

VIDEO COMPREHENSION IN ELEARNING: EFFECTS OF NOTE-TAKING, VIDEO FORMAT, AND WORKING MEMORY

Jonathan Marrujo, Universidad de Buenos Aires

Federico Martín González, Universidad de Buenos Aires

Magalí Martínez, Universidad de Buenos Aires, Consejo Nacional de Investigaciones Científicas y Técnicas, Argentina

Roberto Muiños, Universidad de Buenos Aires

Débora I. Burin, Universidad de Buenos Aires, Consejo Nacional de Investigaciones Científicas y Técnicas, Argentina

ABSTRACT

This study analyzed the contribution of spontaneous note-taking when undergraduates studied expository texts and videos. The study examined whether spontaneous note-taking had any effect on comprehension and if it was different for digital texts, presentation videos, or videos with decorative, irrelevant images. In addition, it explored whether the effects of note-taking on comprehension varied as a function of students working memory capacity. One hundred and twenty college students read expository texts or watched videos with different cognitive loads, answered comprehension questions, and reported solution strategies in an experimental elearning environment. Taking notes significantly improved their performance, and this note-taking efficacy did not vary as a function of presentation format, type of video, or working memory capacity. Overall, in an elearning setting, note-taking for digital text and video online expository comprehension was adopted spontaneously by around 40% of college students, and was equally effective for all formats of instruction. This is relevant for theories of multimedia comprehension, as well as for applied educational settings.

Keywords: *note-taking, comprehension strategy, instructional video, elearning*

PURPOSE

The objective of this study was to analyze the contribution of spontaneous note-taking when undergraduates studied expository texts and videos in both an experimental elearning environment and in their home or habitual place of study (as different from lab or class settings). We examined whether spontaneous note-taking had an effect on comprehension, if this effect was different for digital texts, presentation videos, or videos with decorative, irrelevant images, and

the role of working memory capacity.

LITERATURE REVIEW

An instructional video is a type of multimedia material that includes graphics and images, as well as written text and audio (Mayer, 2021b, Mayer et al., 2020), with expository (explanation of concepts) or procedural (how to do something) content learning objectives. It may show the presence of an instructor (face or full body) and may include animated images or animations. The most common

instructional videos include recorded classes or lectures (with or without graphics or images), voice added to a PowerPoint-style presentation, and picture-in-picture (dual screen or split screen, one showing the content, the other an instructor or an inserted image of the instructor) (Chen & Wu, 2015). Quantitative and qualitative evidence shows that instructional videos are effective and contribute to students' satisfaction with the course (Hew & Lo, 2018; Ruelas & Henderson, 2022). In today's massive presence of online videos, people are likely to have experience with the use of video in general, and for educational purposes in particular. Instructional video should be differentiated from other types of videos in public video apps or social networks, since the main objective for instructional videos is learning (understanding, recall, knowledge, application), and the source of the video is the teacher or an authoritative voice; for the other types of videos, the objectives are influence or popularity (clicks), affective responses (likes), and/or persuasion, and the content processing is assumed to be more superficial (Delgado et al., 2022; Mayer et al., 2020; Welbourne & Grant, 2016).

In this paper, we explored a traditional strategy for the active processing of instructional materials known as note-taking. We analyzed whether, in an experimental elearning platform, college students spontaneously took notes by comparing text and video asynchronous lessons with different cognitive load, and whether taking notes was associated with better comprehension. In addition, we explored whether the effects of note-taking on comprehension varied as a function of students working memory capacity.

Cognitive Theory of Multimedia Learning and Note-taking

The Cognitive Theory of Multimedia Learning (Mayer, 2014, 2021a, 2021b) provides a framework for instructional video research. This theory postulates that the learner, through cognitive processes at different levels, has to actively construct an integrated mental representation of the content that is appropriate to a particular learning task and context. In this framework, people have attentional and working memory channels with limited capacity for visual and auditory processing; instructional material should be designed so as not to overload them (Mayer, 2014, 2021a; Paas & Sweller, 2021; Sweller et al., 2019). The Cognitive

Theory of Multimedia Learning has proposed several principles for multimedia learning materials, based on extensive experimental research (Mayer, 2014, 2021a, 2021b). Among these, the principle of modality postulates that presenting information in a nonredundant way and through several channels can benefit learning and avoid saturating one channel. The theory recommends presenting verbal information auditorily, and images or graphic elements should signal and elaborate coherently what has been said to support the construction of an integrated mental model of the content (Mayer, 2014, 2021a; Reinwein, 2012). The modality principle is accompanied by other principles detailing conditions under which text, audio, images, and graphic elements are most effectively integrated. Video characteristics, such as design, duration, accessibility, and interactive elements, can benefit or hinder learning. For example, a frequent practice in instructional videos is to add decorative but irrelevant images in order to entertain or increase motivation, but this may distract the viewer's attention to these details instead of processing the relevant material and lead to worse comprehension and recall (seductive detail effect; Rey, 2012; Sundararajan, & Adesope, 2020).

