Investigation of Attentional Decay: Implications for Instruction

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Abstract

Given that attention is a limited capacity resource we are only able to selectively attend to a small subset of information at any one time. Endogenously regulating attention during an instructional activity is effortful and can be challenging for children as well as adults. Although improvements in attention regulation have been documented with age, less is known about the duration of time individuals are able to selectively sustain attention during instruction, due in part to methodological limitations. The present study leverages eye-tracking technology to provide an objective examination of attentional decay during a lecture. Adult participants (N=96) watched a geography screencast lecture while a mobile eye-tracker was utilized to measure changes in attention over the course of the lecture. Results indicate that attention declines over time and reductions in attention occur before Minute 15. Implications for instruction are discussed.

Keywords: Attention; Attentional decay

Introduction

Attention is a limited capacity resource - we are only able to attend to a subset of information at any one time. A common framework for understanding attention regulation is the dual model of attention in which attention is hypothesized to be driven by exogenous and endogenous factors. Exogenously regulated attention is hypothesized to be largely an automatic process driven by characteristics of the stimulus (e.g., novelty, brightness); in contrast, endogenously regulated attention is voluntary and controlled, directed according to an individual's goals (e.g., Bornstein, 1990; Jonides, 1981; Miller & Cohen, 2001; Posner, 1980; Pashler, Johnston, & Ruthruff, 2001; Ruff & Rothbart, 2001).

In formal learning environments, the ability to endogenously regulate attention may be particularly important (Erickson, Thiessen, Godwin, Dickerson, & Fisher, 2015). Yet, attention regulation is effortful and lapses in attention are common. Indeed, inattention, or off-task behavior, is a well-documented challenge in education (Roberts, 2001). Prior research has found that children are frequently off-task (e.g., Godwin et al., 2016; Karweit & Slavin, 1981), which may be due in part to the protracted developmental trajectory of endogenously regulated attention which continues to mature into adolescence (Diamond, 2002; Luna, 2009; Posner & Rothbart, 2007; Ruff & Rothbart, 2001). Although the ability to maintain a state of selective sustained attention improves with age (Bartgis, Thomas, Lefler, & Hartung, 2008), issues of inattention in formal learning environments persist beyond K-12 settings and into higher education.

Indeed, college students often exhibit off-task behavior during class dividing their attention between ongoing instruction and their personal technology devices. For example, Tindell and Bohlander (2012) surveyed 269 college students about their texting habits and found that 92% of participants reported sending or receiving a text message in class once or twice, while 30% reported sending or receiving a text message in class daily. Similarly, laptops can be a compelling distraction for students. College students who use their laptops during class widely report that they multitask during lectures. Students report using their laptop during class to check their email (81%), to instant message (68%), play games (25%), peruse the internet (43%), and engage in other non-specified activities (35%) (Fried, 2008). Prior research estimates that 42% of the time students have applications unrelated to the course open on their laptop, providing ample opportunities for self-distraction (Kraushaar & Novak, 2010). Further, Fried (2008) found that laptop use was negatively related to students' learning outcomes, controlling for students' ACT scores, high school ranking, and class attendance. Students own laptop use was negatively related to their self-reports of attention to the lecture; interestingly, students also reported that their peers' laptop use was a significant source of distraction (Fried, 2008). Subsequent experimental research confirmed the detrimental effects of peer laptop use. Sana, Weston, and Cepeda (2013) found that students who were in view of peers who were multitasking on their laptops during a lecture obtained lower learning scores.

Given learners' propensity to be distracted during instruction it raises important questions regarding how aspects of instructional design can be augmented to better support attention regulation. One aspect of instructional design that can be readily modified is the duration of instructional activities. Ten to 15 minutes has often been reported as the duration of time an adult is able to maintain attention (For discussion see: Bradbury, 2016; Hartley & Davies, 1978, Frost, 1965; Wilson & Korn, 2007). However, empirical work supporting this limit is sparse, and some of this work has been criticized due to methodological limitations (for review see: Bradbury, 2016; Wilson & Korn, 2007), which may reduce the utility of this literature to inform theory and guide instructional design.

