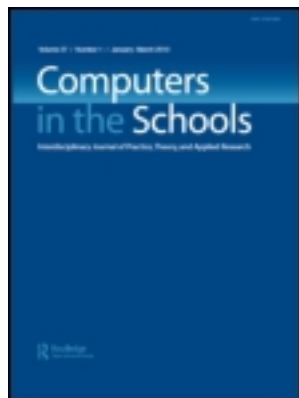


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Publisher: Routledge

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Computers in the Schools

Publication details, including instructions for authors and subscription information:

<http://www.tandfonline.com/loi/wcis20>

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Available online: 14 Sep 2011

To cite this article: Lin Lin & Chris Bigenho (2011): Note-Taking and Memory in Different Media Environments, *Computers in the Schools*, 28:3, 200-216

To link to this article: <http://dx.doi.org/10.1080/07380569.2011.594989>

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Note-Taking and Memory in Different Media Environments

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Through this study the authors investigated undergraduate students' memory recall in three media environments with three note-taking options, following an A x B design with nine experiments. The three environments included no-distraction, auditory-distraction, and auditory-visual-distraction; while the three note-taking options included no-note-taking, taking-notes-on-paper, and taking-notes-on-computer. The results of word recalls from 21 participants showed significant interactions between media environments and note-taking options. In the no-distraction environment, the participants had better word recall taking notes on paper than taking notes on computer or not taking notes. However, in the auditory-visual-distraction environment, the participants had better word recall with no note taking than taking notes on computer or taking notes on paper. The participants' comments provided insights for implications for learning in different media environments.

KEYWORDS *memory recall, media learning environments, note-taking, distraction, dual task*

Learning environments have become increasingly complex with new media and technologies. At least on the surface, there seems to be less distraction in a traditional classroom where students are only surrounded by the blackboard, desks, and textbooks. In comparison, when students start to have access to computers in the classrooms, take classes online, or are engaged in the multimedia user virtual environment (MUVEs), they experience a larger amount of auditory and visual information. These experiences can be

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stimulating and enriching as well as overwhelming and distractive, depending on factors varying from individual learner differences to the scaffolding of learning environments.

Some benefits that scholars have discussed about MUEs include the rich and complex information that is presented and the complex set of interactions that are required to increase participant engagement and cognitive process (Barab, Thomas, Dodge, Carteaux, & Tuzan, 2005; Dede, 2003; Jonassen, 1999; Nelson, Ketelhut, Clarke, Bowman, & Dede, 2005). However, educators have also expressed concerns about these systems because there could be a distracting effect on the learner and the intended learning could be impeded when the multimedia streams do not directly support the learning materials (Nelson & Erlandson, 2008). Similarly, cultural momentum has enabled laptop computers to find their way into the classroom (Maddux & Johnson, 2011). With the advent of netbooks and the iPad, along with the decreasing cost in computers, schools are moving fast in the direction of one-to-one computing in classrooms. As a result, the technologies available to assist learning in classrooms are evolving. For instance, students are increasingly taking notes with their laptops instead of paper-and-pencil notebooks. When they take notes, students may multitask, switching between Word documents, chat windows, and the Internet on their computers. These multitasking activities may be interconnected and create a synergy to facilitate learning; yet they can also compete for attention and distract students from the learning task. There is no correlation between more technologies and better learning. For effective learning to take place, it is necessary to integrate sound multimedia design with the learners' active engagement (Kozma, 1994; Schnotz & Bannert, 2003; Lusk et al., 2009).

The purpose of the authors in this study, therefore, was to understand how the evolving learning environments interact with the cognitive aspects of notetaking for learning. In particular, the authors wanted to know to what extent students might be able to focus and recall information in different media environments, with or without the assistance of different note-taking methods.

PERSPECTIVES AND THEORETICAL FRAMEWORK

In general, the main functions of notetaking are to encode and to store information externally for later review (Di Vesta & Gray, 1972). Notetaking can help increase a learner's attention while listening to a lecture or reading a text, and as a result, help the learner integrate and elaborate upon what he or she hears, sees, or reads with prior knowledge. In addition, notetaking can be used as a review tool to improve recall and retention (Hartley & Davies, 1978).