The Cognitive Theory of Multimedia Learning also suggests promoting active processing, leading to a deeper elaboration of the material (Mayer, 2021a). One of the activities that students usually learn during formal education is note-taking when reading written texts (Di Vesta and Gray, 1972) or during lectures (Jansen et al., 2017). Note-taking is one of the behaviors classified as comprehension strategies, "forms of procedural knowledge that individuals intentionally and planfully use for the purpose of acquiring, organizing, or elaborating information, as well as for reflecting upon and guiding their own learning, comprehension, or problem solving" (Bråten et al., 2020, p. 275). Notes can help in two ways (Di Vesta and Gray, 1972; Jansen et al., 2017): The activity of note-taking can engage the student in a deeper level of processing (the encoding effect), and notes can serve as an external storage of information for later review and recall (the external storage effect). The beneficial effects of note-taking on coding are well established by Meta-analyses of note-taking interventions (Kobayashi, 2006; Reed et al., 2016) that estimated an effect size of $d = 0.75-0.77$

(Kobayashi, 2006) and $g = 0.54$ (Reed et al., 2016). The effect varied according to prior academic level (a larger effect for low level participants), format (a smaller effect for live lecture, larger for audio and video), and length of material (a larger effect for longer material) (Kobayashi, 2006).

Note-taking in Instructional Videos

More recent studies with videos as the learning material have reported positive, medium-sized effects of note-taking (Wong & Lim, 2023), especially under conditions of low prior knowledge (Kane et al., 2017). Wong and Lim (2023) suggested an attentional explanation for the benefits of note-taking. They found that taking notes by hand from a video lecture enhanced learning relative to taking pictures of the presentation or to a control condition. Moreover, the superiority effect of handwritten notes, in line with the coding hypothesis, occurred despite providing a review opportunity immediately prior to the exam, during which photo-takers and control participants presumably gained the advantage of reviewing an accurate transcript of the lecture slides through their photos or printed material, whereas handwritten note-takers had access to only a fraction of this content because their handwritten notes were limited to capturing only half of the lecture material. Taking handwritten notes would keep students' attention on lectures more effectively and significantly reduce mind wandering compared to taking pictures or no notes at all, which would contribute to greater retention of lecture content. Moreover, the picture-taking and control groups did not differ in their recall performance.

However, Delgado et al. (2022) found no overall effect of note-taking in high school students when comparing text and video. Note-taking only improved the comprehension of participants with low comprehension skills in text format. Video notes included a greater number of important ideas than text notes, but this did not predict comprehension. In a similar vein, List and Ballenger (2019) explored learning strategies by comparing text and video comprehension in college students with system logs, behavioral measures, and self-reports of strategy use with an ad hoc inventory after task completion measures. Notes were allowed to be taken and used for comprehension tasks. In general, comprehension did not differ as a function of presentation format. In terms of strategies,

compared to video, the text format led to greater information accumulation, elaboration, and organization. List and Ballenger also speculated that the videos presented decorative images that may have acted as seductive details, reducing the working memory resources available for processing.

Overall, then, there is mixed evidence on the benefits of note-taking when watching instructional videos that depend on previous knowledge and attentional and working memory demands. Different forms of note-taking were also studied as moderating factors: handwritten notes (e.g., pen and paper), on a laptop or notebook (e.g., a Word document or GoogleDoc), or through specific annotation systems (e.g., note-taking functions in the video software itself). These vary both in the experience people have with the strategy and in task demands, so that note-taking can represent either a useful strategy or additional cognitive load. In this sense, Mueller and Oppenheimer (2014) suggested that a specific form of note-taking, handwritten over note-taking on a laptop, provided the greatest benefit. They found note-taking with pen and paper was superior when learning from a videoconference. This study was followed by a larger scale replication, along with a meta-analysis of similar studies (Urry et al., 2021). In both studies, participants took more notes and included more literal words used by the teacher when using the notebook than writing by hand. However, the superiority of taking notes by hand for conceptual (as opposed to factual) performance as found by Mueller and Oppenheimer was not replicated in the larger scale study, nor was it found in the meta-analysis (Urry et al., 2021). Thus, the benefits of note-taking do not appear to depend on the device but on the cognitive processes afforded by them.

Regarding the use of annotation systems, Lee and List (2019) explored learning strategies by comparing comprehension of texts and videos through the notes and comments learners made by using the track changes function in Microsoft Word for annotating texts and a browser-based annotation tool (VideoAnt) for videos. In general, students used more strategies during text rather than video learning. and these strategies were also "higher level," for selecting important information and self-explanation. There is possibly a detrimental effect when participants do not have prior experience and learning with them that leads to

cognitive overload when their use is requested.

In summary, the evidence is mixed as to whether the presentation format of the instructional material, i.e., text or video, leads to greater note-taking, and whether note-taking is related to learning performance. With respect to the latter point, note-taking could be beneficial as long as it does not overload the working memory capacity. In this regard, Jansen et al. (2017) suggested that participants with better cognitive skills, and specifically working memory capacity, might take better quality notes and thus benefit more from their note-taking. Note-taking induces a greater cognitive load, and note-takers have to divide their cognitive resources between attending to and making sense of the information and the process of note-taking (and potentially organizing and elaborating on their notes). In addition, multimedia video lectures require more processing resources than text, and may induce greater cognitive load (List & Ballenger, 2019).

