The Effects of Note-Taking on Mind Wandering and Learning:  

Is Taking Notes on Printed PowerPoint Slides Effective?  

by  

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Abstract

Note-taking is one of the most universally employed strategies for enhancing learning, but are all note-taking styles created equal? The present study compared how taking notes on lecture slide printouts (“full slides”) vs. taking notes on blank lined paper (“freehand notes”) would affect learning, situational interest, and in-lecture mind wandering. After completing a pretest on statistics, participants \( N = 48 \) were randomly assigned to either take freehand notes or take notes on full slides while watching a 30-min introductory statistics lecture video, which was occasionally interrupted with thought probes to measure mind wandering. Participants then completed a questionnaire about their situational interest in the video lecture and statistics, followed by three posttests to assess their learning from the video. Results indicated that there was a nonsignificant trend suggesting that learning was slightly increased for the full slides group, but situational interest did not differ between the two conditions. The full slides group, however, experienced significantly less task-unrelated mind wandering and more on-task thoughts than the freehand notes group, a pattern that was especially clear when the analysis focused on only those participants who actually took notes during the lecture. These results imply that full slide note-taking could be beneficial for keeping students focused during a lecture.
The Effects of Note-Taking on Mind Wandering and Learning:

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Students and teachers in schools all over the world have long wondered how class material can be learned more effectively. Psychological research has provided an ever-growing body of evidence-based information and advice pertaining to this topic. For example, studies have demonstrated the utility of study tactics such as spaced learning, generating questions about important points, and self-testing (Putnam, Sungkhasettee & Roediger, 2016).

Note-taking, arguably the most universally popular strategy for learning class material, has become a topic of particular interest. This is especially true in college, where many classes follow the format of a professor using a PowerPoint presentation to lecture a large group of students with a limited amount of student-professor interaction. Students typically take notes during lectures to create a physical copy of the lecture information for their own personal use and later review. It is important to note, however, that research has demonstrated that the benefits of note-taking as a study strategy go beyond this “later review” function. Some studies have linked note-taking practices to improved encoding of lecture material (Kobayashi, 2005). In addition to this encoding benefit, note-taking has been shown to reduce task-unrelated mind wandering during the lecture, at least for some individuals (Kane et al., 2017). Thus, although previous research suggests that note-taking can be a beneficial practice, it is not yet clear what sort of note-taking is the most beneficial for student learning.

The main goal of my honors thesis study was to compare two common forms of note-taking practices—(a) freehand note-taking on paper and (b) taking notes on a printed copy of full PowerPoint lecture slides—on in-lecture mind wandering and learning. The current study extends prior results of a study conducted by Kane et al. (2017) by examining which form of
note-taking is more effective in reducing mind wandering during learning and increasing student learning (as assessed with pretest and posttest quizzes) in the context of a 30-min video lecture on introductory statistics.

**Two Forms of Note-Taking Examined in the Current Study**

Most students have at least two options for how they take notes during a lecture. First, perhaps the most common form of lecture note-taking is freehand note-taking in a notebook or on blank paper. Despite its popularity, however, the “freehand notes” style is not without its risks. Students may attempt to write down every single detail on the lecture slides verbatim, which could make it difficult for them to pay close attention to the professor’s explanations of the slides as well as to differentiate important points in the lecture from minor details. On the other end of the spectrum, the freehand note-taking approach could also make students more susceptible to “tuning out” from the lecture and experiencing off-topic mind wandering when faced with a blank notebook page. This may lead to sparse notes that are missing a great deal of information, which in turn may impair their later review of the lecture material.

The second option, which has become increasingly more common in recent times, is the use of lecture slides for note-taking purposes. Some professors post the entire PowerPoint file of their lecture online before class, giving students the opportunity to print out the slides and take notes on them during the lecture. This “full slides” note-taking strategy enables students to avoid frantically copying down everything on the slides. It may therefore allow students to focus more on what the professor is saying during the lecture and write down only additional pieces of information not directly stated in the slides (but likely important or useful for later review). Similar to the “freehand” style, however, this “full slides” note-taking approach is not without its potential pitfalls. Students may pay less attention during a lecture (or skip it altogether) when
they know they have access to full PowerPoint slides. They might also be less motivated to take their own notes on the printouts, which would reduce the encoding benefits of note-taking. This lack of engagement could also lead to greater in-lecture mind wandering.

Despite the pros and cons of each note-taking approach considered above, little research comparing the relative effectiveness of these note-taking strategies exists. Most previous studies of note-taking have simply compared the effects of taking notes to the effects of not taking notes. To my knowledge, only one study has examined the effects of freehand note-taking and taking notes on PowerPoint slides (Marsh & Sink, 2010). In this study, the authors found that access to the PowerPoint slides during a lecture improved students’ learning and reduced the time they needed to study for a later test. The present study sought to expand upon the preexisting literature by comparing the effects of full provided slides and freehand notes on learning, situational interest, and mind wandering during a recorded introductory statistics lecture.

