**Auto-pause: The Effect of Regulating the Content Delivery Rate in Online Instructional Videos on Task Completion by Older Adults**

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Increasingly, older adults are turning to online instructional videos to help them complete tasks. However, many online instructional videos are created with a general audience in mind and, as a result, these videos might have an average speech rate that is too fast for older adults to follow due to cognitive and perceptual declines. In this work, we investigate the effect of regulating the rate at which content in instructional videos is delivered on older adults’ ability to complete tasks. We compared two methods of regulating the content delivery rate: uniformly slowing the video or automatically pausing the video. The results show that participants generally complete tasks faster with the auto-pausing method than with the slowing method. Participants can complete tasks faster with the auto-pausing method than with no regulation at all (baseline) after they had become proficient with the auto-pausing method. Overall, our work shows that auto-pausing is a promising method of regulating the content delivery rate of online instructional videos to help older adults complete tasks efficiently.

CCS CONCEPTS • Human-centered computing • Accessibility • Empirical studies in accessibility

**Additional Keywords and Phrases:** older adults, online instructional videos, user-friendly, senior-friendly

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1. Introduction

New technologies are constantly arising and becoming an integral part of everyday activities and tasks. However, prior research has shown that older adults can have difficulty learning to use new technology [1,18,29]. As a result, older adults only use them in the limited ways they have learnt [24] or abandon them entirely [12]. One of the reasons is that these individuals lack the support needed for learning the new technology. Although many products guides and manuals, they often face difficulties using written product instructions [3,17].Thus, older adults may turn to friends and family to help them overcome challenges they may face with the new technologies. However, older adults may lack access to people with the right expertise at all times.

Increasingly, older adults have begun to leverage online instructional videos to complete many tasks on their own. Pew Research has shown that 39% of American older adults watch or download online videos. Twenty-three percent (23%) of that content is educational or instructional material [31]. However, many older adults suffer from age-related decline in cognitive abilities, including working memory capacity, processing speed, spatial abilities, attention focusing, and reasoning. Such limitations make it hard for older adults to understand rapid speech and recall details about what they have seen or heard recently (even for those with normal hearing) [7,25]. These limitations also negatively affect their visual processing rate and reaction time to visual stimuli [10,32]. Because online videos are often created with a general audience in mind, older adults can find it difficult to follow and comprehend existing online video content delivered at a rate that is inappropriate to them. For example, content on YouTube typically has a speech rate faster than the average speech rate of 150 wpm [33], yet older adults struggle to comprehend and recall content that is delivered faster than 150 wpm [2,4,6,15].

To date, the ways in which we can help older adults better understand and follow instructional videos remains an under-explored research question. Many prior works have investigated the effect of slowing audio and/or video playback rate on older adults’ ability to recall, recognize and comprehend visual or audio materials. They report that older adults perform better in terms of their ability to recall, recognize, and comprehend material delivered at a uniformly slower rate than at a faster rate, while the playback rate had little effect on younger adults’ performance [2,4,6,10]. Beyond applying a constant slowing factor, Holland and Fletcher showed that automatically inserting long pauses in audio recordings of stories at phrase, clause boundaries, and sentence endings can serve as an alternative for regulating the rate at which the story was delivered to older adults [15]. Furthermore, older adults demonstrated better recall and recognition performance with longer pauses. The effect of slowing down and inserting pauses specifically into instructional videos to help older adults complete related tasks, however, has not been directly studied.

In this paper, we compare these two methods for regulating the content delivery rate and evaluated them against a normal playback condition. Overall, our work shows that automatically pausing is a promising method of regulating the content delivery rate of online instructional videos to help older adults complete tasks efficiently. Participants found that automatically pausing the instructional videos to be more helpful (24.8% more time-efficient) than uniformly slowing down the instructional videos, and it was also more beneficial (14.4% more time-efficient) than no regulation at all after they had become sufficiently proficient with the method (after using it three times). Furthermore, participants were generally satisfied with the automatic pausing of the instructional videos.

1. Related work

In this section, we covered related work on the benefits of instructional videos to older adults and the effect of adjustment to the multimedia playback content.

* 1. The benefits of instructional videos to older adults

In terms of cognitive and mental support, instructional videos help reduce the cognitive load incurred in information processing and instill confidence in older adults. Like any other videos, instructional videos combine audio and visual stimuli to present information. Prior research has shown that audiovisual presentations of instructional materials can mitigate the negative effects of cognitive decline [13]. They prevent unnecessary visual search between mutually dependent and physically separated information, such as a diagram and its caption. For diagram and caption, a user would have to visually look for the match between the image and text information. Additionally, they make use of both the visual and auditory components of working memory, thereby minimizing the chance of overwhelming cognitive load. Furthermore, they enable information to be encoded both verbally and nonverbally, which leads to high quality and durable knowledge. Other than age-related decline in cognitive abilities, the lack of self-efficacy also plays a major role in deterring older adults from independently and completing a technology-related task. When presented with new technology, many older adults may feel anxiety, discomfort, and a lack of self-efficacy or confidence in their ability to use the technology [8,16,22,29]. Results from a 2017 survey by Pew Research Center shows that American adults older than 65 years old were largely “digitally unprepared” (i.e., not confident in their digital skills and in their ability to find trustworthy information online) and would seek another person for help when given a new electronic device [31]. In addition to the cognitive benefits, instructional videos can increase older adults’ self-efficacy [14]. This characteristic of video instructions is closely tied to the concept of video modeling and observational learning, which is also known as vicarious learning. According to the Cognitive Theory of Bandura [34], one can acquire certain knowledge and build up competencies just by observing other people’s outcomes. Learners may gain self-efficacy by successfully imitating the model’s interaction steps.

From the aspect of task performance, multiple experiments [9,21,27] have shown that older adults perform tasks faster or more accurately when following video-based instructions than other types of instructions. For example, Sierra et al. found that the application of audiovisual instructions as opposed to audio-only instructions enhanced the likelihood of success at a simple assembly task [27]. This result confirms the theory that audiovisual instructions facilitate the spatial and working memory demands of a task [20,30]. Although these demands are particularly challenging for older adults, it is worth noting that this positive effect also applies to the younger adult group in their experiment. Mykityshyn et al. found that older adults who were given instructional videos demonstrated faster and more accurate task performance while calibrating a glucose meter compared to people who were given text-based user manuals, yet there was no difference for younger adults tested under the two conditions [21]. They argued that training with the user manual required users to visualize, imagine, and infer the task sequence, which was more challenging to older adults, who suffered from declines in cognitive abilities. Video training was helpful because it explicitly demonstrated the task sequence, thereby minimizing the reliance on working memory and reading comprehension. Lin and Hsieh [9] investigated if the benefits of multimedia learning (i.e., a method proposed by Richard Mayer [5,19] of presenting the training material with different channels) could override older adults’ reduced cognition in learning. In their experiment, older adults were trained to use a digital camera by three types of training media: animated visuals, narration, and static visuals. The result showed that training with animation and narration resulted in significantly faster task completion than static visuals when the task was difficult. They provided a few explanations for the difference between the animated visuals and the static visuals: (1) older adults respond more actively to dynamically displayed visual stimuli; (2) animation enables older adults to draw connections between procedures; and (3) animation makes the mechanism of the device clearer and helps older adults develop a mental model. Their experiment highlighted the importance of “animating” graphic instructions, which was not emphasized in Mayer’s theory.

* 1. The effect of adjustments to the playback of multimedia content

The effect of playback adjustment on learning performance has been widely studied. We reported related work on the effect of two commonly used adjustments: uniformly slowing down multimedia playback and pausing multimedia playback.

***The effect of uniformly slowing down multimedia playback***

Researchers have examined the effect of uniformly slowing down the playback of speech on older adults’ comprehension. Compared to younger adults, older adults’ ability to comprehend information is much more susceptible to the rate at which the information is being delivered due to a slower information processing rate. For example, Calero and Lazzaroni have found that increasing the speech rate (from 140 wpm to 350 wpm) negatively and disproportionately affected the intelligibility of speech for older adults more than younger adults [4]. Similarly, Cohen has found that older adults performed not as well in a follow-up comprehension test at the faster presentation of 200 wpm compared with 120 wpm when given auditorily presented stories [6]. Furthermore, Bergman has shown that distortions in speech (e.g., reverberation, overlapping, interruption, or a simple increase in words per minute) resulted in a much worse speech intelligibility score for older adults than the younger ones [2]. The intelligibility score is evaluated based on the percentage of words correctly understood by the listeners. However, these findings might not apply to older adults with severe working memory impairment. For example, Small et al. reported that uniformly slowing down the speech rate by 15% was beneficial only for the subject with the most working memory (WM) capacity and detrimental for the subject with the most severe WM impairment among all three older adults with Alzheimer’s disease because the decline in WM would counteract any benefits derived from a reduction in speech rate [28]. Overall, the prior findings suggest that older adults performed better at a slower content delivery rate, as long as they were not suffering from a severe neurological disorder like Alzheimer’s disease.