Present Study

Most of the studies mentioned above were carried out in a controlled laboratory or classroom environments with an instructor guiding and supervising the task, and, in general, with computers provided by the researchers. In contrast, in elearning, students are at home or in their usual place of study with their own computers and resources. They can open other programs or applications while learning, and since there is no direct supervision, they have to self-regulate their own learning session. This puts additional strain on attention and working memory, but, on the other hand, students can self-manage their study and take advantage of their more developed skills and strategies. Therefore, it is of interest to study the spontaneous strategies adopted when reading an expository text or watching an expository video and, in particular, whether note-taking is done spontaneously and whether it leads to better comprehension performance.

The aim of this study was to analyze the contribution of spontaneous note-taking when undergraduates studied expository texts and videos in an experimental elearning environment. It differs from previous studies in that we attempted to explore findings from laboratory and classroom research in an experimental design carried out in a more naturalistic setting. It also differs from

approaches using strategy questionnaires in general, which solicit responses about generic study situations, as in this case the questions about the strategy employed referred to a specific task just completed (Bråten et al., 2020; List & Ballenger, 2019). A sample of first-year undergraduates read expository texts or watched expository videos on an experimental elearning platform, at home or at their usual place of study, to answer comprehension questions, and then they reported what strategies they employed to complete the tasks (whether they took notes or used other strategies). In another face-to-face session, they completed working memory tests. Our analyses of a sample of college students reading texts or watching expository videos in order to answer comprehension questions, performing the task remotely, on an elearning platform, were guided by the following questions:

1. Is spontaneous note-taking mediated by presentation format? Are different spontaneous strategies adopted for text and videos, and for videos with different cognitive loads?
2. Is expository comprehension affected by note-taking?
3. Does the effect of note-taking on comprehension vary as a function of presentation format?
4. Does the effect of note-taking on comprehension vary as a function of working memory capacity?

METHOD

Participants

Two hundred thirty first-year psychology students from a public university in South America were initially enrolled in the study, in exchange for course credit. Two hundred and ten completed all online tasks, and 204 also completed the working memory test (gender: 167 female, 42 male, 1 unreported; age $M = 23.17$, $SD = 6.96$).

IRB Approval

All participants completed an informed consent form, and the project was evaluated and approved by an institutional Ethics Committee, Comité de Conductas Responsables en Investigación at the Facultad de Psicología, Universidad de Buenos

Aires, UBACYT 20020190100077BA.

Materials

Expository Texts and Videos. Two expository texts with low prior knowledge content, based on Wikipedia and other online sources, were created for this sample (*Telescopes in Astronomy* and *Particle Physics*). Each followed the same argument structure: general concept, two more specific concepts, relevant and irrelevant information about each, and a conclusion that tied them together. The word count was 1401 words for *Astronomy*, 1499 for *Physics*. Readability according to Huerta's index, a Spanish adaptation of Flesch's readability index (Fernández Huerta, 1959), was calculated using an automated readability software (<https://legible.es>). The two texts had similar Huerta indexes (*Physics* = 55.82; *Astronomy* = 55.44); both equivalent to the qualitative categories "somewhat difficult" and "preuniversity level." A previous study (Burin et al, 2018) showed that these texts were of low prior knowledge for a sample of similar characteristics.

Both texts were implemented in three formats: digital text (Text), video presentation (Presentation), and video presentation with decorative and dynamic images (Decorative). Both video conditions had the same audio recording of an advanced speech therapy student reading the expository texts. These implementations can be seen in videos demonstrating the task on the Open Science Foundation platform, [<https://osf.io/43spb/>].

Text: Both written expository texts were separated into seven screens, each of which explained a different subtopic and had its own title. In addition, five screens displayed an image (five images in total) to the side or below the text that was decorative but semantically linked to the text. For navigation, participants could use a hierarchical outline of the topics

in a side navigation bar, two links embedded within the text, or linear navigation links at the bottom of the page ("Next"; "Previous"; "Go to questions"). Participants had to click on the "Go to questions" button when they had finished reading and were ready to take the test.

Presentation: Two videos, one for each text, consisting of a slide presentation plus the audio recording described above. Each had seven PowerPoint slides that corresponded to the seven pages of text. Each slide showed the title (same as in Text) and three to five keywords in Arial 24-point font along with the same images as in Text. The keywords appeared synchronized with the audio. The duration of the video was 10 minutes 20 seconds for *Astronomy*, and 10 minutes 26 seconds for *Physics*.

Decorative: Two videos consisting of the same slides plus audio, but with a key difference: the entire screen showed irrelevant, decorative images with an animation effect that changed approximately every 15 seconds, and the keywords appeared in a box in a portion of the screen.