Observational studies suggest that students' attention during lectures may decay rapidly. Johnstone and Percival (1976) observed students during 50minute lectures and found that students' attention waned approximately 10 to 18minutes into the lecture, with lapses in attention occurring with increased frequency by the end of the lecture. However, limited information is provided regarding how attention was operationalized and statistics quantifying inter-rater reliability are not provided. Further the authors' note that attention regulation patterns varied across lectures and instructors, pointing to the importance of understanding the factors that influence students' ability to maintain attention during instruction.

Studies utilizing self-report measures also suggest that students' attention during instruction varies over time. For instance, students watching a video lecture were more likely to report mind-wandering in the second half of the lecture compared to the first half (Risko et al, 2012 as cited in Szpunar, Moulton, & Schater, 2013). However, it is important to note that self-report measures may underestimate lapses in attention and probing students to self-assess their attention raises concern that the data collection process may alter student behavior. Recently, researchers have attempted to utilize novel technology to obtain more objective measures of attention (e.g., eye tracking with Tobii glasses; Rosengrant, Hearrington, Alvrado, & Keeble, 2012), but with small sample sizes detecting generalizable patterns in attention regulation is difficult to ascertain.

Despite exploration of alternative instructional approaches, lectures remain a popular instructional method in higher education. Additional research, with direct and objective measures of attention, is needed to better understand attentional decay during lectures and elucidate the implications for instruction. Incorporating breaks or introducing alternative instructional activities (e.g., discussions, demonstrations, group activities) are often suggested as potential solutions to help students maintain attention during class (e.g., Middendorf & Kalish, 1994); however, without an understanding of the rate of attentional decay it is difficult to determine precisely when breaks or "change-ups" should ideally be implemented. Less is known about how students regulate attention in online environments. Filling this gap in the literature is important given that online enrollments continue to increase with 6.7million students estimated to be taking at least one online course (Allen & Seaman, 2013).

Understanding the decay rate of attention has theoretical and practical implications for instructional design. The present study utilizes an objective measure of attention, eye tracking technology, to elucidate attentional decay by examining the extent to which adults are able to sustain attention during a 20minute geography screencast lecture. The present study aims to (1) assess whether adults' attention decays during an instructional task, and if so how quickly attentional decay occurs, and (2) whether the rate of decay is related to adults' learning outcomes.

Method

Participants

Participants included 96 adults (M_{age} = 21.04, SD = 5.30; Female = 77, Male = 17, and 2 participants who did not report their sex). Participants were recruited from an undergraduate educational psychology participant pool and community in a Midwest city in the United States. Based on self-report, participants were 83% Caucasian, 5% African American, 2% Asian/Pacific Islander, 2% Hispanic, 1% identified as two or more racial/ethnic identities, 1% other, and 5% declined to respond. Participants received either course credit or an incentive ($10 or a prize (e.g., flash drive, notebook)) for participating in the study.

Procedure

Participants listened to a 20minute screencast lecture on physical geography. Attention to the lesson was measured with a mobile eye tracker in order to evaluate attentional decay. A pre-test and immediate post-test were administered to assess learning gains. Additional details regarding the learning assessment and lesson are provided below. Participants were tested by trained research assistants and the second author of this paper.

Learning Assessment

The learning assessment consisted of a paper and pencil pre-test and post-test. The pre-test assessed the novelty of the lesson content. The post-test served to assess the participants' understanding of the lesson. Gains in learning from pre-test to post-test were calculated. The assessment items were constructed with the help of a university instructor for an undergraduate geography course at Kent State University. The pre-test and post-test consisted of 17 test items. The question format was mixed and included: multiple-choice items, fill in the blank items, and figure interpretation questions. Assessment questions were carefully designed such that they tested content that was delivered at different points in the lesson and avoided content presented in approximately the first and last quarter of the lesson (i.e., the lesson consisted of 21 slides and the assessment questions were designed to target information provided in slides 4 through 15). Two presentation orders were created. For Order 1, the test items were randomized and for Order 2, the sequence was reversed. The pre-test and post-test were largely analogous; however, for test items that required participants to convert numeric values (e.g., converting plotted sea-level pressure to complete sea-level pressure) different values were substituted. Additionally, the presentation order of the test items from pre-test to post-test were counterbalanced such that participants who completed Order 1 for the pre-test completed Order 2 at post-test and vice versa. The learning assessment was largely self-paced;

however the experimenter provided a verbal prompt reminding participants to provide their "best guess" if they did not know the answers after 3 minutes 30 seconds.

