Video Tutorials Improve Students' Ability to Recover from Errors

Completed Research

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Abstract

This experiment compared three forms of tutorials: text, video, and segmented videos. It asked participants to follow along with a step-by-step Excel conditional formatting tutorial, and then to transfer this knowledge to a new problem. Participants assigned to the text tutorial were much slower than those assigned the video tutorials. This performance difference was mostly due to the difficulty text participants had in detecting and recovering from errors. Error detection and recovery may explain performance differences found in earlier studies comparing text and video tutorials. Participants reported no difference in cognitive load between the three instructional formats. But, those with low pre-existing Excel skills reported higher cognitive load and made more errors on the knowledge transfer task. This study also found that self-reported Excel competency is only weakly correlated with actual performance on an Excel assessment.

Keywords

Video Tutorials, Cognitive Load, Procedural Learning, Excel Training

Introduction

There is increasing research on video tutorials and their effects (Giannakos 2013; Kilinç et al. 2017). This interest is partially driven by the use of videos in recent educational innovations, such as Moocs and flipped classrooms. It is also prompted by students, as they strongly prefer videos over text (DeVaney 2009; Gillie et al. 2016). While interest in videos is increasing, studies comparing their effectiveness to text have had mixed results (Ainsworth 2006).

This experiment compared the effectiveness of text and video instruction while learning about software. Software processes can be difficult to learn, as they typically involve following a series of steps. Learners must keep track of the overall process, as well as deal with changing screens.

This project took an experimental approach. It controlled for learner pre-experiment ability, as well as measuring cognitive load. Participants were randomly assigned to three experimental conditions: text, video, and segmented video (where the video automatically paused after each major step). Each tutorial provided a brief overview, asked participants to follow along with a step-by-step process, and then required them to transfer their knowledge of the feature to a new scenario.

The objectives of this study are to:

- Understand the impact of instructional format on learning
- Identify underlying variables that explain the impact of instructional format on learning

Literature Review

When finding relevant literature, a significant issue is that not all studies examine the same type of knowledge. For example, the ACT-R learning theory differentiates between procedural and conceptual knowledge (Anderson and Schunn 2000). While there are empirical studies evaluating conceptual knowledge videos, fewer are available for procedural information (Höffler et al. 2007).

Studies comparing text and video tutorials show inconsistent outcomes (Meij and Meij 2014). There are a variety of potential reasons, such as videos not using both audio and video modalities, not engaging the user in active processing, or limiting accessibility (Meij and Meij 2014). Beyond video design features, two experiments finding text superior to videos also suggest two further important variables.

The first study showed students how to look up articles in ERIC (an online database) (Mestre 2012). However, the experimenters did not require them to completely review the video or text first. As a result, students tried to complete the process on their own, and then referred to the material for reference. They reported frustration with looking up specific steps in the videos. The difficulty of using a video for reference is consistently found in other articles as well (Alexander 2013; Käfer et al. 2017). Text appears to be much easier for students to quickly scan through.

The second study located was a master's thesis reporting on training for production workers (Scheurwater 2017). The text and video tutorials resulted in equivalent learning, but the video took longer for participants to complete. This raises the issue of expertise as an important moderating variable. More expert users (such as users learning about the latest version of a process they already know) may be able to read faster than a speaker in a video can talk.

The tutorial topics do not appear to be an important predictor of success. For example, some experiments found mixed or neutral results when teaching Word (Alexander 2013), SPSS (Brar and van der Meij 2017), and Excel (Worlitz et al. 2016). But other studies found a positive effect for video with SPSS (Lloyd and Robertson 2012) and Word (Meij and Meij 2014).

Some studies finding positive effects for videos have carefully controlled for video design. One study using this approach showed that videos result in improved performance, as well as self-efficacy, mood, and flow (Meij and Meij 2015). A similar study also showed that video outperformed text (Meij and Meij 2014).

The inconsistent results raise the need for further study. They also indicate that it is difficult to disentangle the effect of video v. text against discipline, topic, and audience. The only consistent findings are that it is easier to look up material in text, and that expertise may be a moderating variable. Careful design of video and text instruction is key in supporting learners.