***The effect of pausing multimedia playback***

Pauses can be used to support learning new knowledge and gaining new more information from videos. For example, in an experiment related to acquiring cultural knowledge from a feature film, Ogan et al. developed a pause-predict-ponder system that pauses at the moment of high cultural interests, asks students to predict what will happen next, and asks them to ponder if their prediction is correct after watching the rest of the clip [23]. The results indicate that the addition of such a system aids students in acquiring cultural knowledge and significantly increases students’ ability to reason from an intercultural perspective. They noted that a pause in the video can focus the students’ attention, which can help them understand declarative knowledge components. Encelle et al. showed that existing gaps within a video’s audio track (i.e., silences) can be extended with artificial pauses to provide rich audio descriptions for viewers with visual impairment [11]. Doing so does not cause much discomfort, and viewers quickly adapt to the videos with extended pauses. These works showed that leveraging pauses at carefully selected places boost knowledge transfer and do not disrupt the viewing experience much.

Pauses can be inserted during playback to bring down the pace of the speech and slow down the rate of content delivery. Holland and Fletcher argue that instead of simply uniformly slowing the input, multimedia should provide meaningful information for one cycle and then allow time for it to be processed before the next information arrives to avoid a memory “traffic jam” [15]. They show that inserting pauses at natural boundaries of auditorily presented stories enhances older adults’ recognition and recall of the story content.

Pauses have been shown to be valuable when learning a piece of new software from instructional videos. For example, Pongnumkul et al. developed a novel system “Pause-and-Play” that supported learning design software (e.g., Photoshop). When there was a tool change in the video, the system checked whether the user’s active tool matched the current video tool with computer vision. If not, the video would automatically stop, wait for the user to catch up, and display an annotation informing the user of the specific action to take [26]. The system saved the user the manual effort of constantly switching between interacting with the video tutorial and working on the software task, allowing them to focus on the task at hand. No significant difference was found in completion time or error rate, but user feedback showed that the system was helpful and improved the user experience.

Many of the aforementioned prior works [11,15,23] have looked into the effect of pausing multimedia playback on knowledge gain and user experience, but it remains underexplored how pausing multimedia playback might affect the older adults’ ability to complete tasks. Additionally, although Holland and Fletcher propose pausing as an alternative to uniformly slowing [15], they did not compare the effects of uniformly slowing and inserting pauses in their experiment, while we aim to compare both methods in our work. Furthermore, Pongnumkul’s “Pause-and-Play” system was designed to save the effort that would have been spent on managing two pieces of software (the video player and the software), switching focus between the two pieces of software, and finding a missed step; however, it did not produce a significant effect on the task completion time and error rate. A possible reason could be that young participants in their participant pool (18-19 years old) were already proficient with the task flow involved in learning a new software from an instructional video. Also, the young participants’ uncompromised cognitive abilities made it possible for them to quickly acquire the necessary information presented in the videos with little need to rewatch a missed step. We hypothesize that automatically pausing the instructional videos would produce a positive effect on task performance for older adults. Inspired by prior works, one of our objectives is to study the effect of automatically pausing the instructional videos on older adults’ ability to complete related tasks

1. Hypotheses

Given the overwhelming literature demonstrating the effect of content delivery rate on older adults’ ability to comprehend online instructional videos, we study the potential benefits that different regulation techniques can have in reducing this burden. We explore two methods for regulating the content delivery rate: uniformly slowing down the playback of a video and automatically pausing the video. Specifically, we test the following two hypotheses:

*H1: Regulating the content delivery rate of instructional videos would be beneficial to older adults.*

Prior literature has shown that older adults perform better with audio and visual materials that are played at a slower content delivery rate [2,4,6,10]. Although regulating the content delivery rate would imply it will take longer than it would be normally to view the video, older adults might be able to recognize, understand, and retain more of the content during each playthrough of the video and consequently might need to rewatch the video fewer times. Therefore, a potential benefits is that older adults would require less time to complete tasks when watching an instructional video with a regulated content delivery.

*H2: Automatically pausing the video would be more helpful to older adults than uniformly slowing down the video.*

Pausing multimedia content can enhance recall and recognition because it avoids traffic jam in memory, as pointed out by Holland and Fletcher [15]. We hypothesize that uniformly slowing down the video might cause audio distortion that can make it harder for older adults to follow the video than automatically pausing. Additionally, although uniformly slowing down the video may help the user recognize, understand, and retain more of the content, it will also limit how fast she will be able to complete the task. These factors will likely negatively affect user performance.

1. Approaches for regulating an instructional video’s content delivery rate

In this section, we describe how we implement the two approaches for regulating the instructional video’s content delivery rate: uniformly slowing down the playback and automatically pausing the playback.

* 1. Uniformly slowing down the playback

Prior literature reported that older adults performed better in terms of their ability to recall, recognize and comprehend the material at a uniformly slower rate (120, 140, and 150 WPM) than they did at a uniformly faster rate (175, 200, and 350 WPM) [2,4,6,10]. As a result, we implemented the slowing down process to playback videos with the conservative speech rate of 120 WPM, and we achieved this rate using a uniform adjustment factor as done in prior works [4,6]. We adjusted the videos using the following procedure:

1. We counted the number of words in the video’s transcript and divided that by the video length to get the average speech rate of the entire video.
2. We divided 120 WPM by the video’s average speech rate to get the slowing factor.
3. If the slowing factor is less than 1.0, we applied the slowing factor to the video.

One potential limitation of this approach is that it does not take into consideration the possibility that there are parts of the video that may still be faster than 120 WPM after the slowing factor has been uniformly applied to the whole video. Figure 1 illustrates this point using our first instructional video, which has an average speech rate of 155 WPM. Using the process described above, the slowing factor is 120 WPM/155 WPM = 0.77. However, computing the instantaneous speech rate using a sliding window with different window sizes (5,10,15,20,25, and 30 seconds) reveals that many portions of the video before the 40-second mark that have a speech rate above 155 WPM, with some even exceeding 200 WPM. Conversely, there are portions before that mark with a speech rate well below 155 WPM. Thus, applying a uniform slowing factor of 0.77 leads to portions that are not near our target of 120 WPM. Although we were aware of this potential limitation, we chose to implement the slowing down method as done in prior works [4,6] because those works observed better performance in older adults’ cognitive abilities through a uniformly slower rate.

Chart, histogram

Description automatically generatedChart, histogram

Description automatically generated

Figure 1. Speech rate over time for the first instructional video of study 1, when analyzed with a 5, 10, 15, 20, 25, and 30 seconds window. (Left) Speech rate unadjusted. (Right) Speech rate after uniformly slowed to an average of 120 WPM

* 1. Automatically pausing the playback

We also explored automatically pausing the instructional video when the content delivery rate exceeds a particular threshold. Similar to Pause-and-Play [26], our auto-pausing method would need a heuristic for determining when the pause the instructional video. The Pause-and-Play system leveraged the software’s tool change events in the instructional video as potential pause points. A limitation of this approach was that it could only work with instructional videos for designer software, such as Google SketchUp and Adobe Photoshop. Unlike Pause-and-Play, we selected the speech characteristics (speech rate and the natural pauses in the speech) as a heuristic because we believed this method for generating auto-pauses would generalize to more instructional videos, as long as they have an audio track available. More specifically, we used the following process to identify points in the video when pauses should be inserted:

We segment the video by locating silences in the audio stream, where the noise level is lower than 30 decibels (same as level as a whisper [35]) for longer than 0.25 second (typical pause duration in a conversation [36]).

We compute the average speech rate of the whole video as in section 4.1.

We compute the speech rate for each sound segment separated by silent gaps.

If a sound segment has an average speech rate higher than the average speech rate of the video, we add the end of the sound segment to the list of potential pause points.