Lesson

Following the pre-test, participants were asked to watch a 20minute geography lecture presented on a laptop computer (i.e., screencast – video recording of PowerPoint slides with audio narration). The lecture was based on instructional content covered in an undergraduate physical geography course offered in the Department of Geography at Kent State University. The screencast was recorded by an instructor in the department; see Figure 1 for example content. During the lecture, posters were displayed on the walls of the laboratory (4 digital bulletin boards, 1 per wall) to more closely approximate environments in which undergraduates typically complete online classwork (e.g., student centers, dorm rooms, coffee shops). Note that the instructional task was designed to be a self-regulated learning activity. Thus, the experimenter sat behind a partition during the screencast. As a result, participants were not given feedback nor was their attention redirected to the lecture if they went off-task.

Attention

Eye gaze is a common measure of attention: eye gaze has been used as a measure of visual attention (see Henderson & Ferreira, 2004; Just & Carpenter, 1976 for review) as well as a measure of auditory attention (e.g., Reisberg, 1978; Saffran, Aslin, & Newport, 1996). In the present context, eye gaze is a particularly useful measure of attention given that the delivery of instruction occurs via screencast, which uses visual elements (i.e., PowerPoint slides) in combination with audio narration. Although in principle participants could listen to the lecture while looking away from the computer screen, such behavior would indicate a state of *divided attention*. Given the extensive use of eye gaze as a measure of attention in the prior literature combined with an instructional context that utilizes visual materials, we contend that the use of eye gaze as a measure of attention is justifiable.

A mobile eye tracker, Tobii X3-120, was utilized to capture participants' attention to the lecture providing an objective index of attention. Areas of Interest (AOIs) were drawn around each lecture slide in order to calculate the total fixation duration for each minute of the screencast lecture. Then the proportion of time fixating on the lesson was calculated for each minute of the lecture (seconds fixating/60s).

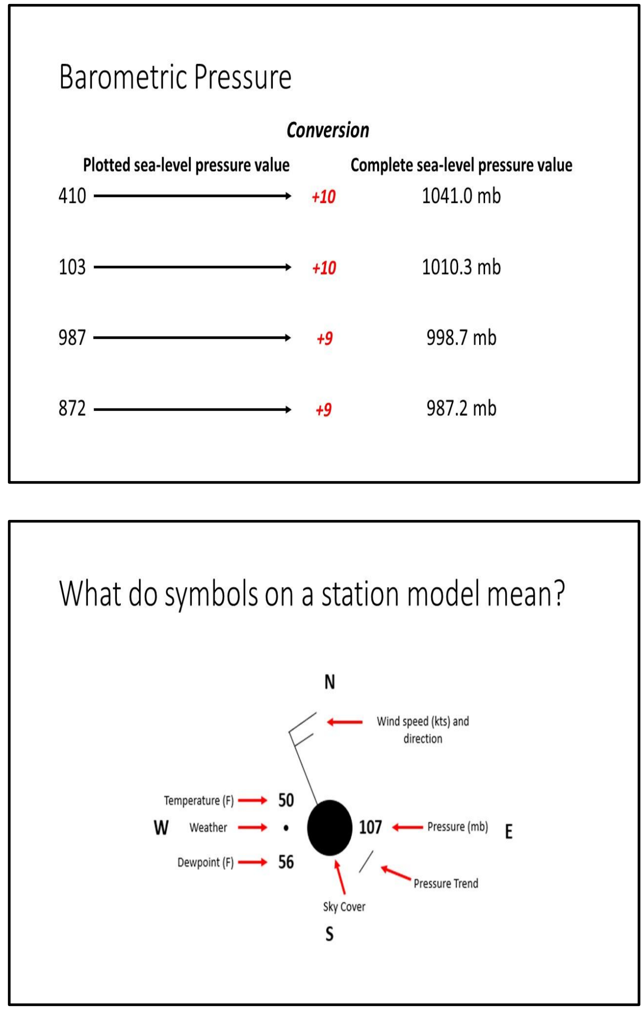

Figure 1: Displays example content from the Geography screencast

Results

Learning Outcomes

Pre-test Scores Pre-test scores were relatively low *M* = 46%, *SD* = 12%) suggesting the content was largely novel to the participants.

