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EMPIRICAL ARTICLE

Turn Off, Tune Out? Testing the Effects of Webcam Use on Learning in Synchronous Online Classrooms

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Synchronous online classes have grown in popularity, sparking debate on student webcam use. In Experiment 1, participants were assigned to attend a lecture with half instructed to turn their webcam on and half instructed to turn their webcam off (interpolated testing was also examined as a buffer against webcam effects). A webcam effect was observed: webcam-on participants outperformed webcam-off participants. Experiment 2 manipulated class-wide webcam use by creating uniform groups in which participants all had webcams on or off at the same time and mixed groups in which webcam use was evenly split. The webcam effect replicated in the mixed condition, but the effect was attenuated in the uniform condition, suggesting that the webcam effect is larger in mixed webcam classes. Additional findings suggest that feelings of accountability and reduced media multitasking for webcam-on participants could contribute to the webcam effect more than social presence.

General Audience Summary

Synchronous online classes that meet live over video conferencing software like Zoom have grown in popularity, with many universities expanding distance education programs. The rise of this course format has sparked debate on student webcam use, particularly about whether university students should be required to attend classes with their webcams on. Two experiments found that participants assigned to attend a lecture with their webcams on outperformed those with their webcams off on a test of the lectured content. This webcam effect persisted in classes in which half of the class turned on their webcams, but the webcam effect was significantly diminished in classes in which everyone used their webcams uniformly—all on or all off at any given time. These findings suggest that students could improve their learning by attending online classes with their webcams on, and that the benefits of using a webcam would be largest when not everyone has their webcam on at the same time. The results also suggest that promoting accountability and reducing media multitasking may be particularly important for improving learning in online classes.

Keywords: distance education, webcam, synchronous online classes, social presence, accountability

Synchronous online courses spiked in popularity during the shift to online instruction due to COVID-19 campus closures (Flaherty, 2020). Though in-person classes have largely returned, administrators predict that universities will offer more synchronous remote courses moving forward (Garrett et al., 2021) and a majority of students and faculty report growing optimism about online learning (Bay View Analytics, 2022). Since most research in distance education has focused on asynchronous courses, and best educational practices for synchronous distance courses are still unclear.

One area of concern is maintaining students' attention. Both instructors and students report major challenges with maintaining student motivation and attentional engagement in remote classes (Bay View Analytics, 2022; Gillis & Krull, 2020). In both in-person and asynchronous lectures, multitasking on laptops (Aguilar-Roca et al., 2012; Fried, 2008; Hembrooke & Gay, 2003; Risko et al., 2013)

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This study was not formally preregistered. Full materials and data are available online at https://osf.io/9acrj/.

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and smartphones (Dietz & Henrich, 2014) has been shown to impair learning. These devices are difficult to avoid in live lecture settings but become unavoidable in synchronous online classes. Moreover, students in online classes could be particularly tempted to disengage and multitask because they do not feel as accountable as in a live lecture where they can be fully seen.

One prescription for promoting accountability and engagement is for instructors to require students to participate in synchronous online classes with their webcams on (Niess, 2020; Norman, 2017). Webcam use could potentially enhance feelings of copresence (Ijsselsteijn & Riva, 2003), or social presence, a factor argued to be critical for engagement in online classes within the Community of Inquiry framework (Garrison et al., 1999). Garrison et al. (1999) defined social presence as learners' ability to "project their personal characteristics into the community" (p. 89). Studies have found correlations between social presence and learning and motivation in online classes (Weaver & Albion, 2005). Studies of students in distance courses have shown that behaviors indicative of social presence like contributing to course discussions can predict student learning outcomes (Hostetter, 2013; Joksimović et al., 2015). Webcam-on students project their image into synchronous online classrooms for their instructors and peers to see—perhaps an even stronger instantiation of social presence than contributing to discussion forums. As such, it seems likely that students with their webcams on in class experience more social presence, which could improve engagement, learning, and motivation relative to webcam-off students.