We remove pause points that are too close to each other because pausing too frequently could disrupt the viewing experience. Ideally, we would like to only pause at the end of a sentence and exclude pauses in the middle of a sentence; however, it is challenging to reliably detect the ends of sentences in continuous speech. As a result, we use the following steps to avoid pausing more than once per sentence:

We compute the average time duration of a sentence (seconds per sentence) in a video by dividing the average number of words in an English sentence (15 words per sentence) by the average speech rate (words per seconds) for that video.

We filter out pauses that would be less than the computed average time duration for a sentence after the previous pause.

We show an example of the process identified the automatic pause points for the first instructional video in Study 1 in Figure 2.

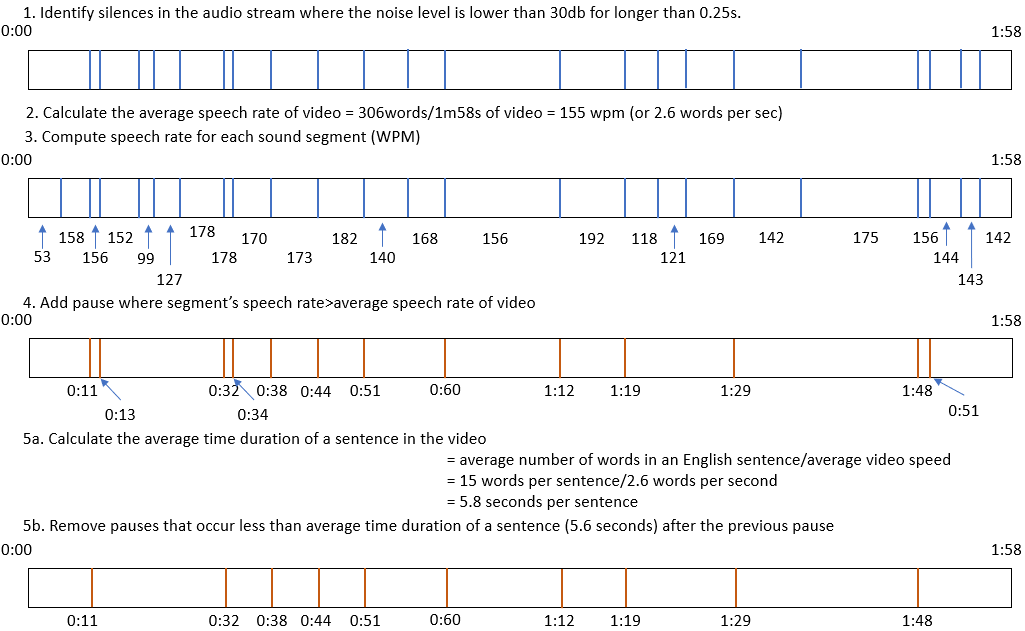


Figure 2. An example of how pauses were generated for the first instructional video in Study 1

1. StudY 1: Comparison of Techniques for regulating Content Delivery Rate
   1. Goal

In Study 1, we tested if regulating the instructional video’s content delivery rate would be help participants complete tasks (H1). This study was designed to also examine if adding automatic pauses or uniformly slowing down the video was more effective (H2).

* 1. Participants.

We recruited 18 older adults (age 65+; 10 males, and 8 females) through word-of-mouth, flyers on community notice boards, and recruitment ads on social media platforms like Facebook and Kijiji. We did not have any inclusion or exclusion criteria regarding educational background or profession to maximize the diversity of our cohort. To conduct the study during the COVID-19 pandemic, the study was done remotely by recruiting participants who owned an Internet-enabled desktop computing device so that they could interact with the study software.

* 1. Apparatus

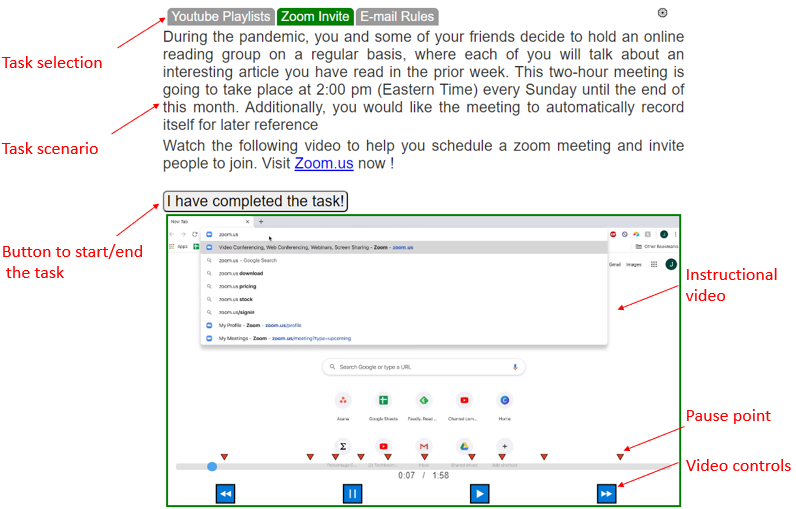


Figure 3. The figure shows the Web-based study interface for the study

We developed a web page hosted on *GitHub Pages* to act as the study interface (Figure 3). The web page supported three different tasks, each associated with a different web application: Zoom, Outlook, and YouTube. We created a special account for each of these applications so that participants would not have to create accounts or use their personal ones. For each task, the interface showed the scenario that participants were asked to complete and an instructional video which participants were asked to watch and follow. The web page automatically logged data in the background, such as when the participant begins to watch the video, the task completion time, and the number of pauses. During the study, we asked participants to share their screens so that we could observe their actions as they perform the tasks. With the participants’ consent, we audiotaped the interview phase of the study, but no video data was recorded to protect their privacy.

* 1. Procedure

We first introduced participants to the purpose of the study and informed them of the data that would be collected. After receiving their consent to participate and have their activities recorded, we assigned participants to different conditions according to Table 2 and asked them to read and complete the task scenario while watching the instructional videos. They were free to pause, replay, rewind and fast-forward the video as they would in real life. We gave participants a maximum time limit of 20 minutes to complete each task to avoid fatigue or frustration; we marked trials that were not completed within the time limit as “failed”. At the end of the study, we conducted a short semi-structured interview to learn about any issues that they may have encountered and any thoughts participants may have about their experience.

* 1. Instructional video and task scenarios

Participants performed three web-related tasks. Prior to the study, we verified with participants to make sure they have no knowledge on how to complete the tasks used in the study. For each task, we asked participants to watch a related instructional video and to complete the goals presented to them in a scenario.

Table . Details for the instructional videos

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Video | Length (s) | # of auto-pauses inserted | Average speech rate  (WPM) | Auto-pause time points (s) |
| [How to schedule a Zoom meeting](https://drive.google.com/file/d/1lOsZW6YqpfzaM8OeBrB3A_FnTnEgRb1j/view?usp=sharing) | 118 | 10 | 155 | 11,32, 38.2, 44.4, 51, 60, 71.6, 78.9, 89.2, 107.8 |
| [How to create rules to move emails in Outlook](https://drive.google.com/file/d/1h_nhGxo4fJLdrDhAcukpRRTbOq-cWQF5/view?usp=sharing) | 122 | 10 | 168 | 9.6, 20.7, 26.5, 45.5, 56.5, 64, 84.2, 95.4, 109.2, 121.9 |
| [How to create a music playlist on YouTube](https://drive.google.com/file/d/1zPuvGNYV_pzMmY14KN_HGCRE1eSnJg9w/view?usp=sharing) | 126 | 9 | 165 | 13.7, 33, 43.7, 55.1, 64.8, 74.4, 81.2, 89.6, 109.1 |

Participants were shown videos for how to complete different tasks.

The videos were already available on YouTube and were not created by the research team. Each video was around two minutes in length and was rendered at 1080p resolution or more. Statistics related to the speech and pause rates of the videos can be found in Table 1.

For each video, we designed a scenario with goals that aligned with what the instructional video taught. Additionally, we wrote the scenarios to include high-level goals that participants would need to satisfy while performing the task, but we did not include the specific steps for how the goals should be completed, for example, “type in zoom.us in the address bar to log on to Zoom”. Additionally, we wrote the scenarios such that the goals were not presented in the same order that they would be covered in the instructional videos. We designed the scenarios this way to closely simulate what might happen in real life when a user approaches an instructional video for help: a sheet of clearly written text instructions does not happen to be available and the task a user needs help with might not be always approached in the exact same order as covered in the instructional video.

