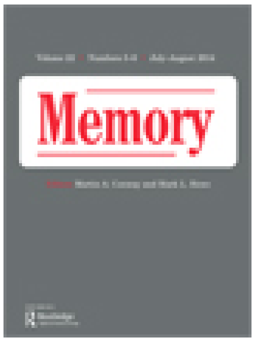

Memory

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ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/pmem20

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To cite this article: Dillon H. Murphy, Kara M. Hoover & Alan D. Castel (2023): The effect of video playback speed on learning and mind-wandering in younger and older adults, Memory, DOI: 10.1080/09658211.2023.2198326

To link to this article: https://doi.org/10.1080/09658211.2023.2198326

Published online: 05 Apr 2023.

MEMORY
https://doi.org/10.1080/09658211.2023.2198326

The effect of video playback speed on learning and mind-wandering in younger and older adults

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ABSTRACT

Prior work has demonstrated that watching videos at faster speeds does not significantly impair learning in younger adults; however, it was previously unclear how increased video speed impacts memory in older adults. Additionally, we investigated the effects of increased video speed on mind-wandering. We presented younger and older adults with a pre-recorded video lecture and manipulated the video to play at different speeds. After watching the video, participants predicted their performance on a memory test covering the material from the video and then completed said memory test. We demonstrated that although younger adults can watch lecture videos at faster speeds without significant deficits in memory, older adults' test performance is generally impaired when watching at faster speeds. Additionally, faster playback speeds seem to reduce mind-wandering (and mind-wandering was generally reduced in older adults relative to younger adults), potentially contributing to younger adults' preserved memory at faster speeds. Thus, while younger adults can watch videos at faster speeds without significant consequences, we advise against older adults watching at faster speeds.

ARTICLE HISTORY
Received 8 December 2022
Accepted 27 March 2023

KEYWORDS
Video speed; memory; mind-wandering; aging; cognitive load

With the advent of COVID-19 forcing people to go online, the essentiality of technology has become paramount. In fact, in a survey from the Pew Research Center in 2021 that surveyed 4,623 U.S. adults, 90% of surveyed adults reported that the Internet has been important to them during the pandemic with 58% saying that the Internet has become essential. This has been seen in numerous populations including an uptick in adults who are 65 and older (McClain et al., 2021). The rise of technology usage has led to more widespread and frequent use of online learning. Online learning has made edification more accessible to many populations such as older adults who are homebound or otherwise struggle with transportation or mobility issues. As learning has been found to sustain engagement and enhance well-being in older adults (Jenkins, 2011; Jenkins & Mostafa, 2015; Leung & Liu, 2011; Narushima, 2008), the rise in online courses provides a unique and accessible means of improving psychological well-being in even the most vulnerable populations. Thus, research investigating online learning and the tools that may optimise older adults' learning is not only relevant but essential.

Although typically perceived as being unfamiliar or resistant to technology, three out of four older adults reported using technology in 2021 as a means of staying connected. In the same survey, three out of 10 older adults reported using technology to pursue a passion or interest via how-to videos, online classes, and other forms of learning (Kakulla, 2021). One potential benefit of this newer form of online learning is that older adults can manipulate their instructional videos. Specifically, they can watch them whenever they want, as many times as they want, and at whatever speed that they want. This may be especially important as age-related changes in cognition may necessitate adjustments to instructional videos to optimise learning. Thus, online learning could allow for better or more efficient learning, but older adults may need to adjust such technology in ways that support their unique cognitive abilities.

In terms of the playback speed of instructional videos, recent work suggests that watching videos at faster speeds does not significantly impair learning in college-aged students if they do not exceed double (2x) the speed of the original video (see Murphy et al., 2022; see also Lang et al., 2020; Nagahama & Morita, 2017; Wilson et al., 2018; but see Foulke & Sticht, 1969; Song et al., 2018; Vemuri et al., 2004). As such, students can enhance

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*The authors certify that they have no affiliations with or involvement in any organization or entity with any financial or non-financial interest in the subject matter or materials discussed in this manuscript. The ideas and data appearing in the manuscript have not been disseminated before (e.g., at a conference or meeting, posted on a listserv, shared on a website). Experiment 3 was formally preregistered, and the stimuli and data have been made available on the Open Science Framework: https://osf.io/fkdqg/?view_only = e6023841347d4c75b84a1ff391030ccf.

learning outcomes by taking advantage of this increased efficiency (watching a 2x speed takes half the time as watching at 1x speed; see also Pastore & Ritzhaupt, 2015) if students use the time saved towards other activities that bolster learning (such as re-watching videos again at 2x speed shortly before an exam; see Murphy et al., 2022). Thus, watching instructional videos at faster speeds can be an advantageous learning strategy for college-aged students.

Humans generally speak at a rate of 150 words per minute (Peelle & Davis, 2012), and at 2x speed, the speech rate of instructional videos likely surpasses 300 words per minute. Although prior work has indicated that speech comprehension begins to decline at around 275 words per minute (see Foulke & Sticht, 1969), which may suggest that doubling the playback speed of an instructional video should reduce comprehension, people can be trained to understand speech rates of up to 475 words per minute (Goldhaber, 1970; Orr et al., 1965; see Manheim et al., 2018 for training in older adults; see also Schmitt & Moore, 1989). Thus, with increased exposure and practice, college students can watch instructional videos at faster speeds without major drawbacks (and most students report watching at faster speeds, see Murphy et al., 2022). However, in contrast to college-aged students who are frequently exposed to instructional videos at faster speeds, older adults may lack the potential experience with faster videos and comprehending faster speech rates. Thus, while memory is generally preserved at faster speeds in younger adults (Murphy et al., 2022), due to reduced exposure to videos of such speeds, older adults may exhibit poorer learning.

Age-related cognitive deficits may also impact the ability of older adults to comprehend videos at faster speeds. Older adults, even with normal hearing, often express having difficulty following rapid conversational speech (Gordon-Salant & Fitzgibbons, 2001; Vaughan & Letowski, 1997; Wingfield et al., 1985). This may be explained by age-related impairments in processing speed (Cerella & Hale, 1994; Salthouse, 1996) which suggest that older adults' slowed processing systems would fall behind in the recognition and analysis of rapid speech. This is supported by numerous studies showing that older adults have a particularly difficult time comprehending and recalling artificially accelerated speech (Gordon-Salant & Fitzgibbons, 1993; Konkle et al., 1977; Riggs et al., 1993; Stine & Wingfield, 1987; Tun et al., 1992; Wingfield et al., 1985). Further, time restoration in the form of pauses aids in the recall of artificially accelerated speech in younger adults more than older adults (e.g., Wingfield et al., 1999), and older adults show a preference for slower speech rates (Wingfield & Ducharme, 1999). Thus, increasing the speed of an instructional video, therefore also artificially accelerating the instructor's speech, may detrimentally affect older adults while not significantly affecting younger adults.

Older adults also have been found to have impaired working memory (Dobbs & Rule, 1989) compared with younger adults which may play an additional detrimental role in the effect of faster video speed on older adults' memory. Due to age-related deficits in working memory, the increased cognitive load (i.e., how much information can be maintained in working memory at a given time) from watching videos at faster speeds may lead to memory deficits in older adults but not younger adults (who have superior working memory abilities). Specifically, the Cognitive Load Theory posits that to-be-learned information is stored in working memory before being transferred to long-term memory (see Sweller, 1988, 1989; see also Leahy & Sweller, 2011; Paas et al., 2003, 2004; van Merriënboer & Sweller, 2005). Because of the limits to working memory (see Baddeley & Hitch, 1974; Cowan, 2010; Gilchrist et al., 2008; Miller, 1956), the increased rate of to-be-learned information at faster speeds may overwhelm the process of transferring information from working memory into long-term memory (see Sweller et al., 2011), particularly in older adults.

Rather than watching at faster speeds which can preserve memory and increase efficiency in younger adults, older adults may prefer and potentially benefit from watching instructional videos at slightly slower speeds (e.g., 0.75x). Slowing the rate of instructional videos may be an advantageous study strategy to compensate for any cognitive deficits accompanying older age (see Hess, 2005; Park & Festini, 2017; Salthouse, 2010) by providing older adults with more processing time and reducing their cognitive load. However, younger adults without such deficits may perform worse at slower speeds if the resulting increased video duration reduces attention to the videos.