**Effects of Note-Taking on Learning: A Brief Literature Review**

In-class note-taking is based on the well-supported idea that taking notes leads to greater retention and more accurate recall than simply listening to the lecture. It is now widely recognized that the two primary functions of note-taking are external storage (for future study or reference) and encoding (which enables the inclusion of the learner’s associations, inferences, and interpretations), but some earlier work recognized only the external storage function of note-taking (Carter & Van Matre, 1975). Subsequent research, however, lent support to the external storage and encoding model of note-taking functionality (Einstein, Morris & Smith, 1985; Kiewra, 1989).

It is important to emphasize, however, that most students typically produce low-quality notes that are either word-for-word transcripts of the lecture, missing key concepts, or lacking in
some other way (Kiewra, 1989). Such low-quality notes can have a significant negative impact not only on the encoding function of note-taking but also on the later reviewing of the lecture notes. In the context of the present study, one could argue that participants who are given printouts of the lecture slides are less likely to engage in mindless verbatim copying of the lecture slides and/or produce lecture notes that fail to include some key pieces of information from the lecture.

One of the most widely known research findings about note-taking is the superiority of handwritten notes to typed notes for enhancing learning. Specifically, in a recent study that received considerable media attention, Mueller and Oppenheimer (2014) compared the effectiveness of longhand note-taking (using pen and paper) and laptop note-taking. Mueller and Oppenheimer found that students who took notes by hand performed better on a later test of lecture information recall than those who typed their notes on a computer, especially for conceptual questions that required a good understanding of the lecture content. This occurred despite the fact that the students who typed their notes wrote down more information. According to Mueller and Oppenheimer’s (2014) analysis, the main problem with laptop note-taking is that because typing can be much faster than handwriting, the participants in the laptop note-taking condition tried to type almost everything they heard. This led to them failing to engage in deeper processing of the information, which is necessary to gain a greater understanding of the material. In contrast, taking notes by hand is a slower process that forces the writer to choose the most important concepts to write down. Moreover, students who took notes by hand also tended to put the lecture information in their own words, a process that is associated with improved encoding of the material (Mueller & Oppenheimer, 2014).
In an experiment with great implications for the present study, Marsh and Sink (2010) investigated the effects of distributing printouts of their PowerPoint slides before versus after a physics lecture. They found that students who received slides before the lecture not only needed less time to prepare for a final test but also performed better on that test. These findings provided initial support for the benefits of taking notes on printed copies of PowerPoint lecture slides on efficient encoding as well as later reviewing of the lecture content. Having access to printed slides may also lead students to take notes that explain the slides rather than simply copying lecture content, which could be a sign of deeper processing with more favorable memory outcomes.

The current study was built on an earlier study conducted in the Miyake lab (Kane et al., 2017), which was a collaborative, large-scale study conducted at two different institutions (the University of Colorado Boulder and the University of North Carolina, Greensboro). Kane et al. examined how mind wandering during a video lecture on introductory statistics affected students’ learning of the lecture content as well as their situational interest (i.e., students’ interest in statistics triggered by the lecture). In addition, Kane et al. (2017) examined whether freehand note-taking (versus not taking any notes and focusing instead on viewing the lecture video) might reduce task-unrelated mind wandering.

In Kane et al.’s (2017) study, participants were randomly assigned to either the note-taking condition or the non-note-taking condition. Participants watched a 52-minute introductory statistics lecture video that consisted of a PowerPoint presentation with an accompanying voice recording. During the lecture, participants’ mind wandering was measured with thought probes that periodically interrupted the video to ask them what they had just been thinking about. After the video lecture, they completed a questionnaire that assessed their situational interest in the
lecture and statistics, followed by posttests assessing their understanding and mastery of the video lecture content.

Results found that although the note-taking group as a whole did not demonstrate significantly lower rates of mind wandering during the lecture, individuals who took high-quality notes (notes that included most or all of the lecture’s important points) experienced less mind wandering. Moreover, they found that mind wandering was by far the greatest predictor of later posttest performance and situational interest outcomes (Kane et al., 2017). Interestingly, the study also found that the sizeable impact of mind wandering was not always detrimental to students, because some off-task thoughts about lecture-related ideas (e.g., relating what they heard earlier in the lecture to something they already know) were actually positively associated with learning (Kane et al., 2017).

The Current Study

The present study was modeled after Kane et al.’s (2017) study described above, but several changes were introduced. Most importantly, the current study compared the “freehand note-taking” condition and the “full slides” condition (instead of the comparison between the “freehand note-taking” and “no note-taking” conditions). Moreover, to assess not only the extent of encoding benefits but also external storage benefits of note-taking, we asked participants to complete the posttest quizzes both before and after they were allowed to review their notes. Specifically, the performance on the posttest taken before the reviewing of the notes should primarily reflect the encoding benefits of note-taking, whereas the performance on the posttest taken after reviewing notes should reflect both the encoding and external storage benefits.