We showed each scenario to the participants before they were asked to watch the video and complete the task (see Figure 3). This allowed the participants to understand what the goals were before they started the task. The tasks are briefly described below:

* **Scenario 1: Creating a Zoom meeting (13 steps).** During the pandemic, you and some of your friends decide to hold an online reading group on a regular basis, where each of you will talk about an interesting article you have read in the prior week. This two-hour meeting is going to take place at 2:00 pm (Eastern Time) every Sunday until the end of this month. Additionally, you would like the meeting to automatically record itself for later reference.
* **Scenario 2: Creating an Outlook e-mail rule (10 steps).** Facebook has been sending you emails on a regular basis. You would like to have all emails from Facebook go automatically into its own folder called "Facebook" instead, including both the future and the current emails.
* **Scenario 3: Creating a YouTube playlist (11 steps).** You came across three music videos on YouTube: *Sara Bareilles-Gravity, Taylor Swift-Love Story*, and *Katy Perry-Roar Official*. You really liked them. Now you have decided to find these three music videos and create a playlist with these three music videos. You want to name this playlist, “My Favourite Songs”.
  1. Conditions

Table . The 3x3 Graeco Latin square used for condition assignment in Study 1. AP stands for “Automatic Pausing,” CTL stands for “Control,” SLOW for “Slowing,” and S# stands for “Scenario #”.

|  |  |  |  |
| --- | --- | --- | --- |
| Participants | Trial 1 | Trial 2 | Trial 3 |
| P1, P4, P7, P10, P13, P16 | S1×CTL | S3×SLOW | S2×AP |
| P2, P5, P8, P11, P14, P17 | S2×SLOW | S1×AP | S3×CTL |
| P3, P6, P9, P12, P15, P18 | S3×AP | S2×CTL | S1×SLOW |

In this study, we compared three content delivery methods (*Method*): control (*CTL*), slowing (*SLOW*), and auto-pausing (*AP*). Under the *CTL* condition, we present the instructional videos to the participants with the content delivery rate unaltered. Under the *SLOW* condition, we present the instructional videos to the participants with the video speed slowed down by a constant slowing factor as explained in section 4.1. Under the *AP* condition, we presented the instructional videos to the participants with automatic pauses inserted within the video as explained in section 4.2. Figure 3 shows an example of the study interface presenting an instructional video using the *AP* method; the red upside-down triangles indicated where automatic pauses had been inserted into the video, similar to “Pause-and-Play” [26]. Upon an auto-pause, participants could choose to either engage with the task while the video stayed paused or continue with the video.

We used a 3x3 Graeco-Latin Square study design with two blocking factors to counter-balance the *Method* and *Scenario* (Table 2). We repeated this counterbalancing for every three participants. It is worth noting that we treated *Scenario* as an independent variable in the analysis because some participants might find the task in a scenario more difficult than the others.

* 1. Dependent variables

For each task, we measured the completion time and the number of pauses. The completion time was defined as the total time it took for the participants to watch and complete the tasks. The number of pauses was defined as the number of times the participants manually paused the video. We also collected the participants’ preference rating of each condition as additional subjective measures for comparison. The ratings were given along a three-point scale: 1 - Not satisfied, 2 - Neutral, and 3 - Satisfied.

* 1. Analysis

We used a General Linear Model (multi-factor ANOVA) with two independent variables (delivery rate and task type) to analyze the task performance data. We analyzed the satisfaction ratings for each content delivery method with a Friedman test.

* 1. Results

Table 3. Completion time, number of pauses, and satisfaction ratings for each condition

| Content delivery method | Completion time (s) | Number of manual pauses | Satisfaction ratings (median) |
| --- | --- | --- | --- |
| *CTL*  *AP*  *SLOW* | 619.94 ± 129.76  545.83 ± 220.76  726.33 ± 262.66 | 5.83 ± 1.85  4.21 ± 1.01  6.0 ± 2.63 | 1  2  2.5 |

Table . Summary of comparison results (\* indicates significance)

| Variable | Result |
| --- | --- |
| Completion time | *AP* < *SLOW* \* |
| Number of manual pauses  Satisfaction rating | *AP* < *SLOW* & *CTL* \*  *CTL* < *AP* & *SLOW* \* |

All participants completed the tasks successfully in under 20 minutes. In this section, we report the results (summarized in Table 3 and Table 4) and discuss findings from the first user study.

**Completion time**. The results showed that there was a significant main effect of *Method* on the task completion time (F (2,45) = 3.58, p<0.05, = 0.11). A post-hoc pairwise comparison using Fisher LSD method revealed that the completion time for the *AP* condition (M = 545.83, SD = 220.76) and the *SLOW* condition (M = 726.33, SD = 262.66) were significantly different (p=0.011). No significant difference was found when comparing each of the two methods for regulating the content delivery rate with the *CTL* condition. No significant effect of the *Scenario* on the completion time was observed (F (2,45) = 2.55, p=0.089, = 0.081). Furthermore, the *Method* × *Scenario* interaction effect was not significant (F (4,45) = 1.50, p=0.217, = 0.095).

**The number of manual pauses.** The analysis showed that there was a significant main effect of the content delivery method on the number of pauses (F (2,45) = 6.16, p<0.05, = 0.18). A post-hoc pairwise comparison using Fisher LSD method showed that the number of pauses for the *AP* condition (M = 4.21, SD = 1.01) was significantly less than that for the *CTL* (M = 5.83, SD = 1.85) and the *SLOW* (M = 6.0, SD = 2.63) conditions. The results suggested that at least some of the automatic pauses in the *AP* condition overlapped with participants’ intended pause location and participants needed to pause less manually. No significant effect of the *Scenario* on the number of pauses was observed (F (2,45) = 0.62, p=0.542, = 0.02). Additionally, the *Method* × *Scenario* interaction effect was not significant (F (4,45) = 2.55, p=0.052, = 0.12).

**Subjective feedback.** A significant difference in ratings was found among the three conditions ( ). A followed up post-hoc pairwise comparison showed that the rating for the *AP* (median = 2) and the *SLOW* (median = 2.5) conditions were significantly higher than the *CTL* condition (median = 1). No significant differences were found between the *AP* and the *SLOW* conditions. The results suggested that participants preferred the two methods for regulating the content delivery rate of the instructional videos. Thirteen participants believed that the two methods for regulating the content delivery rate gave them more “time to react” to the video content. For example, P5 told us that “…slowing down helps me catch up because my reaction is slow.” P9 commented that “…auto-pause gives me time to think and reflect…sort of like a buffer.” However, four participants pointed out some drawbacks of these two methods. Two of them complained that the video speed was too slow in the *SLOW* condition. For example, P1 noted that “…the speaker speaks in a very drawn-out manner. It makes me fall asleep.” Two did not agree with the locations of the automatic pauses. For example, P2 felt that” …sometimes the video stopped in the wrong place…it’s better for us to choose where to pause.”

* 1. Proficiency and task performance

We observed that participants found the *AP* and *SLOW* conditions more satisfying than the *CTL* condition, but we did not observe a significant difference in participants’ rating between *AP* and *SLOW*. Performance-wise, participants needed to manually pause the video playback less often with the *AP* condition than with the *SLOW* and *CTL* conditions. Additionally, participants completed the tasks faster with the *AP* condition than the *SLOW* condition. Thus, the results from Study 1 only partially supported H1 (regulating the content delivery rate in instructional videos would be beneficial to older adults) but did support H2 (automatically pausing the video would be more helpful to older adults than uniformly slowing down the video).

Although participants were faster with the *AP* condition than the *CTL* condition, we did not observe a significant difference between the two conditions (p>0.05). This is perhaps due to the novelty of the *AP* condition, and participants might be able to complete tasks significantly faster with the *AP* condition than the *CTL* condition once they are more experienced and proficient with the method. To test if those who are proficient with the *AP* method do complete tasks significantly faster in the *AP* condition than the other ones, we performed an additional analysis on the performance data. For each condition, we separated the participants into two groups: those who completed the tasks faster than the average completion time for that condition, and those with a slower than average completion time. By chance, 10 participants belonged to the ‘faster than average’ group, and 8 participants belonged to the ‘slower than average’ group for each condition; however, they were a different set of people for each condition. With the data organized in this way, we then performed tests to determine if those who were proficient with a particular method were able to complete tasks significantly faster with that method over other methods. In a similar vein, we also performed tests to determine if those who were not proficient with a particular method yet were able to complete tasks significantly faster with other methods over that method. The results are summarized in Table 5 and Table 6.