Learners who watch videos at faster speeds may do so to reduce the videos' duration, potentially promoting focus and attention to the video. Although there could be some benefits to watching instructional videos at slower speeds, perhaps primarily in older adults, longer video durations may result in increased mind-wandering (i.e., when attention shifts from the target item to self-generated thoughts unrelated to the current task; see Smallwood & Schooler, 2006 for a review). Mind-wandering is generally thought to be detrimental to learning such that more frequent mind-wandering results in poorer retention of the to-be-learned material (see Hollis & Was, 2014, 2016; Lindquist & McLean, 2011; Risko et al., 2012; Szpunar, 2017; Szpunar et al., 2013a, 2013b; see Blondé et al., 2021 for a review of the effects of mind-wandering on episodic memory). As such, preserved memory at faster speeds in younger adults may occur due to decreased mind-wandering (although Wilson et al. (2018) found little effect of video speed on mind-wandering), perhaps compensating for any costs of the increased cognitive load at faster speeds.

Compared with younger adults, mind-wandering is typically reduced in older adults (Arnicane et al., 2021;

Giambra, 1989; Jackson & Balota, 2012; Krawietz et al., 2012; Maillet & Rajah, 2016; McVay et al., 2013; Seli et al., 2017; see Jordão et al., 2019 for a review). This may be attributable to increased motivation (Seli et al., 2021), greater positive affect, and/or more conscientiousness (Frank et al., 2015), all attributes that are enhanced in older age. As a result, older adults may not need to resort to increasing video speed to reduce mind-wandering. Thus, although slower speeds may increase mind-wandering in younger adults, older adults' decreased processing speed and enhanced motivation may result in slower video speeds being beneficial for their learning.

In the present study, we were interested in determining how faster and slower video speeds differentially impact learning, as well as predictions of test performance, in younger and older adults. Additionally, we investigated how video speed impacts mind-wandering and how mind-wandering interacts with video speed. We presented younger and older adults with a pre-recorded video lecture and manipulated the video to play at different speeds. After watching the video, participants predicted their performance on a test covering the material from the video and then completed the test. Generally, we expected preserved memory at faster speeds in younger adults but impaired memory at slower speeds. In addition, we expected that increased speeds would impair memory in older adults while slower speeds may enhance older adults' memory. In terms of mind-wandering, we expected faster speeds to reduce mind-wandering in younger and older adults while slower speeds would increase mind-wandering in younger adults but not older adults due to age-related deficits in processing speed which may be compensated for by a slower speech rate.

Experiment 1

In Experiment 1, younger and older adults watched a video on real estate appraisals at either 0.75x speed, normal speed (1x), or 2x speed, predicted their performance on a memory test, then completed the memory test. These three speeds were chosen as they represent realistic conditions in which people may adjust video speed to ensure some levels of comprehension and were consistent with the boundary conditions in which younger adults demonstrate preserved comprehension (see Murphy et al., 2022). We expected age-related deficits in performance at faster speeds but the preservation of memory for older adults at slower speeds.

Method

Participants

Younger adults (age range: 18-25; $n = 148$; $M_{age} = 20.22$, $SD_{age} = 1.30$; 122 female, 25 male, 1 other; 57 Asian/Pacific Islander, 3 Black, 24 Hispanic, 49 white, 15 other/unknown; in terms of the highest level of education achieved, 1 some High School, 28 High School Graduate, 90 some college but no degree, 24 Associates degree, 5 Bachelor's degree) were recruited from the University of California Los Angeles (UCLA) Human Subjects Pool. Participants were tested online and received course credit for their participation. Older adults (age range: 64-94; $n = 178$; $M = 72.47$, $SD = 5.45$; 106 female, 71 male, 1 other; 3 American Indian/Alaskan Native, 3 Asian/Pacific Islander, 2 Black, 1 Hispanic, 168 white, 1 other/unknown; 2 some High School, 39 High School Graduate, 38 some college but no degree, 20 Associates degree, 45 Bachelor's degree, 34 Graduate degree (Masters, Doctorate, etc.)) were recruited from Amazon's Cloud Research (Chandler et al., 2019; see https://go.cloudresearch.com/knowledge/how-are-participants-on-prime-panels-compensated for information regarding compensation). Participants were excluded from analysis if they admitted to cheating (e.g., writing down answers) in a post-task questionnaire (they were told they would still receive credit if they cheated). This exclusion process resulted in one exclusion from the younger adult group and no exclusions from the older adult group. In each experiment, we aimed to collect around 50 younger adults and 50 older adults in each condition. The sample size was selected based on prior exploratory research and the expectation of detecting a medium effect size. A sensitivity analysis indicated that, with this sample size, assuming alpha $= .05$, we had an 80% chance of detecting a *medium* (Cohen's $d = .31$) difference between younger and older adults.

Materials

Participants watched a lecture video taken from Murphy et al. (2022). The video was on real estate appraisals (12 min and 56 s with 2,031 spoken words) and was modified to play at three different speeds (0.75x, 1x, and 2x). This yields a speech rate of 126 words per minute at 0.75x speed, 157 at 1x speed, and 314 at 2x speed. The video contained presentation slides along with a video of the lecturer on the left side of the screen; the video did not contain captions or subtitles. To measure learning, we also used 20 test questions (four-option multiple-choice and true or false) from Murphy et al. (2022).

Procedure

Younger and older adults were randomly assigned to watch videos at either 0.75x speed ($n = 117$), 1x speed ($n = 107$), or 2x speed ($n = 102$). Participants were told that they would be watching a short video and then taking a test on the material covered in the video. They were also instructed to watch the video in full-screen mode and not to pause the video or take any notes. Participants then watched the video, made a prediction of their test performance, and took the test; each phase took place immediately after the preceding phase). Participants could take as long as they wanted to make their predictions and the test was self-paced such that participants could take as long as they needed to respond to each

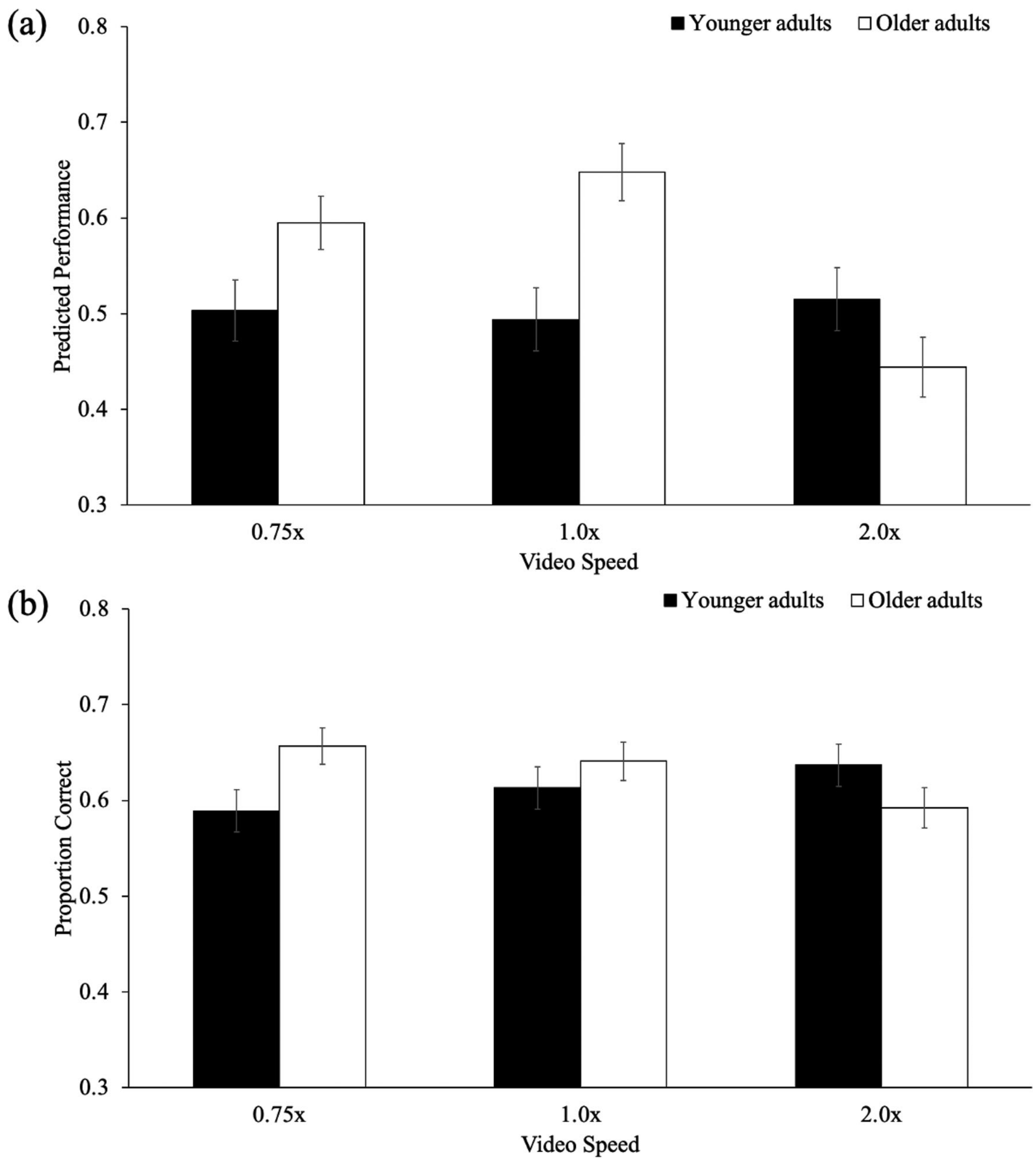

Figure 1. Younger and older adults' predictions of performance (a) and performance on the comprehension test (b) as a function of video speed in Experiment 1. Error bars reflect the standard error of the mean.

question. When making predictions, participants were asked how many of the 20 questions they expected to get correct. Lastly, participants completed a short questionnaire about their habits and preferences related to playback speed.

