Proportion of viewing time					
Distraction	0.11 (0.01)	2.22 (0.27)	5.59 (0.53)	0.23 (0.27)	−1.61 (0.53)
Lecture	0.80 (0.02)	−1.35 (0.27)	1.12 (0.53)	−0.23 (0.27)	−1.65 (0.53)
Other	0.09 (0.01)	2.52 (0.27)	6.91 (0.53)	0.24 (0.27)	−1.40 (0.53)
Proportion of viewing time: distraction					
Control	0.05 (0.01)	2.72 (0.45)	9.51 (0.87)	1.13 (0.45)	−0.28 (0.87)
Low saliency	0.08 (0.01)	0.80 (0.46)	−0.67 (0.90)	0.25 (0.46)	−1.87 (0.90)
High saliency	0.19 (0.03)	1.22 (0.43)	0.94 (0.85)	−0.69 (0.43)	−1.06 (0.85)
Proportion of viewing time: lecture					
Control	0.88 (0.03)	−2.53 (0.45)	7.00 (0.87)	−1.18 (0.45)	−0.15 (0.87)
Low saliency	0.83 (0.03)	−1.97 (0.46)	4.39 (0.90)	−0.39 (0.46)	−1.56 (0.90)
High saliency	0.71 (0.04)	−0.63 (0.43)	−0.38 (0.85)	0.67 (0.43)	−1.09 (0.85)
Proportion of viewing time: other					
Control	0.07 (0.02)	3.47 (0.45)	14.2 (0.87)	0.51 (0.45)	−1.22 (0.87)
Low saliency	0.09 (0.02)	2.39 (0.46)	6.35 (0.90)	0.46 (0.46)	−1.34 (0.90)
High saliency	0.11 (0.02)	2.31 (0.43)	6.38 (0.85)	−0.16 (0.43)	−1.27 (0.85)
Memory test performance					
First segment	0.56 (0.02)	−0.27 (0.27)	−0.57 (0.53)		
Second segment	0.48 (0.02)	−0.10 (0.27)	−0.57 (0.53)		
Third segment	0.60 (0.03)	−0.12 (0.27)	−0.60 (0.53)		