Post-test Scores Participants' exhibited evidence of learning as their post-test scores (*M* = 74%, *SD* = 13%) were significantly higher than their pre-test scores (*M* = 46%; paired $t(94) = 19.89$, $p \leq .0001$); see Figure 2. Gain scores were calculated by subtracting each participant's pre-test score from their post-test score. On average, participants increased their pre-test scores by 28% (*SD*=14%, Range: -.06 to .59). Note that one participant did not complete the post-test and thus they were not included in the present analysis.

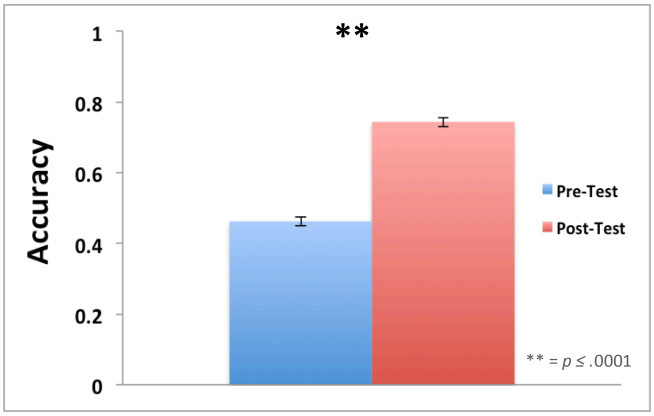

Figure 2: Mean accuracy rates (proportion of correct responses) for the pre-test and post-test. Error bars represent the standard errors of the means.

Attentional Decay

Extraction and analysis of the eye tracking data is currently underway. Thus, the preliminary eye tracking results reported below are from a subset of the sample (n=28). The proportion of time participants spent fixating on the lecture was calculated for each minute of the screencast (seconds fixating/60s) in order to objectively measure fluctuations in attention over time and assess the rate of decay. The mean proportion of time participants spent fixating on the screencast was .37 (SD = .13) with considerable variability observed across participants (Range: .16 to .68).

A repeated-measure ANOVA was conducted to examine the effect of time (20 levels: minutes 1-20) on attention. A significant effect of time was found in which attention declined over time: $F(6.59, 177.84) = 12.03$, $p < .0001$; see Figure 3. Note that Mauchly's Test of Sphericity indicated a violation of the assumption of sphericity ($\chi^2(189) = 383.75$, $p < .0001$); thus, the Greenhouse-Geiser correction was applied ($\varepsilon = .347$).

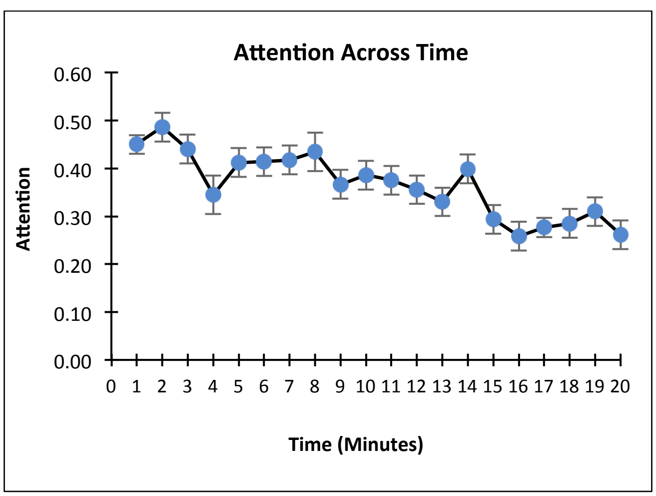

Figure 3: Displays the mean proportion of time participants' fixated on the lecture (attention) as a function of time (1min time segments). Error bars represent the standard errors of the means.

Table 1: Results from the paired sample t-tests assessing changes in attention (proportion of time fixating on the lesson) at key time segments of the screencast (Minutes: 1, 5, 10, 15, and 20).