Results

To examine participants' predictions of performance, we conducted a general linear model using Jamovi. Specifically, we modelled predictions for each participant as a function of age (young, old) and video speed (continuous). As shown in Figure 1a, results revealed an effect of age [$t(322) = -2.38$, $p = .018$, $\beta = -.26$] such that older adults expected to answer a greater proportion of questions correctly ($M = .57$, $SD = .26$) than younger adults ($M = .50$, $SD = .20$). Additionally, results revealed an effect of speed [$t(322) = -2.66$, $p = .008$, $\beta = -.14$] such that the faster the speed, the worse participants expected to do on the test. Age interacted with speed [$t(322) = 3.21$, $p = .001$, $\beta = .35$] such that speed was not a significant predictor of predictions for younger adults [$t(322) = .37$, $p = .708$, $\beta = -.03$] but speed was negatively related to predictions for older adults [$t(322) = -4.31$, $p < .001$, $\beta = -.32$]. Specifically, compared with younger adults, older adults expected to perform better at 0.75x speed [$t(320) = 2.15$, $p = .032$] and

1x speed [$t(320) = 3.48$, $p < .001$] but not at 2x speed [$t(320) = -1.57$, $p = .118$].

Next, we modelled performance on the test as a function of age (young, old) and video speed (continuous). As shown in Figure 1b, a general linear model did not reveal an effect of age [$t(322) = -1.13$, $p = .259$, $\beta = -.12$] such that older adults answered a similar proportion of questions correctly ($M = .63$, $SD = .14$) as younger adults ($M = .61$, $SD = .17$). Additionally, results did not reveal an effect of speed [$t(322) = -.55$, $p = .582$, $\beta = -.03$] but age interacted with speed [$t(322) = 2.69$, $p = .007$, $\beta = .30$] such that speed was not a significant predictor of performance for younger adults [$t(322) = 1.46$, $p = .145$, $\beta = .12$] but speed was negatively related to performance for older adults [$t(322) = -2.38$, $p = .018$, $\beta = -.18$]. Specifically, older adults performed better at 0.75x speed compared with younger adults [$t(320) = 2.36$, $p = .019$] but there were no differences at 1x [$t(320) = .94$, $p = .346$] or 2x speed [$t(320) = -1.49$, $p = .138$].

We were also interested in the relationship between participants' predictions of performance and their scores on the test. Specifically, we calculated a *calibration* (see Rhodes, 2016) score for each participant by subtracting a given participant's performance from their prediction. Calibration modelled as a function of age (young, old) and video speed (continuous) did not reveal an effect of age [$t(322) = -1.57$, $p = .116$, $\beta = -.17$] such that older adults were similarly calibrated ($M = -.07$, $SD = .26$) as younger adults ($M = -.11$, $SD = .22$). However, results revealed an effect of speed [$t(322) = -2.22$, $p = .027$, $\beta = -.12$] such that calibration was more negative (i.e., more underconfidence) at faster video speeds. Age did not interact with speed [$t(322) = 1.37$, $p = .173$, $\beta = .15$].

Discussion

In Experiment 1, while younger adults expected to perform similarly at each of the video speeds, older adults expected to do worse on the test at faster playback speeds. Test performance generally reflected these predictions such that younger adults were able to watch the video at a faster speed without significant performance deficits but faster playback speeds lead to worse performance in older adults. Thus, the results of Experiment 1 indicate that watching videos at faster speeds may be an effective study strategy for younger adults (consistent with Murphy et al., 2022), while older adults' best performance was at slower speeds.

Experiment 2

In Experiment 2, we investigated whether mind-wandering varies between age groups while watching videos at different speeds. Similar to Experiment 1, we presented younger and older adults with a lecture video at either 0.75x, 1x, or 2x speed but included mind-wandering probes every 60 s. Specifically, we asked participants to describe their current cognitive state (e.g., focused on the task, distracted, etc.). Consistent with prior work in younger adults (Wilson et al., 2018), we expected more mind-wandering at slower speeds, but older adults may also show reduced mind-wandering in general (see Jordão et al., 2019).

Method

Participants

All participants in Experiment 2 did not participate in Experiment 1. Younger adults (age range: 18-36; $n = 150$; $M_{age} = 20.70$, $SD_{age} = 2.56$; 114 female, 32 male, 4 other; 2 American Indian/Alaskan Native, 73 Asian/Pacific Islander, 2 Black, 22 Hispanic, 44 white, 7 other/unknown; 19 High School Graduate, 94 some college but no degree, 19 Associates degree, 17 Bachelor's degree, 1 Graduate degree) were recruited from the UCLA Human Subjects Pool. Participants were tested online and received course credit for their participation. Older adults (age range: 61-93; $n = 176$; $M = 72.58$, $SD = 5.86$; 116 female, 60 male; 4 American Indian/Alaskan Native, 2 Asian/Pacific Islander, 4 Black, 163 white, 3 other/unknown; 4 some High School, 44 High School Graduate, 40 some college but no degree, 17 Associates degree, 41 Bachelor's degree, 30 Graduate degree) were recruited from Amazon's Cloud Research (Chandler et al., 2019). No participants were excluded for admitting to cheating. A sensitivity analysis indicated that, with this sample size, assuming alpha = .05, we had an 80% chance of detecting a *medium* (Cohen's $d = .31$) difference between younger and older adults.

Materials and procedure

The materials and procedure were similar to Experiment 1. Again, younger and older adults were randomly assigned to watch videos at either 0.75x speed ($n = 103$), 1x speed ($n = 122$), or 2x speed ($n = 101$). However, participants were asked about their mind-wandering every 60 s. Specifically, every 60 s, the video stopped, and participants were asked to characterise their current conscious experience as one of five options: 1) totally focused on the current task, 2) thinking about their performance on the task or how long it is taking, 3) distracted by information present in the room (sights and sounds), 4) or zoning out/mind-wandering, or 5) "Other" (taken from Unsworth & McMillan, 2014). Participants were given as much time as they needed to respond. Because of the different video durations, participants watching at 0.75x speed were probed 18 times, participants watching at 1x speed were probed 13 times, and participants watching at 2x speed were probed seven times.

Results

To examine mind-wandering rates, we first coded participants' responses to the mind-wandering probes as either

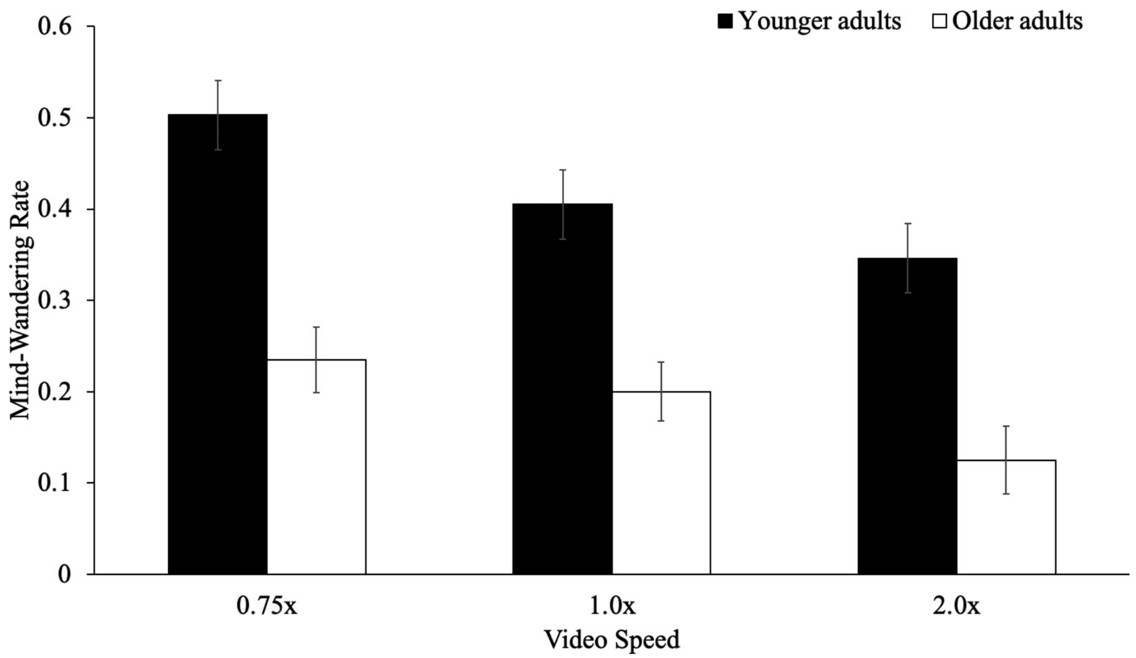

Figure 2. Younger and older adults' mind-wandering rates as a function of video speed in Experiment 2. Error bars reflect the standard error of the mean.