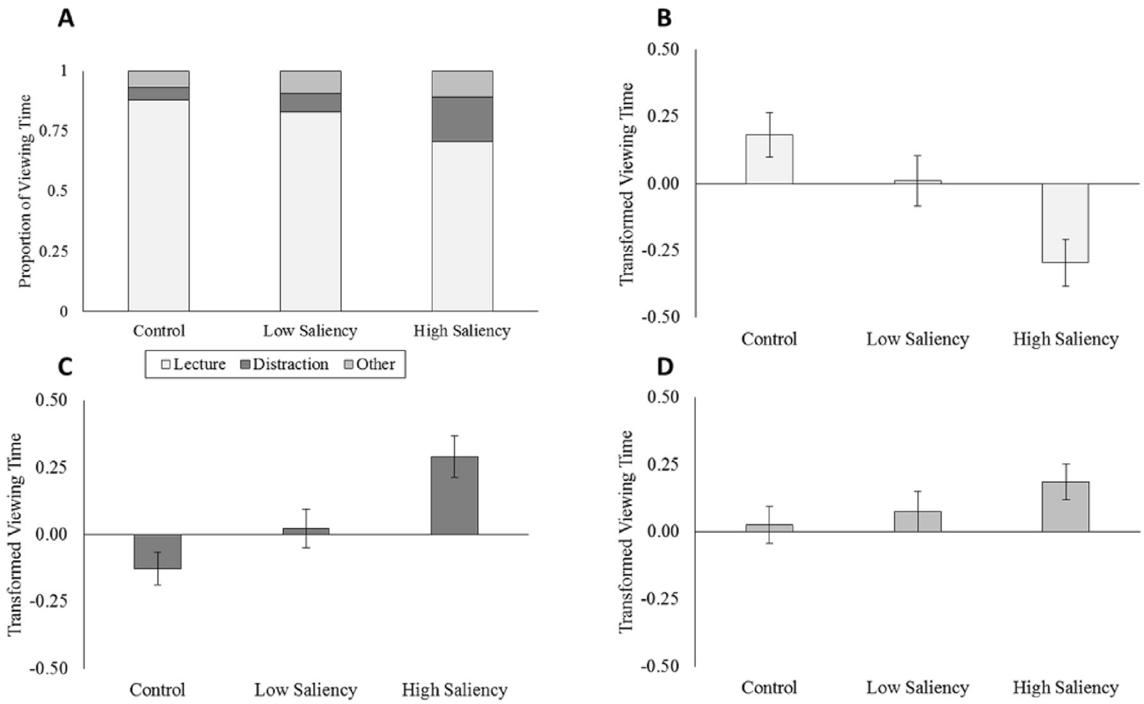

Fig. 4. The mean untransformed (Panel A) and transformed proportions of viewing time of the Lecture (Panel B), Distraction (Panel C), and Other locations (Panel D) for the three Distractor Saliency conditions (Control, Low Saliency, and High Saliency) in Experiment 2. Error bars denote one standard error of the mean.

test showed a marginal difference between the High and Low Saliency conditions ($M_{diff} = -0.31$, $SE = 0.13$, $p = 0.044$). Again, these findings of time spent viewing the Lecture closely replicated those obtained in Experiment 1.

3.3.2. Memory performance

3.3.2.1. Overall memory performance. A mixed repeated-measures ANOVA was conducted with Video Segment (First, Second, Third) entered as the within-subject variable and Distractor Saliency (Control, Low Saliency, High Saliency) entered as the between-subjects variable. There was a main effect of Video Segment, $F(2,156) = 10.14$, $p < 0.001$, $\eta_p^2 = 0.12$, indicating a primary and recency effect (see Table 3, bottom row). However, there was no main effect of Distractor Saliency, $F(2,78) = 0.52$, $p = 0.60$, $\eta_p^2 = 0.01$, nor was there a Video Segment by Distractor Saliency interaction, $F(4,156) = 0.64$, $p = 0.64$, $\eta_p^2 = 0.02$ (see Fig. 5). As we were chiefly interested in memory performance for the Second Segment (when the distraction manipulation occurred), we conducted a follow-up one-way ANOVA for the Second Segment testing the between-subject effects of Distractor Saliency (Control, Low Saliency, High Saliency). This revealed no significant differences in memory performance between the three conditions, $F(2,78) = 0.99$, $p = 0.376$, $\eta_p^2 = 0.02$ (Fig. 5).

3.3.2.2. Recognition versus recall. An important change of the memory test in Experiment 2 was that it now contained both recognition questions (as in Experiment 1) and recall questions (newly added to Experiment 2). This allowed us to test whether differences in memory for lecture content as a function of Distractor Saliency existed for recalled content separate from recognized content. To this end, we next broke down the memory test into its recognition and recall questions for the critical Second Segment. Two one-way ANOVAs were conducted for both recognition and recollection questions to see whether either recognition performance alone differed across conditions. No significant differences were found for either the recognition questions, $F(2,78) = 1.21$, $p = 0.305$, $\eta_p^2 = 0.03$, or recall questions, $F(2,78) = 0.44$, $p = 0.643$, $\eta_p^2 = 0.01$ (Table 2). As such, despite finding that participants in the High Saliency condition viewed the distraction more than the other two conditions, we once again found no evidence for reduced memory for lecture content as a result of the distraction.

3.3.3. State mind wandering

While memory for the lecture content was not affected by the distraction in either experiment, it is possible that the participants' mind wandering was affected, as measured by the DSS. Accordingly, a one-way ANOVA was conducted to examine whether state mind wandering differed as a function of Distractor Saliency (Control, Low Saliency, High Saliency). This analysis showed no main effect of Saliency Condition, $F(2,78) = 0.260$, $p = 0.772$, $\eta_p^2 = 0.00$, meaning there was no difference in the ability of either the Low Saliency or High Saliency distractions to induce mind wandering (see Table 2). There was, however, a significant correlation between the test score for each Video Segment and the DSS (First Segment: $r = -0.368$, $p = 0.001$; Second Segment: $r = -0.385$, $p < 0.001$; Third Segment: $r = -0.420$, $p < 0.001$; $N = 81$). This result replicates previous findings that mind wandering is negatively correlated with memory test performance (e.g., Risko et al., 2013), and is important as it suggests that finding no difference among the distraction conditions on either test performance or mind wandering was not the result of a measurement problem.