The decorative images were obtained by using some of the terms mentioned in the text (audio) as keywords for an online search, e.g., "nuclear forces" and an image of a nuclear explosion and "optical telescopes are built with mirrors" and an image of mirrors. The images did not contain any words. Unlike the previous two conditions, in which the images were semantically related, few in number ($N = 5$), static, and displayed to one side of the text, in this condition there were more images (one every 15 seconds or so) that appeared dynamically and were displayed centrally. In addition, the images could be associated with a particular word but not one related to the general meaning of the text. The duration of the videos was the same as

Table 1. Digital Reading Strategies Questionnaire Items

Items
Read full text/watch full video, then answered based on what I remembered
Took notes on paper
Opened Word/Notepad document and took notes, or copy-pasted text fragments
Right-clicked and opened text/video in a different tab, or looked at text/video by clicking on Back
Took a screenshot, or picture of text/video with cellphone to have the material to answer
Searched on Google, Wikipedia, or similar
Searched the questions on YouTube or another video platform
Consulted other people through chat, Facebook, Whatsapp, or similar when answering

that of the Presentation condition.

Comprehension Questionnaire. Each text or video was followed by 10 multiple-choice questions of four alternatives in which literal information, bridging or local inferences, integration and elaboration across several paragraphs and sections were evaluated.

Strategies. An adaptation of the *Digital Reading Strategies Questionnaire* (Martínez et al., 2019) was employed. The questionnaire asks to mark the activities performed during the tasks, and for each item, participants had to mark whether they had performed the activity for the first text or video, for the second, for both, or on neither. The questionnaire items are shown in Table 1.

Sample session videos, including the three presentation formats, the Comprehension questions, and the Strategies Questionnaire, are available on the Open Science Foundation platform, [<https://osf.io/43spb/>].

Working Memory. An adapted version of *Wechsler Adult Intelligence Scale's Letter-Number Sequencing* subtest (Wechsler, 2003) for small group assessment was used. Scoring was computed as described in the manual (Wechsler, 2003).

Procedure and Design

Participants received the informed consent form as well as the working memory test during a face-to-face session. They were then assigned an online, remote condition in which they read texts/watched expository videos, followed by the Comprehension Questionnaire and the Strategies Questionnaire.

Each participant read or viewed the two contents in two different formats, one for *Astronomy* and one for *Physics*. An incomplete randomized block design was used due to the length of the expository materials. Each participant was randomly assigned one of the following six combinations: Text / Presentation; Presentation / Text; Text / Decorative; Decorative / Text; Presentation / Decorative; Decorative / Presentation.

Experimental conditions were implemented within six “courses” (each study condition was a course) with Moodle 3.6.2 and hosted in a different domain than the university so as not to be confused with the curricular subjects. Videos were uploaded to YouTube and inserted into the corresponding module of the course or experimental condition. When the participant clicked on the link, the video

was played within the course, or they could open it in a new browser window.

The general instructions recommended spending about an hour on the tasks; however, as in real life elearning, participants could complete the tasks at their own pace, even interrupting and restarting minutes or hours later, on their own computer at home. The only restriction imposed by the platform was that they could not view the comprehension questions before they had read/watched the corresponding video, and they had to complete the previous tasks to answer the Strategy Questionnaire.

Data Analyses

Analyses were conducted with R 3.6.2 (R Core Team, 2019). To test for the effects of strategy, presentation format, and working memory on comprehension, linear mixed models were implemented with lme4 1.1-21 (Bates et al., 2015), lmerTest 3. 1-0 (Kuznetsova et al., 2017), and for descriptives, summary tables and graphs, and contrasts, tidyverse 1.2.1 (Wickham, 2017), psych 1.8.12 (Revelle, 2018), sjPlot 2.7.1 (Lüdtke, 2019), ggeffects 0.14.0 (Lüdtke, 2018), and emmeans v.1 .4.1 (Lenth, 2019).

To analyze the association between strategy and presentation format, a contingency analysis with χ^2 was performed. To test the effects of strategy, presentation format, and working memory, linear mixed models with random intercepts for participants were implemented to address an incomplete block design as well as individual variability (van der Berg, 2021; Winter, 2013). For the analyses, different models were compared with a baseline model without fixed factors (Winter, 2013). A baseline generalized linear mixed model (lmer) was constructed, with Comprehension as the dependent variable and the random intercept for participants, and then compared with successive models with the same structure but including as fixed factors Model 1: Strategy; Model 2: Strategy by Format; and Model 3: Strategy by WM. The models were implemented with the lmer function, fitted by maximum likelihood. The models were followed with post hoc mean comparisons, with Kenward-Roger method for degrees of freedom and Tukey's correction for number of contrasts.

Data were stored at <https://osf.io/9e3au/>, and analytic R code at <https://osf.io/ub3wg/>.

RESULTS

Strategies and Presentation Format

Given the present study's focus on note-taking, the reported solution strategies were categorized as follows: (1) Passive: just read/watch video and remember; (2) Notes: take notes on paper or digitally; (3) Digital: strategies based on digital affordances, such as using a browser navigation functions to access information (right click, Back, History), taking computer screenshots or cell-phone photos, searching for answers on Google or Wikipedia, watching YouTube or additional videos, and asking on social networks. The proportions of overall responses were: 43.81% Passive, 41.90% Notes, and 14.29% Digital.