mind-wandering (distracted by information present in the room (sights and sounds) or zoning out/mind-wandering) or not mind-wandering (totally focused on the current task/thinking about their performance on the task or how long it is taking); "Other" responses were not considered mind-wandering or not mind-wandering. We then computed the proportion of the time participants indicated that they were mind-wandering.

We first investigated how mind-wandering changed throughout the course of the video. Specifically, we conducted a multilevel model (MLM) where we treated the data as hierarchical or clustered (i.e., multilevel) with items nested within individual participants. Since mind-wandering for each probe was binary, we conducted a logistic MLM. In this analysis, the regression coefficient is given as a logit unit (i.e., the log odds of mind-wandering). We report exponential betas (e^B) which give the coefficient as an odds ratio (i.e., the odds of mind-wandering divided by the odds of not mind-wandering). Thus, e^B can be interpreted as the extent to which the odds of mind-wandering changed. Specifically, values greater than 1 represent an increased likelihood of mind-wandering while values less than 1 represent a decreased likelihood of mind-wandering.

We modelled mind-wandering as a function of checkpoint (the number of mind-wandering probes encountered at that point) and age (young, old).[1] Results revealed that mind-wandering increased as the video endured [$e^B = 1.13$, $z = 11.10$, $p < .001$]. Additionally, there was an effect of age [$e^B = 8.09$, $z = 7.95$, $p < .001$] such that younger adults mind-wandered more than older adults. Moreover, age interacted with checkpoint [$e^B = .91$, $z = -4.46$, $p < .001$] such that older adults' mind-wandering rate increased more as the video endured [$e^B = 1.19$, $z = 9.65$, $p < .001$] compared with younger adults [$e^B = 1.08$, $z = 5.65$, $p < .001$].

To further examine participants' mind-wandering, we modelled mind-wandering rates for each participant as a function of age (young, old) and video speed (continuous). As shown in Figure 2, a general linear model revealed an effect of age [$t(321) = 7.83$, $p < .001$, $\beta = -.79$] such that older adults reported less mind-wandering ($M = .19$, $SD = .26$) than younger adults ($M = .42$, $SD = .28$). Additionally, results revealed an effect of speed [$t(321) = -3.39$, $p < .001$, $\beta = -.17$] such that the faster the speed, the less mind-wandering participants reported. However, there was not an interaction between age and speed [$t(321) = -.40$, $p = .691$, $\beta = -.04$].

Next, we modelled participants' predictions of performance as a function of age (young, old) and video speed (continuous). As shown in Figure 3a, a general linear model revealed an effect of age [$t(322) = -4.68$, $p < .001$, $\beta = -.50$] such that older adults expected to answer a greater proportion of questions correctly ($M = .55$, $SD = .27$) than younger adults ($M = .42$, $SD = .24$). However, results did not reveal an effect of speed [$t(322) = -.17$, $p = .864$, $\beta = -.01$] and age did not interact with speed [$t(322) = .86$, $p = .391$, $\beta = .09$].

We also modelled performance on the test as a function of age (young, old) and video speed (continuous). As shown in Figure 3b, a general linear model did not reveal an effect of age [$t(322) = -.70$, $p = .485$, $\beta = -.08$] such that older adults answered a similar proportion of questions correctly ($M = .60$, $SD = .14$) as younger adults ($M = .59$, $SD = .17$). Additionally, results did not reveal an effect of speed [$t(322) = -.74$, $p = .458$, $\beta = -.04$] and age

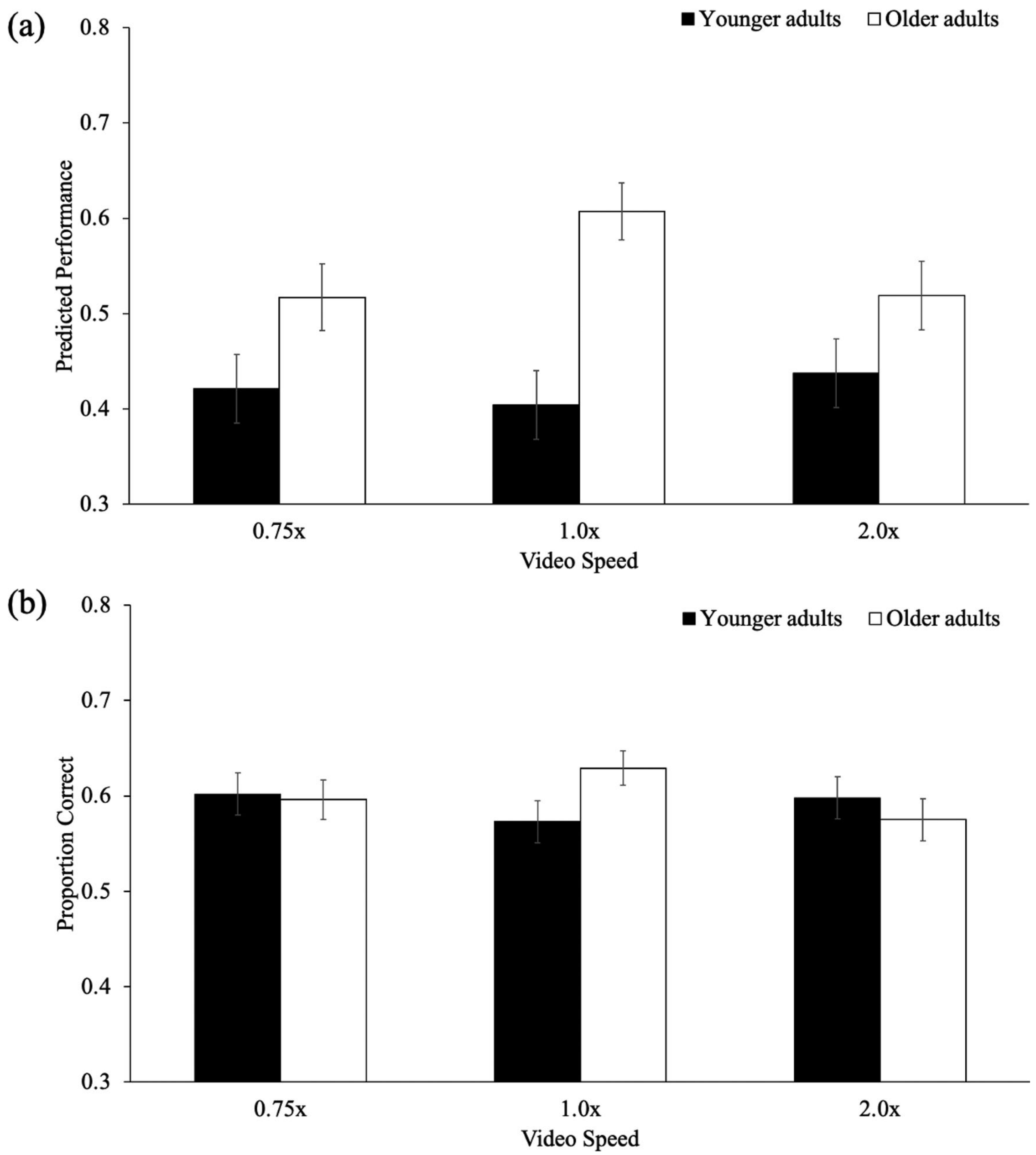

Figure 3. Younger and older adults' predictions of performance (a) and performance on the comprehension test (b) as a function of video speed in Experiment 2. Error bars reflect the standard error of the mean.

did not interact with speed [$t(322) = 1.06$, $p = .289$, $\beta = .12$]. We also examined the relationship between mind-wandering rate and performance. Results revealed a negative relationship [Pearson's $r(323) = -.24$, $p < .001$] such that as mind-wandering increased, performance decreased.

