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A Comparative Study of Handwriting and Computer Typing in Note-taking by University Students

Análisis comparativo entre escritura manual y electrónica en la toma de apuntes de estudiantes universitarios

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Abstract
Taking notes is a common strategy among higher education students, and has been found to affect their academic performance. Nowadays, however, the use of computers is replacing the traditional pencil-and-paper methodology. The present study aims to identify the advantages and disadvantages associated with the use of computer (typing) and pencil-and-paper (handwriting) for taking notes by college students. A total of 251 social and health science students participated in the study. Two experimental conditions were chosen: taking notes by hand (n=211), and taking notes by computer (n=40). Those that used computer-written notes performed better on tasks based on reproducing the alphabet, writing sentences, and recognizing words ($p<.05$). However, those using handwritten notes performed better on free recall tasks ($p<.05$). Differences between the two conditions were statistically significant rejecting the hypothesis of equality between groups ($X^2=60.98$; $p<.0001$). In addition, the discriminant analysis confirmed that 77.3% of students were correctly classified by the experimental conditions. Although the computer allowed for greater velocity when taking notes, handwriting enhanced students' grades when performing memory tasks.

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Resumen
La toma de apuntes es una estrategia generalizada del alumnado de Educación Superior y se ha constatado su influencia en el rendimiento académico. El uso del ordenador está desplazando al método tradicional de lápiz y papel. El presente estudio pretende arrojar luz en base a las ventajas y los inconvenientes derivados del uso de uno u otro método en la toma de apuntes en las aulas universitarias. Un total de 251 estudiantes universitarios de ciencias sociales y ciencias de la salud participaron en el estudio. Se plantearon dos condiciones experimentales, toma de notas de forma manual (n=211) y de manera electrónica (n=40). Se hallaron diferencias a favor del grupo que usó el ordenador en las tareas basadas en completar el abecedario, escribir frases y reconocer palabras anotadas previamente (p<.05). Sin embargo, en la tarea de recuerdo libre los resultados reflejaron un mejor desempeño del grupo que tomó notas manualmente (p<.05). Se rechazó la hipótesis de igualdad entre los grupos (X^2=60.98; p<.0001). Además, el análisis discriminante confirmó que el 77,3% de los alumnos fueron clasificados correctamente según su condición experimental. El uso del ordenador resultó muy útil cuando se trataba de anotar datos con rapidez; sin embargo, en las tareas de recuerdo los alumnos de escritura manual obtuvieron mejores puntuaciones que los de escritura electrónica.

Keywords / Palabras clave
Note-taking, handwriting, computer-writing, short-term memory, levels of processing, higher education.
Tomar notas, escritura manual, escritura electrónica, memoria a corto plazo, niveles de procesamiento, educación superior.

1. Introduction

Traditional handwriting is becoming increasingly uncommon as the use of electronic devices increases. Computers are part of the work routines of a large number of professions, and electronic devices are used at all stages of the education cycle as learning tools for academic purposes (to study, to complete assignments, to take classroom notes and to search for information) (Sevillano-García, Quicios-García, & González-García, 2016). Many people record their thoughts by typing in multiple digital settings (blogs, websites, twitter messages, comments on social networks etc.). In fact, it is not uncommon to associate progress and innovation in the teaching and learning process with the use of computerised systems. It seems that in some schools in the USA and Germany, handwriting is no longer part of the curriculum. Students learn the alphabet as it appears on a computer keyboard (Paschek, 2013: 19). In short, handwriting is becoming less common due to the use of computers and smartphones.

Some studies have been very persistent in emphasising the advantages of keyboard typing over handwriting (Rogers & Case-Smith, 2002). This enthusiasm is not new: throughout history, whenever new technological tools have appeared, in one way or another they have moved into the field of education. This was the case, for example, with the now obsolete typewriter, whose educative values were highlighted in several publications of the time (Conard, 1935).

Recently there has been renewed interest in verifying the advantages or disadvantages of writing by hand or with a keyboard. However, results are far from being conclusive (Longcamp, Zerbato-Poudou, & Velay, 2005; Sülzenbrück, Hegele, Rinkenauer, & Heuer, 2011).