There was a significant and high association between the strategy adopted for the first and second text / video, percent agreement = 74.3, $\chi^2(4) = 128.33, p < .0001$. Reliability in terms of Cohen's kappa index was $\kappa = .58, 95\% \text{ CI } [.49-.67]$; and when calculated only for those who watched two videos ($N = 71$), percent agreement = 83.1, $\kappa = .72, 95\% \text{ CI } [.58-.86]$.

Table 2 shows the conditional proportion for each strategy adopted by presentation format. Each type of presentation format was approximately similar, and the association between strategy and presentation format was not significant, with a contingency coefficient $C = .062, \chi^2(4) = 1.6438, p = .801$. The proportion of students who took notes did not differ significantly by presentation format: Text vs. Presentation: $\chi^2(1) = 0.348, p = .555$; Text vs. Decorative: $\chi^2(1) = 0.127, p = .722$; Presentation vs. Decorative: $\chi^2(1) = 0.015, p = .903$.

Table 2. Conditional Proportion (Percent) of Strategy Reported, by Presentation Format

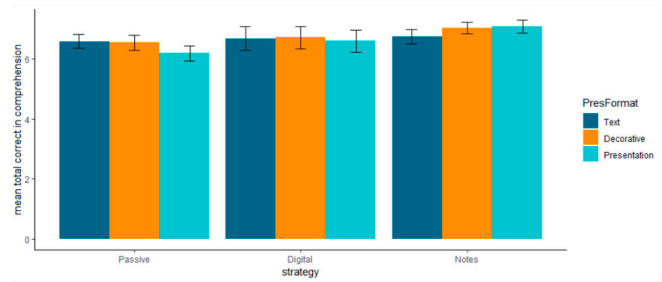
Strategy	Text	Decorative	Presentation
Passive	47.5	43.8	40.1
Notes	39.6	42.4	43.8
Digital	12.9	13.9	16.1

Effects of Strategy, Presentation Format, and Working Memory on Comprehension

The dependent variable, responses to comprehension questions (correct / incorrect), was inspected first. Internal consistency for

comprehension was Cronbach's $\alpha = .65, 95\% \text{ CI } [.58-.72]$. For each participant, a comprehension score was calculated for each Comprehension Questionnaire (10 items for each content) as the sum of correct answers (max score = 10). Figure 1 shows comprehension score (M, SE) as a function of strategy and presentation format.

Figure 1. Comprehension Score (M, SE) by Strategy and Presentation Format



To analyze the effects of the strategy, presentation format, and working memory on comprehension, we made a baseline generalized linear model (lmer function) with Comprehension as dependent variable, and random intercepts for participants was compared with it, resulting in three models: Model 1, a fixed factor for Strategy (Passive, Digital, Notes), Model 2: multiplicative fixed factors for Strategy (Passive, Digital, Notes) and Format (Text, Video Presentation, Video Decorative), and Model 3: multiplicative fixed factors for Strategy (Passive, Digital, Notes) and WM. The contrasts were: for Strategy, treatment contrast with Passive as the reference level; and for Format, we built effects or sum-to-zero custom contrasts (van der Berg, 2021) comparing Text versus Videos, and Video Presentation versus Video Decorative. Working memory was standardized (zWM).

First, we compared the baseline model with Model 1 (Strategy). The deviance difference between the models (Baseline = 1631.3, Model 1 = 1624.3) was significant, $\chi^2(2) = 7.03, p = .029$; and Model 1 had lower AIC and BIC indexes. This showed that the fixed factor (Strategy) had a significant effect on Comprehension. Given that $ICC = 0.41$, the random factor was appropriately included. Estimates from the model were similar to those obtained with paired post hoc mean comparisons from the model, with Kenward-Roger degrees of freedom method and Tukey correction

for number of contrasts. For better clarity, the latter are reported. The estimated comprehension for Passive, $M = 6.42$, $SE = 0.15$, 95% CI [6.13–6.71] was significantly lower than Notes, $M = 6.94$, $SE = 0.15$, 95% CI [6.65–7.24], $t(364) = -2.63$, $p = .024$, but it was not significantly different than Digital, $M = 6.75$, $SE = 0.23$, 95% CI [6.29–7.20], $t(417) = -1.25$, $p = .423$.

In second place, Model 2, with Strategy and Format as fixed factors, assessed their effect and interaction over comprehension. We compared Model 1, Strategy, with Model 2, Strategy by Format. In this case, the deviance difference between the models (Model 1 = 1624.3, Model 2 = 1621) was not significant, $\chi^2(6) = 3.295$, $p = .771$, and Model 2 had higher AIC and BIC indexes. This result implies that including Format did not significantly contribute to modelling comprehension. Marginal R^2 for Model 2 was low, 0.025. Estimates from the model show again simple effect of Strategy as in Model 1, $b_{Notes} = 0.54$, $SE = 0.20$, $t(359) = 2.70$, $p = .007$, but no other significant coefficient.

