



Technology in Note Taking and Assessment: The Effects of Congruence on Student Performance

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This study examined the encoding specificity principle in relation to traditional and computer-based note taking and assessment formats in higher education. Students ($N = 79$) took lecture notes either by hand ($n = 40$) or by computer ($n = 39$) and then completed either a computer or a paper-based assessment. When note taking and assessment formats were congruent, students scored significantly higher on the assessment when compared to students whose note taking and assessment format were incongruent. These findings highlight the importance of research on how in-class technology may affect student performance, and suggest that faculty and administrators seek to coordinate and standardize the use of assessment and note taking technologies where possible.

Keywords: Technology; encoding specificity principle; assessment; note taking; education human factors; online education.

INTRODUCTION

As technology use has increased in higher education, students' and instructors' use of computers for taking lecture notes and administering assessments have both become viable, and even advantageous, options. While some students still prefer to take lecture notes by hand using pen and paper, many students are now turning to laptop, tablet, or other forms of portable computers to try to maximize their efficiency in note taking in the classroom (Mogey et al., 2007; Russell & Haney, 1997). Likewise, computer-administered assessments conserve institutional resources associated with printing and photocopying, often allow for greater flexibility in accommodating students with disabilities (Hasselbring & Glaser, 2000), and may reduce the time it takes for instructors to grade and return assessments. Computer-administered assessments also facilitate online education, and some studies have shown that hybrid formats increase the flexibility afforded to students without comprising students' achievement, retention,

or satisfaction in comparison to traditional instruction (e.g., Delialioglu & Yildirim, 2008; Rudland, Schwartz, & Ali, 2011). Finally, researchers argue that computer-based note taking and assessment may better prepare students for workplaces where paper-based memos, filing systems, and written reports are increasingly replaced by email, computer databases, and PowerPoint presentations (Kirkwood & Price, 2011). These and other arguments in support of technology have led some to go so far as to suggest that technology's widespread adoption is 'inevitable' in the field of higher education (Bennett, 2002).

As the use of technology in higher education has increased, education researchers have studied how increasing technology in the classroom has affected student learning, although the implications of these studies for best practices in the classroom have not always been clear. For example, proponents of computers in the classroom have speculated that students' cognitive resources during a lecture are higher when taking notes via computer (Igo, Brunning, & McCrudden, 2005), and that computer-based notes allow students to more easily augment, edit, or share notes as they review material before an assessment (Katayama, Shambaugh, & Doctor, 2005). And in fact, some studies have shown that students perform better on the basis of whether computers or paper and pencil are used for note taking or assessment (e.g., Fiorella & Mayer, 2012; Goldberg, Russel, & Cook, 2003).

However, not all researchers agree that computerized note taking and assessment is advantageous to students. Some researchers argue that assessment and note-taking *fluency*, the rate at which students can record notes or answer examination questions, is more important than whether or not students write by hand or on a computer (Connelly, Gee, & Walsh, 2007; Pevery et al., 2007). For example, students who were fast note takers in the Connelly et al. (2007) study performed better on assessments regardless of the assessment format. Some researchers also contend that computer note taking is inefficient in the sense that typing becomes so automatic that computer-based notes do not form lasting memory traces (Harper, 2008; Larwin, 2012), whereas students who utilize a fluent manual note-taking method maintain an active representation of the information that increases student learning (Piolat et al., 2005). Studies that have examined the qualitative content of student work completed using computers or traditional methods found few differences between computer and handwritten assessments (Escudier, Newton, Cod, Reynolds & Odell, 2011; Igo & Kiewra, 2007; MacCann, Eastment, & Pickering, 2002). Morgan, Brickell, Crook (2002) found that students' hand-written notes were, as expected, less fluent and more incomplete than students who took notes using a computer, but also that students who had taken hand-written notes were more likely to go back and try to make more thoughtful inferences about the main points of a lecture, leading to enhanced learning.

