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US AIR FORCE ACADEMY

Rewriting History: Historical Research with the Digital Pen

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The views expressed in this paper are those of the authors and do not necessarily reflect the official policy or position of the Institute of Information Technology Applications, the Department of the Air Force, the Department of Defense, or the US Government.

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ABSTRACT

This study examined the use of technology to enhance the educational experience. The study, which involved 28 Cadets from the United States Air Force Academy, was designed to examine the benefits of using a digital pen for note taking in the classroom. The Department of History offers a Historiography and Methods class (History 330), where cadets research historical data. The cadets plan, research and write a 5000-7000 word term paper. Throughout the semester, each cadet is required to keep a research journal to track notes, data and sources. Normally this is done with pen and paper on note cards or notebooks. For this study, one class was randomly assigned to complete their research using traditional methods (pen and paper) while the other class was given a digital pen to complete their project. Each week, cadets completed a survey rating the ability of the note taking method that was being used. When the final draft was turned in, an end-of-course survey was completed by the class using digital pens. Participation was voluntary and surveys were anonymous. Digital pen participants were enthusiastic initially but attitudes changed with increased use of the pen. The pen itself proved to be cumbersome because it was much larger than a normal pen. Combined with the fact that research notes were taken in a small field journal, note taking was more difficult. The software interface for the pen was a Microsoft product providing a familiar desktop environment. The most significant advantage identified by digital pen users involved the following elements of efficiency: 1) automatic transfer of notes to the computer, 2) writing faster than typing, 3) portability, 4) simplicity. Cadets rated the pen above average for performance and concluded that with a few modifications, the pen could enhance the note taking process. The paper closes with recommendations on these modifications and possible future studies.

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Introduction

The human mind processes information through two separate channels—a verbal channel that processes what is heard and a visual channel that processes what is seen. (Moreno *et al.*, 2003) Each channel processes the incoming information within the limits of its load capacity for working memory. Working memory is the process by which incoming information is held for active access while long term memories are accessed so that the new memories can be linked to previous knowledge and, in turn, become new long term memories. Several factors can influence the load capacity of working memory (e.g. the complexity of the new information, the accessibility of the previous knowledge, and the presence of other, competing information.) Together these factors can be referred to as the “cognitive load” (Soloman n.d.). The greater the cognitive load, the more difficult it is to form well-organized, complete new memories. Some information will be lost (i.e. no long term memory formed), while other information may enter long term memory, but in such a way that later access is inefficient.

Cognitive load can be reduced by practice, so that a task no longer requires as much conscious attention and attention can then be given to other factors that require processing. For example, as children, we held crayons, traced letters and learned to spell during the process of learning to write. For most adults, these processes now require little attention to perform. Similarly, for college-aged students, the pen and paper note-taking process can be handled relatively automatically, reducing the cognitive load. This shift allows the processing channels to process new information more effectively, leading to intensified changes in long-term memory for the new information.

Today’s students are inundated with new technology aimed at enhancing their educational experience. This technology usually requires training before it can benefit the user. In some cases, the training may hinder the learning process because it adds to the cognitive load (Huffaker 2003). The digital pen gives us a chance to study the impact of a new technology using a process already mastered by most adults and that requires minimal training to implement. The most significant advantage identified by our digital pen users involved the following elements of efficiency: 1) automatic transfer of notes to the computer, 2) writing faster than typing, 3) portability, 4) simplicity. If the pen proves to be easy to use, the benefits would occur at virtually no cost to the user.

The digital pen looks and writes like a regular ballpoint pen but operates using an integrated digital camera that takes digital snapshots of the user’s writing and captures this data in the pen’s memory. The user must write on watermarked paper/journal to allow the pen’s camera to map the data that is written. The information is stored in the pen’s memory until it is connected to a computer where the information is uploaded automatically. Data are digitized, organized and shared immediately using common word processing software (Adapx Inc. 2008).

Background

Three note-taking possibilities are generally utilized at the US Air Force Academy: 1) using pen and paper to take notes with no computer interface; 2) typing notes directly into a computer during a lesson, leaving no hard copy; and 3) using a stylus with a Tablet PC, allowing a student to directly input notes into their computer by either typing or writing.