Lastly, we modelled calibration as a function of age (young, old) and video speed (continuous). Results revealed an effect of age [$t(322) = -4.48$, $p < .001$, $\beta = -.49$] such that older adults were better calibrated ($M = -.05$, $SD = .26$) than younger adults ($M = -.17$, $SD = .22$). However, results did not reveal an effect of speed [$t(322) = .29$, $p = .770$, $\beta = .02$] and age did not interact with speed [$t(322) = .23$, $p = .821$, $\beta = .02$].

Discussion

In Experiment 2, mind-wandering decreased at faster playback speeds and older adults reported less mind-wandering than younger adults, consistent with prior work on mind-wandering and aging (Jordão et al., 2019). The faster playback speeds may encourage less mind-wandering as greater attention is needed to comprehend information under these conditions (see also Wilson et al., 2018). Additionally, although older adults had higher expectations regarding their learning (and were better calibrated; cf. Hertzog et al., 2002), younger and older adults performed similarly on the test. In terms of the playback speed, both younger and older adults expected similar performance at each of the playback speeds and test scores generally reflected this trend. Thus, in contrast to Experiment 1, Experiment 2 indicates that watching at faster speeds may not be harmful to older adults when frequently responding to thought probes, perhaps indicating that the probes guide vigilance, awareness, and reflection on learning under these more demanding conditions.

Experiment 3

In Experiment 3, we aimed to replicate the effects observed in Experiments 1 and 2 in a preregistered study 1) with different materials to increase the generalizability of our findings, 2) recruiting and compensating younger and older adults in the same way, 3) directly comparing participants watching the video with and without mind-wandering probes, 4) using validity/attention checks to ensure participant engagement, and 5) probing all participants the same number of times rather than confounding video speed and the number of probes (although this design confounds the lag between probes and video speed). We expected to replicate the effects observed in Experiments 1 and 2 such that older adults will mind-wander less than younger adults, older adults will show a decrease in test performance at faster speeds (and predictions will map on to this trend), and the presence of mind-wandering probes will reduce this deficit at 2x speed in older adults.

Method

Participants

All participants in Experiment 3 did not participate in Experiments 1 or 2. All participants were recruited from Amazon's Cloud Research (Chandler et al., 2019). After exclusions, our sample consisted of 173 younger adults (age range: 18-29; $M_{age} = 23.98$, $SD_{age} = 3.36$; 123 female, 46 male, 4 other; 14 Asian/Pacific Islander, 26 Black, 17 Hispanic, 110 white, 6 other/unknown; 5 some High School, 36 High School Graduate, 42 some college but no degree, 23 Associates degree, 47 Bachelor's degree, 20 Graduate degree) and 199 older adults (age range: 65-93; $M_{age} = 72.43$, $SD_{age} = 5.72$; 118 female, 81 male, 2 American Indian/Alaskan Native, 3 Asian/Pacific Islander, 5 Black, 186 white, 3 other/unknown; 40 some High School, 36 High School Graduate, 23 Associates degree, 57 Bachelor's degree, 43 Graduate degree). Four participants (all younger adults) were excluded for admitting to cheating. Participants were also excluded for failing either of two attention checks. The first attention check occurred after participants watched the video and they were asked what the video was about: history of Asia, history of the Roman Empire, history of Spanish colonisation, or history of Dutch trading. The second attention check occurred after taking the test and participants were asked which of these items would be used for cooking: baseball, pants, cabinet, or pan. One older adult and 21 younger adults were excluded for failing to pass an attention check. A sensitivity analysis indicated that, with this sample size, assuming alpha = .05, we had an 80% chance of detecting a *medium* (Cohen's $d = .29$) difference between younger and older adults.

Materials and procedure

Participants watched a lecture video taken from Murphy et al. (2022) on the history of the Roman Empire (14 min and 27 s with 2,403 spoken words) which was modified to play at two different speeds (1x and 2x speed). This yields a speech rate of 166 words per minute at 1x speed and 332 at 2x speed. The video contained presentation slides along with a video of the lecturer on the left side of the screen; the video did not contain captions or subtitles. To measure learning, we also used 20 test questions (four-option multiple-choice and true or false) from Murphy et al. (2022).

The procedure was similar to Experiment 2. Again, younger and older adults were randomly assigned to watch videos at either 1x speed or 2x speed. Additionally, some participants were given mind-wandering probes, but others were not given any mind-wandering probes. However, in contrast to Experiment 2, there were a total of seven mind-wandering probes, regardless of video speed. Specifically, participants watching at 2x speed were probed at a rate of around once per minute while participants watching at 1x speed were probed once every two minutes. This procedure yielded 48 older adults watching at 1x speed with no mind-wandering probes, 42 younger adults watching at 1x speed with no mind-wandering probes, 49 older adults watching at 1x speed with mind-wandering probes, 41 older adults watching at 1x speed with mind-wandering probes, 51 older adults watching at 2x speed with no mind-wandering probes, 43 younger adults watching at 2x speed with no mind-wandering probes, 51 older adults watching at 2x speed with mind-wandering probes, and 47 younger adults watching at 2x speed with mind-wandering probes.

Results

We coded participants' responses to the mind-wandering probes the same way as in Experiment 2. We first modelled mind-wandering modelled as a function of checkpoint (the number of mind-wandering probes encountered at that point), age (young, old), and speed (1x, 2x). Results revealed that mind-wandering increased as the video endured [$e^B = 1.56$, $z = 8.76$, $p < .001$]. However, there were no significant interactions with checkpoint [all *ps* > .081]. Next, we modelled mind-wandering rates for each participant as a function of age (young, old) and video speed (1x, 2x). As shown in Figure 4, a general linear model did not reveal an effect of age [$t(184) = .06$, $p = .951$, $\beta = .01$] such that older adults reported similar

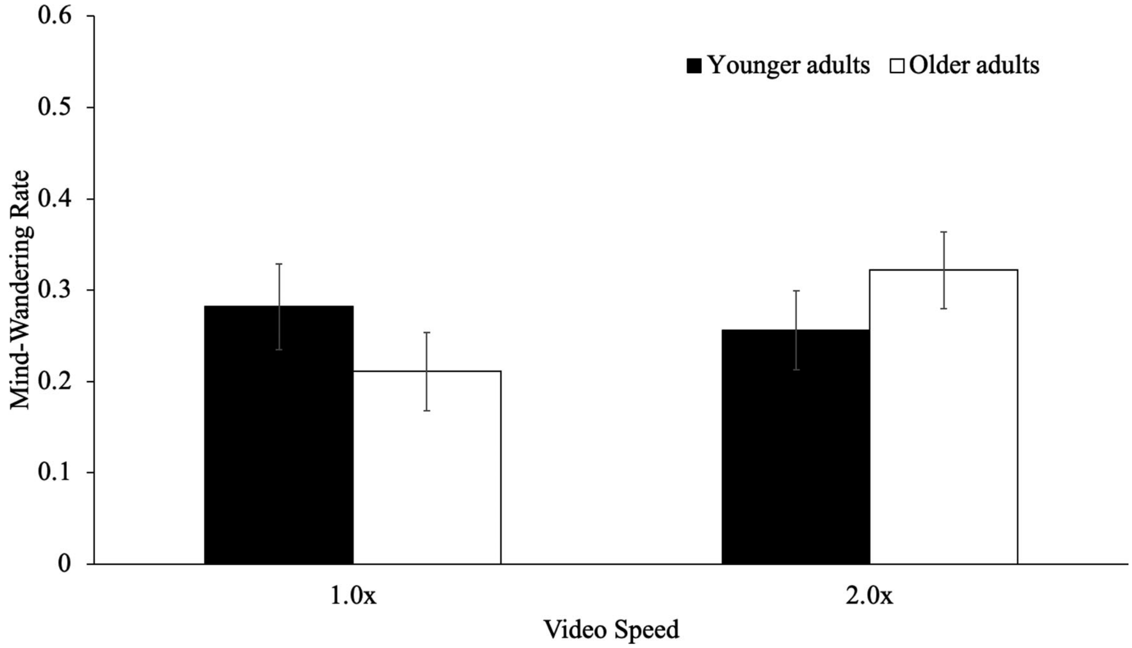

Figure 4. Younger and older adults' mind-wandering rates as a function of video speed in Experiment 3. Error bars reflect the standard error of the mean.

mind-wandering ($M = .27$, $SD = .31$) as younger adults ($M = .27$, $SD = .29$). Additionally, results did not reveal an effect of speed [$t(184) = .98$, $p = .329$, $\beta = .14$] such that mind-wandering rates were similar at 1x ($M = .24$, $SD = .29$) and 2x speed ($M = .29$, $SD = .31$). Moreover, there was not an interaction between age and speed [$t(184) = -1.57$, $p = .119$, $\beta = -.46$].