The main focus of the study was determining whether or not the two types of note-taking (freehand note-taking and full slides note-taking) lead to differential outcomes for the three
categories of the dependent measures: (a) the posttest scores, (b) the levels of situational interest assessed right after the video lecture, and (c) the frequency of mind wandering during the video lecture. On the basis of the results of the Marsh and Sink (2010) study (the only study published so far that compared freehand note-taking with full slides note-taking), the following three hypotheses were examined:

- **Hypothesis 1**: Participants in the full slides condition will perform better on all three posttests than those in the freehand notes condition. This superiority of the full slides condition might be even greater after participants have the chance to review their notes.

- **Hypothesis 2**: Participants in the full slides condition will have higher situational interest than those in the freehand notes condition.

- **Hypothesis 3**: The full slides condition will lead to lower mind wandering rates than the freehand notes condition.

It is important to point out that all these hypotheses assume that participants actually take notes in both conditions. If they do not write anything down during the video lecture, their results may look substantially different (e.g., they might have more mind wandering in the full slides condition). For this reason, I will examine the actual notes taken by all participants and tested the three hypotheses above with and without a small number of participants who took very little (just a few words written) or no notes ($n = 4$, all in the full slides condition).

Consistent with Kane et al.’s 2017 study, the current study assessed various individual differences variables (e.g., prior statistics knowledge and interest, self-efficacy for learning statistics, media multitasking tendencies) as potential moderators. In addition, my analysis focused on the main experimental effects of two note-taking methods. Those individual differences variables will be analyzed later as pilot data to support the development of a larger-scale study.
Method

Participants

Forty-eight undergraduate students (31% male) at the University of Colorado Boulder participated in this study. All participants were 18 to 25 years old and participated for partial fulfillment of a research participation requirement for an introductory psychology course. Half of the participants were randomly assigned to either a freehand notes or full provided slides condition. This was achieved via a pre-randomized sequence sheet. Two additional participants also started the study, but because they did not meet the predetermined eligibility criteria in terms of age and previous statistics experience, they were not included in the analysis (see below).

Materials and Equipment

For this 90-min, single-session study, each participant sat in an individual testing room in front of a Mac Mini computer with an Acer 22-inch LED-LCD monitor. During the video lecture portion of the experiment, they wore Koss UR-20 headphones. Participants were also given Sharp EL243S calculators during the pretest and posttest portions of the procedure.

Those in the full slides condition were given stapled packets containing black and white printouts of the lecture slides that contained pertinent information (duplicate slides and slides with pictures were not included). Those in the freehand notes condition were given two stapled double-sided sheets of lined paper. All participants used a ballpoint pen to take notes and complete the paper-based posttests.

Procedure

After the initial consent process, the study took place in five stages. Because the individual differences data were not analyzed for this thesis, the parts of the study that are related
to individual differences and were not directly relevant to the testing of the three main hypotheses will be explained only briefly.

**Stage 1: Individual differences assessment.** After giving informed consent, participants responded to two “screening” questions: (a) their age and (b) all the statistics courses they have taken (high school, online, etc.). If they indicated that they were younger than 18 years old \( n = 0 \) or already had any prior college statistics experience \( n = 2 \), they were dismissed from the study and not included in the data analysis reported below.

Next, participants responded to several individual differences measures (not analyzed in this study): (a) a note-taking questionnaire; (b) a media multitasking questionnaire; and (c) a math/statistics interest and beliefs questionnaire.

**Stage 2: Pretest and learning confidence/self-efficacy assessment.** After completing the aforementioned questionnaires, participants moved on to the computerized pretest, which assessed how much they already knew about the content of the video lecture. This pretest consisted of ten multiple-choice questions, and participants were given scratch paper and a calculator to use during the pretest. The ten questions were deliberately made challenging to new learners of statistics so that we could better assess an increase in accuracy from the pretest to the posttest. An example multiple-choice question is as follows:

You have a sample of 5 scores. Here are the deviation scores for 4 of them: \(-8, -4, -1, +1\). What is the value of the missing fifth deviation score?

A. -3  
B. -2.4  
C. 0  
D. +2  
E. +4  
F. +12  
G. +14  
(The correct answer is F.)
Participants were told to simply try their best, as there was no penalty for guessing. After each question, there was a follow-up item that assessed participants’ confidence in their answer. This response scale’s anchors were: 1 = Little confidence, 2 = Somewhat confident, and 3 = Highly confident. The dependent measures for this pretest were (a) the number correct out of ten questions and (b) the average of the ten confidence ratings (from 1-3).