An initial poll of cadets (26) found that most used pen and paper to take notes, except in technical courses where note-taking software was provided. Although all cadets of the 2010 graduating class and later are equipped with a Tablet/stylus PC and handwriting recognition software, most choose to take notes with pen and paper. Many reasons were given, such as poor software functionality, problems with handwriting recognition for the Tablet function of the laptop, and instructors not allowing computers to be used during class.

The digital pen seemed to offer an ideal combination of technology and functionality. Users would be able to capture their notes on paper and upload that information to the computer immediately; eliminating the need to re-type what had been written. The cadets would have their notes on paper and electronically. The need to have an electronic copy has become a priority. Many instructors have become more reliant upon computers, the internet, and the intranet to communicate with cadets, give assignments, and receive the final product.

The goal of this project was to determine the potential benefit of using the digital pen for note-taking in the classroom and to determine if the benefit was significant enough to warrant a change or further analysis of how cadets take notes. The simple nature of the digital pen, akin to writing with a pen on paper, leads us to hypothesize that the added capability to interface with a computer may enhance a person's learning process and/or save time. These findings may serve as a tentative benchmark for further research with the digital pen.

Methodology

The Air Force Academy's Department of History offers a Historiography and Methods class (History 330) where cadets analyze and research historical data. No freshmen enroll in this class; most students are sophomores or juniors. Throughout the semester, each cadet is required to keep a research journal to track notes, data, and sources. With these notes, the cadets plan, research, and write a 5000-7000 word term paper. Normally, cadets compile course notes by using pen and paper on note cards or notebooks.

Four History 330 classes were offered in the spring 2009 semester. Two of the four courses were chosen at random to participate in this study. One class (13 cadets) used pen and paper while the other class (13 cadets) used the digital pen and paper to take notes. Of the 26 cadets who participated in the study, only one senior was without the

Tablet PC. That cadet was provided handwriting recognition software for her computer. Cadets in both groups completed a weekly survey (see Attachment 1), answering questions about the note-taking system used. Once the final draft of the research paper was turned in, digital pen users were given a final survey to get feedback about their note-taking process (see Attachment 2). Answers for both survey groups were anonymous.

The Adapx Penx was used for this research project. The pen has 64MB of memory and stays charged for five to seven days of typical use (2-4 hours a day). It is charged via USB port on the computer. It can hold up to 50 pages of letter-sized paper before download is required. This pen is commonly used in the field for data gathering and, therefore, the pens were larger than standard pens because of their need to be durable. The “Rite in the Rain” All-Weather Digital journal with the special watermarked paper was used for note taking. The journal is a small (4.5” x 7.25”) bound notebook with a hard cover. Microsoft OneNote was used as the interfacing software between the pen and the computer. OneNote relies on Microsoft’s handwriting recognition software (Adapx Inc. 2008).

The cadets were given an hour of training using the pen approximately two weeks into the semester. Most of the time was spent loading the software and ensuring all computers had the required handwriting recognition software. Cadets practiced writing with the digital pens on a test page to ensure all software was functioning properly. The OneNote software provided an excellent tutorial so little time was spent training cadets on the use of OneNote.

Cadets in each class completed a survey each week for three weeks between the seventh and tenth week of the semester. This corresponded to the research time through completion of their first draft. Both classes received three questions regarding their note taking process (see first three questions in Attachment 1). The digital pen surveys had eight additional questions regarding use of the digital pen itself (see questions four through eleven in Attachment 1). An end-of -course survey was completed by the class using the digital pen (see Attachment 2).

During the first part of the semester, special attention was given to the survey feedback to determine if any unforeseen disadvantages were being experienced by cadets using the digital pen. Depending upon the situation, the research project would have been re-evaluated and a positive solution would have been employed to correct any problems. Had this flexibility not existed, the project would have been terminated. No such difficulties were experienced during this study.

Data Analysis and Findings

Survey participation was not mandated and typically, 2-4 cadets would not complete the surveys on a weekly basis due to absence and other duties that kept them from the classroom. Some survey questions were not answered using consistent units across

participants. For example, questions measuring time based on minutes per week were sometime responded to using minutes per day. Units were converted prior to analysis for consistency. A few surveys were only partially filled out and some not filled out at all. Participants were included in the following summaries and analyses even if their data were not complete.