A complicating factor in the interpretation of many of the aforementioned investigations of computer-administered assessments take notes on computers and assessments by hand, or vice versa. Theoretically, this *incongruence* between a student's study and assessment environment is problematic for student learning for several reasons. First,

principles of both *context- and state-dependent memory* have shown that changing students' learning environments across time (e.g., Abernethy, 1940) or differences in mood states between study and assessment (Goodwin et al., 1969) both impair academic performance. Recent research by Landrum (2010) estimates that 68% of his students preferred to take notes using electronic copies of his PowerPoint slides – given that most assessments are not administered in PowerPoint format, context dependent memory would predict that students would remember this information more poorly as a result. Second, the *encoding specificity principle* suggests that congruence between the encoding and retrieval of a memory cue during note and test taking should be kept consistent to maximize student performance (Tulving & Thomson, 1973). In a now-classic illustration of this principle, Godden and Baddeley (1975) asked underwater divers to study a list of words either on dry land or underwater, and then assessed their recall for that list a short time later. Godden and Baddeley (1975) found that divers remembered the lists best when their study and assessment environments were congruent—divers that had studied the words underwater were better at recalling them underwater, and divers who had studied the words on land were better at recalling them on land. In the context of education, the encoding specificity principle suggests in general that students will perform better on assessments when the study and assessment environments are similar. More specifically, the encoding specificity principle suggests the possibility that students who use congruent technology for note taking and assessment will outperform students who use incongruent methods.

The experiment reported here tested the notion that students' performance would be influenced by the congruence or incongruence of the methods the students used to take notes and assessments. Specifically, this study examined whether students' performance on assessments changed depending on whether there was congruence between taking notes and a subsequent assessment either by hand or by computer. We frame the study in relation to theories of context- and state-dependent memory and the encoding specificity principle, and therefore we predicted that students who had congruent note-taking and assessment formats would outperform students whose note-taking and assessment formats were incongruent. We sought to also show that performances on assessments were not a product of the students' attitudes toward the format of the instrument being used, but rather, were a product of the congruency of the instruments alone.

METHOD

Participants

Seventy-nine upper division psychology students (ages 19–45, mean age 22.7 years) at an ethnically diverse university in Los Angeles chose to volunteer after reading an informed consent document that gave an overview of the procedure. The entire experiment, including the informed consent procedure, was also reviewed and approved by the university's internal review board. The participants were enrolled in either a course in cognitive psychology or course in statistical methods for social sciences. Both courses had two laboratory sections of roughly equal size, for a total of four laboratory sections. No student was enrolled in more than one of the four laboratory sections.

Design and Procedure

We employed a 2 (note-taking method: computer or hand) \times 2 (assessment method: computer or hand) between-subjects experimental design to measure how congruent and incongruent note taking and assessment formats affected student learning. This design created four different possible combinations of note-taking and assessment conditions, two of which were congruent and two of which were incongruent: 1) taking notes and assessments by hand (congruent); 2) taking notes and assessments using a computer (congruent); 3) taking notes by hand and assessments using a computer (incongruent); and 4) taking notes using a computer and assessments by hand (incongruent). With the exception of the note taking and assessment formats, all of the students in the study otherwise completed the same procedure. Upon entering the classroom, students received instructions that they were about to participate in a study for course credit. Students assigned to conditions requiring a computer for note taking did so using a blank Microsoft Word document at a desktop workstation in the classroom. Students assigned to take notes by hand were provided blank paper at similar desktop workstations. Next, a brief introduction by the experimenter explained to students that they were about to hear a pre-recorded lecture about writing term papers based on the American Psychological Association's (APA) *Publication Manual* (6th ed., 2010). The experimenter told students that they should take notes on the lecture because they would be quizzed on the material when the lecture was concluded.

After a brief period where students could ask clarifying questions, all students watched and listened to a 15-minute lecture on APA style and formatting. The lecture was pre-recorded by a professional actor whose voice corresponded to slides in a timed Microsoft PowerPoint presentation. The voiceover script contained information that was on the slides as well as elaboration on material that was not on the slides. This was done to try to match the elaborative style of an actual lecture in higher education. The use of a pre-recorded, timed PowerPoint presentation ensured that the students in all four conditions listened to the same lecture.