Then, Model 3, Strategy by zWM, was compared to Model 1 (excluding cases with missing observations for WM). As in the previous case, the deviance difference between the models (Model 1 revised = 1581, Model 3 = 1579.2) was not significant, $\chi^2(3) = 1.843$, $p = .606$, and Model 3 had higher AIC and BIC indexes. This result implies that including zWM did not significantly contribute to comprehension modelling. Marginal R^2 for Model 3 was low, 0.022. Estimates from the model show again simple effect of Strategy as in Model 1, $b_{Notes} = 0.48$, $SE = 0.20$, $t(346) = 2.35$, $p = .019$, but no other coefficient was significant.

DISCUSSION

The aim of this paper was to analyze note-taking in expository comprehension when students had to read text or watch videos, and then answer comprehension questions, in an experimental elearning scenario in which students worked at home with their own resources and at their own pace. The self-reported behavior when reading or watching the video and answering the questions (e.g., strategies) were categorized as Passive, just read or watched video and try to remember; Notes, taking notes on paper or digitally (Urry et al., 2021); or Digital, using strategies based on digital

affordances (e.g., browser navigation, screenshots, online searches). Strategy was consistent in both comprehension tasks, as revealed by significant and medium to large contingency coefficients, which suggests that the questionnaire reliably measured spontaneous strategic comprehension behavior. Overall, around 44% of students just read or watched and proceeded to answer questions, whereas 56% of the sample implemented active comprehension strategies, and of those, around 42% spontaneously took handwritten or digital notes. This result is relevant because it reveals that almost half of college students resort to taking notes, even with other possible resources at hand (e.g., digital strategies) and in relatively low-stakes, remote tasks. Other results are discussed in terms of the research questions.

Is spontaneous note-taking mediated by presentation format?

The proportion of students who adopted a particular strategy did not significantly vary as a function of presentation format, and, specifically, the proportion who took notes did not differ significantly by presentation format. Around 40%–42% of students take notes when studying online materials, be it text or video, and whether the videos are more decorated and contain more distracting images. This result differs from List and Ballenger (2019), who found that text led to greater information accumulation, elaboration, and organization, although in the present study we did not qualitatively analyze notes taken but only the frequency of that behavior. It also differs from Lee and List (2019), who found that students used more strategies during text than video learning, but in their case, note-taking required using the Word comment function and a proprietary annotation function in videos, which may have been less familiar for participants. Our study suggests that when college students can spontaneously employ a known tool for note-taking (e.g., taking notes by hand or in digital format), they adopt this strategy with the same frequency when studying text and videos.

Is expository comprehension affected by note-taking?

Strategy as a factor significantly contributed to comprehension in a model against a baseline of random intercepts for participants, which captured their baseline individual differences, and

also in models including Presentation format and WM as factors. This result implies that strategy contributed to comprehension above and beyond participants' individual differences. Compared to passively reading or watching the videos, taking notes significantly improved performance. This result is in line with previous studies affirming the benefits of note-taking (Kane et al., 2017; Kobayashi, 2006; Urry et al., 2021; Wong & Lim, 2023), and extends them to college students when studying from text and videos in remote elearning. Also, it differs from Delgado et al. (2022), who did not find an overall superiority of note-taking (but did find interactions, to be discussed later). This discrepancy in results might be due to participants' age (high school vs. college), or setting (school vs. remote), or task factors (e.g., text characteristics).

On the other hand, strategies classified as Digital, relying on digital affordances, did not significantly differ either from Notes or from Passive, possibly due to its very large variance. This category comprises many behaviors and fewer students who performed them and thus would need a targeted approach in future studies.

Does the effect of note-taking on comprehension vary as a function of presentation format?

Delgado et al. (2022) found that note-taking only improved secondary students' comprehension with low comprehension skills in text format, but not for video. We did not find interactions of presentation format and strategy on comprehension; these different results, as stated before, could be explained by participants' age, study setting, or task factors.

List and Ballenger (2019) suggested that multimedia materials with decorative but irrelevant seductive details could detract resources needed for content processing, so that note-taking would be less effective under that condition. However, we did not find an interaction of presentation format by strategy on comprehension, and particularly comparing presentation videos with decorative dynamic images videos. Paired with the efficacy of note-taking, this result means that note-taking was equally effective under the three conditions.

Does the effect of note-taking on comprehension vary as a function of working memory capacity?

Jansen et al. (2017) posited that participants with better working memory capacity could take

more or better notes and thus benefit more from note-taking. This line of thinking is also present in List and Ballenger's (2019) multimedia cognitive load hypothesis. However, counter to these suggestions, we did not find an interaction between working memory capacity and strategy on comprehension. Together with the general efficacy of note-taking, this result means that note-taking benefited equally all participants regardless of their working memory capacity. In this regard, it should be noted that strategy adoption was spontaneous, so that it may be the case that students implemented the note-taking strategy because they had experience with it or knew how to perform it, which is different from intervention studies, or studies where note-taking is constrained by the researchers' design, as for example the annotation systems employed in Lee and List (2019).