Common Questions across Both Groups

Two of the three common questions (questions 1 and 3), asked about amounts of time cadets spent managing notes and developing their papers. For each cadet, a total amount of time per week was reported and then averaged across the three weeks, and then group averages were formed (see Table 1). In order to determine if there were significant differences in the amount of time spent between the two groups, independent, two-tailed t-tests were performed. Cadets using the digital pen spent significantly less time managing notes compared to non-digital pen users. The group difference for paper development was not significant.

Table 1. Three-week Note Management and Paper Development Averages (Standard Deviations) for the Two Groups

Task	Non-Digital pen users	Digital pen users	t-test comparison
Managing Notes	172 min (89)	79 min (76)	$t(23) = 2.8, p = .01$
Paper Development	186 min (94)	159 min (101)	$t(23) = 0.7, p > .05$

In addition to examining the amount of time spent on task, it is important to understand how cadets take notes. For the class without the digital pens, 10 of 13 cadets took notes with standard pen and paper. Students used binders, notebooks, note cards, and paper to capture their data. One cadet used both the computer and handwritten notes, and two others used their computer to take notes by directly typing information into the computer.

The cadets using the digital pen took notes in the special journal to capture data. They digitized the data leaving both a hard copy and the digitized copy of their notes. In the third week, two cadets stopped using the digital pen. One chose to continue note taking by using a normal pen and paper. The other cadet chose to type notes directly into the computer.

Additional Questions for Users of Digital Pens

In addition to the above questions, digital pen users were asked several questions directly relating to the use of the digital pens. Averages and standard deviations across cadets for each week are summarized in Table 2 for the questions regarding performance ratings (1 being ineffective and 10 being optimal); transfer time, percent of writing recognized, and the amount of time spent correcting the digitized notes. Respondents were also asked

weekly if percent of writing recognized had improved (10 being significant improvement and 1 being no improvement). For both the 1-2 week and 2-3 week survey periods, the modal response was 5, with a small number of cadets stating no improvement at all; no cadets responded higher than a 6. The question regarding improvement in amount of time spent correcting errors and the question asking for the most significant discovery about using the pen are not summarized as they were often left blank by respondents.

Table 2. Averages (Standard Deviations) Regarding Digital Pen Use across the Three Weeks

Variables	Week 1	Week 2	Week 3	Average
Performance Rating	8 (1.7)	7 (2.1)	6 (1.5)	7 (1.3)
Transfer Time	11 (9.3)	22 (23.4)	13 (15.3)	15 (10.3)
Percent Recognized	77 (17.7)	64 (20.1)	71 (22.9)	70 (15.2)
Time Correcting	12 (9.7)	29 (15.7)	22 (12.1)	20 (13.5)

* N for each condition indicated in parentheses in Table 3

It is possible that cadet ratings of pen performance were affected by the difficulties they had transferring the data, or time spent correcting errors in digitized text. Therefore we performed Spearman's Rho correlations to see if there were any systematic relationships between these variables. Note however, there was some restriction of range in all the measured variables and, for most cases; the number of cadets used in the correlations was less than the full group N. Table 3 summarizes the correlation relationships. Only two correlations were significant. By the third week the larger the percentage of handwriting correctly recognized, the higher the performance rating for the pen. Related to this, the larger the percentage of handwriting recognized, the less time spent correcting the digitized text. The correlations for the averages across the three-weeks were not significant, indicating large intra-participant variation across the three time periods.

Table 3. Spearman Correlations (Number of Cadets in Calculation)

Variables	Week 1	Week 2	Week 3	Average
Perf & Trans Time	-.44 (10)	-.22 (8)	-.38 (7)	-.51 (12)
Perf & Perct Recog	.43 (10)	.15 (8)	.82 (7) *	.20 (12)
Perf & Time Corr	-.49 (10)	.80 (6)	-.58 (6)	.23 (12)
Perct Recog & Time Corr	-.33 (10)	.03 (7)	-.92 (6) *	-.13 (12)

*significant at $\alpha = .05$

A final open-ended question on the weekly survey asked the cadets to list the advantages and disadvantages of using the digital pen. These responses were consolidated so that the number of cadets giving similar responses is shown in parentheses next to the item (see Table 4). The most often cited advantage was that writing with a pen is easier / faster than typing. The most often cited disadvantage was the time required to translate and fix errors in digitized text, although general handwriting recognition problems and the bulkiness of the pen were also often cited as disadvantages.