Following the lecture, the experimenter collected the students' handwritten or typed notes and each student received a quiz containing 20 free-response questions about material covered by the lecture. The quiz format required students to either type or write their short responses depending on the condition they had been assigned to. Students were told that they had 10 minutes to complete the quiz, and all students completed the quiz in that time. After finishing the quiz, students filled out a questionnaire to assess their attitudes toward technology use, attitudes about handwritten notes, and attitudes about school in general. Finally, all students were thanked and debriefed.

Measurement

Quiz Performance. Two experimenters served as redundant quiz graders, each separately grading every participant's quiz responses. Because prior research has suggested that graders can be biased for or against handwritten responses (e.g., Powers, Fowles, Farnum, & Ramsey, 1994), research assistants converted all handwritten responses into typed text prior to grading so that all quiz responses were presented to the graders in the same format. The two graders reviewed the quizzes using a

comprehensive rubric of correct answers that had been developed prior to the experiment. The graders were asked to assign a full point for each correct answer, or a half-point for answers that they judged to be partially correct. After each judge had finished, the scores were compared to one another to ensure that the rubric had been effective at standardizing how quiz answers were scored, and the scores were found to have very high interrater reliability ($r(77) = .95, p < .001$). This high level of reliability suggests that when assigning scores to participants quizzes, there was a high level of agreement as to whether a response warranted a full or half point. Where inconsistencies between graders did happen to exist, the average of the two final scores in the analysis was recorded.

Academic Engagement. Academic motivation was assessed with a five-item scale designed to measure students' effort exerted in school, importance of grades and education, extent of finishing homework on time, and a general enjoyment of school. Each of the five items was anchored by 1 (*strongly disagree*) to 4 (*strongly agree*) scale. The items were averaged to create a mean score for the scale with larger numbers indicating higher academic engagement. Previous research using this scale with a sample of 273 Mexican-origin adolescents in the U.S. found that the scale was reliable (Cronbach's $\alpha = .71$; see Plunkett & Bámaca-Gómez, 2003, for a review). Although the sample used in this study is less than half the sample in which the scale was previously validated, the high levels of face validity and simplicity of the questions contained in the scale (e.g. "In general, I enjoy school.") raises confidence in the reliability of the scale in this instance.

Attitudes Related to Note-Taking Instruments. Attitudes toward note taking in the classroom served as covariates for this analysis. A 19-item questionnaire adopted from a computer use attitude assessment scale (Loyd & Loyd, 1985) measured attitudes toward technology use and hand written notes. The response choices were anchored from 1 (*strongly disagree*) to 4 (*strongly agree*). The items were averaged for a mean score of attitudes towards both handwriting and computer use preference in the classroom separately, with larger numbers indicating a more favorable attitude toward the particular method.

RESULTS

An Analysis of Covariance (ANCOVA) was conducted to determine the differences in the congruency hypothesis. There was no main effect found for starting with a computer to take notes, $F(1, 72) = 0.17, p = .68$. However, an effect of ending with a computer to take the quiz was found, $F(1, 72) = 4.39, p = .04, \eta^2_p = .06$, and this was attributed to the significant difference in word count observed ($t(77) = 7.19, p < .001$, Cohen's $d = 1.66$) between conditions that ended with a computer and those who did not.

As shown in Figure 1, a significant interaction was found that supported the congruency hypothesis, $F(1, 72) = 10.62, p = .002, \eta^2_p = .13$. Groups utilizing congruent methods of note and test taking scored higher on average ($M = 6.39, SD = 3.04$) than their incongruent counterparts ($M = 5.21, SD = 2.77$).

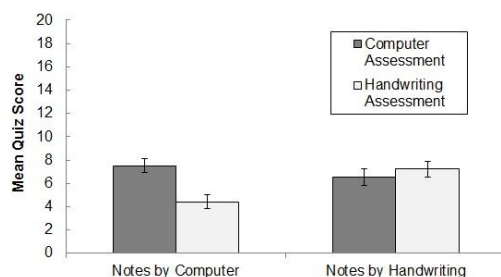


Figure 1. Mean quiz scores for note-taking and testing methods. A significant interaction was found for those who had congruent note-taking and testing methods.