Once they finished the pretest, participants responded to some questions about their learning confidence and self-efficacy, which essentially asked about how well they think they would be able to learn from the forthcoming video lecture. These data about learning confidence and self-efficacy were not analyzed in the current study.

**Stage 3: Video lecture.** Participants then watched and took notes on a statistics lecture video. During the video, their mind wandering frequency was assessed with sixteen periodic thought probes that appeared approximately every two minutes, with none appearing in the first two and a half minutes.

Before the video, the experimenter distributed either printouts of the most important lecture slides (for participants in the full slides condition) or blank lined paper (for those in the freehand notes condition). For both conditions, the experimenter encouraged participants to take notes as if they are in a real class and will be tested on the material later. The experimenter also told participants that they could not pause or rewind, just like a real lecture.

The experimenter then read the on-screen instructions for the mind wandering probes aloud to the participant. It was explained to the participant that while watching the video, they may sometimes find themselves thinking about something besides the lecture content on the screen. They were assured that this was perfectly normal and the study was interested in what people may think about during learning contexts such as lectures. The experimenter explained
that the computer would periodically interrupt the video to ask what the participant had just been thinking about right before the probe screen appeared. Throughout the instructions, it was repeatedly emphasized that the participant should reply with what they had been thinking about in the exact instant before the probe appeared, rather than attempting to reconstruct their thoughts over the previous seconds or minutes. The experimenter then walked the participant through the seven response options for the mind wandering probes:

1. On-task on the lecture: For thoughts about what was being discussed in the video at that time.
2. Lecture-related ideas: For thoughts about some aspect of the lecture topic, but not what was on the screen at that moment.
3. How well I’m understanding the lecture: For evaluative thoughts about one’s comprehension (or lack thereof) of the lecture material.
4. Everyday personal concerns: For thoughts about normal everyday events, life concerns, or personal worries.
5. Daydreams: For fantasies or unrealistic thoughts.
6. Current state of being: For thoughts about one’s current physical or mental state (e.g. thinking about being hungry, sleepy, or fascinated).
7. Other: For thoughts that do not fit into the other categories.

Each of the 16 probes administered during the video lecture consisted of the question “What were you just thinking about?” above the above numbered list in white text on a green screen. Participants responded by pressing the numerical key that corresponded to their choice.

Mind wandering was assessed by measuring the number of probes on which participants selected one of options 4-7, which were considered to be task-unrelated thoughts. Option 1 represented on-task thought. Options 2 and 3 represented thoughts that were off-task but task-related, although it should be noted that previous research has shown that only the thoughts associated with option 2 (but not option 3) have beneficial effects. Each type of mind wandering was measured by the number of probes of that type that the participant selected out of the 16 total thought probe responses.

The approximately 30-min lecture video (31:25, to be exact) was modified from the
longer (52:00) version used by Kane et al. (2017). It consisted of a PowerPoint slideshow with text and graphics accompanied by a lecture voiceover. The lecture began by explaining how statistics can be useful in our day-to-day lives. It then explained descriptive statistics using the example of SAT scores. The lecture also explained measures of central tendency (mean, median, and mode) and showed how to calculate them in the context of the SAT score example. After this, it explained range and standard deviation before demonstrating how to calculate standard deviation through the five-step process of computing the mean, deviation scores, sum of squares, variance, and finally, the standard deviation. The video also reinforced this standard deviation calculation process by walking through a second example.

Stage 4: Assessment of outcome measures (situational interest and posttests). After the video lecture, the experimenter took away the note-taking materials before getting the participant started on the situational interest questionnaire. This 10-item questionnaire consisted of three subscales: (a) interest in the lecture (e.g. “I thought this video lecture was interesting”), (b) perceived utility of the lecture (e.g. “I think what I learned from this video lecture is useful for me to know), and (c) inherent interest in statistics as a field (e.g. “I think the field of statistics is an important discipline”). The items were presented in a randomized order, and there were four reverse-coded items. The response scale anchors were: “1 = Strongly disagree, 2 = Somewhat disagree, 3 = Neither disagree nor agree, 4 = Somewhat agree, 5 = Strongly agree.” The dependent measure was the average ratings for each subscale, with reverse-coded items from the questionnaire flipped accordingly before computing the group averages for each category of situational interest. Although I examined all three subscales, the main focus was on the first two subscales (interest in the lecture and perceived utility of the lecture), because it seemed unlikely that a 30-min video lecture could substantially increase students’ inherent interest in statistics.
This situational interest questionnaire was administered differently from the other questionnaires, because it was timed to equate the retention interval between the video and the posttests. Each item was on the screen for 10 s; participants could choose their answer at any point in the 10-s period, but they could not advance before 10 s, and the questionnaire would automatically proceed to the next question after 10 s.