Learning Theory

Video and text design relies upon learning theory. The most relevant theory for video is the multimedia theory of information processing. Multimedia theory builds on the concept that auditory and visual input are processed in different parts of the brain (Mayer 2005a). It proposes that people learn better when coordinated pictorial and verbal information is presented (Mayer 2001, 2005b). Unfortunately, this additional information can lead to overload (Paas et al. 2008).

Since it is easy to overload leaners, measuring participant effort during the learning process is key. A well-validated theory for this task is Cognitive Load Theory (Leppink et al. 2015). It proposes that there are three elements that influence difficulty. Intrinsic load is the material's inherent difficulty and is increased by element interactivity. Extraneous load is generated by the material's presentation, such as separating related material in time or spatially. Germane load are resources dedicated to dealing with intrinsic load, but may not be additive to the other two types (Leppink et al. 2014)

Many different things can increase extraneous cognitive load. For example, one challenge of moving from text to videos is that learners lose control over the pace of instruction. Called the "Transient Information Effect," it results in information being presented too fast enable processing (Mayer and Moreno 2003).

One technique developed to reduce cognitive load is segmentation. Segmenting reveals the underlying structure of a topic by breaking it into parts (Spanjers et al. 2010). Segmentation lowers a learner's cognitive load and increases learning (Hassanabadi et al. 2011). Segmentation's effect is more prevalent for more difficult and high element interactivity problems (Hasler et al. 2007). Unfortunately, there is evidence for an expertise reversal effect with segmentation, where breaking content into parts hurts experts (Khacharem et al. 2013).

Guidelines for Video

A set of eight best practices have been developed and tested in experiments finding a positive effect when replacing text with videos (van der Meij and van der Meij 2013). The following list provides an abbreviated summary.

1. Use an appropriate and clear title
2. Use animations with voice-over narration.
3. Enable interactivity through careful pacing and enable users to control the video
4. Preview the task in the conversational style and showing use in context
5. Provide procedural rather than conceptual information
6. Keep tasks clear and simple, helping users build a plan, see the interconnection between actions and system reactions, and use highlighting to guide attention.
7. Keep videos short
8. Strengthen demonstrations with practice.

These guidelines are similar to those in the minimalist manual approaches (Carroll and Van der Meij 1995). Minimalist manuals have been shown to outperform traditional manual (Ginns et al. 2006). Minimal manuals follow these four principles:

1. Action oriented approach
2. Anchor the tool in the task domain
3. Support error recovery and recognition
4. Support reading to do, study, and locate.

Beyond these four principles, the minimal manual approach has significant emphasis on supporting error recovery. This has been shown to lead to a moderate positive effect size (d=0.59) on learning (Ginns et al. 2006).

Experimental Design

This experiment compared the effectiveness of text against two videos. The first video was a normal YouTube-style video that allowed scrubbing and reviewing. The second video automatically paused after each step (referred to as segmented video). The experiment consisted of an initial survey, a skills test, one of three tutorials, and a final survey. It had the following two research questions.

Research Question 1. What is the impact of instructional format on learning?

Research Question 2. What underlying variables explain the impact of instructional format on learning?

Participants

A total of 48 participants were recruited for the study. They were undergraduate and graduate business students recruited from the author's Introduction to MIS classes, each of which contained significant Excel content. Participants were randomly assigned to each of the three instructional materials.

Several participants were excluded from data analysis. Two participants showed evidence of significant language barriers; their surveys were excluded from analysis. The screen-recording system proved unstable, preventing screen recordings for 17 sessions (resulting in 31 usable videos).

Tutorial Design

The text tutorial showed how to use Microsoft Excel's conditional formatting feature. It began with an overview using screenshots and text to demonstrate how to selectively highlight cells. The second step-by-step task asked participants to follow along as it demonstrated how to apply green font to numbers less than 250. The final knowledge transfer task asked participants to create a new rule formatting numbers between 10-20 with a black fill and white font. Overall, the tutorial contained seven screenshots and 252 words.