We also modelled participants' predictions of performance with age (young, old), the presence of mind-wandering probes (present, absent), and video speed (1x, 2x) as predictors. As shown in Figure 5a, a general linear model revealed an effect of age [$t(364) = 2.13$, $p = .034$, $\beta = .22$] such that younger adults expected to answer a greater proportion of questions correctly ($M = .55$, $SD = .26$) than older adults ($M = .49$, $SD = .27$). Additionally, results revealed an effect of speed [$t(364) = -3.31$, $p = .001$, $\beta = -.34$] such that participants watching at 1x speed ($M = .57$, $SD = .25$) expected to perform better on the test than participants watching at 2x speed ($M = .48$, $SD = .28$). There was not an effect of the presence of mind-wandering probes [$t(364) = .05$, $p = .964$, $\beta < .01$] such that participants with probes ($M = .52$, $SD = .27$) expected to perform similarly on the test as participants without probes ($M = .52$, $SD = .27$). The presence of probes did not interact with speed [$t(364) = .20$, $p = .839$, $\beta = .04$] or age [$t(364) = .23$, $p = .820$, $\beta = .05$]. However, speed interacted with age [$t(364) = 2.37$, $p = .019$, $\beta = .48$] such that younger adults' predictions of performance were similar regardless of speed [$t(364) = -.65$, $p = .517$, $\beta = -.10$] while older adults' predictions of performance decreased at a faster speed [$t(364) = -4.17$, $p < .001$, $\beta = -.58$]. There was not a three-way interaction between speed, age, and the presence of probes [$t(364) = -.12$, $p = .903$, $\beta = -.05$].

We also modelled performance on the test with age (young, old), the presence of mind-wandering probes (present, absent), and video speed (1x, 2x) as predictors. As shown in Figure 5b, a general linear model revealed an effect of age [$t(364) = -2.45$, $p = .015$, $\beta = -.24$] such that older adults performed better on the test ($M = .57$, $SD = .19$) than younger adults ($M = .52$, $SD = .18$). Additionally, results revealed an effect of speed [$t(364) = -3.95$, $p < .001$, $\beta = -.39$] such that participants watching at 1x speed ($M = .59$, $SD = .18$) performed better on the test than participants watching at 2x speed ($M = .51$, $SD = .19$). There was not an effect of the presence of mind-wandering probes [$t(364) = 1.34$, $p = .182$, $\beta = .13$] such that participants with probes ($M = .56$, $SD = .19$) performed similarly on the test as participants without probes ($M = .53$, $SD = .18$). The presence of probes did not interact with speed [$t(364) = .88$, $p = .382$, $\beta = .17$] or age [$t(364) = .22$, $p = .827$, $\beta = .04$]. However, speed interacted with age [$t(364) = 3.55$, $p < .001$, $\beta = .70$] such that younger adults' performance was similar regardless of speed [$t(364) = -.27$, $p = .784$, $\beta = -.04$] while older adults' performance decreased at a faster speed [$t(364) = -5.50$, $p < .001$, $\beta = -.74$]. There was a three-way interaction between speed, age, and the presence of probes [$t(364) = 3.06$, $p = .002$, $\beta = 1.21$] such that when there were no mind-wandering probes, both younger [$t(364) = -2.08$, $p = .038$, $\beta = -.43$] and older adults' performance decreased at a faster speed [$t(364) = -2.75$, $p = .006$, $\beta = -.53$]; however, when there were mind-wandering probes, younger adults' performance was similar at 1x and 2x speed [$t(364) = 1.72$, $p = .087$, $\beta = .35$] while older adults' performance decreased at a faster speed [$t(364) = -5.03$, $p < .001$, $\beta = -.96$]. However, we again examined the relationship

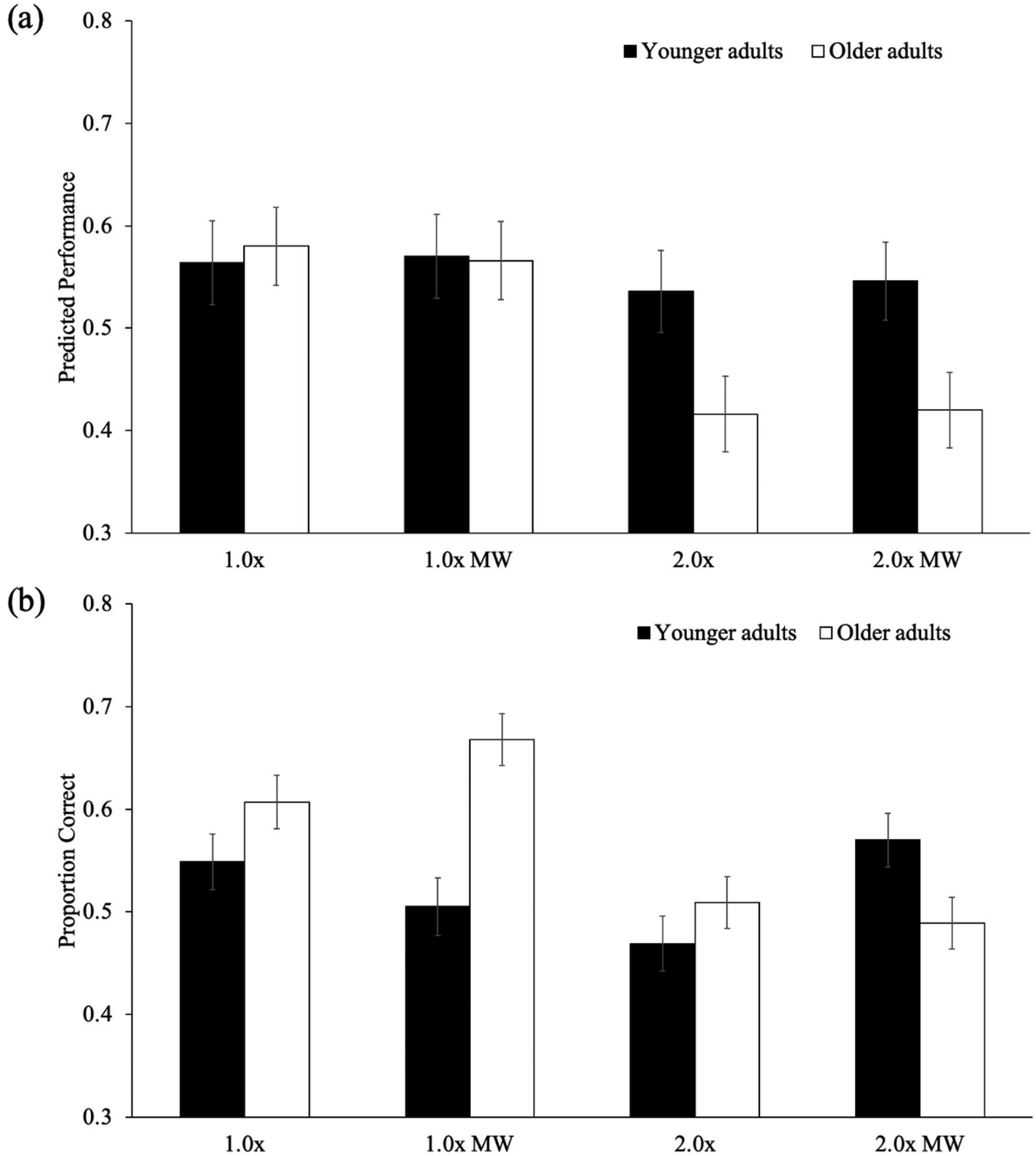

Figure 5. Predictions of performance (a) and performance on the comprehension test (b) for younger adults and older adults with no mind-wandering probes or with mind-wandering probes (MW) as a function of video speed in Experiment 3. Error bars reflect the standard error of the mean.

between mind-wandering and performance. Results revealed a negative relationship [Pearson's $r(186) = -.21$, $p = .004$] such that as mind-wandering increased, performance decreased.