Research on notetaking has produced mixed results. Some studies show that students improve their recollection of information when taking notes

(Bligh, 2000; Howe, 1970; Johnstone & Su, 1994; Kiewra, DuBois, Christian, & McShane, 1988) while others indicate that there is no difference between taking notes and not taking notes (Kiewra, 1985). Some research shows that students fail to record the most important points when they take notes (Hartley & Cameron, 1967; Howe, 1970; Kiewra, 1985). Yet, in studies where note taking plus review was compared to note taking only and no note taking, the note taking plus review yielded better recall in general (Fisher & Harris, 1973; Richards & Friedman, 1978). In addition, Wittrock (1974, 1979) suggested that note taking is beneficial when learners generate paraphrased notes to incorporate prior knowledge. Novellino (1985) compared notetaking on the computer to notetaking using pencil and paper in a lecture environment, and found that participants who were poor typists did better with recall while taking notes using pencil and paper, and the skilled typists had better recall while taking notes on the computer.

Whether taking notes helps or not probably depends on the cognitive load that the students can handle in the note-taking process (Baddeley, Chincotta, & Adlam, 2001). Note taking depends on the working memory (Baddeley, 2007). When taking notes, the learner needs to maintain a short-term memory in order to acquire, represent, select, and understand the continuous flow of incoming new information, and to update and interact with prior knowledge (Piolat, Olive, & Kellogg, 2005). Katayama and Robin (2000) argued that the primary obstacle of good-quality notes is the amount of cognitive overload experienced by the students.

Cognitive load theory (Sweller, 1988) suggests that a learner carries three forms of cognitive processing load: intrinsic load, extraneous load, and germane load. Intrinsic load is imposed by the nature and level of difficulty of the new information; extraneous load is imposed by the methods and materials in the learning process; and germane load is the mental process of taking new information and integrating it with old information in order for learning to occur. The total cognitive load of the three added together should not exceed the cognitive processing resources of the learner; otherwise, learning shuts down under overload. The intrinsic load tends to be fixed. Yet, the extraneous load and germane load can be manipulated through instructional design and note-taking strategies so as to maximize the cognitive resources available for the learner to process the intrinsic load and to improve learning outcomes (Kirschner, 2002).

Paivio presented a two-channel theory (1986), which models information input to a learner as entering through two channels: a vocal channel (the processing of words) and an imagery channel (the processing of images). Paivio argued that it is easier for a learner to utilize attentive resources on two tasks differing in nature (one a word-task, the other an image-task) than on two similar tasks (two word-tasks or two image-tasks). Computer-based learning environments may incorporate text, video, and pictures to load the learner's input channels in a complementary manner and enrich the

learner's experiences (Clark & Mayer, 2003). Yet, good multimedia design is necessary to minimize the extraneous cognitive load by filling multiple senses and channels of the learner with complementary information without redundancy, confusion, or an over-reliance on working memory (Miller, 1956; Sweller, 1988).

Little research has been done to examine the relationship between working memory capacity, as needed in note-taking, and multimedia learning. Both working memory capacity and multimedia learning are influenced by attentional control (Mayer, 2001). Mayer (2001) described multimedia learning as based on three essential processes requiring attentional control: selecting, organizing, and integrating relevant information. Notetaking requires similar processes of attentional control: The learner must attend to the goal and the available information, select and organize the relevant information, and integrate the working memory and long-term memory to achieve the learning goal. Given the potential overlap of the processes of multimedia learning and working memory required by notetaking, it is necessary to examine the effects of notetaking and learning in different media environments.