The text tutorial was converted into two video versions. Both videos used a voice-over, as well as pan and zoom to increase participants' ability to focus on the essential portions of the screen. Click events were highlighted to make them more visible. The segmented video was identical to the regular video, with the exception that it stopped after each major step. Participants were required to click on a large arrow to continue. Participants were allowed to scrub forward/backwards in the videos, as well as review sections at any time. Only one person re-watched a section successfully (several others tried, but were unable to locate the desired material).

All three versions of the tutorials used the same desktop computer with a 1680x1048 resolution monitor. This allowed the tutorial to be placed on the right half of the screen, and Excel on the left-half of the screen. Participants were able to follow along without needing to switch between programs.

Experimental Procedure and Instruments

Data were gathered in individual sessions with each participant. Each session consisted of a pre-test, Excel competency exam, tutorial, and post-test.

A pre-test survey was created to assess each participant's computer skills. A pre-existing set of Likert questions asked participants to rate their competency with spreadsheets, word processing, and the Internet (Munro et al. 1997). The same Likert scale was used to gather participants' confidence in their ability to use ten separate Excel features (ranging from number formatting to sorting).

A 5-minute Excel competency assessment was then given to each participant. Each of the ten steps matched to a specific feature asked about in the pre-test.

After the Excel competency test, participants began one of the three tutorials. During the session, a Mirametrix eye tracker recorded each participant's gaze. An opensource eye tracking software named Ogama recorded the screen, along with each participant's eye gaze and mouse movements (Voßkühler et al. 2008).

Participants finished the session by completing a cognitive load survey. This began with a single question measuring overall cognitive load (Paas et al. 1994). It also contained a more complex survey that broke cognitive load into factors (Leppink et al. 2014).

The sessions were generally short, taking between 20-40 minutes. Participants were allowed to ask questions about the surveys, but not about the tutorials. Participants who got lost during the tutorials were verbally instructed to go back and review the steps more carefully.

Design Validation

The Excel competency assessment confirmed that none of the participants knew how to use the conditional formatting feature prior to the tutorial. It showed that they entered with a wide range of Excel skills.

The survey asking participants to rate their Excel competency proved to be a poor measure of actual performance. The single question asking them to rate their spreadsheet knowledge had a weak 0.326 correlation with performance on the Excel skill test ($p=0.029$). The questions asking about their ability to use specific features was also a poor measure. Only two of the ten questions correlated with actual performance ($p>0.05$).

Participants rated themselves highly on each task, even on those which were not successfully completed. For example, while none of the participant knew how to use conditional formatting, they still averaged 4.5 (on a scale from 1-7, with 1 being not at all confident and 7 totally confident). The following table shows the results.

	Successfully Completed in Excel		**Performance Correlation with Self-Reported Confidence (p>0.05)**									
Task	**Yes**	**No**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1. Use currency format	48	0	NA									
2. Apply cell fill	46	2		NA								
3. Change font color	42	6			NA							
4. Apply red border	38	10				0.41						

5. Conditional Formatting	0	48					NA				
6. Add numbers	30	18						NA			
7. Use Now()	28	20							NA		
8. Use Sum()	42	6								0.37		
9. Insert line chart	41	7									NA	
10. Sort numbers	38	10										NA
Average Confidence (1-7)			**6.5**	**6.6**	**6.7**	**6.5**	**4.5**	**6.0**	**5.6**	**6.2**	**6.2**	**6.3**

Table 1: Excel Competency Validation

Since neither of the surveys were valid predictors of actual Excel performance, they were not used for any analysis. The performance assessment in Excel was used instead.

Participants assigned to the three conditions were equivalent. A Kruskal-Wallis H test for equivalence among 3 randomly-assigned groups showed no statistically significant difference. Variables tested included self-reported computer skill, pre-test Excel survey competency, and performance on the Excel competency assessment.

Results

Most participants were successful in completing the tutorials. Only 4 of the 48 participants were unable to complete the knowledge transfer task (which was defined as using conditional formatting to apply at least one rule to the intended column). While most participants were successful, there were significant differences in performance between the three groups.