Table . Summary of comparisons for participants who were faster than average with each condition  
(\* indicates significance)

|  | Condition | | |
| --- | --- | --- | --- |
| Variable | *CTL* (n=10; p1, p2, p3, p4, p6, p9, p11, p12, p15, p16) | *SLOW* (n=10; p1, p2, p3, p4, p6, p7, p8, p10, p12, p15) | *AP* (n=10; p1, p2, p3, p4, p5, p9, p11, p14, p15, p18) |
| Completion time  Number of pauses | n.s.  *AP* < *SLOW* \* | n.s.  n.s. | *AP* < *SLOW* & *CTL* \*  *AP* < *SLOW* & *CTL* \* |

Table . Summary of comparisons for participants who were slower than average with each condition  
(\* indicates significance)

|  | Condition | | |
| --- | --- | --- | --- |
| Variable | *CTL* (n=8; p5, p7, p8, p10, p13, p14, p17, p18) | *SLOW* (n=8; p5, p9, p11, p13, p14, p16, p17, p18) | *AP* (n=8; p6, p7, p8, p10, p12, p13, p16, p17) |
| Completion time  Number of pauses | n.s.  n.s. | *AP* < *SLOW* \*  *AP* < *SLOW* \* | n.s.  n.s. |

For participants who were faster than average with the *AP* condition, there was a significant effect of the content delivery method on the completion time (F (2,27) =9.05, p <0.05,=0.40). A post-hoc analysis showed that the completion time for the *AP* condition (M = 382.81, SD = 122.48) was significantly less than the *CTL* (M = 601.82, SD = 173.45) and the *SLOW* condition (M = 742.88, SD = 250.83). Additionally, the effect of the content delivery method on the number of pauses was also significant (F (2,27) =5.33, p = <0.05,=0.28), and the number of pauses for the *AP* condition (M = 4.70, SD =1.05) was significantly less than that for the *CTL* (M = 5.70, SD =1.42) and the *SLOW* (M = 5.90, SD = 1.85) conditions. This suggests that for participants who were proficient with the *AP* condition, they were able to complete the task faster and manually paused the video less with *AP* than with *SLOW* and *CTL*. We also examined the effect of the content delivery method on the completion time and the number of pauses for participants who were faster than average with the *SLOW* condition and then similarly with the *CTL* condition. We observed that for participants who were faster than average with the *CTL* condition, the number of pauses (F (2,27) =4.25, p <0.05,=0.24) for the *AP* condition (M = 258.79, SD = 75.01) was significantly less than that for the *SLOW* condition (M = 390.73, SD = 124.22), but the *AP* and *SLOW* conditions were not significantly different from the *CTL* condition (M = 342.06, SD = 102.13).

For participants slower than average with the *SLOW* condition, there was a significant effect of the content delivery method on the completion time (F (2,21) = 6.28, p = <0.05,= 0.38) and the number of pauses (F (2,21) =6.71, p <0.01,=0.39). The *AP* condition resulted in a significant faster completion time (M = 511.81, SD = 304.3) than the *SLOW* condition (M = 940.25, SD = 248.27), it also resulted in significant a smaller number of pauses (M = 3.75, SD = 0.70) than the *SLOW* condition (M = 7.25, SD = 2.695).

This additional analysis showed that auto-pausing instructional videos can potentially help participants who are proficient with the method complete tasks faster than slowing down the video or watching it at a normal speed. In contrast, it also showed that participants who were proficient with the *CTL* condition or the *SLOW* condition were not significantly faster with those methods. These results suggested that participants’ task completion time might be significantly faster with the *AP* condition than with the *CTL* condition once they have gained enough experience to be proficient with the method.

1. Study 2: Effect of more exposure to Auto-Pausing method
   1. Goal

In study 1, no significant difference in the completion time between the *AP* and the *CTL* condition was found except in the group of participants who were proficient with the *AP* condition. We hypothesized that this might have to do with the novelty of the *AP* condition and more exposure to the *AP* condition might result in a significantly faster completion time. Therefore, in Study 2, we investigate specifically whether there is a significant difference between participants’ completion time with the *AP* condition and the *CTL* condition once participants are familiar with the Auto-Pausing method after using it multiple times.

* 1. Participants

We followed the same recruitment procedures as in Study 1. For Study 2, we recruited 12 new participants for the study (age 65+, 8 males, and 4 females).

* 1. Apparatus and procedure

We employed the same web-based study interface and video conferencing software as we did in Study 1. We asked participants to complete 6 tasks with 6 different web applications: Outlook, YouTube, Google Drive, Gmail, Google Maps, and Google Calendar. Two of the tasks and their associated applications were from study 1. We increased the number of tasks because we would like each participant to be exposed multiple times to the conditions and we selected more applications to avoid skill transfers between different tasks within the same application. Similar to Study 1, for each application, we created an account for the participants to use so that they would not have to create accounts or use their personal ones. As for the procedures, we followed the same procedure used in Study 1.

* 1. Instructional videos and task scenarios

As with Study 1, we verified with participants to make sure they have no knowledge on how to complete the tasks used in the study. We then asked participants to first read a scenario describing the goals which participants were asked to complete. Afterward, we asked participants to watch a related instructional video.

Table . Details for the instructional videos

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Video | Length (s) | # of auto-pauses inserted | Average speech rate  (WPM) | Auto-pause time points (s) |
| [How to create rules to move emails in Outlook](https://drive.google.com/file/d/1h_nhGxo4fJLdrDhAcukpRRTbOq-cWQF5/view?usp=sharing) | 122 | 10 | 168 | 9.6, 20.7, 26.5, 45.5, 56.5, 64, 84.2, 95.4, 109.2, 121.9 |
| [How to create a music playlist on YouTube](https://drive.google.com/file/d/1zPuvGNYV_pzMmY14KN_HGCRE1eSnJg9w/view?usp=sharing) | 126 | 9 | 165 | 13.7, 33, 43.7, 55.1, 64.8, 74.4, 81.2, 89.6, 109.1 |
| [How To create and share Google Drive folders](https://drive.google.com/file/d/1epYtDI3kmCdWVKSizmll6GXjk0sEaRr5/view?usp=sharing) | 129 | 12 | 179 | 9.4, 21.6, 28.1, 46.9, 54.2, 71.9, 78.8, 84.2, 91.5, 107.3, 118.5, 126.1 |
| [How to set up a Gmail auto reply Message](https://drive.google.com/file/d/1zJ7LFsSc2UbkZshIanxa7LtM_FSApZHP/view?usp=sharing) | 132 | 9 | 160 | 23.2, 31.5, 39.5, 52.8, 78.6, 86.7, 97.7, 106.6, 132.2, |
| [How to measure distance on Google Maps](https://drive.google.com/file/d/1KNczy44QJpN_7nDeuTY7rwrpJUl3rGud/view?usp=sharing) | 140 | 11 | 169 | 6.1, 14.88, 22.7, 42.4, 50.09, 71.86, 83.27, 92.93, 105.86, 118.25, 127.74 |
| [Setting Google Calendar reminders tutorial](https://drive.google.com/file/d/15QOywe9Hsb6GImwusZNMnkkpF2Sv9fEb/view?usp=sharing) | 125 | 9 | 189 | 25.9, 36.7, 49.3, 59.1, 67.7, 84.4, 101.2, 111.2, 124.6 |

Again, we used existing instructional videos found on YouTube, with a length of around two minutes each, and rendered at 1080p resolution or more.

We asked participants to complete containing goals presented to them in a set of scenarios that aligned with what the instructional videos taught. We reused 2 scenarios (*Creating an Outlook e-mail rule* and *Creating a YouTube playlist*) from Study 1 and created 4 new scenarios. We excluded the Setting a Zoom meeting scenario from Study 1 because it required about 4 more steps than the new scenarios created for Study 2.