RESEARCH PURPOSE AND QUESTIONS

The purpose of this study was to understand how the evolving learning environments equipped with new media and technology were interacting with the cognitive aspects of notetaking for learning. The authors focused on the encoding function of notetaking to examine the participants' working memory or short-term memory. The authors also focused on the distractive aspect of the more complex media environments, knowing that distraction, the opposite of attention control, is a natural part of the learning process. The authors sought to know: (a) what is the role of notetaking in different media environments? (b) does the act of notetaking itself help better memory recall? and (c) to what extent can students focus and recall, with or without notetaking, in different media environments? It is hoped that the results of this study will help provide insights for educational researchers and practitioners when they design multimedia learning environments or integrate new media and technologies in the classrooms.

Adopting the classic experimental method of using word lists for memory recall (Atkinson & Shiffrin, 1971), students' abilities to recall words in three different media environments were investigated: one with no distraction, one with auditory distraction, and one with auditory and visual distraction. Additionally, the roles that note-taking options, including no note taking, taking notes on paper, and taking notes on computer, played in students' abilities to recall the words were examined. The three media environments combined with three note-taking options formed nine experiments. Distraction in the form of additional information unrelated to the information to be

recalled, was intentionally built into the design of the experiment. This was for the purpose of examining students’ attention, memory strategies, and the interactions between the note-taking methods and media environments. In addition, while long-term memory is usually the target for studies, this study focused on short-term memory since short-term memory is an important pathway to long-term memory (Baddeley, 2007). As new media and technologies are increasingly integrated in teaching and learning environments, it is important to examine the interactions between the learners’ individual learning strategies (such as notetaking) and the learning environments (with or without auditory and visual complexities).

METHOD

Design of the Experiments

A total of nine videos were created. Each video was less than two minutes in length and displayed 20 words in sequence, with a single target word in the center of the screen. Each target word was presented for five seconds. Each word was typed in bold, Arial 26 font size, caps, and in black font color against a white background. All the words were of the 8th grade vocabulary level based on the Flesch–Kincaid Grade Level Formula (Kincaid, Fishburne, Rogers, & Chissom 1975). Table 1 provides an example of the nine lists of words.

TABLE 1 Sample List of Target Words Recalled in One of the Nine Experiments

1. HOOF
2. DEVELOP
3. SINK
4. AMAZON
5. BLESSING
6. ENHANCE
7. FLOOR
8. BENCH
9. RESEARCH
10. REASON
11. SOAP
12. CHIMNEY
13. CANDY
14. WINE
15. TOWEL
16. DELICIOUS
17. HARDSHIP
18. BETWEEN
19. DRAIN
20. ELECTRIC

Each video was assigned to one of three media environment conditions: no distraction, auditory distraction, and auditory–visual distraction. The three video clips assigned to the condition of no distraction were silent and simply displayed the target words. The three clips assigned auditory distraction included a different spoken word at the presentation of each target word. Each spoken word was also chosen from the 8th grade vocabularies, and was randomly assigned to the target word so that there was no intended connection between the target word and the spoken word. No further auditory or visual distractions were involved in this condition. The three clips assigned the auditory–visual-distraction condition also included a different spoken word for each target word. In addition, they were layered by two other videos as distractions (Eriksen & Schultz, 1979). The additional two videos were presented in the upper left and lower right corners of the screen. Figure 1 is a screen shot of one of the video clips.

While watching a video, the participants were also assigned one of the three note-taking-task options: no note taking, taking notes on paper, or taking notes on computer. Thus, the study followed an A x B design with three levels for each factor, creating the nine experiments (see Table 2). All participants were to participate in all nine experiments. The two experimental factors for this study were media environments and note-taking options.