Attending online classes with a webcam could also promote success by encouraging student accountability. Prior work has shown student accountability to be an important factor for their success in a course. One study found that class attendance rates were higher in a course with graded pop quizzes compared to attendance rates in a class with similar quizzes administered for extra credit (Shapiro, 2009). Likewise, in three experiments investigating classroom response systems used to administer prelecture questions, Jones et al. (2013) found that when students answered the questions for credit, they performed significantly better on a later exam than students who answered the questions without stakes. Team-based learning, which may promote accountability through the social pressures of working with peers, has also been shown to promote learning by incentivizing preparation before class and active participation (Stein et al., 2016). There is also some evidence to show that students feel more accountable in online classes when required to use their webcams, with some students reporting difficulty concentrating when they do not use webcams in online classes (Maimaiti et al., 2021).

More specifically, webcam-on students might also feel more accountable not to multitask when they are visible to their peers and instructor. Multitasking has been shown to consistently impair learning, both from text (Clinton-Lisell, 2021) and lectures (Barks et al., 2011; Kuznekoff & Titsworth, 2013; Sana et al., 2013). Attempts to intervene against media multitasking like drawing awareness to distracted behaviors or restricting access to distracting websites often have limited success (Biedermann et al., 2021). Consistent with this hypothesis, one study showed that participants who watched a recorded lecture with their webcam on with their self-view visible outperformed students who watched with their webcam off (Austin et al., 2022). Austin and colleagues speculated that this effect could parallel an "audience effect," in which exposing participants to an audience can cause them to behave in ways more consistent with the perceived audience's principles than they would alone (Froming et al., 1982). Students who show more effort toward learning tend to be more liked by their teachers (Saidah et al., 2019), so students attending class with their webcams on may be particularly inclined to "act the part" of a good student and avoid off-task behaviors.

However, webcam requirements for class attendance can burden students. In one end-of-semester survey, students cited concerns about appearance, weak internet, and lack of private space as reasons for attending classes with their webcams off, concerns that disproportionately affected underrepresented minority students (Castelli & Sarvary, 2021). In another set of experiments, participants randomly assigned to attend a Zoom lecture with their webcam on, including a mirrored view of themselves, reported more appearance anxiety than webcam-off participants (Tien et al., 2023). Though webcam use did not significantly affect performance on a final test of participants' learning, a mediation analysis revealed that increased appearance anxiety led to impaired performance. Another study found that participants who engaged in substantial video conferencing during the COVID-19 pandemic reported experiencing "Zoom fatigue," or mental exhaustion after sustained periods of video conferencing (Amponsah et al., 2022). These factors could cause webcam policies to backfire and impair student learning if students are distracted or cognitively drained by turning their webcams on.

Other strategies for engaging attention and promoting learning could be more effective than webcam mandates. For instance, instructors could implement practice testing, which has been shown to improve learning relative to restudy in a variety of learning environments (Yang et al., 2021). Interpolating lecture videos and tests has been found to reduce mind wandering, improve note taking, and improve test scores compared to participants who restudied on the same schedule (Szpunar et al., 2013, 2014). Indeed, some have even proposed that practice testing benefits learning over restudy by reducing mind wandering (Wong & Lim, 2022), so interpolated quizzing during lecture could be particularly useful given the attention economy in remote classrooms. Given these findings, interpolated quizzing could differentially benefit webcam-on and webcam-off students in synchronous online classrooms. Learners tested while their attention is divided can also be protected from the negative effects of multitasking compared to distracted learners who instead restudy (Buchin & Mulligan, 2017; Mulligan & Picklesimer, 2016). As such, webcam-off students could have more to gain from interpolated quizzing than their webcam-on counterparts.

The Present Study

The present study examined how webcam use affects memory for educational material. In Experiment 1, participants watched a live lecture, administered by an experimenter, with their webcams randomly assigned to be on or off. Half of the material was presented with interpolated quizzes, and half was presented with no quizzes. We predicted that participants who had their webcams on would perform better than participants with their webcams off, with the expectation that webcam-on participants would pay more attention and multitask less than webcam-off participants. We also anticipated that performance would be significantly better for material presented with quiz questions compared to material presented with no quiz questions. Finally, we predicted an interaction between webcam use

and interpolated quizzing such that quizzes would benefit webcam-off participants more than webcam-on participants.