Impact of Tutorial Format on Learning

Research Question 1. What is the impact of instructional format on learning?

While an equivalent number of participants in each condition successfully completed the tutorials, they took very different amounts of time. Videos were the most efficient format, requiring an average of 200 seconds for the entire tutorial. Auto-pausing videos took longer, at 271 seconds. Paper was the least efficient format, with an average of 318 seconds. Table 1 shows the average time and count for each instructional condition.

Condition	Number of Participants	Successful Screen Recordings	Participants Unsuccessful at Knowledge Transfer	Avg. Tutorial Completion Time (s)
Text	16	9	1	318
Video	17	10	2	200
Paused Video	15	12	1	271

Table 1: Learning by Condition

While the tutorials took different amounts of time, participants reported similar levels of cognitive load. This was confirmed by a one-way ANOVA test of the one-question measure from Paas and van Merriënboer (1993), as well as the more complete Lepplink et al. (2014) instrument. A two-way ANOVA test did not find an interaction effect between cognitive load and Excel competency.

Excel competency did have a relationship with several variables. First, it had a -0.289 correlation with cognitive load (p=0.063). Participants with lower Excel competency exerted more effort. Second, Excel competency had a -0.312 correlation with time needed to complete the knowledge transfer task. However, competency did not correlate with the time required to follow along with the step-by-step task.

Explanation of Performance

Research Question 2. What underlying variables explain the impact of instructional format on learning?

Why did each instructional condition take such different lengths of time to complete? Reviewing the screen recordings showed that the majority of the differences were a result of error detection and recovery. Of the 31 successful recordings, 14 participants made an error that required them to backtrack and redo part of the tutorial. The most common error point was on the “New Formatting Rule” screen (shown below). Participants would frequently hit “OK” after inputting the condition instead of using the “Format” button to set a new format.

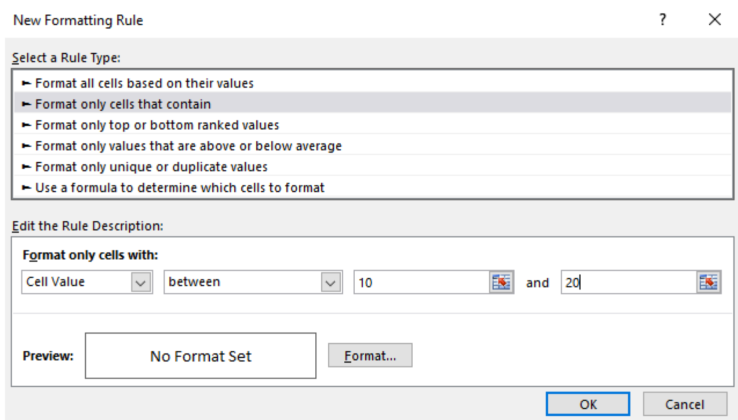

Figure 1: Problematic Input Screen

Most errors occurred during the step-by-step portion of the text tutorial. Seven of the nine paper participants with successful recordings got lost during this task, spending an average of 68 seconds off-track. Participants struggled to both detect and recover from errors. They generally spent significant time in the following step, not realizing their error was in clicking “OK” in the previous step.

In contrast, only 4 of the 12 participants using the step-by-step video made errors. Unlike the paper users, they were also able to quickly realize they made a mistake and get back on track. Participants using the non-paused videos were most successful of the three groups, with none of the participants clicking “OK” at the wrong time.

In the knowledge transfer portion of the exam, the participants showed more consistent performance. Between 2-3 participants in each group got off-track. These participants were much more likely to be those with low Excel skills, a correlation of 0.563 correlation (p=0.02).

Condition	Overview Time Avg.	Step-by-step Time Avg.	Step-by-step Off-track Time Avg.	Knowledge Transfer Time Avg.	Knowledge Transfer Off-track Time Avg.
Text	45	200	68	74	12
Paused Video	61	108	12	102	16
Video	53	71	0	77	14
Grand Total	54	123	24	86	14

Table 2: Time Required for Each Experimental Condition

The distribution of errors by Excel competency were not evenly distributed. During the step-by-step task, participant errors appeared to be the result both of Excel competency, as well as the instructional format. During the knowledge transfer phase, errors are more connected with participant excel competency. This can be seen in the follow figure.