4. Discussion

In Experiment 2 we replicated both the effects in allocation of spatial attention and memory performance observed in Experiment 1. Increasing the saliency of distracting information on the researcher's laptop lead to an increase in the time spent viewing the researcher's laptop (i.e., the Distraction), and less time viewing the Lecture. However, this coopting of overt spatial attention during the lecture was not reflected in memory for the content presented during the lecture (assessed both in terms of recognition and recollection of lecture content). Additionally, mind-wandering rates were not found to vary by Distractor Saliency. Implications of these findings are discussed in the next section of this paper.

5. General discussion

In the two experiments presented here, we have built on previous work examining the impact of peer-induced distraction in the classroom by (1) monitoring participants' direction of gaze while they watched a lecture video and (2) manipulated the type of information presented on a nearby peer's laptop. In doing so, we examined whether varying the saliency of distracting information on a nearby peer's laptop lead to changes in; (a) the capture of a participant's overt spatial attention while watching a lecture video; (b) memory for the lecture; and (c) subjective reports of feelings of distraction, difficulty

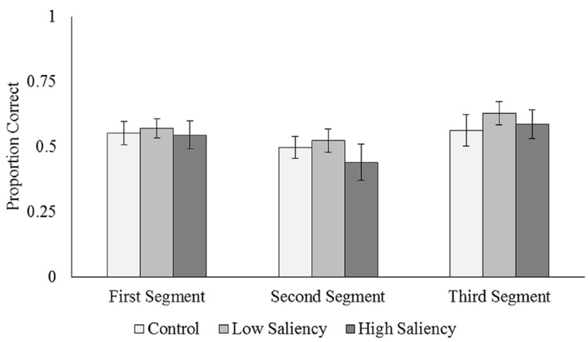

Fig. 5. The mean memory test performance in each block, for each distraction condition in Experiment 2. Error bars denote one standard error of the mean.

remembering lecture information, and mind wandering. We found that participants spent significantly more time looking at the researcher's laptop, and less time attending to the lecture, when the researcher was engaged in lecture-unrelated activities compared to when the researcher was on-task. This was particularly the case when the distraction present on the researcher's laptop was highly salient (i.e., when they were watching a soccer match). These objective indices of distraction were corroborated by participants' self-reports of distraction, and are consistent with previous findings by Sana et al. (2013) where participants reported feeling more distracted when a peer was multitasking. Unlike previous studies, however, we found no effect of distraction on memory for the lecture content.

The most ecologically important finding from our experiments is that individuals were able to spend a significantly greater amount of time distracted by, and attending to lecture-unrelated information on the researcher's laptop, while incurring no decrements in memory for lecture information. Here, we offer several explanations for this finding that are of important consideration for ongoing research into the impact of in-class distraction on learning. One possibility is that students are economical in terms of how they distribute their cognitive or attentional resources over time. That is, students may be able to strategically and opportunistically disengage and re-engage attention to the lecture based on the changing demands that the content places on learning. When the learning material is familiar, or requires little effort (i.e., when demands on learning are low), students may opportunistically re-distribute attention elsewhere – such as towards internal thought (mind wandering), or towards other stimuli in the environment (such as information on a peer's laptop.

Another somewhat less interesting explanation for why we found no effect of distraction on memory is that our memory test may not have been sensitive enough to detect performance costs associated with not attending to the lecture. Perhaps it is the case that we failed to test for content precisely when the participants were not attending to the lecture. One way to address this in a future experiment would be to test memory for content presented while the participant is gazing at the distracting laptop. However, the strength of the current method is that the sort of content-test we employed here is the same as that used in a typical lecture course. It certainly may be the case that students periodically miss pieces of information throughout a lecture as their attention ebbs and flows. However, it may not matter for test performance either because students are able to fill-in gaps in their knowledge using information from other parts of the lecture, or because the missed material is not included in the memory test.