Some of these studies have been done with schoolchildren, emphasizing the superiority of handwriting with regard to both the reproduction of letters of the alphabet and the quality of written composition (Berninger, Abbott, Augsburger, & Garcia, 2009; Connelly, Gee, & Walsh, 2007). Others have highlighted the cognitive processes associated with digital writing, such as working memory (Bui & Myerson, 2014; Smoker, Murphy, & Rockwell, 2009), and the «qwerty» effect (Jasmin & Casasanto, 2012). The «qwerty» effect refers to the influence of the position of letters on the keyboard and the meaning of words. What we do know, however, is that taking notes in the classroom facilitates learning. It seems that a positive correlation exists between the amount of classroom notes taken and the amount of information encoded during the class (Bui, Myerson, &

Hale, 2013). This advantage can be explained by the word generation effect (Rabinowitz & Craik, 1986), which indicates that when information is re-elaborated by a student it is more easily remembered than when it is only heard or read. However, quality of notes can be much more important than quantity, and this is consistent with the levels of processing theoretical framework (Craik & Lockhart, 1972). Extensive literature exists about this topic, mainly based on studies using handwriting (see meta-analysis in Kobayashi, 2005). As stated by Bui & al. (2013), it is possible that taking notes in class using digital devices changes the balance between quantity and quality. However, more empirical research on its effects on learning is needed.

Nowadays, considering the expansion of new technologies, the number of students taking notes with a computer or tablet is significantly increasing (Cassany, 2012; Weaver & Nilson, 2005), and the old fashioned pen-and-paper method is decreasing. Some studies encourage the use of electronic devices as aids for learning strategies (Hyden, 2005; Tront, 2007), whereas other researchers argue exactly the opposite claiming that these resources hinder and diminish students' academic performance (Fried, 2008; Kay & Lauricella, 2011; Ragan, Jennings, Massey, & Doolittle, 2014).

Bui & al. (2013) designed several experiments to study the relationship between remembering information and different strategies for taking classroom notes. In one experiment, some participants took notes using laptops and others by hand. Those using computers obtained better results in short-term memory tasks, and the conclusion was that participants who used laptops to take classroom notes wrote more content and recalled more information in free short-term recall tasks. Recently, Beck (2014) tried to replicate and expand the experiment by Bui & al. (2013), but obtained considerably different results. He studied the differences between both short-term and long-term memory tasks. Beck's (2014) study found that the computer was a powerful tool for registering quantitative information. Although university students taking notes with a laptop recorded significantly higher amounts of information, they did not reach significant differences in short-term or long-term memory tasks. However, students taking handwritten notes scored higher in memory tasks.

The lack of conclusive research about the advantages and disadvantages of using different approaches to taking classroom notes in different behavioral areas is noticeable, and it motivated us to study the consequences of several learning processes in higher education. Since it is increasingly common to see university students using computers (or tablets) as writing tools for taking classroom notes, writing assignments, and so on, the aim of our research was to discover the differences in the amount and quality of recalled information according to the notetaking procedure used: traditional handwriting or computer writing. Consequently, particular attention was paid to analysing the effects of information coding and recording methods on memory, in the framework of levels of processing (Cermak & Craik, 2104; Craik & Lockhart, 1972; Lockhart & Craik, 1990). This approach argues that tasks requiring only superficial processing result in lower recall performance than tasks requiring deeper processing. Thus, a hypothesis was formulated stating that the use of a computer, as it allows for a higher speed of notetaking, increases the quantity of classroom notes, but that the lower amount of time that computer-typing students spend processing is detrimental to the memory trace of the information.

2. Method

2.1. Participants

A total of 251 students of the University of Cadiz were evaluated. The students came from social and health science programmes (Psychology n=134; Pre-school Teacher Education programme, n=57; and Primary School Teacher Education programme, n=60). A total of 54 students were men and 197 women, and their average age was 19.2, SD=1.2. They voluntarily participated in the study. All students were Spanish speakers, 9% were left-handed and 91% right-handed. Participants were distributed into two groups: (1) those who regularly took classroom notes using

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computer devices (n=40); and (2) those who regularly took handwritten classroom notes (n=211). The size of the groups reflects the sociological reality of students' routine use of computers (or tablets) when taking classroom notes in the university.