Experiment Setting, Participants, and Data Collection

The nine experiments were conducted during nine-week periods with the undergraduate pre-service teachers from two classes of a course entitled Computers in the Classrooms. One class had 23 students and the other had 24 students, for a total of 47 subjects. Both classes were taught in the same

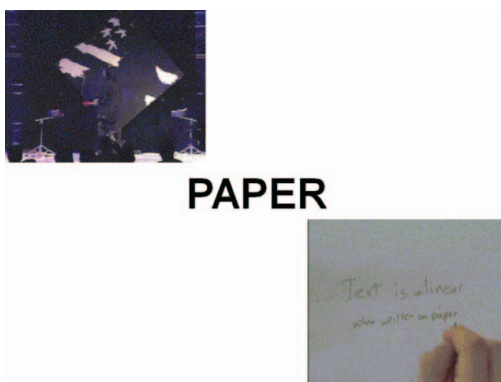


FIGURE 1 A screen shot of a target word in one of the auditory and visual distraction videos/experiments (color figure available online).

TABLE 2 The Design and the Sequence of the Nine Experiments

Sequence of experiments	Note-taking options	Media environments (Less than 2 minutes' videos)
1	1.1: No-note-taking	No distraction: a list of 20 target words presented in sequence; each target word presented for 5 seconds in silence
2	1.2: Taking-notes-on-paper	
3	1.3: Taking-notes-on-computer	
4	2.1: No-note-taking	Auditory distraction: a list of 20 target words presented in sequence; each target word presented for 5 seconds, and accompanied by a different spoken word
5	2.2: Taking-notes-on-paper	
6	2.3: Taking-notes-on-computer	
7	3.1: No-note-taking	Auditory and visual distraction: a list of 20 target words presented in sequence; each target word presented for 5 seconds, accompanied by a different spoken word, and layered with two other videos and music
8	3.2: Taking-notes-on-paper	
9	3.3: Taking-notes-on-computer	

computer classroom, with a PC desktop for each student, and a PC desktop for the instructor. The instructor's desktop was projected on a big screen in the front of the classroom. All nine experiments were conducted by the same researcher, one per week during the semester. Each experiment lasted for approximately 10 minutes, including about two minutes of watching the target words and eight minutes of recalling the words and responding to four to five open-ended questions. All participants watched the videos with the target words on the big screen.

Participants were instructed to memorize as many target words as they could when watching the video. Depending on the experiments, they were asked not to take notes, or to take notes on the pieces of paper provided by the researcher, or to take notes on the desktops in front of them. Whether taking notes on the paper or on the computer, participants were informed that their notes would be taken away immediately after the videos, and that they would not be able to review their notes during the recall. Immediately following the completion of each video, participants were given a simple recall task. They were asked to go to an online survey and type in the words they could recall and respond to the four to five open-ended questions. The open-ended questions included: (a) What was going through your mind when you were watching the words and trying to remember them? (b) What strategies did you use to try to recall the words? (c) Did the notetaking on the paper (or on the computer) help, or did it interfere with your effort to remember the words? Please explain. (d) What would have helped you better remember and recall the target words? (e) Other thoughts or comments.

All 47 students were invited to be in all nine experiments. However, not all students attended the classes every week. As a result, the final data

analysis was based on 21 students who participated in all nine experiments. The average age of the 21 participants was 22 years old, ranging from 19 to 25 years old. There were 2 male students and 19 female students. Although disparate in gender, this difference was parallel to the ratio of the pre-service teacher–student population of the college.

After all data were collected, they were processed in the following manner: First, each participant was assigned a unique participant ID and any information that might identify the participant identity was eliminated. Second, the responses were cleaned so that the recalled words were separated by a comma or space. Third, the recalled words were counted; confabulations were removed. Forth, the cleaned data were uploaded to the Access database for query for complete data sets across all conditions to determine the participant pool for analysis. Fifth, the complete data sets for each condition were exported to SPSS for analysis.

Additionally, open-coding was used to analyze the comments provided by the 21 participants by two researchers independently. NVivo software was used to group the comments into categorical folders, and then the categories were further grouped into themes (Glaser & Strauss, 1967). The themes were labeled and agreed upon between the two researchers before being reported in this article.

RESULTS

The collected data were coded and entered into a relational database, allowing for each participant's results to be tracked and sorted according to the analysis being run. The mean number of correct responses for each experiment can be found in Table 3.