The instructions for the first posttest came immediately after the timed situational interest questionnaire. This test was identical to the pretest, with the same 10 multiple-choice statistics questions and confidence items after each question. Participants were given the same calculator and a new sheet of scratch paper.

After this first posttest, the experimenter turned off the computer monitor and distributed the physical copy of the second posttest. This test required participants to perform a step-by-step calculation of the standard deviation of five scores (2, 3, 4, 7, 9). They were required to show their work for each of the five steps: 1. Compute the mean; 2. Compute the deviation scores; 3. Compute the sum of squares; 4. Compute the variance; and 5. Compute the standard deviation.

After completing the second posttest, participants were given their notes to review for three min. Once the three min were up, participants completed the third and final posttest, which required them to perform the same calculations on a different set of five scores (2, 6, 9, 10, 13).

The two posttests that required step-by-step calculations of standard deviation were graded out of five points. Each point was earned by using the right equation and finding the correct answer for one step of the standard deviation calculation process. If a participant made a mistake on an earlier step and used their incorrect answer in the calculations for a subsequent step, they received half a point for that step as long as they used the right equation.
Stage 5: Demographic & statistics experience questionnaire. After the third posttest, the experimenter turned the monitor back on and the participant completed a brief questionnaire about their gender, age, major, and whether or not they had ever learned about means, medians, or standard deviations in a prior class. This questionnaire was administered at the end of the experiment to avoid the potential negative effects of stereotype threat (Spencer, Steele & Quinn, 1999) that could result from indicating gender (considering the study’s mathematical focus).

Results

A series of independent two-sample t-tests were conducted in the software R in order to determine the effects of note-taking style on learning, situational interest, and mind wandering during the video lecture. There were two experimental conditions: freehand notes \( (n = 23) \) and full (provided) slides \( (n = 25) \).

As noted earlier, the three hypotheses I tested made the important assumption that students in both conditions would actively take notes. Thus, I examined the note-taking materials from all participants to ensure that every participant took notes during the video lecture. This investigation revealed that four participants in the full slides condition took very few notes, if any, on the provided slides. To determine whether the inclusion of these four participants had an impact on the results, I also conducted the same analyses without those four non-note-takers in the full slides condition \( (n = 21) \).

The descriptive statistics and the results of the t-tests are summarized in Table 1. In that table and the subsequently presented figures, the three tested conditions are the freehand note condition, the full slides condition with all participants, and the full slides condition without the four participants who did not take any or very little notes.
**Table 1.**

Descriptive statistics for predictor and outcome variables by note-taking condition.

<table>
<thead>
<tr>
<th></th>
<th>Freehand notes (FH)</th>
<th>Full slides (FS)</th>
<th>FS without non-note-takers</th>
<th>FH vs FS</th>
<th>FH vs FS without non-note-takers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (sd)</td>
<td>Mean (sd)</td>
<td>Mean (sd)</td>
<td>t (p)</td>
<td>t (p)</td>
</tr>
<tr>
<td><strong>Pretest</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MC Scores (out of 10)</td>
<td>3.13 (1.58)</td>
<td>2.52 (1.45)</td>
<td>2.81 (1.4)</td>
<td>1.40 (0.17)</td>
<td>0.71 (0.48)</td>
</tr>
<tr>
<td>MC Confidence (1-3, 1= “Little confidence”, 3= “Highly confident”)</td>
<td>1.60 (0.37)</td>
<td>1.63 (0.35)</td>
<td>1.63 (0.34)</td>
<td>-0.23 (0.82)</td>
<td>-0.63 (0.53)</td>
</tr>
<tr>
<td><strong>Posttest</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MC Scores (out of 10)</td>
<td>5.52 (2.04)</td>
<td>5.12 (2.33)</td>
<td>5.67 (2.11)</td>
<td>0.63 (0.53)</td>
<td>-0.23 (0.82)</td>
</tr>
<tr>
<td>MC Confidence (1-3, 1= “Little confidence”, 3= “Highly confident”)</td>
<td>2.39 (0.42)</td>
<td>2.21 (0.51)</td>
<td>2.23 (0.55)</td>
<td>1.32 (0.19)</td>
<td>1.11 (0.27)</td>
</tr>
<tr>
<td>Calculation scores (before review)</td>
<td>3.89 (1.36)</td>
<td>4.00 (1.29)</td>
<td>4.21 (1.14)</td>
<td>-0.28 (0.78)</td>
<td>-0.85 (0.40)</td>
</tr>
<tr>
<td>Calculation scores (after review)</td>
<td>4.17 (1.23)</td>
<td>4.28 (1.01)</td>
<td>4.40 (0.86)</td>
<td>-0.33 (0.75)</td>
<td>-0.72 (0.48)</td>
</tr>
<tr>
<td><strong>Situational Interest</strong> (1-5, 1= “Strongly Disagree”, 5= “Strongly Agree”)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interest in Lecture</td>
<td>2.91 (0.44)</td>
<td>3.03 (0.69)</td>
<td>3.00 (0.68)</td>
<td>-0.69 (0.49)</td>
<td>-0.50 (0.62)</td>
</tr>
<tr>
<td>Perceived Utility of Lecture</td>
<td>3.58 (0.63)</td>
<td>3.51 (0.68)</td>
<td>3.54 (0.64)</td>
<td>0.39 (0.70)</td>
<td>0.21 (0.84)</td>
</tr>
<tr>
<td>Interest in Statistics</td>
<td>2.29 (0.74)</td>
<td>2.19 (0.92)</td>
<td>2.06 (0.87)</td>
<td>0.43 (0.67)</td>
<td>0.93 (0.36)</td>
</tr>
<tr>
<td><strong>Mind Wandering</strong> (out of 16)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>On-task</td>
<td>5.91 (4.18)</td>
<td>7.88 (3.09)</td>
<td>8.62 (2.56)</td>
<td><strong>-1.87 (0.07)</strong></td>
<td><strong>-2.56 (0.01)</strong></td>
</tr>
<tr>
<td>Off-task</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Understanding</td>
<td>1.74 (1.66)</td>
<td>1.16 (1.31)</td>
<td>1.24 (1.37)</td>
<td>1.35 (0.18)</td>
<td>1.09 (0.28)</td>
</tr>
<tr>
<td>Lecture-related ideas</td>
<td>2.30 (1.36)</td>
<td>2.56 (1.42)</td>
<td>2.52 (1.36)</td>
<td>-0.64 (0.53)</td>
<td>-0.53 (0.60)</td>
</tr>
<tr>
<td>Task-unrelated</td>
<td>6.14 (3.18)</td>
<td>4.40 (3.16)</td>
<td>3.62 (2.65)</td>
<td><strong>1.79 (0.08)</strong></td>
<td><strong>2.73 (0.01)</strong></td>
</tr>
</tbody>
</table>