The effects observed from this analysis persisted while controlling for the student's attitudes toward handwriting methods for note taking, $F(1, 72) = 1.39, p = .24$, as well as their attitudes toward computer use for taking notes, $F(1, 72) = 2.76, p = .10$, which were both non-significant predictors of test performance. No significant difference in academic motivation was found between groups ($t(78) = 1.197, p = .24$).

DISCUSSION

The analyses reported here revealed an instance of the encoding specificity principle in the classroom as it relates to student note and test-taking congruence. The data indicate a strong, positive relationship between the congruency of instruments used for note and test taking and performance, whereby performance was best for groups when instruments were congruent regardless of student attitudes about hand-written or computer-based note taking or assessment. Although there was a strong preference indicated in the sample for the use of computers in the classroom, we found that students who took notes and assessments by hand actually outperformed students who took notes by hand but were quizzed via computer. Furthermore, the lack of a significant difference in academic motivation in our sample suggests that the students were working with equal diligence on the quiz across all conditions.

The data reported here indicate that students benefit when congruent mediums are used for note and test taking, and while our study represents only one experiment conducted at one university, we see no reason why similar effects would not extend to other educational environments. We note that incongruencies between note-taking and assessment techniques are on the rise across a broad range of educational institutions. In high schools, the prevalent method of note taking in the classroom is handwriting, but these same students are likely to also own and use a personal computer to complete schoolwork at home (Mogey et al., 2007). In online classes, computers and web pages are providing opportunities to students to learn at a distance, but the style of note taking used by distance learners is generally not addressed. Our point is not to say that the use of technology in higher education is negative; in fact, we believe it to be inevitable. However, we argue that faculty and administrations should not only be cognizant of how

technology affects student learning, but also of how *interactions* between traditional and new methods of learning affect student learning and assessment outcomes.

Interactions between multiple influences are not always easy to detect in education, and therefore our findings may also provide some possible alternative explanations for some of the seemingly inconsistent conclusions noted in the previous research on the advantages and disadvantages of technology in education. For example, the results of studies demonstrating positive (e.g., Goldberg et al., 2003) or negative (e.g., MacCann et al., 2002) effects of computers on student performance may have had more to do with whether the researchers tested a population of students who frequently worked via a computer at home or in class, and less to do with the use of a computer per se. Additional research is clearly required to better understand such interactions. We note that we did not record how familiar or experienced the students in our study were with taking notes by hand or by computer. Would students who have extensive amounts of experience with both methods be able to perform well with incongruent instruments due to a high level of fluency with both methods? Future research regarding note-taking and assessment methods in the classroom should address efficacy levels of instrument use by the student to expand on the boundaries of the encoding specificity principle in the classroom.

Additionally, it is important to note that this study represented only a single trial conducted in a controlled setting, with a modest sample size. Even though the observed effect was relatively strong, evaluating the influence of this principle over the course of an entire semester would further increase the ecological validity of this encoding specificity claim. Additional cognitive and memory components not investigated here may also be affecting the results produced by the students. Researchers may also wish to consider student backgrounds and other sociological variables that were not considered in this study in future research. A brief survey of student technology and handwriting preference was employed, but the interaction of this experience and environment was not considered in depth. Future research on assessment efficacy in the classroom could benefit from fresh perspectives on these topics.

Finally, we point out that the ecological validity of our study may depend on differences in how students typically take notes or are administered assessments among institutions of higher learning. Each university is unique, and the effect observed in this research may also be dependent on different teaching styles, policies, procedures, and available student technology. Therefore, we also suggest that each learning institution consider replicating variations on the research reported here in their own environments. We certainly do not wish to suggest that schools should necessarily spend scarce resources to standardize learning and testing environments, nor that they abandon the use of limited technology when the resources to support congruence in both note taking and assessment are insufficient. However, where possible, it may be valuable for teachers and administrators to be aware of the effects that incongruent study and assessment technologies may be having on student learning, and where possible, decrease incongruence using existing resources. Our hope is that the work reported here, and future work to follow, may provide a new method of maximizing student productivity in the classroom by increasing learning efficiency via congruent technology.