Lastly, we modelled calibration with age (young, old), the presence of mind-wandering probes (present, absent), and video speed (1x, 2x) as predictors. Results revealed an effect of age [$t(364) = 3.91$, $p < .001$, $\beta = .40$] such that older adults were underconfident ($M = -.07$, $SD = .23$) while younger adults were a bit overconfident ($M = .03$, $SD = .28$). However, results did not reveal an effect of speed [$t(364) = -.67$, $p = .505$, $\beta = -.07$] or the presence of mind-wandering probes [$t(364) = -.89$, $p = .375$, $\beta = -.09$]. The presence of probes did not interact with speed [$t(364) = -.40$, $p = .688$, $\beta = -.08$] or age [$t(364) = .08$, $p = .935$, $\beta = .02$], and speed did not interact with age [$t(364) = -.03$, $p = .974$, $\beta = -.01$]. There was a three-way interaction between speed, age, and the presence of probes [$t(364) = -2.26$, $p = .024$, $\beta = -.92$] but there were no significant comparisons of interest.

Discussion

In contrast to Experiment 2, age and video speed did not affect mind-wandering rates. However, replicating Experiment 1, while younger adults were generally unaffected by video speed, faster speeds impaired test performance in older adults. Additionally, the mind-wandering probes may have had some influence on test performance such that when there were no mind-wandering probes, both younger and older adults' performance decreased at 2x speed but when there were mind-wandering probes, younger adults' performance was similar at 1x and 2x speed while older adults' performance still decreased at 2x speed. Thus, although we did not replicate all effects observed in Experiments 1 and 2, the present findings generally indicate that younger adults can watch lecture videos at faster speeds without significant deficits in memory, older adults' test performance is generally impaired when watching at faster speeds.

Combined analyses

Given some of the inconsistent outcomes across the three experiments (which could be due to the minor differences in experimental design or sampling variation), we conducted a combined analysis across experiments to provide a clearer picture of how different video speeds impact mind-wandering, predictions of performance, test performance, and calibration in younger and older adults while also controlling for differences in mind-wandering procedures.

First, we modelled mind-wandering rates as a function of speed and age. We also included the different mind-wandering procedures as a covariate to control for this potential confound. Results revealed an effect of age [$t(505) = 4.75$, $p < .001$, $\beta = .43$] such that older adults reported less mind-wandering than younger adults. However, results did not reveal an effect of probe procedure [$t(505) = -1.22$, $p = .221$, $\beta = -.11$] or speed [$t(505) = -1.05$, $p = .295$, $\beta = -.05$], and age did not interact with speed [$t(505) = -1.58$, $p = .114$, $\beta = -.14$]. Age interacted with the mind-wandering probe procedure [$t(505) = -3.82$, $p < .001$, $\beta = -.70$] such that mind-wandering rates in younger adults were higher when probed every minute compared with when all video speeds had seven probes with different intervals between probes based on playback time [$t(505) = -3.44$, $p < .001$, $\beta = -.46$] but there were not differences in mind-wandering rates using different procedures in older adults [$t(505) = 1.91$, $p = .057$, $\beta = .24$]. Speed interacted with the mind-wandering probe procedure [$t(505) = 2.75$, $p = .006$, $\beta = .25$] such that mind-wandering rates decreased at faster speeds when probed once per minute [$t(505) = -3.25$, $p = .001$, $\beta = -.17$] but there were not differences in mind-wandering rates when all video speeds had seven probes with different intervals between probes based on playback time [$t(505) = 1.05$, $p = .295$, $\beta = .08$]. There was not a three-way interaction between speed, age group, and probe procedure [$t(505) = -1.14$, $p = .256$, $\beta = -.21$].

Next, we modelled participants' predictions of performance as a function of age and speed. We also included the presence of mind-wandering probes as a covariate. Results revealed an effect of age [$t(1016) = -2.48$, $p = .013$, $\beta = -.15$] such that older adults expected to answer more questions correctly than younger adults. There was not an effect of the presence of probes [$t(1016) = -1.87$, $p = .061$, $\beta = -.12$] but there was an effect of speed [$t(1016) = -3.24$, $p = .001$, $\beta = -.10$] such that participants expected to perform worse on the test at faster speeds. Speed interacted with age [$t(1016) = 4.72$, $p < .001$, $\beta = .29$] such that younger adults' predictions of performance were similar regardless of speed [$t(1016) = 1.01$, $p = .311$, $\beta = .05$] while older adults' predictions of performance decreased as speed increased [$t(1016) = -5.82$, $p < .001$, $\beta = -.24$]. Specifically, compared with younger adults, older adults expected to perform better at 0.75x speed [$t(1012) = 2.73$, $p = .006$] and at 1x speed [$t(1012) = 4.07$, $p < .001$] but expected to do worse at 2x speed [$t(1012) = -2.27$, $p = .023$]. Age did not interact with the presence of probes [$t(1016) = -1.32$, $p = .188$, $\beta = -.16$], speed did not interact with the presence of probes [$t(1016) = 1.71$, $p = .088$, $\beta = .10$], and there was not a three-way interaction between speed, age, and the presence of probes [$t(1016) = -.84$, $p = .403$, $\beta = -.10$].

We also modelled performance on the test as a function of age and speed. Again, we included the presence of mind-wandering probes as a covariate. Results revealed an effect of age [$t(1016) = -2.39$, $p = .017$, $\beta = -.15$] such that older adults performed better on the test than younger adults. There was not an effect of the presence of probes [$t(1016) = -.69$, $p = .489$, $\beta = -.04$] but there was an effect of speed [$t(1016) = -4.51$, $p < .001$, $\beta = -.14$] such that test scores decreased at faster speeds. Speed interacted with age [$t(1016) = 3.86$, $p < .001$, $\beta = .24$] such that younger adults' performance was similar regardless of speed [$t(1016) = -.45$, $p = .656$, $\beta = -.02$] while older adults' performance decreased at faster speeds [$t(1016) = -6.13$, $p < .001$, $\beta = -.26$], but the only significant pairwise comparison between younger and older adults was at 1x speed [$t(1012) = 4.38$, $p < .001$] such that older adults performed better at 1x speed than younger adults [both other $ps > .074$]. Age did not interact with the presence of probes [$t(1016) = .37$, $p = .710$, $\beta = .05$], speed did not interact with the presence of probes [$t(1016) = .91$, $p = .361$, $\beta = .06$], and there was not a three-way interaction between speed, age, and the presence of probes [$t(1016) = 1.00$, $p = .317$, $\beta = .12$]. We also examined the relationship between mind-wandering rate and performance. Results revealed a negative relationship [Pearson's $r(511) = -.22$, $p < .001$] such that as mind-wandering increased, performance decreased.

Lastly, we modelled calibration as a function of age and speed with the presence of mind-wandering probes as a covariate. Results did not reveal an effect of age [$t(1016) = -.90$, $p = .370$, $\beta = -.06$], speed [$t(1016) = -.26$, $p = .798$, $\beta = -.01$], or the presence of probes [$t(1016) = -1.42$, $p = .155$, $\beta = -.09$]. Speed interacted with age [$t(364) = -.03$, $p = .974$, $\beta = -.01$] but neither simple effect reached significance [both *p*s > .076]. The presence of probes did not interact with speed [$t(1016) = 1.11$, $p = .268$, $\beta = .07$] or a three-way interaction between speed, age, and the presence of probes [$t(1016) = -1.50$, $p = .133$, $\beta = -.19$].

General discussion

Prior work has demonstrated that watching videos at faster speeds (up to double the speed) does not significantly impair learning in younger adults (see Murphy et al., 2022; see also Lang et al., 2020; Nagahama & Morita, 2017; Wilson et al., 2018; but see Foulke & Sticht, 1969; Song et al., 2018; Vemuri et al., 2004). However, it was previously unclear how increased video speed impacts memory in older adults. Additionally, we investigated the effects of increased video speed on mind-wandering. In the present study, we had younger and older adults watch an informational video (on either real estate appraisals or the history of the Roman Empire), predict their performance on a test, then complete the test.

In Experiment 1, without any mind-wandering probes, increasing playback speed did not impair memory in younger adults, consistent with prior work (e.g., Murphy et al., 2022). However, as playback speed increased, memory performance decreased in older adults, potentially the result of older adults' impaired processing speed (Cerella & Hale, 1994) and working memory abilities (Dobbs & Rule, 1989). Specifically, the increased cognitive load (see Sweller, 1988, 1989; see also Leahy & Sweller, 2011; Paas et al., 2003, 2004; van Merriënboer & Sweller, 2005) at faster playback speeds may have overwhelmed older adults' ability to process and effectively encode the incoming information.