Condition	Excel Competency	Tutorial Time	Step-by-step Time	Knowledge Transfer Time	Step-by-step Off-track Time	Knowledge Transfer Off-track Time
Paper	9	36	401	41	107	-
	9	23	74	43	-	-
	9	53	233	72	140	-
	8	47	108	61	-	-
	7	39	183	70	39	-
	7	36	104	53	11	-
	7	59	187	70	40	-
	6	85	297	119	148	36
	6	28	216	137	128	75
Segmented Video	9	52	85	59	-	-
	9	59	82	50	-	-
	9	61	78	92	-	-
	9	66	109	53	-	-
	8	62	122	48	-	-
	8	61	98	99	-	29
	8	76	123	109	-	-
	8	60	102	28	35	-
	7	57	60	286	-	60
	6	59	164	104	44	-
	3	61	140	235	17	98
	3	61	129	63	45	-
Video	9	56	59	35	-	-
	9	57	59	37	-	-
	9	24	104	47	-	-
	8	56	82	112	-	-
	8	56	95	61	-	-
	6	57	58	55	-	-
	6	58	58	52	-	-
	6	53	61	92	-	-
	5	56	68	158	-	120
	5	57	61	116	-	18
Measure	Scale 1-10, 10 being higher	Seconds	Seconds	Seconds	Seconds	Seconds

Figure 2: Time Required for Participants to Complete Tasks

Limitations

One common issue in dealing with instructional material is learning styles. Should learners have the choice between different materials? While popular, a critical examination relying on experimentally-based research shows learning styles do not have credible evidence (Pashler et al. 2008). As a result, this project does not include learning style as a moderating variable.

Issues with the screen-recording software left the sample size smaller than intended. However, the study design compensates for this weakness. Using an experimental design with random assignment (along with several methods controlling for participant characteristics), allows more confidence than a quasi-experimental or correlational study design. The sample size is comparable to similar work; a meta-analysis of instructional animations/images found a mean sample of 55 and median of 40 for the entire study (Höffler et al. 2007). Another literature review of similar studies found an average of 13 participants per experimental condition (Meij and Meij 2014).

Another potential limitation in the design of the study is the textual tutorial; was it badly designed? If so, this fault illustrates an essential weakness of the paper instructional format. All three formats used identical wording, and the textual screenshots mirrored the video content. Random selection mean that all learners undoubtedly had a similar bias towards clicking "Ok" at the end of a step (even when not told to do so). But this bias was exacerbated by the inherently static nature of the paper format.

Moments where instructional material confront learner misconceptions are hardly unique to conditional formatting. Many tutorials will present a task not fitting user expectations or habits. How easily learners detect these divergences, fall into the errors, and recover is a key part of the learning experience. This study shows that video is superior to paper in handling these experiences.

Conclusion

This experiment compared text, video, and segmented videos. Participants were randomly assigned to three experimental conditions. All participants completed an Excel competency pre-test, as well as filled out cognitive load surveys. Participants' screens were recorded to analyze their behavior.

The primary outcome of the experiment showed that participants in the text condition were much more likely to make mistakes than those using videos. Videos allowed participants to detect their mistakes and complete the step-by-step tutorial in half of the time of those using screenshots and written instructions. While participants using the video were allowed to rewind or review the video, only one successfully took advantage of this feature (several others attempted to find content, but were unable to locate it).

Surprisingly, participants in the three conditions did not report different levels of cognitive load. Cognitive load was correlated with learner Excel expertise, showing that students with lower skills exerted more effort. Low-skill participants had more difficulty completing the knowledge transfer task.

This study has two important implications for future work. First, self-reported Excel skills weakly correlate with actual Excel skills on a performance test. Since prior expertise is a critical variable in explaining learning performance, future work should not rely upon self-report data. Second, error detection and recovery are major benefits of video instruction. Off-task time largely explains time performance differences between the instructional conditions.

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