The result indicated that (a) when there was no distraction, the participants performed best while taking notes on paper; second, while taking

TABLE 3 Mean Scores and Standard Deviations of the Number of Correct Answers for 21 Participants Under Three Media Environments and Three Note-Taking Options (A Total of Nine Experiments)

Media environments	Note-taking options	<i>M</i>	<i>SD</i>
No distraction	1.1: No-note-taking	9.33	3.17
	1.2: Taking-notes-on-paper	13.00	3.63
	1.3: Taking-notes-on-computer	9.81	2.89
Auditory distraction	2.1: No-note-taking	9.00	2.97
	2.2: Taking-notes-on-paper	10.81	3.27
	2.3: Taking-notes-on-computer	11.14	4.43
Auditory and visual distraction	3.1: No-note-taking	9.57	4.30
	3.2: Taking-notes-on-paper	8.24	3.39
	3.3: Taking-notes-on-computer	8.95	4.01

notes on the computer, and third, while not taking notes. (b) When in auditory distraction environments, the participants performed best while taking notes on the computer; second, while taking notes on the paper; and third, while not taking notes. (c) When in auditory and visual distraction conditions, participants performed best while not taking notes; second, while taking notes on the computer; and third, while taking notes on the paper.

A two-way ANOVA was run on the experimental variables: media environments and note-taking options. This analysis focused on the number of correct responses recorded by each participant under each of the nine experiments. The result showed a significant main effect of environment, $F(2,40) = 6.71$, $p = .003$. It did not come as a surprise that the more complex the environment became where the target was being presented, the greater the impact on the number of words recalled correctly during the recall task. The effect here was that the recall accuracy decreased as the complexity of the environment increased. However, the main effect of note-taking was not significant to marginally significant, $F(2,40) = 2.71$, $p = .079$. The interaction of media environments and note-taking options was highly significant, $F(4,80) = 9.78$, $p < .001$. Looking more closely at the interaction of media environments and note-taking options, the researchers found that note taking on paper and note taking on computer interacted with the environments while no note taking provided little interaction (See Figure 2).

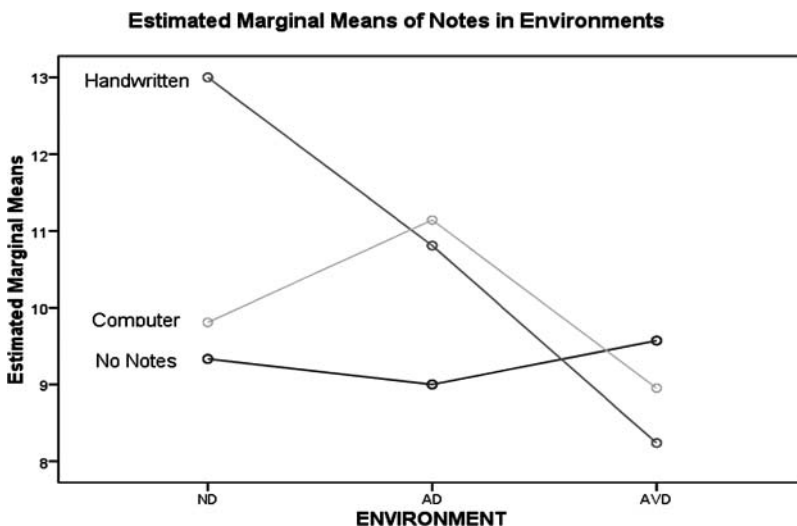


FIGURE 2 The marginal mean scores of participants' word recall (discrete points) in three environments (ND: no distraction; AD: auditory-distraction; AVD: auditory-visual-distraction) and with three different note-taking options (no notes: no-note-taking; computer: taking-notes-on-computer; handwritten: taking-notes-on-paper).

DISCUSSION

The goal of the researchers was to examine the possible existence of note-taking effects on working memory recall in different media environments (i.e., no distraction, auditory distraction, and auditory and visual distraction). The participants' responses to the open-ended questions are used as well as existing literature to try to understand the results.