Table 4. Advantages and Disadvantages of using the Digital Pen (number of similar responses)

Advantages	Disadvantages
Writing in notebook easier/faster than typing on computer (7)	Requires time to translate and fix errors (4)
Don't need computer to take notes (3)	Trouble with handwriting recognition (3)
Notes in two different media (2)	Pen is bulky, too big (3)
Stores up to 50 pages without uploading (2)	Special paper required for use (2)
Easy to transfer notes to computer	Takes time to organize on the computer (2)
Data is converted quickly	Notebook too small for easy use (2)
Ease of use of system	More work for the same product
Motivates research	Have to adjust handwriting style
Small and quick	
Adapts to handwriting style	

At the end of the course, the twelve cadets using the digital pen completed a final survey (see attachment 2). The following summary includes questions five through eight as they offered more general feedback regarding the use of the pen. Question five asked for tricks/practices discovered/developed to make using the digital pen easier. Cadets stated that writing more slowly and more clearly (e.g. cursive rather than block print) enhanced the pen's ability to capture data. Spacing their words out and including more words in their writing also seemed to enhance the text recognition process. Question six asked the users to rate the overall performance of the pen using the same 1-10 scale as on the weekly surveys. The average rating was 6.8, with a standard deviation of 2.47. Of interest is that eight of the twelve cadets gave a rating of eight or higher, but two cadets rated it three or lower. Question seven asked for suggestions for future improvement for the manufacturing of the pen which included better handwriting recognition software, smaller pens, and the ability to write on normal sized paper. Cadets were asked in question eight what applications for the digital pen were used/envisioned for coursework outside of that assigned for HIST 330. Suggestions included taking notes for other classes, using the pen when a computer is not available, drawing, sketching and math. Feedback provided by the cadets surveyed offered these important user insights and should be examined for future pen and software improvements.

Conclusions

In our culture, people are continuously looking for new ways to save time and to manage mental processing demands (i.e. cognitive load). The digital pen may be a product that is able to accomplish this with minimal training. In fact, a majority of the cadets in this study typically used pen and paper to take notes in all of their classes, and seventy-five percent of the non-digital pen users choose to take notes with standard pen and paper in the current course. Further, the most common advantage listed for the digital pen was its ease of use and that it was faster than typing on a computer. These results suggest that digital pens can offer a potential solution to the time and cognitive load challenge by combining the use of a familiar, traditional note-taking technique with the technological benefits of digitized text.

The possible benefits of the pen are compelling when considering the different amounts of time spent managing notes. The non-digital pen users spent significantly more time on average managing notes (172 minutes weekly), compared to the digital pen users (79 minutes weekly), although there was a very large amount of variance across cadets within each group. A further investigation of how cadets managed their notes may highlight what processes contribute to this time savings. Many factors could underlie these averages, only some of which directly relate to the pen (e.g. personal liking for the pen and perceived ease of use, cadet personality, outside stressors, and general course motivation). Future research will allow further exploration of the possible time saving feature of the digital pen for note-taking and other tasks that might show even greater time-saving benefits (e.g. field data that must be entered into electronic spreadsheets; rapid sharing of diagrammatic field notes across large distances).

A noted disadvantage of the digital pen was the need to correct errors in the digitized text, which would negatively impact the time-saving benefit of the pen and reduce a person's likelihood to use the pen at all. The current data showed two significant correlations between percent of handwriting recognized and the factors of pen performance and amount of time spent correcting errors. The positive relationship between pen performance and percent of handwriting recognized suggests the importance of advancing handwriting recognition software. Interestingly enough, of the eight disadvantages stated by cadets, three were related to handwriting and text recognition problems, and they were the most frequently listed disadvantages. Cadets experimented with different methods addressing these limitations (e.g. cursive writing, and spacing out text). Some cadets reported that as the volume of data recorded in the journal increased, the program was more able to recognize the handwriting. The negative relationship between percent of text recognized and time spent correcting errors again, suggests the importance of enhanced handwriting recognition software. Understanding the parameters that influence data capture with the pen and incorporating other cadet feedback (e.g. awkwardness due to the large pen size and small notebook paper) will impact the handwriting quality, the number of translation errors, and the desire to use the pen. Ultimately, such improvements could increase the time-saving benefits of this technology.