Note: Bold fonts indicate a statistically significant difference (p<.05), whereas bold italics indicate a marginally significant difference (.10>p>.05).
Multiple Choice Pretest Scores and Confidence

Although the pretest accuracy and confidence scores simply represent a baseline against which we compared the posttest scores, it is worth noting that, likely due to the small sample size, the freehand notes group did slightly better (and was slightly more confident) on the pretest than the full slides groups. Just as we expected, however, there was no significant difference between the three groups’ scores.

Hypothesis 1: Multiple Choice and Calculation Posttest Scores and Confidence

Hypothesis 1: Participants in the full slides condition will perform better on all three posttests than those in the freehand notes condition. This superiority of the full slides condition might be even greater after participants had the chance to review their notes.

As summarized in Table 1, the two groups did not differ in their confidence ratings for the multiple-choice posttest. The main focus of Hypothesis 1, however, is the two groups’ posttest scores.

Like the confidence ratings, the multiple-choice posttest scores showed no significant differences between the groups (Table 1). As expected, both conditions improved from their pretest scores, possibly showing learning for both groups, as illustrated in Figure 1. Contrary to Hypothesis 1, however, the full slides group did not perform significantly better than the freehand notes group (with or without participants who did not take notes).

Despite this lack of significance, there was an intriguing pattern in the multiple-choice scores: The degree of improvement from pretest to posttest is marginally greater for the full slides group than the freehand notes group, even though the results were not significant and thus do not support Hypothesis 1.
Figure 1.
Scores (out of 10) on the multiple choice pretest and posttest.

The paper-based second and third posttest scores are shown in Figure 2. The second posttest, which measured calculation abilities without reviewing notes, also found no significant results (see Table 1). However, the data again displayed a minor trend: the full slides group performed slightly better than the freehand notes group, and they did even better when the analysis focused on the participants who actively took notes during the video lecture.

Figure 2.
Scores (out of 5) on the calculation posttests before and after note review.
The third and final posttest measured the same calculation abilities after participants had reviewed their notes for three min. As seen in Figure 2, both groups saw some improvement from the previous calculation test after being allowed to review the notes, but the amount of improvement from the second to the third posttests was relatively small for both the freehand notes group and the full slides group. This was surprising, especially considering that the full slides group had access to all the key slides used in the lecture. There were once again no significant differences between the groups (see Table 1). The same slight (but nonsignificant) pattern from the previous posttest was also observed: the full slides group without non-note-takers performed better than the entire full slides group, who in turn performed better than the freehand notes group.

In summary, although there was a minor (nonsignificant) trend indicating that the full slides group learned more than the freehand notes group, the statistical results were generally inconsistent with Hypothesis 1. In particular, the access to the full slides did not lead to larger gains in posttest performance for the full slides group, suggesting a rather modest impact of full slides for later review, at least when the reviewing took place shortly after the video lecture.