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Turkish Abstract**Not Alma ve Değerlendirmede Teknoloji: Öğrenci Performansında Uyumun Etkileri**

Bu çalışma kodlama özgüllüğü prensibini yükseköğretimde geleneksel ve bilgisayar tabanlı not alma ve değerlendirme formatlarıyla ilişkili olarak incelemiştir. Öğrenciler (N=79) elle (n=40) veya bilgisayarla (n=39) derste not almışlar ve bilgisayarda veya kâğıtta değerlendirme yapmışlardır. Not alma ve değerlendirme formatları aynı olduğunda, öğrenciler not alma ve değerlendirme formatları aynı olmayan öğrencilerle karşılaştırıldığında değerlendirmede kayda değer şekilde daha yüksek not almışlardır. Bu bulgular sınıf içi teknolojinin öğrenci performansını nasıl etkileyebileceği konusunda çalışmanın önemini vurgulamakta ve yöneticilere ve öğretim elemanlarına mümkün olduğu kadar not alma teknolojilerini ve değerlendirmeyi standartlaştırma ve uyum sağlamayı önermektedir.

Anahtar Kelimeler: Teknoloji, Kodlama Özgüllüğü Prensibi, Değerlendirme, Not Alma, Eğitimde İnsan Faktörleri, Online Eğitim

French Abstract**La Technologie en Prise de Notes et en Évaluation: les Effets de la Congruence sur la Performance des Apprenants**

Cette étude a examiné le principe d'encodage spécifique par rapport à la prise de notes traditionnelle, la prise de notes sur ordinateur et les formats d'évaluation dans l'enseignement supérieur. Les apprenants (N=79) ont pris des notes de cours à la main (n=40) ou par ordinateur (n=39). Puis ils ont complété l'évaluation sur ordinateur ou l'évaluation sur papier. Quand la prise de notes et l'évaluation était congruents, les apprenants ont obtenu de meilleurs résultats sur l'évaluation par rapport aux étudiants dont la prise des notes et le formats d'évaluation étaient incongrues. Ces découvertes soulignent l'importance de la recherche sur comment la technologie en classe peut affecter la performance de l'étudiant. Aussi, ils suggèrent que les facultés et les administrateurs cherchent à coordonner et standardiser l'utilisation de l'évaluation et la prise de notes technologies où possible.

Mots Clés: Technologie; Principe D'encodage Spécifique; Evaluation; Prise de Notes; Educations Des Facteurs Humains; Education en Ligne.

Arabic Abstract**التكنولوجيا في تدوين الملاحظات والتقييم: أثر الإسجام على أداء الطلاب**

فحصت هذه الدراسة مبدأ خصوصية الترميز بالنسبة إلى علاقتها في الأسلوب التقليدي و أسلوب الحاسوب في تدوين الملاحظات والتصميم التقييمي في التعليم العالي. قام الطلاب بأخذ الملاحظات عن طريق الكتابة باليد أو عن طريق الكمبيوتر ومن ثم قاموا بإكمال تقييم باستخدام الورق أو باستخدام الكمبيوتر. عندما كان تدوين الملاحظات متطابقاً مع التقييم، سجل الطلاب نتيجة أعلى مقارنة بالطلاب الذين لم تكن تدويناتهم و تقييمهم متطابقاً. أقت هذه النتائج الضوء على أهمية البحث حول إمكانية تأثير التكنولوجيا المستخدمة داخل الغرفة الصفية على أداء الطلاب، وتقترح على الكلية والمسؤولين التوصل إلى تنسيق و توحيد استخدام التقييم و تكنولوجيا تدوين الملاحظات حيثما كان ممكناً استخدامها.