* **Scenario 1: Creating an Outlook e-mail rule (10 steps).** Facebook has been sending you emails on a regular basis. You would like to have all emails from Facebook go automatically into its own folder called "Facebook" instead, including both the future and the current emails.
* **Scenario 2: Creating a YouTube playlist (11 steps).** You came across three music videos on YouTube: *Sara Bareilles-Gravity, Taylor Swift-Love Story*, and *Katy Perry-Roar Official*. You really liked them. Now you have decided to find these three music videos and create a playlist with these three music videos. You want to name this playlist, “My Favourite Songs”.
* **Scenario 3: Creating a folder (9 steps).** You are planning to create a folder named "Trip photos" on Google Drive to store all the pictures you have taken during your last trip with your friend Celine. After creating the folder, you want to share it with Celine, so that she can view and edit the folder, as well as upload her pictures there later.
* **Scenario 4: Setting an auto-reply (8 steps).** You are going on a trip from July 1st to July 15th and you have asked Alice to take over your work during your vacation. The next thing you want to do is to have Gmail automatically reply to any incoming e-mails. You’d like for people to easily see in the subject for your auto-reply that you’re on vacation and will be back on July 15. And if people read the message itself, you’d like to tell them to e-mail Alice at alice@hotmail.com if they need immediate assistance.
* **Scenario 5: Measuring distance (9 steps).** You plan to do some construction work in your backyard. To do this, you need to figure out the perimeter of your backyard for your home (*6107 Long St, Los Angeles, CA 90043*) so that you can estimate the cost.
* **Scenario 6: Setting a reminder (10 steps).** You have scheduled a regular medical checkup with your doctor at 11:00 am from June 28th to July 31st every week on Monday and Wednesday. In case you might forget about it, you’d like to have your calendar to remind you about them 2 hours before each appointment.
  1. Conditions

Table 8. Condition assignment used in Study 2. AP stands for “Automatic Pausing,” CTL stands for “Control,” and S stands for “Scenario.”

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 | Trial 6 |
| P1 | S1×AP | S2×CTL | S3×AP | S4×CTL | S5×AP | S6×CTL |
| P2 | S1×CTL | S5×AP | S6×CTL | S4×AP | S2×CTL | S3×AP |
| P3 | S2×AP | S3×CTL | S1×AP | S5×CTL | S6×AP | S4×CTL |
| P4 | S2×CTL | S6×AP | S4×CTL | S5×AP | S3×CTL | S1×AP |
| P5 | S3×AP | S1×CTL | S2×AP | S6×CTL | S4×AP | S5×CTL |
| P6 | S3×CTL | S4×AP | S5×CTL | S6×AP | S1×CTL | S2×AP |
| P7 | S4×AP | S5×CTL | S6×AP | S1×CTL | S2×AP | S3×CTL |
| P8 | S4×CTL | S2×AP | S3×CTL | S1×AP | S5×CTL | S6×AP |
| P9 | S5×AP | S6×CTL | S4×AP | S2×CTL | S3×AP | S1×CTL |
| P10 | S5×CTL | S3×AP | S1×CTL | S2×AP | S6×CTL | S4×AP |
| P11 | S6×AP | S4×CTL | S5×AP | S3×CTL | S1×AP | S2×CTL |
| P12 | S6×CTL | S1×AP | S2×CTL | S3×AP | S4×CTL | S5×AP |

We compared two content delivery methods (*Method*): control (*CTL*) and auto-pausing (*AP*). The *CTL* condition left the video speed unaltered, while the *AP* condition inserted automatic pauses in the instructional videos by following the two criteria discussed in Section 4.2. More details can be found in Table 7.

In Study 2, we asked each participant to complete six different scenarios under two conditions: three scenarios under the *AP* condition and another three under the *CTL* condition. We counterbalanced the order of the six tasks, as shown in Table 8 ordering of the tasks (where AP stands for “Automatic Pausing,” CTL stands for “Control,” and S stands for “Scenario”).

* 1. Dependent variables

Beyond completion time, the number of manual pauses, we included two additional variables in the second study: the number of replays, and the replay time. We added these two variables for study 2 because in study 1 we observed that the action of replaying the video occurred more frequently than we expected but we did not capture this data. We defined the number of replays as the number of times a participant rewatched a portion of the video. In logging the number of replays, we would be able to test whether automatic pausing influences how often the participants needed to rewatch any portion of an instructional video vs. when they viewed an instructional video without any method regulating the content delivery rate. We defined the replay time as how long a participant spends rewatching parts of the video that she has already viewed. In logging the number of replays, we would be able to test whether automatic pausing influences how much of an instructional video the participants needed to rewatch vs. when they viewed an instructional video without any method regulating the content delivery rate. We again collected the participants’ satisfaction rating of each condition as a subjective measure. In Study 2, we used a 7-point scale ranging from 1 (very dissatisfied) to 7 (very satisfied).

* 1. Analysis

Similar to study 1, we used a General Linear Model (multi-factor ANOVA) with two independent variables (delivery rate and task type) to analyze the task performance data. We analyzed the satisfaction ratings for each content delivery method with a Friedman test.

* 1. Results

Table 9. Summary of comparison results for Study 2 (\* indicates significance)

| Variable | *CTL* | *AP* | Comparison |
| --- | --- | --- | --- |
| Completion time  # of manual pauses  # of replays  Replay time  Satisfaction (median) | 579.05 ± 184.44  10.28 ± 2.77  7.14 ± 3.47  151.33 ± 45.73  6 | 495.52 ± 171.28  2.33 ± 1.37  4.02 ± 1.80  120.58 ± 36.50  6.5 | *AP* < *CTL* \*  *AP* < *CTL* \*  *AP* < *CTL* \*  *AP* < *CTL* \*  *AP* < *CTL* \* |

We use a General Linear Model (multi-factor ANOVA) with two independent variables (content delivery method and task scenario) to analyze the task performance data. We summarize our findings in Table 9.

**Completion time.** The results indicated that there was a significant effect of the content delivery method on the completion time (F (1,60) =4.46, p = <0.05, = 0.057). More specifically, the completion time for the *AP* condition (M=495.52, SD = 171.28) was significantly less than that for the *CTL* condition (M=579.05, SD = 184.44), unlike the first study where there was no significant difference between the *AP* condition and the *CTL* condition. The task scenario had no effect on the completion time (F (5,60) = 0.94, p = 0.46, = 0.061). The content delivery method × task scenario interaction effect was not significant (F (5,0) =1.74, p = 0.14,= 0.1).

**The number of manual pauses.** The results showed that the effect of the content delivery method on the number of pauses was significant (F (1,60) =77.58, p <0.01,= 0.54). The number of pauses for the *AP* condition (M=2.33, SD = 1.37) was significantly smaller than the number of pauses for the *CTL* condition (M=10.28, SD = 2.77). The task scenario had no effect on the number of pauses (F (5,60) =1.14, p = 0.349,= 0.0038). Moreover, the content delivery method × task scenario interaction effect was not significant (F (5,60) =1.70, p =0.149,= 0.056). Similar to Study 1, the auto-pauses reduced the number of manual pauses the participants needed to make.

**The number of replays.** A significant effect of the content delivery method on the number of replays was found (F (1,60) =26.42, p = <0.01,= 0.29), but the effect of the task scenario was not observed (F (5,60) =0.61, p = 0.70,= 0.032). The number of replays in the *AP* condition (M = 4.02, SD = 1.80) was significantly less than in the *CTL* condition (M=7.14. SD = 3.47). Additionally, the content delivery method × task scenario interaction effect was not significant (F (5,60) =0.61, p = 0.69,= 0.035). The results indicated the auto-pause method reduced the number of times that participants needed to rewatch any part of the video.

**Replay time.** The effect of the content delivery method on the replay time was significant (F (1,60) =10.12, p <0.01,= 0.124), while the effect of the task scenario was not significant (F (5,60) = 1.82, p=0.123,= 0.11). The *AP* condition (M = 120.58, SD = 36.50) took significantly less replay time than the *CTL* condition (M=151.33, SD=45.73). Also, the content delivery method × task interaction was not significant (F (5,60) =0.89, p = 0.49,= 0.055). The results showed that the auto-pause method reduces the time the participants spent rewatching the video, which potentially contributed to the overall reduction in the completion time.

**Satisfaction rating.** A Friedman test was performed on the ratings, and a significant effect was found between the two content delivery methods ( ). The result suggested participants were more satisfied with the *AP* condition (Median = 6.5) than the *CTL* condition (Median=6).