Recommendations and Future Research

Other digital pen products that already address some of the user issues are available in the market. For example, the Livescribe digital pen is more ergonomically designed and uses standard note-book-sized paper which can be bought or printed on an individual's personal printer. It is also able to record lectures as you are writing, and includes other applications such as calendars, calculators, and basic math (Livescribe 2009).

Unfortunately, it lacks handwriting recognition software, but other programs can be purchased to interface with this pen. The abundance of digital pen options and customized software options for those pens allow the user to explore and test different pen "packages". Future research can explore which of the packages might be better suited for different learning objectives in different types of courses and activities. For example, some digital pens might be more suitable for note-taking while others might be better for collecting data in the field.

Future studies should modify the methodology used in the current study in order to increase our ability to understand the impact of using the digital pens in tasks similar to the current task, as well as generalize to other tasks. More specifically, a larger sample size and an extended data collection time span would provide more conclusive results. Future data should include measures of the impact on student learning in addition to the subjective responses to the usability of the pen itself. Feedback from the instructors should also be included to better evaluate the impact on student learning. Because different people learn in different ways (e.g. visual and verbal), assessing how the use of digital pen interacts with learning styles would increase understanding of who might benefit when from using the pens.

Beyond the classroom, the digital pen offers other potential benefits of interest to the Military and other emergency responders. For example, the integration of digital pen capabilities with wireless and command-and-control features could facilitate the sharing of first-responder field notes with commanders at a distance, enabling better decision-making. There are also many potential everyday uses of the pens that could enhance a user's range of activities due to the continual development of new software applications for the pens. The potential benefits of the pens should be further evaluated to better guide future implementation of the technology.

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Attachment 1

Weekly Survey Questions

1. How much time do you spend managing your notes outside of class? (Total minutes per week.)
2. How do you manage your notes? Please explain your methodology.
3. Besides managing your notes, how much time do you spend developing your paper outside of class (e.g., research, writing outlines, drafts)? (Total minutes per week.)
4. Rate the performance of the pen this week on scale of 1 - 10, with 10 representing optimal performance and 1 as ineffective.
5. How much time is required to transfer your notes from the digital pen to the computer? (Total minutes per week.)
6. Approximately what percent of your handwriting was recognized without error by the handwriting recognition software?
7. Is this an improvement from last week? Rate the improvement on a scale of 1 to 10 (with 10 being significant improvement and 1 being no improvement)
8. Approximately how much time did you spend correcting typographical errors in your digitized notes on the computer? (Total minutes per week.)
9. Is this an improvement from last week? Rate the improvement on a scale of 1 to 10 (with 10 being significant improvement and 1 being no improvement)
10. Please state a minimum of one advantage and one disadvantage that you noticed about using the digital pen system for this most recent academic week.
11. What do you regard as the most significant discovery you made about your digital pen this week.

Attachment 2

End of Study Survey

1. How did you take notes?
2. In light of the completed project (and what you know now), how would you change your note taking process to make your research and writing easier?
3. What characteristics would the perfect note-taker possess?
4. What is your overall opinion of the note-taking process that you used?
5. Did you discover/develop any tricks/practices to make using your digital pen easier?
6. How would you rate the overall performance of the pen on a scale of 1-10 (1 worst, 10 best).
7. What suggestions would you offer to the manufacturers of the pen to help them improve their product?
8. Did you discover any other applications for the digital pen outside of your assigned coursework for HIST 330?
9. Do you envision any piece of technology that could have made your note taking process easier?

About the Institute

The Institute for Information Technology Applications (IITA) was formed in 1998 to provide a means to research and investigate new applications of information technology. The Institute encourages research in education and applications of the technology to Air Force problems that have a policy, management, or military importance. Research grants enhance professional development of researchers by providing opportunities to work on actual problems and to develop a professional network.

IITA coordinates a multidisciplinary approach to research that incorporates a wide variety of skills with cost-effective methods to achieve significant results. Proposals from the military and academic communities may be submitted at any time since awards are made on a rolling basis. Researchers have access to a highly flexible laboratory with broad bandwidth and diverse computing platforms.

To explore multifaceted topics, the Institute hosts single-theme conferences to encourage debate and discussion on issues facing the academic and military components of the nation. More narrowly focused workshops encourage policy discussion and potential solutions. IITA distributes conference proceedings and other publications nation-wide to those interested or affected by the subject matter.