In Experiment 2, we asked participants to report their conscious experience throughout the video. Results revealed that watching videos at faster speeds reduced mind-wandering, a potentially contributing factor to the preserved memory found in younger adults in prior work (Murphy et al., 2022). Additionally, older adults reported less mind-wandering than younger adults, consistent with prior work (Giambra, 1989; Jackson & Balota, 2012; Krawietz et al., 2012; Maillet & Rajah, 2016; McVay et al., 2013; Seli et al., 2017; see Jordão et al., 2019 for a review). However, we did not observe a decrease in test performance at faster speeds in either younger or older adults.

In Experiment 3, we aimed to replicate the effects observed in Experiments 1 and 2 using a different video, younger and older adults recruited from the same source, and a different mind-wandering probe procedure. Results replicated the interaction between video speed and age demonstrated in Experiment 1 such that the faster video speed did not negatively impact younger adults, but older adults' test performance was impaired at 2x speed. However, we did not replicate the mind-wandering patterns observed in Experiment 2. Specifically, although mind-wandering increased as the video endured, younger and older adults reported similar rates of mind-wandering, and mind-wandering was similar at 1x and 2x speed.

We also conducted an analysis of all data across experiments to reveal which patterns were consistent across variations in experimental design. Overall, results revealed that older adults mind-wandered less than younger adults (consistent with prior work, see Arnicane et al., 2021; Giambra, 1989; Jackson & Balota, 2012; Krawietz et al., 2012; Maillet & Rajah, 2016; McVay et al., 2013; Seli et al., 2017; see Jordão et al., 2019 for a review) the present study, the mind-wandering probes occurred and the type of probing appeared to impact whether participants mind-wandered less at faster speeds. In terms of predictions of test performance, younger adults' predictions of performance were similar regardless of speed, but older adults expected to do worse at faster speeds. Older adults performed better on the test, but younger adults' performance was similar regardless of speed while older adults' performance decreased as speed increased. Thus, the present study collectively suggests that increasing video speed can be detrimental to older adults, but this may have less of an effect on younger adults (consistent with prior work; Murphy et al., 2022).

There are a few possible explanations for the discrepancies between some of the findings from each experiment. First, although we have no reason to expect the topic of the video to impact memory at different speeds, there could be important differences in prior knowledge between younger and older adults regarding real estate law (e.g., older adults likely have more experience owning and selling properties) and the history of the Roman Empire (e.g., older adults may have more prior knowledge of world history that could benefit the encoding of new historical information). Second, there were small differences in how we probed participants' mind-wandering. In Experiment 2, participants were probed every minute, resulting in a different number of probes for participants in the different speed conditions. However, in Experiment 3, participants were all probed the same number of times to ensure equal treatment such that each participant provided the same number of responses, but this necessarily resulted in a different amount of time between probes for participants in the different speed conditions. These subtle procedural differences may have had an impact on how participants reported their conscious experiences. Future research could examine a wider array of topics that varies in the level of subjective interest to participants to determine if video speed differentially impacts younger and older adults depending on the topic. Additionally, future work could examine how various forms and frequencies of mind-wandering probes could impact learning. It is also unclear whether any memorial processing occurred during mind-wandering probes. Future work could utilise overt rehearsal methods (see Tan & Ward, 2000; Ward et al., 2003) to determine whether mind-wandering probes allow any additional encoding of the to-be-remembered information.

Prior work has examined whether the presence of thought probes during a task influences performance. For example, Wiemers and Redick (2019) embedded thought probes at random intervals in a sustained attention to response task (SART). However, performance on the SART task did not differ regardless of whether thought probes were included or not, indicating that thought probes may not be reactive (i.e., asking participants to self-report cognitive processes may change those processes; see Double et al., 2018 for a discussion of reactivity in memory). There is evidence that more mind-wandering probes during a video lecture can reduce mind-wandering (Greve & Was, 2022; Schubert et al., 2020), that mind-wandering increases as the interval between probes increases (Seli et al., 2013), and that probes do not affect behavioural performance (Robison et al., 2019). In the present study, it remains unclear whether there were some reactive effects of the mind-wandering probes. However, we did not aim to examine how mind-wandering probes of different frequencies (number of probes) and lag (time between probes) impact memory at different speeds. Future work could directly examine different mind-wandering procedures to elucidate how mind-wandering changes at different video speeds. Moreover, in the present study, the mind-wandering probes occurred at potentially predictable intervals, perhaps allowing participants to strategically suppress mind-wandering in anticipation of each probe (Seli et al., 2018); future work may benefit from probing learners at random intervals and/or determine if participants attempted to predict upcoming probes.

Mind-wandering probes aside, in Experiments 1 and 3 we demonstrated a clear interaction between age and video speed such that video speed did not impact younger adults but faster speeds impaired test performance in older adults. While we are cautious in interpreting our results because we did not see this trend in Experiment 2 (perhaps due to the presence of the mind-wandering probes), we generally advise against older adults watching videos at faster speeds. Although younger adults may be well practiced in watching videos at 2x speed (see Murphy et al., 2022), older adults may learn best by slowing down lecture videos. However, future work should replicate these effects in younger and older adults with different racial and educational backgrounds, and levels of expertise (as perhaps, for example, older adults who have a background in real estate may benefit from watching these videos at faster speeds). Additionally, we only examined memory immediately after watching the videos. Although prior work has not found differences in memory following a delay in younger adults (e.g., Murphy et al., 2022), future work could also examine age-related differences in memory performance at longer retention intervals and include more general comprehension questions. Moreover, we did not ask participants about background distractions or specifics regarding their video volume which may have affected the results. Older adults may benefit from increased volume and less background noise due to perceptual changes in older age (e.g., Ben-David et al., 2012; Schneider et al., 2000), and while we assumed that the participants in the present study selected and used an adequate/comfortable volume setting (and adjusted volume as needed), future work could examine these issues in more detail.

In the present study, although the instructor audio is impacted by faster playback speeds, the content presented on the screen remains the same regardless of the video speed. Our observation that faster speeds generally lead to poor performance in older adults is consistent with prior work indicating that memory for a spoken message is enhanced by the presence of a supporting video track in younger (but not older) adults, a difference that could be accounted for by working memory capacity (Stine et al., 1990). Thus, younger adults may have some advantage in integrating information across modalities and video speed may not be the only theoretical mechanism contributing to older adults' decreased performance at faster speeds.

It is important to note that older adults performed similarly on the memory tests in Experiments 1 and 2 compared with younger adults (and in Experiment 3, older adults did better on the test than younger adults). This contrasts with common beliefs that older adults are worse at learning in comparison to younger adults (e.g., "can't teach an old dog new tricks"; also see Hummert et al., 1994 for common stereotypes about aging). Prior work has demonstrated that older adults mind-wander less than younger adults (Arnicane et al., 2021; Giambra, 1989; Jackson & Balota, 2012; Jordão et al., 2019; Krawietz et al., 2012; Maillet & Rajah, 2016; McVay et al., 2013; Seli et al., 2017), although we only observed this trend in Experiment 2. A potential explanation for the preserved test performance in Experiment 2 is older adults' reduced mind-wandering which could be the result of a variety of factors such as increased engagement when watching the videos (cf., Jordão et al., 2019). Since mind-wandering was negatively related to performance, the reduction in mind-wandering exhibited by older adults (only in Experiment 2) may compensate for age-related cognitive impairments that have a detrimental effect on learning, allowing older adults to perform similarly to younger adults. This suggests that older adults may learn as successfully as younger adults in certain situations due to the compensatory role of increased focus and reduced mind-wandering. However, younger and older adults reported similar mind-wandering rates in Experiment 3, and older adults outperformed younger adults so future work should further examine the role of mind-wandering in memory performance. Future work may also benefit from assessing learners' level of motivation which has been shown to be negatively related to mind wandering (see Brosowsky et al., 2020; Seli et al., 2019) and could impact interest and retention.

In sum, we demonstrated that although younger adults can watch lecture videos at faster speeds without significant deficits in memory, older adults' test performance is generally impaired when watching at faster speeds. Additionally, faster playback speeds may reduce mind-wandering (and mind-wandering may be reduced in older adults), potentially contributing to younger adults' preserved memory at faster speeds and older adults' overall similar performance to younger adults. Such findings provide insight into the adaptive way technology can optimise older adults' learning by compensating for age-related cognitive deficits that typically impair learning. Such technology may also allow older adults to use certain compensatory abilities (e.g., potentially reduced mind-wandering) to learn as successfully as younger adults from recorded videos. Ultimately, online videos provide a convenient and accessible way of learning that can support the unique cognitive abilities of both younger and older adults under certain conditions to harness the myriad of benefits that learning provides people of all ages.

Notes

1. We did not include speed in this model because each group had a different number of checkpoints.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This research was supported by the National Institutes of Health (National Institute on Aging; Award Number R01 AG044335 to Alan Castel).

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