Participants were asked to inform what strategies they used while watching the videos and during the word recalls. If they took notes on paper or on the computer, they were also asked if the note taking helped or interfered with their effort to remember or recall the words. They were further asked to provide information on what else could have helped them to remember or recall the words or other comments they would like to provide.

Seven themes emerged as the participants described the strategies they used while watching the videos and during the time when they tried to recall the target words. The themes were (a) grouping; chunking; making stories; making sentences; linking the target words; connecting to familiar things; (b) repeating the target words; (c) reviewing the words/notes; (d) using the note-taking process to help remember (e.g., writing the words big; typing multiple times, remembering typing patterns); (e) picturing or visualizing the target words; (f) making sense between the target word and spoken word; and (g) focusing on the target words. Table 4 provides sample statements of these themes.

The strategies that participants used in helping them remember and recall the target words changed in different media environments. Table 5 displays the numbers of participants who indicated using the different strategies in the different experiments.

The strategies that participants described using while watching the videos and during the word recall provide good insights into their performances. For instance, the results showed that participants had significantly better word recall in the experiment when they watched the video in no distraction (ND) and had the opportunity to take notes on the paper (hand-written or TP) than in any other experiments. Looking at the strategies they used while watching the video and recalling the words, it was clear that most participants (18 out of 21 participants) were able to use good cognitive strategies such as chunking, grouping, and making connections of the target words to things familiar in their lives to help them remember and recall the words. However, few participants were able to use such strategies as the environments became more complex or when they did not take notes on the paper (only 5–8 participants out of 21 mentioned using these strategies in other experiments).

Interestingly, taking notes on paper (TP) did not help the participants at all when they watched the target words in the auditory visual distraction (AVD) experiment. Comments from participants showed a scattered picture

TABLE 4 Strategies Used by the Participants, Coupled by Sample Statements from the Participants While Watching the Videos and Recalling the Target Words in the 9 Experiments

Strategies	Sample statements (while watching the video)	Sample statements (during the word recall)
Grouping, chucking, making stories, making sentences, linking the target words, connecting to familiar things	Telling stories with the words for example, my son likes monkeys and Sponge Bob, my daughter is toilet training right now, things like that.	I would look at the new word and then make a sentence out of it and all the words that came before it.
Repeating the target words	I just knew I needed to repeat the words in my head enough to engrave them in my mind temporarily.	I tried to repeat the whole list with each new word added.
Picturing or visualizing the target words	I tried to picture a scene with all these items in the setting	I am trying to visualize the notes I took and the words as they appeared on the screen.
Reviewing the words/notes	I simply copied the words after seeing them on the screen, and quickly looked over them before exiting	I just looked over my notes many times to try to remember them
Focusing on the target words	I tried to focus on the words on the screen instead of the words that were read to us	Just trying to basically focus on the words I'm supposed to remember, not any of the others
Making sense between the target word and spoken word	trying to remember what the guy was saying and if it connected with the words shown on the screen	trying to recall the comparison of what I heard and what I saw so I could recall
Using the note-taking process to help remember (e.g., writing the words big; typing multiple times; remembering typing patterns)	I wrote the words out a lot bigger than normal.	looking at the keyboard and running through the alphabet letter by letter
Having difficulty focusing	I was a little distracted by the pictures, the song and the different words being called out	
Miscellaneous (e.g., no strategies, don't know, not sure)	None	I'm not sure

of strategies they tried to use in AVD + TP. The strategies ranged from trying to group the words (5 participants), to trying to use the note-taking process to help remember the words (7 participants), to trying to focus on the target words (5 participants). During the recall, participants either simply focused on remembering the target words (8 participants) or had no strategies

TABLE 5 Numbers of Participants Who Used Each of the Strategies While Watching the Videos and During the Word Recall in the 9 Experiments