2.2. Material and procedure

Participants completed all tasks in groups of approximately 40 students, using their own laptops or pen and paper. All students received information about his/her participation in a general psychology experiment, but they initially did not receive further explanation about the purpose of the study. The experiment was conducted during normal class time. The students participated voluntarily in the experiment, and they did not receive extra credits or any other academic compensation. At least two researchers were present during the experimental sessions in order to supervise students' activities. Three different tasks were administered:
- Task 1. Repetitive surface processing task: write the letters of the alphabet in alphabetical order as many times as you can in 30 seconds. When the time was up, the examiner stopped the stopwatch and said loudly, «Time's up», and all participants had to stop writing. Participants who were taking classroom notes by hand were provided with a sheet of paper. Students who used computers were asked to open a new word document, save it as a «.doc» file, and then submit it immediately to an e-mail address provided. The specific verbal instruction for this task was: «Write the letters of the alphabet in alphabetical order as many times as possible». Responses scored one point for each alphabet completed in the correct alphabetical order.
- Task 2. Verbal fluency repetitive task: write all the sentences you can in 2 minutes. The first sentence should start with the verb «write» (for handwriting participants) or with the verb «read» (for computer writing participants). Handwriting students received the following instruction: «Please write as many sentences as you can in the time given. The first sentence must start with «write» or, in the case of computer writing students, «to read»; all the others can be anything you like». Each correctly written and consistent sentence scored one point. Sentences considered illegible, misspelt, incorrect and/or inconsistent scored zero.
- Task 3. Memory Task. A list of 35 common words was presented. Words were written in the left column of a piece of paper or on the computer screen. Handwriting participants had to copy them in the right column of the paper, and computer typing participants had to copy the list on the right side of the word document. When the task was finished, all assignments were collected, and a «distracting task» was administered on a new piece of paper or document. The distracting task consisted of solving as many 5-figure multiplications as possible during 5 minutes. Immediately after the distracting task, participants were given 5 minutes to write all the words they could recall from the original word list that they had previously copied on a sheet of paper or on the computer (memory task). Next, a 5 minute break was provided. Finally, a word recognition task was administered, which consisted of a list of 40 words (35 true and 5 false) presented on a sheet of paper or on the computer screen. Participants had to indicate which words corresponded to the stimulus words that had originally been presented.
All tasks were administered in one 40-minute experimental session, during the 2014-15 and 2015-16 academic years. Tasks 1 and 2 were designed based on methodology used by Berninger & al. (2009). Task 3 was designed following methodology used by Smoker & al. (2009). Sessions were held in university classrooms where participants usually received their regular teaching. The lighting and sound conditions were acceptable and the students' collaboration was satisfactory. Reliability between two observers was calculated for all students' responses (reliability average was 95.8%).

3. Results

In order to analyse the differences between students' scores on the three tasks proposed, a statistical descriptive analysis was carried out (table 1).

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Table 1. Descriptive statistics and effect size for different tasks and experimental conditions (Handwriting and Computer writing)				
	Computer writing	Handwriting		
	M (SD)	M (SD)	d	r
Alphabet rate	2.00 (.14)	1.39 (.04)	5.92	.94
Correct sentences	11.10 (.99)	8.23 (.28)	3.94	.89
Incorrect sentences	.52 (.13)	.32 (.04)	2.07	.72
Recognition correct	31.52 (.64)	29.97 (.33)	3.04	.83
Recognition errors	8.47 (.64)	10.71 (.34)	-4.37	-.90
Recall correct	7.22 (.38)	8.71 (.25)	-4.63	-.91
Recall errors	1.40 (.36)	.95 (.11)	1.69	.64

Table 1 shows that the group that worked with a computer wrote the alphabet a greater number of times and achieved a higher number of correct sentences. Moreover, their performance was higher in the recognition task. However, the results were the opposite in the recall task in which participants who were using handwriting obtained better results. The differences between both groups are considerable considering the effect size.