LIMITATIONS AND FUTURE RESEARCH

As for the limitations of this study, it should be noted that the strategies were self-reported. Although these self-reports referred to behavior on a particular task shortly after completing that task, which has been shown to have high validity (Bråten et al., 2020), future research could obtain concurrent behavioral measures, such as time on task or eye-fixation movements, which would require a lab setting. In this vein, future research could examine these tasks in the lab to establish whether there are differences with this remote implementation.

STRENGTHS AND CONCLUSION

Overall, this study showed that in an elearning setting, note-taking for digital text and video online expository comprehension is adopted spontaneously by around 40% of college students and is equally effective for all formats of instruction. This result is relevant for theories of multimedia comprehension and for applied educational settings.

ACKNOWLEDGMENTS

This study was supported by UBACYT 20020190100077BA and PIDAE_2020_52 grants.

References

- Bates, D., Machler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed effects models using lme4. *Journal of Statistical Software*, 67, 1–48. <https://doi.org/10.18637/jss.v067.i01>
- Bråten, I., Braasch, J. L. G., & Salmerón, L. (2020). Reading multiple and non-traditional texts. *Handbook of reading research, Volume V*, 79–98. <https://doi.org/10.4324/9781315676302-5>
- Burin, D.I., Irrazabal, N., Injoque-Ricle, I., Saux, G., & Barreyro, J. P. (2018). Self-reported Internet skills, previous knowledge and working memory in text comprehension in E-learning. *International Journal of Educational Technology in Higher Education* 15, 18. <https://doi.org/10.1186/s41239-018-0099-9>
- Chen, C. M., & Wu, C. H. (2015). Effects of different video lecture types on sustained attention, emotion, cognitive load, and learning performance. *Computers & Education*, 80, 108–121. <https://doi.org/10.1016/j.compedu.2014.08.015>
- Delgado, P., Anmarkrud, Ø., Avila, V., Altamura, L., Chireac, S., Pérez, A., & Salmerón, L. (2022). Learning from text and video blogs: Comprehension effects on secondary school students. *Education and Information Technologies*, 27, 5249–5275. <https://doi.org/10.1007/s10639-021-10819-2>
- Di Vesta, F. J., & Gray, G. S. (1972). Listening and note-taking. *Journal of Educational Psychology*, 63(1), 8–14. <https://doi.org/10.1037/h0032243>
- Fernández Huerta, J. (1959). *Medidas sencillas de lecturabilidad*. *Consigna*, 214, 29–32.
- Hew, K. F., & Lo, C. K. (2018). Flipped classroom improves student learning in health professions education: A meta-analysis. *BMC Medical Education*, 18, 38. <https://doi.org/10.1186/s12909-018-1144-z>
- Jansen, R. S., Lakens, D., & IJsselsteijn, W. A. (2017). An integrative review of the cognitive costs and benefits of note-taking. *Educational Research Review*, 22, 223–233. <https://doi.org/10.1016/j.edurev.2017.10.001>
- Kane, M. J., Smeekens, B. A., Von Bastian, C. C., Lurquin, J. H., Carruth, N. P., & Miyake, A. (2017). A combined experimental and individual-differences investigation into mind wandering during a video lecture. *Journal of Experimental Psychology: General*, 146(11), 1649–1674. <https://doi.org/10.1037/xge0000362>
- Kobayashi, K. (2006). Combined effects of note-taking and reviewing on learning and the enhancement through interventions: A meta-analytic review. *Educational Psychology*, 26(3), 459–477. <https://doi.org/10.1080/01443410500342070>
- Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2017). lmerTest package: Tests in linear mixed effects models. *Journal of Statistical Software*, 82(13), 1–26. <https://doi.org/10.18637/jss.v082.i13>
- Lee, H. Y., & List, A. (2019). Processing of texts and videos: A strategy-focused analysis. *Journal of Computer Assisted Learning*, 35(2), 268–282. <https://doi.org/10.1111/jcal.12328>
- Lenth, R. (2019). Emmeans: Estimated marginal means, aka least-squares means. R package version 1.4.1. <https://CRAN.Rproject.org/package=emmeans>
- List, A., & Ballenger, E. E. (2019). Comprehension across mediums: The case of text and video. *Journal of Computing in Higher Education*, 31(3), 514–535. <https://doi.org/10.1007/s12528-018-09204-9>
- Lüdecke, D. (2018). Ggeffects: Tidy data frames of marginal effects from regression models. *Journal of Open Source Software*, 3(26), 772. <https://doi.org/10.21105/joss.00772>
- Lüdecke, D. (2019). sjPlot: Data visualization for statistics in social science. R package version 2.7. 1.
- Martínez, M., Marrujo, J., Perillo, M., González, F. M., & Burin, D. (2019). Reading comprehension in e-Learning: support strategies and working memory. *Ocnos*, 18 (2), 31-43. https://doi.org/10.18239/ocnos_2019.18.2.1988
- Mayer, R. E. (2014). Cognitive theory of multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 43–71). Cambridge University Press. <https://doi.org/10.1017/CBO9781139547369.005>
- Mayer, R. (2021a). Cognitive theory of multimedia learning. In R. E. Mayer & L. Fiorella (Eds.) *The Cambridge handbook of multimedia learning* (3rd. ed., pp. 57–72). Cambridge University Press. <https://doi.org/10.1017/9781108894333.008>
- Mayer, R. E. (2021b). Evidence-based principles for how to design effective instructional videos. *Journal of Applied Research in Memory and Cognition*, 10(2), 229–240. <https://doi.org/10.1016/j.jarmac.2021.03.007>
- Mayer, R. E., Fiorella, L., & Stull, A. (2020). Five ways to increase the effectiveness of instructional video. *Educational Technology Research and Development*, 68(3), 837–852. <https://doi.org/10.1007/s11423-020-09749-6>
- Mueller, P. A., & Oppenheimer, D. M. (2014). The pen is mightier than the keyboard: Advantages of longhand over laptop note-taking. *Psychological Science*, 25(6), 1159–1168. <https://doi.org/10.1177/0956797614524581>
- Paas, F., & Sweller, J., (2021). Implications of cognitive load theory for multimedia learning. *Cambridge handbook of multimedia learning* (3rd ed., pp.73–81). Cambridge University Press. <http://doi.org/10.1017/9781108894333.009>
- R Core Team. (2019). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from <https://www.R-project.org/>