Strategies	Number of participants who used the strategies								
	ND			AD			AVD		
	TN	TP	TC	TN	TP	TC	TN	TP	TC
Grouping, chunking, making stories, making sentences, linking the target words, connecting to familiar things									
while watching the video	8	18	5	7	6	8	5	5	7
<i>during the word recall</i>	11	18	7	7	11	10	11	4	2
Repeating the target words									
while watching the video	7	1	2	1	2	3	3		1
<i>during the word recall</i>	7		5	2	1		3		
Reviewing the words/notes									
while watching the video		1	3		1	1		1	2
<i>during the word recall</i>		1			4	5	1	1	7
Using the note-taking process to help remember (e.g., writing the words big, typing multiple times, remembering typing patterns)									
while watching the video			6		6	5		7	5
<i>during the word recall</i>			2			1			
Picturing or visualizing the target words									
while watching the video	1	1	1						
<i>during the word recall</i>	1		3	2					
Making sense between the target word and spoken word									
while watching the video				2	3	1		1	
<i>during the word recall</i>				5	2	1	1	1	
Focusing on the target words									
while watching the video	2	1	1	4	2	2	7	5	4
<i>during the word recall</i>		1		2	3	4	4	8	7
Having difficulty focusing									
while watching the video				4			6	2	2
<i>during the word recall</i>									
Miscellaneous (e.g., no strategies, don't know, not sure)									
while watching the video	3		3	3	1	1			
<i>during the word recall</i>	2	1	4	3			1	7	5
Total numbers of participants' responses									
while watching the video	21	21	21	21	21	21	21	21	21
<i>during the word recall</i>	21	21	21	21	21	21	21	21	21

Note: ND: no distraction; AD: auditory distraction; ADV: auditory visual distraction; TN: not taking notes; TP: taking notes on paper; TC: taking notes on computer.

(7 participants). To a degree, this explained why the participants performed worst during word recall when taking notes on the paper in the auditory visual distraction experiment.

In fact, in all three auditory visual distraction experiments, participants had difficulty using cognitive strategies to help them remember or recall words. They seemed to be overwhelmed. As shown in Table 5, more participants indicated that they simply focused on remembering the target words, or that they had difficulty focusing, or that they had no strategies in these three experiments than in the other experiments.

In general, participants performed the worst in their word recall in the three auditory–visual-distraction experiments than in the no-distraction or auditory-distraction experiments. Comparing the three auditory–visual-distraction experiments, participants did a little better when they did not take notes at all. Eleven participants indicated that they were able to use some grouping strategies when they did not take notes in the auditory–visual-distraction experiment. It seemed that participants were able to focus better when not having to take notes in the midst of the chaos.

Comparing taking notes on paper to taking notes on computer, taking notes on paper in general received more positive comments, especially in less distractive environments. For instance, all 21 participants positively commented on taking notes on paper in the no distraction environment. Table 6 provides information on the reasons given. As the environments became

TABLE 6 The numbers of participants who made comments regarding taking notes on paper and taking notes on computer in the three media environments

Positive and negative comments about taking notes	The numbers of participants who made the Comments					
	ND		AD		AVD	
	TP	TC	TP	TC	TP	TC
Helped use more senses	2	1	2			
helped attention/focus	1		1			
helped keep eyes on target word						1
helped group and visualize words more easily	8		2	1	2	
helped remember more and longer words	4		2	1	1	
helped reinforce the words	1	1		2	1	1
helped spelling and remember keyboard patterns		2		1		
reviewing notes helped	2	1	2	1		
spoken words helped			3			
taking notes helped (but no reason was provided)	3	3	4	8	3	6
positive comments	21	8	16	14	7	8
Interfered due to attention to spelling		1	2	2		1
more focused on taking notes than remembering		8	1		3	2
less time to study or make up stories				1	1	1
distracted by another task (note-taking)		1		1	1	2
distracted by keys clicking		2				
too many distractions			2		3	3
stored but not remembered		1		1	2	1
taking notes didn't help (but no reason was provided)				1	4	2
negative comments	0	13	5	6	14	12
Taking notes didn't help nor interfere	0			1		1
Total participant responses	21	21	21	21	21	21

Note: ND: no distraction; AD: auditory distraction; ADV: auditory visual distraction; TP: taking notes on paper; TC: taking notes on computer.

more distractive, participants had more critiques on taking notes and felt that taking notes became another distraction rather than assistance. One interesting issue to note is that somehow taking notes on computer made a few participants feel that they would need to spell the words correctly, although no spell check tool was available to remind them of the spelling. This urge to correct wrong spelling was a help for some but an interference for others.