Comparisons	Mean(*SD*)	*t*	*p*
Min 1 vs. **Min 5**	.45(.13) .41(.15)	2.19	.04
Min 1 vs. **Min 10**	.45(.13) .39(.16)	2.72	.01
Min 1 vs. **Min 15**	.45(.13) .29(.17)	5.98	<.0001
Min 1 vs. **Min 20**	.45(.13) .26(.17)	5.69	<.0001
Min5 vs. **Min 10**	.41(.15) .39(.16)	1.02	.32
Min 5 vs. **Min 15**	.41(.15) .29(.17)	4.11	<.0001
Min 5 vs. **Min 20**	.41(.15) .26(.17)	4.69	<.0001
Min10 vs. **Min15**	.39(.16) .29(.17)	3.32	.003
Min10 vs. **Min20**	.39(.16) .26(.17)	3.62	.001
Min15 vs. **Min20**	.29(.17) .26(.17)	1.11	.28

In line with prior reports, pairwise comparisons indicate significant attentional decay at Minute 15 (M = .29) compared to Minute 1 (M = .45, p < .0001), Minute 5 (M = .41, p < .0001), and Minute 10 (M = .39, p = .003), but no evidence of decay comparing Minute 15 to Minute 20 (M = .26, p = .28); see Table 1. Critically, reductions in attention are seen *before* Minute 15 (see Figure 1). Indeed significant attentional decay was evident at both Minute 5 (p=.04) and Minute 10 (p=.01) compared to Minute 1; see Table 1.

For each participant, the total reduction in attention from the beginning of the lesson to the end of the lesson was calculated by subtracting the proportion of time participants' were fixating on the lesson at Minute 20 from Minute 1. On average, the reduction in the proportion of time that participants attended to the lesson at Minute 1 compared to Minute 20 was 19% (M = .19, SD = .18). Individual variability in the total reduction in attention was observed (Range -.14 to .60) with some participants exhibiting large reductions in attention and a small minority of participants (n=2) who exhibited more attentive behavior at Minute 20 compared to Minute 1.

Reductions in attention were not found to be associated with learning gain scores ($r(26) = .26$, $p = .18$). Although the total reduction in attention was not related to participants learning outcomes, it is possible the rate at which attention decays may be more closely related to learning. Rate of decay would provide more nuanced information as individuals can have similar overall reductions in attention but may have achieved these scores through very different progressions (e.g., going off-task immediately after the lesson commences vs. exhibiting a gradual reduction in attention – or possibly exhibiting reductions in attention only after the content had been encoded). Analyses are currently underway exploring these possibilities and examining whether the rate of decay predicts learning.

Discussion

The present study helps to address some of the methodological limitations of prior research by leveraging eye-tracking technology to provide an objective examination of how attention decays while listening to a lecture. Endogenously maintaining attention during an instructional activity is challenging - even for adults. These preliminary results indicate that over the course of a 20minute screencast lecture, adults' attention declined. In line with prior reports, we observed reductions in attention at Minute 15. However, decrements in attention were observed even earlier in the lesson (e.g., Minute 5 and Minute 10).

In order to increase ecological validity of the study, the lecture and accompanying PowerPoint slides were based on instructional content covered in an undergraduate physical geography course. The assessments were also designed through consultation with a university instructor from the Department of Geography. As a consequence of using genuine instructional materials, some content is presented *both* visually and auditorily while other content may only be presented visually. While it could be possible to design a lesson that delivers content through a single modality, this would necessarily reduce the ecological validity of the lessons and the study. As noted in the Method section above, eye gaze is a common measure of attention and direction of eye gaze has been used in the prior literature to measure both visual and auditory attention. Thus, eye gaze can be considered a reasonable index of attention in the present study.

These findings have direct implications for instructional practice given that lectures are a common instructional tool in higher education. Further, many undergraduate courses entail lectures that are at least 2-3 times longer than the lecture employed in the present study (see Kumar, Dialani, Wong, Khattar, 2018; Middendorf & Kalish, 1994). Future research should examine whether reductions in attention and the rate of decay vary for instructional sessions that pose a heavier demand on attention due to extended instructional duration.

These findings also have clear and important implications for online instruction. This study delivered the instructional content as a screencast. Given the current prevalence and anticipated growth of online education (Allen & Seaman, 2013) combined with the frequent use of screencast lectures to deliver online instruction, it is imperative to understand how individuals regulate attention to screencasts. Attention is a limited resource and as such it is important to leverage research in the learning sciences to design and deliver instruction in a way that is sensitive to this cognitive constraint.

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