- Reed, D. K., Rimel, H., & Hallett, A. (2016). Note-taking interventions for college students: A synthesis and meta-analysis of the literature. *Journal of Research on Educational Effectiveness*, 9(3), 307–333. <http://dx.doi.org/10.1080/19345747.2015.1105894>
- Reinwein, J. (2012). Does the modality effect exist? And if so, which modality effect? *Journal of Psycholinguistic Research*, 41(1), 1–32. <https://doi.org/10.1007/s10936-011-9180-4>
- Revelle, W. (2018). Psych: Procedures for personality and psychological research. R package version = 1.8.12. Illinois: Evanston. <https://CRAN.R-project.org/package=psych>
- Rey, G. D. (2012). A review of research and a meta-analysis of the seductive detail effect. *Educational Research Review*, 7(3), 216–237. <https://doi.org/10.1016/j.edurev.2012.05.003>
- Ruelas, D. M., & Henderson, D. (2022). A comparison study on the utilization of instructional videos in a health professions online graduate program. *Journal of Educators Online*, 19(1). <https://doi.org/10.9743/JEO.2022.19.1.7>
- Sundararajan, N., & Adesope, O. (2020). Keep it coherent: A meta-analysis of the seductive details effect. *Educational Psychology Review*, 32(3), 707–734. <https://doi.org/10.1007/s10648-020-09522-4>
- Sweller, J., van Merriënboer, J. J., & Paas, F. (2019). Cognitive architecture and instructional design: 20 years later. *Educational Psychology Review*, 31(2), 261–292. <https://doi.org/10.1007/s10648-019-09465-5>
- Urry, H. L., Crittle, C. S., Floerke, V. A., Leonard, M. Z., Perry III, C. S., Akdilek, N., Albert, E. R., Block, A. J., Bollinger, C. A., Bowers, E. M., Brody, R. S., Burk, K. C., Burnstein, A., Chan, A. K., Chan, P. C., Chang, L. J., Chen, E., Chiarawongse, C. P., Chin, G., ... Zarrow, J. E. (2021). Don't ditch the laptop just yet: A direct replication of Mueller and Oppenheimer's (2014) study 1 plus mini meta-analyses across similar studies. *Psychological Science*, 32(3), 326–339. <https://doi.org/10.1177/0956797620965541>
- van den Berg, S. M. (2021). Analysing data using linear models (5th ed.). University of Twente. https://ris.utwente.nl/ws/portalfiles/portal/253344321/Analysing_data_using_linear_models_5th_Ed_January_2021.pdf
- Wechsler, D. (2003). WAIS III: Test de Inteligencia para Adultos. Buenos Aires, AR: Paidós
- Welbourne, D. J., & Grant, W. J. (2016). Science communication on YouTube: Factors that affect channel and video popularity. *Public Understanding of Science*, 25(6), 706–718. <https://doi.org/10.1177/0963662515572068>
- Wickham, H. (2017). Tidyverse: Easily install and load the 'tidyverse'. R package version 1.2.1. <https://CRAN.R-project.org/package=tidyverse>
- Winter, B. (2013). Linear models and linear mixed effects models in R with linguistic applications. arXiv:1308.5499. <http://arxiv.org/pdf/1308.5499.pdf>
- Wong, S. S. H., & Lim, S. W. H. (2023). Take notes, not photos: Mind-wandering mediates the impact of note-taking strategies on video-recorded lecture learning performance. *Journal of Experimental Psychology: Applied*, 29(1), 124–135. <https://doi.org/10.1037/xap0000375>