**Participant’s feedback.** The participants’ feedback regarding the *AP* of the instructional videos was generally positive. Similar to Study 1, the participants’ feedback echoed the sentiment that auto-pause serves as a buffer for their memory. For example, P2 said “… (with auto-pause) I had more time to digest all the information and do the task.” Participants also viewed the auto-pause system as a “highlighter” that marked potentially important points in the video. For example, P5 commented “…to me, the pauses are like the video’s highlights so I know where to look in the video…I could quickly find a particular step just by looking at the video’s timeline.”

Additionally, the *AP* condition made watching the instructional videos less stressful. For example, P9 reported, “…Trying to keep up with the video at its regular speed stresses me out…auto-pause gives me some breathing room.” However, the *AP* method was not without problems: participants had divided opinions on the suitable number of auto-generated pauses in the videos. P4 desired fewer pauses, saying, “…There are way too many pauses…I can memorize many of the steps so most of the pauses are unnecessary to me…I’d say five pauses are more than enough for a five-minute video.” In contrast to P4, P11 requested more pauses. He commented, “…I’d suggest adding more pauses… one for every single action like a mouse click or pressing a key.” The effort associated with manually unpausing the video after each pause was also seen as an issue for some participants. P8 commented, “…I wish the video could just auto-play after two seconds to save me some effort.”

Table . Summary of comparison results after the nth trial with each condition (\* indicates significance)

| Variable | Trial 1 | Trial 2 | Trial 3 |
| --- | --- | --- | --- |
| Completion time  # of pauses  # of replays  Replay time | n.s.  *AP*<*CTL* \*  *AP* <*CTL* \*  n.s. | n.s.  *AP* <*CTL*\*  *AP* <*CTL* \*  *AP* <*CTL* \* | *AP* <*CTL*\*  *AP* <*CTL*\*  *AP* <*CTL* \*  *AP* <*CTL* \* |

**Proficiency and task performance.** The overall results indicated that it took the participants less time to complete the tasks in the *AP* condition than in the *CTL* condition. One of the possible explanations is that participants needed to spend less time replaying the video. Another explanation could be that the time the participants spent viewing the video was longer than necessary. A similar point was made by one participant: “…I got so caught up in the video that I didn’t pause. Before I realized it, I have already watched a huge chunk of the video... there’s no way I could remember all that information, so I had to go back and watch the video again” (P6). Although the exact reason entails further verification, the auto-pausing method has demonstrated its time efficiency in this study.

Additionally, to determine when participants became more proficient with the *AP* method than the *CTL* condition, we compared the performance data based on the number of trials each participant had completed at the time. The results of a one-way ANOVA showed that the task completion time with *AP* only became significantly different from *CTL* in the third trial (F (1,22) = 5.46, p <0.05,= 0.19), shown in Table 10. For the third trial, participants spent less time with the *AP* condition (M = 452.50, SD = 118.41) than with the *CTL* condition (M = 580.17, SD = 147.64). This meant that by the third time participants used the *AP* method, participants were able to complete tasks more proficiently with it.

1. Discussion and LimitationS
   1. Improving the techniques

The results from the two studies indicated that automatically pausing the instructional videos as a method for regulating the content delivery rate was beneficial in helping older adults completing tasks and that it was more helpful than simply slowing down the instructional videos by a uniform factor. However, our current implementation of the auto-pause method had several limitations and could be improved in different ways.

**Improving auto-pause with visual information.** Although the auto-pause method was effective with the videos used in the study, our approach for identifying where to insert automatic pauses might not generalize to other videos well. For example, some speakers may read through their scripts with almost no natural pauses or may speak with a lot of unintended pauses, which will make it difficult for the algorithm to accurately identify gaps of silence within the speech. Furthermore, the inclusion of background music in some videos will exacerbate the technical challenge. Thus, a natural way to improve upon our auto-pause method is to analyze other aspects of the instructional video beyond the audio stream, such as the visual components. For example, if the number of steps (and therefore changes on the screen) happening within a window of time exceeds a certain threshold, pauses could be inserted to allow the viewer to focus on a smaller number of steps at a time.

**Improving slowing dynamically.** Although the results from the experiments suggested that uniformly slowing down the instructional videos was not as helpful to the older adults in terms of reducing the task completion time, it did not mean that slowing down the instructional videos should be completely abandoned as a method for regulating the content delivery rate. The results merely indicated that applying a constant slowing factor over the whole video (like the slowing option on YouTube) might not be an ideal way of implementing the slowing condition. It is possible that there were parts of the video that might not have been slowed enough and other parts that were slowed too much. For future research, it could be worth revisiting whether just slowing down the video would be effective by exploring better ways of doing it. For example, one could consider applying a slowing factor to a locally fast-paced segment instead of applying the factor over the whole video. Additionally, we also believe there are also specific situations where slowing could be useful. For example, if a short step was carried out too quickly (e.g., clicking a button), a “slow-motion” effect could be applied to the associated frames to give the older adults longer exposure to that step and a clearer view of the step.

* 1. Improving the interface: notifying viewers of impending auto-pause

Although the small triangles on the video seek bar were supposed to indicate a pause point to the older adults, the auto-generated pauses still surprised some of the participants during the video playback. For example, a participant in Study 2 complained about the auto-pause system stopping the video too suddenly: “…sometimes when I was watching the video, all of a sudden, the video stopped, and it caught me off guard…I don’t like it…” (P5). One of the participants suggested adding some kind of notification ahead of an upcoming auto-pause: “…It would be nice to have some kind of notification. Otherwise, I’d think there’s something wrong with my internet connection…” (P7). To avoid abrupt and unexpected pauses, visual notifications should be included shortly before automatic pauses will occur.

* 1. Encouraging the adoption of the auto-pause method.

Study 2 shows that automatically pausing instructional videos was helpful to older adults. Our analysis shows that auto-pausing resulted in faster task completion time over the control after participants use it a third time. Thus, users will need to use auto-pausing multiple times before they become proficient with the method. However, if the method were to be deployed, it is possible that users might abandon the method after only trying it once or twice. Therefore, further research and design effort is needed to explore how to encourage users to continue to use the method enough times to experience its benefits.

* 1. Experiment design limitation

Despite our promising results, the experiment design had several limitations. We only tested the effect of regulating the content delivery rate on web-technology-related tasks for older adults. It is unknown how well this effect might apply to other types of tasks. Also, our recruitment process focused on older adults who possess a computer, and therefore the results might be biased towards users who have a particular level of familiarity and knowledge with technology.

1. Conclusion

In this paper, we examined the effect of regulating the content delivery rate in instructional videos on older adults’ task performance. We explored automatically pausing the instructional videos and uniformly slowing down the instructional videos. We investigated whether regulating the content delivery rate is beneficial to older adults and whether automatically pausing the video or slowing it down is the more effective method for doing so. The results indicated that participants prefer auto-pausing over watching the video at a normal rate and that automatically pausing the instructional videos helped participants complete tasks faster than when they watch the video at a normal or uniformly slowed-down rate. When using the auto-pausing method for the first time, participants paused the video manually fewer times and replayed the video less than with normal playback. When using the method for the second time, participants also needed to replay less of the content than when they watched it at normal speed. By their third time using the method, participants completed tasks faster with auto-pausing than in the control condition. Overall, auto-pausing can help older adults follow and use instructional videos to complete their tasks, and users can become proficient with the method after using it three times.

As videos are increasingly becoming an important source of information that older adults could rely on to complete their tasks independently, especially in countries like the United States where 26% of the older adults live alone [37], creating tools to relieve older adults of the trouble of painstakingly scrubbing on and rewatching an instructional video is of great social value. With the auto-pausing method, older adults would be able to complete their tasks at hand faster and have more time to focus on other aspects of their lives. Additionally, it is worth noting that the auto-pausing method could be implemented with little cost, and it requires no software compatibility with the video. Finally, the auto-pausing method is easy to learn as we have shown that in our study the participants became proficient after three trials.