In responding to what would have helped to better remember and recall words, three themes emerged. One theme was about the presentation of the word list, another was regarding the opportunity or time to do something about the words or notes, and the third was about the ability to focus. For instance, participants commented that it would help if the words were in colors or had pictures associated with the words, if there were fewer words on the list or the words appeared on the screen longer, or if the words would appear in alphabetical order or in an order that is easier to make sense of. Several participants indicated that it would help if the same word on the screen was spoken. Further, some participants indicated that it would help to be able to watch the video again, or to have time to study the words, review the notes, or chunk and create stories of the words. Additionally, participants indicated that they wished they could focus better or pay more attention to the words, or there were no distractions, especially in the auditory–visual distraction-experiments. As indicated by a participant, “Having no noise or song in the background would have helped a tremendous amount” (in auditory–visual-distraction and no-note-taking experiment). Another participant commented: “I think I remember and recall best through just looking at the words and not doing anything else” (in the auditory–visual-distraction and note-taking-on-paper experiment). Note taking was not always seen as a help. Depending on the experiments, some participants indicated that taking notes would help (in not-taking-notes experiments), while others indicated that not-taking-notes would help (especially in auditory–visual-distraction experiments). More participants preferred to take notes on the paper than taking notes on the computer.

LIMITATIONS AND FURTHER STUDIES

One limitation of the study was that the classic experiment method rather than the authentic learning environments were used to examine the interaction between note-taking methods and media environments. Obviously, students do not usually need to recall a random list of unrelated words in their studies. Thus, future studies should be conducted with students taking notes on a real lesson or lecture delivered in different media environments. Such a study would be more closely aligned with what students might do in class.

Another limitation was the number of participants who completed all levels of the study. The study started with 47 participants who were to complete nine conditions as part of a repeated measures design. However, only

21 participants completed all nine conditions, decreasing the power of our statistical tests. This decrease in statistical power increased the chance of error in our findings. This might be specifically true in the case of a Type II error where we may have been unable to identify additional interaction effects between method of notetaking and environment. Additionally, this also increased the chance of making a Type I error, resulting in our claim that the computer may have served as a mediator in the interaction between computer-aided notetaking and the environment consisting of audio distractions. As future work in this area is considered, the authors plan to work with designs that should help maintain the number of participants over the duration of the study, thus increasing power and reducing the chance of error. Any repetition of this study should modify the approach to decrease attrition over the course of the study.

The third limitation of the study was related to the target words used in the study. Paivio (1969) found that concrete and high-imagery words resulted in stronger memory than more abstract words and low-imagery words. While the researchers attempted to equalize the lists for number of syllables and familiarity of the words, participants noted in their comments that some of the lists seemed easier to remember. It is possible that some of the words were more visual than others, which may have resulted in higher retention rates. Words such as *delicious* and *research* may be harder to remember than objects that can be easily visualized such as *chimney* and *table*. Additionally, some of the object words may have been more familiar to some participants than others based on cultural and prior personal experiences. The level of significance in this interaction leads the researchers to believe a closer look at word choices is warranted in future studies.

CONCLUSION

To a degree, the results of the study implied that in a non-distractive environment, one should take notes by hand on paper. When the environment is expected to be highly distracting, with both auditory and visual inputs, the best option is not to take notes but focus on the task. Even so, one still only picks up less than 50% of the total information being presented. When there is only auditory distraction, taking notes on the computer can be a preferred option. We believe these findings are sufficient to warrant further studies in this area to validate these results, and to further examine what different note-taking options mean for learning in multimedia environments.

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