Hypothesis 2: Situational Interest

**Hypothesis 2:** Participants in the full slides condition will have higher situational interest than those in the freehand notes condition.

As noted earlier, three categories of situational interest measures were examined: (a) interest in the lecture, (b) perceived utility of the lecture, and (c) interest in statistics as a field. As shown in Table 1, there were no significant differences between the full slides and freehand notes groups in any of the three situational interest measures. These results are inconsistent with Hypothesis 2.
Hypothesis 3: In-Lecture Mind Wandering

Hypothesis 3: The full slides condition will lead to lower mind wandering rates than the freehand notes condition.

Mind wandering responses were divided into on-task (option 1) and off-task thoughts (options 2-7). Off-task responses could be about one of three things: lecture-related ideas (option 2), the participant’s understanding of the lecture material (option 3), or task-unrelated thoughts (options 4-7).

The percentages of these four types of thoughts (on-task, lecture-related, understanding, and task-unrelated) are visually illustrated in Figure 3. As indicated in these pie charts, the proportion of on-task thoughts was substantially greater in the full slides group (the middle panel) than in the freehand notes group (the left panel), especially when the analysis focused on those participants who took active notes (the right panel). These group differences are supported by the statistical analyses, as summarized in Table 1.

Figure 3.
Proportions of mind wandering types for each group, calculated from responses to 16 thought probes.
Participants in the full slides condition nearly showed a significantly greater amount of on-task thoughts than participants in the freehand notes condition. Upon exclusion of the four non-note-takers, the difference becomes statistically significant. As seen in Figure 3, a similar situation was found on the other end of the mind wandering spectrum. The full slides condition had much less task-unrelated mind wandering than the freehand notes condition. Again, focusing only on those participants who took active notes made the group difference statistically significant. These results are consistent with Hypothesis 3.

The two forms of task-related but off-topic mind wandering (lecture-related ideas and understanding of the lecture material) did not show any significant differences between the two note-taking conditions (Table 1). As shown in the Figure 3 pie charts, participants taking freehand notes thought about their understanding of the lecture somewhat more frequently than participants with full slides, but the difference was small.

Discussion

This study was conducted to compare the effectiveness of two common forms of note-taking (freehand notes vs. full slides) in enhancing the learning from the lecture and situational interest as well as in reducing in-lecture mind wandering. Although the sample size was small (total $N = 48$) and thus lacked statistical power, the study nonetheless yielded interesting and promising results (see Table 1 for a summary). Inconsistent with my hypotheses derived from the results of the Marsh and Sink (2010) study, I found no significant group differences in posttest scores (Hypothesis 1) or situational interest (Hypothesis 2) favoring the full notes group, but the two types of notes had a significant impact on participants’ mind wandering during the video lecture. Specifically, as hypothesized, the full slides group had significantly less in-lecture mind
wandering than the freehand notes group (Hypothesis 3), especially when the analysis focused on only those participants who actively took notes.

In the rest of this Discussion section, I will discuss the implications of the reported results. Then I will conclude this thesis by pointing out the limitations of the study and outlining future research directions.

**Implications of the Study**

Given that the group differences for the posttest results in the current study were nonsignificant, my findings do not replicate the findings of Marsh and Sink (2010). This difference is likely attributable to the limited sample size and the resulting lack of statistical power of the current study ($N = 48$). As noted in the Results section, however, the degree of learning (i.e., the increase of multiple-choice test scores from the pretest to the posttest) was somewhat (albeit nonsignificantly) greater for the full slides group than for the freehand notes group. With a greater sample size (e.g., the sample size of 187 from Kane et al.’s 2017 study that compared note-taking and no-note-taking conditions), it is possible that the hypothesized group differences in posttest performance may emerge.

Another possible reason for the discrepancy between the current results and the Marsh and Sink (2010) study is that there are some key procedural differences between the two studies. For example, Marsh and Sink (2010) used a within-subjects design that had every participant watch two lectures for each condition. They also allowed participants to review their notes from one lecture per condition. In addition, they had some subjects wait 12 min before testing them on the lecture material, while others came back a week later. Thus, Marsh and Sink’s use of the within-subjects design, rather than the between-subjects design, increased their study’s statistical power. Their delayed testing in some conditions also increased the likelihood that the external
storage (or later review) functions of note-taking would have a measurable positive impact on participants’ later test performance.

It is important to note, however, that the present study extended Marsh and Sink’s (2010) study in some important ways: I examined how note-taking styles affect not only posttest performance but also situational interest and in-lecture mind wandering. Although the situational interest results were inconclusive in the current study, I found that taking notes on full slides led to significantly lower rates of task-unrelated mind wandering and higher rates of on-task thoughts than taking freehand notes, as long as participants actually took notes on the printout of the full slides. Given that mind wandering was previously shown to be a significant predictor of learning outcomes (Kane et al., 2017), this finding has great implications for pedagogical approaches.