To compare whether the differences between the two groups were statistically significant, a one-way analysis of variance was calculated. In order to do this, the necessary quantitative principles were compared. The Kolmogorov-Smirnov ($p<.05$) comparison indicated that the sample was not normally distributed. Therefore, the ANOVA calculation as a procedure for hypothesis testing was not appropriate. Consequently, we chose the non-parametric Mann Whitney U test to check the null hypothesis: the differences between the two groups in the three tasks were not significant (table 2).

Table 2. Results of the Mann Whitney U test comparing computer writing and handwriting groups		
	Z	p
Alphabet Rate	-4.65	.000*
Correct Sentences	-2.66	.008*
Incorrect Sentences	-1.75	.080
Recognition Correct	-3.16	.002*
Recognition Errors	-2.82	.005*
Recall Correct	-2.31	.021*
Recall Errors	-.89	.371

*p<.05

As can be seen in table 2, the differences between computer writing and handwriting experimental conditions were significant for several tasks. As was expected, students who took classroom notes by computer wrote the alphabet a higher number of times than those who used handwriting ($p<.0001$). In addition, the number of correct sentences written by the students was higher in the computer writing group ($p<.008$). Similarly, the number of incorrect phrases was also higher for this group, although non-significant differences between groups were found ($p>.05$).

With regard to the short-term memory tasks -the recognition and recall tasks- the differences were in function of the experimental conditions (computer writing and handwriting). In the recognition task participants using computer writing scored higher than those using handwriting. Differences were statistically significant for correct answers and errors. Students who used the computer got a higher number of correct responses on recognition tasks ($p<.002$), while handwriting students obtained a statistically significant higher number of errors ($p<.005$).

In the free recall task, the handwriting group achieved a better result. The number of recalled words was higher and statistically more significant for this group than for the computer writing group ($p<0.021$). The handwriting group made fewer errors, but the differences were not statistically significant ($p>.05$).

In addition, a discriminant analysis was performed between the two experimental conditions in order to obtain a mathematical function to classify students according to the discriminating variables, namely their scores in the three tasks. This technique provided a supervised statistical analysis data-vector classification procedure of the two categories (handwriting and computer writing conditions). The analysis was based on a mathematical decision-boundary-hyperplane able to statistically categorise both groups of participants, reducing the probability of misclassification. This distribution was compared to the data obtained in the experiment and a scattering matrix was constructed. This matrix was able to corroborate a diagonal line with the total proportion of correctly-classified participants. Moreover, the extra-diagonal data points represented the false positive and false negative classification process (table 3).

Table 3. Results of discriminant analysis to predict in which experimental conditions (Computer writing and Handwriting) participants were grouped

		Predicted group membership (*)		
		Computer writing	Handwriting	Total
Frequency	Computer writing	33.0	7.0	40
	Handwriting	50.0	161.0	211
%	Computer writing	82.5	17.5	100
	Handwriting	23.7	76.3	100

(*) 77.3% original grouped cases correctly classified.

According to the discriminant analysis, 82.5% of participants from the condition «computer writing» were correctly classified. In addition, 76.3% were classified as belonging to the condition «handwriting». As a result, the data suggested that there was a characteristic pattern addressing the differences in the memory task achievement as a function of the information-recording approach. Because the number of participants in both conditions was dissimilar, it was concluded that a total of 77.3% of the original groups were correctly classified by the discriminant analysis.
At the same time, an equal group contrast using the Wilks' Lambda test statistic was carried out. Then the result was calculated by Chi-square estimation. This multivariate analysis of variance rejected the equality between groups hypothesis (Wilks' Lambda =.780; X^2=60.98; p<0.0001). Consequently, it was concluded that the differences between participants of both experimental conditions were statistically significant, supporting the results shown in table 3.