REFERENCES

1. Yvonne Barnard, Mike D. Bradley, Frances Hodgson, and Ashley D. Lloyd. 2013. Learning to use new technologies by older adults: Perceived difficulties, experimentation behaviour and usability. *Computers in Human Behavior* 29, 4: 1715–1724. https://doi.org/10.1016/j.chb.2013.02.006

2. M. Bergman. 1971. Hearing and aging: Implications of recent Research findings. *International Journal of Audiology* 10, 3: 164–171. https://doi.org/10.3109/00206097109072554

3. C. Bruder, H. Wandke, and L. Blessing. 2006. Improving mobile phone instruction manuals for seniors. *Gerontechnology* 5, 1. https://doi.org/10.4017/gt.2006.05.01.006.00

4. C. Caleako and A. Lazzaroni. 1957. SPEECH INTELLIGIBILITY IN RELATION TO THE SPEED OF THE MESSAGE. *The Laryngoscope* 67, 5: 410???419. https://doi.org/10.1288/00005537-195705000-00003

5. Ruth Colvin Clark and Richard E. Mayer. 2012. Applying the Multimedia Principle: Use Words and Graphics Rather Than Words Alone. *e-Learning and the Science of Instruction*: 66–89. https://doi.org/10.1002/9781118255971.CH4

6. Gillian Cohen. 1987. Review article: Speech comprehension in the elderly: The effects of cognitive changes. *British Journal of Audiology* 21, 3: 221–226. https://doi.org/10.3109/03005368709076408

7. Sara J. Czaja, Neil Charness, Arthur D. Fisk, Christopher Hertzog, Sankaran N. Nair, Wendy A. Rogers, and Joseph Sharit. 2006. Factors predicting the use of technology: Findings from the Center for Research and Education on Aging and Technology Enhancement (CREATE). *Psychology and Aging* 21, 2: 333–352. https://doi.org/10.1037/0882-7974.21.2.333

8. Sara J. Czaja and Joseph Sharit. 1998. Age differences in attitudes toward computers. *Journals of Gerontology - Series B Psychological Sciences and Social Sciences* 53, 5: 329–340. https://doi.org/10.1093/geronb/53B.5.P329

9. Ching-Ting Jamie Hsieh Dyi-Yih Michael Lin. 2012. The role of multimedia in training the elderly to acquire operational skills of a digital camera. 58.

10. Deena Ebaid and Sheila G. Crewther. 2019. Visual information processing in young and older adults. *Frontiers in Aging Neuroscience* 11, MAY: 1–12. https://doi.org/10.3389/fnagi.2019.00116

11. Beno Ît Encelle, Magali Ollagnier Beldame, and Yannick Prié. 2013. Towards the usage of pauses in audio-described videos. *W4A 2013 - International Cross-Disciplinary Conference on Web Accessibility*: 0–3. https://doi.org/10.1145/2461121.2461130

12. Cara Bailey Fausset, Linda Harley, Sarah Farmer, and Brad Fain. 2013. Older Adults’ Perceptions and Use of Technology: A Novel Approach. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* 8010 LNCS, PART 2: 51–58. https://doi.org/10.1007/978-3-642-39191-0\_6

13. Pascal W.M. Van Gerven, Fred Paas, and Huib K. Tabbers. 2006. Cognitive aging and computer-based instructional design: Where do we go from here? *Educational Psychology Review* 18, 2: 141–157. https://doi.org/10.1007/s10648-006-9005-4

14. Denise Gramss and Doreen Struve. 2009. Instructional videos for supporting older adults who use interactive systems. *Educational Gerontology* 35, 2: 164–176. https://doi.org/10.1080/03601270802421434

15. Carol A. Holland and Janet Fletcher. 2000. The effect of slowing speech rate at natural boundaries on older adults’ memory for auditorially presented stories. *Australian Journal of Psychology* 52, 3: 149–154. https://doi.org/10.1080/00049530008255382

16. Kerrie Laguna and Renée L. Babcock. 1997. Computer anxiety in young and older adults: Implications for human-computer interactions in older populations. *Computers in Human Behavior* 13, 3: 317–326. https://doi.org/10.1016/S0747-5632(97)00012-5

17. Rock Leung, Charlotte Tang, Shathel Haddad, Joanna McGrenere, Peter Graf, and Vilia Ingriany. 2012. How older adults learn to use mobile devices: Survey and field investigations. *ACM Transactions on Accessible Computing* 4, 3. https://doi.org/10.1145/2399193.2399195

18. F H Marcellini Mollenkopf L Spazzafumo I Ruoppila, Fiorella Marcellini, Heidrun Mollenkopf, Liana Spazzafumo, and Isto Ruoppila. 2000. *Acceptance and use of technological solutions by the elderly in the outdoor environment: findings from a European survey*.

19. Richard E. Mayer. 2014. Cognitive theory of multimedia learning. *The Cambridge Handbook of Multimedia Learning, Second Edition*: 43–71. https://doi.org/10.1017/CBO9781139547369.005

20. Scott D. Moffat, Alan B. Zonderman, and Susan M. Resnick. 2001. Age differences in spatial memory in a virtual environment navigation task. *Neurobiology of Aging* 22, 5: 787–796. https://doi.org/10.1016/S0197-4580(01)00251-2

21. Amy L. Mykityshyn, Arthur D. Fisk, and Wendy A. Rogers. 2002. Learning to use a home medical device: Mediating age-related differences with training. *Human Factors* 44, 3: 354–364. https://doi.org/10.1518/0018720024497727

22. Sankaran N. Nair, Chin Chin Lee, and Sara J. Czaja. 2005. Older adults and attitutdes towards computers: Have they changed with recent advances in technology? *Proceedings of the Human Factors and Ergonomics Society*: 154–157. https://doi.org/10.1177/154193120504900201

23. Amy Ogan, Vincent Aleven, and Christopher Jones. 2008. Pause, predict, and ponder: Use of narrative videos to improve cultural discussion and learning. *Conference on Human Factors in Computing Systems - Proceedings*: 155–162. https://doi.org/10.1145/1357054.1357081

24. Katherine E. Olson, Marita A. O’Brien, Wendy A. Rogers, and Neil Charness. 2011. Diffusion of technology: Frequency of use for younger and older adults. *Ageing International* 36, 1: 123–145. https://doi.org/10.1007/s12126-010-9077-9

25. Richard Pak, Wendy A. Rogers, and Arthur D. Fisk. 2006. Spatial ability subfactors and their influences on a computer-based information search task. *Human Factors* 48, 1: 154–165. https://doi.org/10.1518/001872006776412180

26. Suporn Pongnumkul, Mira Dontcheva, Wilmot Li, Jue Wang, Lubomir Bourdev, Shai Avidan, and Michael F. Cohen. 2011. Pause-and-play. 135. https://doi.org/10.1145/2047196.2047213

27. Edmundo A Sierra, Arthur D Fisk, and Wendy A Rogers. *MATCHING INSTRUCTIONAL MEDIA WITH INSTRUCTIONAL DEMANDS*.

28. Jeff A. Small, Elaine S. Andersen, and Daniel Kempler. 1997. Effects of working memory capacity on understanding rate-altered speech. *Aging, Neuropsychology, and Cognition* 4, 2: 126–139. https://doi.org/10.1080/13825589708256641

29. M. Tacken, F. Marcellini, H. Mollenkopf, I. Ruoppila, and Z. Széman. 2005. Use and acceptance of new technology by older people. Findings of the international MOBILATE survey: ‘Enhancing mobility in later life.’ *Gerontechnology* 3, 3. https://doi.org/10.4017/gt.2005.03.03.002.00

30. N. Tubi and A. Calev. 1989. Verbal and visuospatial recall by younger and older subjects: use of matched tasks. *Psychology and aging* 4, 4: 493–495. https://doi.org/10.1037/0882-7974.4.4.493

31. What They Watch Online | Pew Research Center. Retrieved October 23, 2020 from https://www.pewresearch.org/internet/2007/07/25/what-they-watch-online/

32. 1997\_-\_Theodore\_Bashore\_-\_TheDeclineofCognitiveProcessingSpeedinOldAge[retrieved\_2021-02-18].pdf.

33. The National Center for Voice and Speech - Tutorials. Retrieved April 23, 2021 from http://www.ncvs.org/ncvs/tutorials/voiceprod/tutorial/quality.html

34. Social foundations of thought and action: A social cognitive theory. - PsycNET.

35. What Noises Cause Hearing Loss? | NCEH | CDC. Retrieved June 12, 2021 from https://www.cdc.gov/nceh/hearing\_loss/what\_noises\_cause\_hearing\_loss.html

36. Pauses can make or break a conversation -- ScienceDaily. Retrieved June 5, 2021 from https://www.sciencedaily.com/releases/2015/09/150930110555.htm

37. By the numbers: May 2016. Retrieved August 31, 2021 from https://www.apa.org/monitor/2016/05/numbers