Task-unrelated mind wandering was significantly reduced in the full slides condition in this study, but how did this occur? Having the slides in front of them enabled participants to pay more attention to the lecture rather than focusing on writing down all information presented by the professor. Being able to attend to and follow the flow of the lecture with less interruptions for extensive verbatim copying of the slides could have plausibly led to the high amount of on-task thoughts that were observed in the full slides group. In a similar vein, participants with printouts of lecture slides may have taken notes explaining the lecture content rather than just copying it. The act of engaging in this deeper form of processing might have led to more frequent on-task thinking, and it could have also had a reductive impact on task-unrelated thinking.

Although the two types of note-taking examined in the current study did not statistically differ from each other in terms of enhancing learning, the modest trend observed suggested that full slides might be a bit more helpful than freehand notes. These results are tentative but
promising, especially when combined with the beneficial effects full slides had on mind wandering. Professors who make their lecture slides available online before class for students to print and utilize when taking notes may be able to enhance their students’ focus in class, with potential benefits to learning as well.

This practical implementation, however, relies entirely on students taking the initiative and printing out the slides before class. Many students might choose to bring their laptop to class and follow along with the lecture slides digitally, which would remove the benefits of manual note-taking (as demonstrated by the changes in my data when the non-note-takers are removed from the full slides group). Using a laptop could also encourage typing of notes, which leads to inferior encoding (Mueller & Oppenheimer, 2014), or media multitasking, which distracts both the multitasker and their peers. One way to avoid these pitfalls would be to simply ban laptops in the classroom, an effective but unpopular decision that many instructors have already made. Instructors should work to encourage full slide note-taking, especially if future studies lend further support to Marsh and Sink’s (2010) findings about how they enhance learning and my findings about their effects on mind wandering.

Limitations and Future Directions

Limitations of the study. It is important to acknowledge that this study has several limitations. The most obvious of these was sample size; because of time constraints, I was only able to collect data from 48 participants. The resulting lack of statistical power may have made it difficult to detect some condition differences, especially the group differences in posttest performance. Another major limitation was the very short delay for note review between the first and second calculation posttests. It was expected that reviewing either type of notes would lead to considerably better performance on the second calculation test, especially for the full slides
group, but the change was modest for both groups. Other studies of note-taking, including the study by Marsh and Sink (2010), included at least one condition in which participants waited for a day or even a whole week between the lecture and the test or between two tests. The benefit of taking notes on the slides as a tool for later review may have been more clearly observed if participants were allowed to review after a longer delay.

My study is also limited by the fact that I did not conduct a detailed analysis of the notes that participants took during the video lecture (beyond checking to ensure that each participant actually took notes). The notes taken by students undoubtedly varied in quality and quantity; analyzing this might have revealed a new individual-level variable influencing learning, situational interest, and/or mind wandering. In a similar vein, the other individual differences that I assessed with questionnaires (e.g., math interest and beliefs) were not analyzed in this study; examining whether (and how) these measures potentially moderate the effect of note-taking on learning and mind wandering could be useful. In particular, it might be interesting to examine the note-taking questionnaire administered in this study. It is possible that participants could have been instructed to use a note-taking style that does not match their personal preference. Participants who took notes in a style they preferred could have had an advantage over those who did not like the style they were assigned to.

**Future directions.** As noted earlier, my plan is to use the data reported here to refine the experiment and conduct a larger-scale version of the present study with the assistance of my colleagues. Our knowledge of the limitations of the current study will allow me to avoid the same pitfalls in the new study, which will have a much larger sample size (at least 100 participants for each group). My plan for the new larger-scale study is to add two new experimental conditions in addition to the two (full slides & freehand notes) compared in the
The current study: (a) no notes and (b) partial slides. Participants in the no notes condition will simply focus on the understanding the lecture content as much as they can without taking any notes. Participants in the partial slides condition will receive the same set of printed out lecture slides as the full slides condition, but some key portions of the slides (e.g. some sentences and numerical equations) will be omitted, requiring them to fill in the blanks as well as take their own notes. With the added conditions and larger sample, the new and improved study will hopefully yield more robust and trustworthy results.

Most previous studies of note-taking strategies, with the exception of Kane et al. (2017), have essentially made a blanket statement about what strategy works best for everyone. However, it is likely that certain note-taking styles would work better for some people than others. Any future study examining the effects of different note-taking styles on learning, mind wandering, or other educationally relevant variables should carefully investigate individual differences factors as potential moderators.

Finally, it would be ideal if this work could eventually be expanded via a classroom study, preferably in a sizeable college undergraduate lecture class. Such a study would increase the external validity of the findings of the current study and much of the preexisting literature, which may convince educators to take the results more seriously for the good of their students.
References