4. Discussion and conclusions

This paper analyses how taking classroom notes by hand or computer is related to academic performance and immediate recall. Nowadays, digital keyboarding is very common in university classrooms, and there is a huge variety in the way that university students take notes and in what devices they use. Therefore, studies are being carried out to establish which procedures may increase significant information recall, and how students interpret content.
The activity in which higher education students usually spend most of the time during traditional lectures is taking notes (Moin, Magiera, & Zigmond, 2009). According to some studies, this activity involves cognitive processing and offers a higher probability for later recovery of content than when students only pay attention to the lecturer's information without taking notes (Dunlosky, Rawson, Marsh, Nathan & Willingham, 2013). Notetaking is a multidimensional process because the students must pay attention to the explanation, select the relevant information and then translate it into specific phrases (Steimle, Brdiczka, & Mühlhäuser, 2009; Stefanou, Hoffman, & Vielee, 2008). Several higher order cognitive processes are involved in taking classroom notes, such as attention and memory. Considering the memory process, it seems that taking notes facilitates recall of information both qualitatively and quantitatively (Einstein, Morris & Smith, 1985; Fisher & Harris, 1973). This is one of the reasons why taking classroom notes is a very common student activity.
The results of this experiment suggest that the computer is an efficient tool for recording information because students using the computer could write the alphabet a greater number of

times than those writing by hand. This data coincides with Beck's (2014) study, which also found an improvement in the quantitative registration of information. Computer writing users also wrote more sentences than handwriting students did, which could be because these types of surface processing tasks can be enhanced by new technologies. However, the results we found in memory tasks significantly differed from those obtained by Bui & al. (2013), and are coincident with the data found by Beck (2014) in that handwriting students performed statistically significantly better than computer writing participants in the short-term free recall task. However, in the recognition task, computer writing students scored significantly higher results.

How can we explain these results? One possible explanation can be found in the levels of processing framework (Cermak & Craik, 2014; Craik, 2002). Performing a task that involves considering words as objects or sets of letters, as happens in taking classroom notes using computer devices, leads to very superficial processing. This kind of processing consequently affects the encoding and recall of content. The superficial processing may be successful in tasks that do not require deep processing, such as a recognition task involving short-term memory encoding. This explanation would support some results of our experiment. However, when a task involves processing words as semantic units, processing at a deeper level of analysis is required, making it more likely that the words will be remembered and that students will obtain better results in a free recall task. Using the computer as a tool for notetaking involves an initial advantage by increasing the amount of information recorded, as can be seen in the results for Tasks 1 and 2, but this efficiency is lower when the task demands a deeper coding level: this is more efficiently achieved using handwriting. The computer writing achievement is higher in those tasks where the retrieval of information requires a lower level of processing, whereas handwriting students' performance is higher when the task requires a deeper encoding (Mueller & Oppenheimer, 2014; Treisman, 2014). When the information input needs to be «translated» to specialised codes, it leads to the formation of more complex mnemonic representations. For example, listening to a lecture requires a phonological processing, but writing the ideas heard also requires their «translation» into orthographic processing, which can facilitate information recall. The advantage of computer writing is clear as to the amount of notes that can be taken; however, this is not automatically transferred to the quality of the information collected. We can process information more deeply when we can organise it more significantly, and this can lead to longer-term learning (Bui & al., 2013).

There is still extensive room for research in this area, but it is possible that to progress from an automatic repetition of letters or words (Tasks 1 and 2 of our experiment) to writing full semantic and grammatically meaningful sentences (as happens when taking classroom notes in university settings) can be more efficiently done by hand. This way of taking notes increases memory processing because it appears to encourage more complex and stable memory links (Smoker & al., 2009). The Spanish writer Rafael Sánchez Ferlosio said that «in order to struggle against the secondary effects of amphetamine abuse, I spent a lot of time practising calligraphic tasks» (El País Semanal, 25-10-2015: 62). There is no data to support his intuition. However, in the face of current controversy, teachers could be making a mistake in suppressing handwriting from the school curriculum (Clayton, 2015): «Those who are skilled at handwriting will always have an advantage over those that just use computer writing as the only means of written communication. Technological advances could progress backwards and it is not unlikely that handwriting will replace keyboards in the future as the best way to interact with computers» (Clayton, 2015: 65). The current study suggests a research topic, linking the way university students take classroom notes to levels of information processing, and the possibilities of semantically coding the information. The differences that exist between handwriting and computer writing registering procedures should be analysed for tasks that require deeper levels of processing than simple transcription. Similarly, both short-term and long-term recall differences should be assessed.

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