A third, and somewhat more interesting, explanation that is highly relevant to ongoing research into in-class student distraction is that different tasks may consume different types of cognitive resources (i.e., visuo-spatial vs. verbal, see Baddeley & Hitch, 1974; Wickens, 2002; 2008). In our experiments, although the lecture video had both visual and auditory components, the visual component was relatively trivial while the auditory component conveyed all of the important information (the video just included the lecturer speaking). In contrast, the distracting task engaged in by the laptop user was solely visual in nature, whether it was reading or watching a soccer game. As a result, participants may have been able to efficiently engage with auditory information from the lecture while being visually distracted by the researcher's laptop. This possibility is consistent with Cognitive Load Theory, which suggests that mixing modalities reduces extraneous cognitive load because the demand on working memory is now split between visual and auditory processors (Mousavi, Low, & Sweller, 1995). In addition, as Liu et al. (2015) also point out, the dual visual and auditory format of lectures (in addition to the availability of students' lecture notes) complement one another in that mixing modalities creates redundancies or 'back-ups' that can be accessed should one modality suffer interference. Performance costs may thus be more likely to occur if the lecture material is largely visual in nature. However, we suggest that our design and results have a certain degree of ecological validity as at a practical level, distractions via peer laptops (as in Sana et al., 2013) in a typical classroom or lecture-hall are also likely to be visual in nature, and a typical lecture is also highly auditory in nature. Accurate predictions as to the costs on learning from in-class distractions, such as multitasking peers, are thus likely to rely on assessing the overlap in the types of cognitive resources engaged by the lecture and extraneous distractions in question.

Lastly, multitasking during a lecture may have dissociable effects on the user and on directly-in-view peers. Competing cognitive tasks have certainly been found to negatively affect performance (Broadment, 1958; Pashler, Johnston, & Ruthruff, 2001; Treismen, 1960; Van Merrienboer & Sweller, 2005), and so it makes sense that several studies have found negative effects of multitasking on a user's memory for lecture information (Barak et al., 2006; Fried, 2008; Gaudreau et al., 2014; Hembrooke & Gay, 2003; Junco, 2012; Ravizza et al., 2014; Risko et al., 2013; Sana et al., 2013; Wood et al., 2012). However, when a student is passively observing a distracting stimulus, the effect on performance may be different. For instance, Lin, Robertson, and Lee (2009) found that reading comprehension did not suffer when a television program was merely present in the background, whereas performance decrements did occur when participants were instructed to attend to both the assigned readings *and* the television program. In other words, although multitasking on a laptop in the classroom may certainly provide an *opportunity* for peers to be distracted, performance costs may only occur when individuals make an effort to engage in the distracting content. In the experiments presented here, although participants may have been distracted by their peer's use of the laptop in that they looked at the laptop, they may not have allocated enough resources to processing the content on the laptop to elicit performance costs.

In closing, recently there has been an explosion of interest surrounding the impact of laptops in the classroom, both for the users of the laptops, and for other students directly in view of those students' laptops. Although there is overwhelming evidence that multitasking negatively impacts a user's learning, there has been much less work examining the impact on students who are in view of a multitasking peer. Although multitasking peers might negatively affect the learning of those around them in some situations (e.g., Sana et al., 2013), the present findings suggest this does not always appear to be the case. Performance costs on peers are likely to be governed by important ecological factors such as fluctuating demands placed on learning of the content, the overlap between different types of information-processing resources, and the degree to which individuals readily become engaged with the distracting content versus casually observing it.

Acknowledgements

This research was supported by a Natural Science and Engineering Research Council of Canada (NSERC) discovery grant to Daniel Smilek, and an NSERC Postgraduate Doctoral Scholarship to Brandon Ralph.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.compedu.2016.04.006.

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