Experiment 1

Method

Participants

A total of 123 participants were recruited, 104 from Mississippi State University (MSU) and 19 from the University of California, Riverside (UCR).[1] All were undergraduate students recruited from psychology department research pools in exchange for partial course credit. Six were excluded from the analyses for reporting that they failed to follow directions for webcam use ($N = 117$). This sample was sufficient to observe a medium-sized effect ($d = .53$) with 80% power and $\alpha = .05$. Participant age ranged from 18 to 66 ($M = 20.3$, $SD = 5.3$).

Design

Experiment 1 used a 2 (webcam condition: webcam on vs. webcam off; between-subjects) × 2 (quiz condition: quiz vs. no quiz; within-subjects) mixed design. To manipulate the webcam condition, participants were randomly assigned to attend the lectures with their webcam on or off, with compliance monitored by the experimenter. To manipulate the quiz condition, participants saw two lectures: one of which had interpolated quiz questions (quiz condition) and another that did not (no quiz condition). The order of the lectures was held constant, so lecture assignment to quiz condition and quiz condition order was counterbalanced simultaneously across participants (see Figure 1).

Materials

All materials are available on the Open Science Framework (Ramirez Perez et al., 2023). Two lectures about printmaking and cheesemaking were adapted from Ditta et al. (2023). The lectures consisted of a slideshow with 11 slides (not including any quiz slides) for each topic and a script that was delivered live by the experimenter who screen-shared the slides during each session. All slides had a title and 2–6 bullets of statements. Together, both lectures took about 25 min. Half of the slides contained relevant images, but the script did not refer to the images. Two versions of each lecture were created: one with five multiple-choice interpolated quiz questions and one with none. The quiz questions were presented on their own slide with no additional information on the topic.

Two tests were created, each consisting of 20 multiple-choice questions with four answer options each. Test questions were written to cover the main points of each lecture. A three-question survey was designed to measure participants' self-presentational concern, in which participants self-reported their feelings of self-consciousness, worry about their appearance, and worry about the appearance of their surroundings using a 5-point Likert scale ranging from *never* to *always*. Five questions using the same Likert scale were constructed about multitasking. They asked about the extent to which participants engaged in media multitasking behaviors like web browsing, email, and social media, how much participants looked at their own or others' video, and how often participants experienced off-task thoughts.

Webex (https://www.webex.com/) and Zoom (https://zoom.us/) video conferencing software were used. In both environments, users can see other participants' video feed in a grid. When a presenter begins screen sharing, the layout shifts so that users see the shared screen which takes up most of the window, and the other users appear in a row above or below the shared screen. In this layout, users can see from three to eight other attendants, depending on the size of the video feeds on the user's window. The presenter's video feed is typically shown first, followed by any active speaker, then video-on participants, and finally, all other participants. The order of participants will shift if a new person becomes the active speaker, but in the present study only the experimenter spoke and all other participants were muted during the lectures. If a participant has their webcam off, a black box with their name will be visible. Participants could customize aspects of their view by changing the relative sizes of the shared screen and video feeds, opening panels including the meeting's chat box or participants list, and popping out features into new windows. Participants did not receive specific instructions on how to customize their meeting settings.

Procedure

Both experiments received ethical approval from Mississippi State University's institutional review board using an exempt protocol (IRB-21-059). Participants were provided a link to join a virtual meeting during each scheduled timeslot. Participants recruited through MSU used Webex and participants recruited through UCR used Zoom as their conferencing software due to university licensing agreements. The number of participants per session ranged from 2 to 18, with the average session including 7.6 participants ($SD = 5.3$). Session size varied between participant groups due to no-shows and scheduling availability for participants. However, because webcam-off and webcam-on participants were run in the same sessions, session size did not differ between these two conditions. The experimenter started a session at least 10 min before the scheduled meeting time. As participants entered, they were told to wait for the study to begin and provided a Qualtrics link which contained their digital consent form. Participants who were running late could join within 5 min of the scheduled start time, otherwise, the room was locked to additional participants.

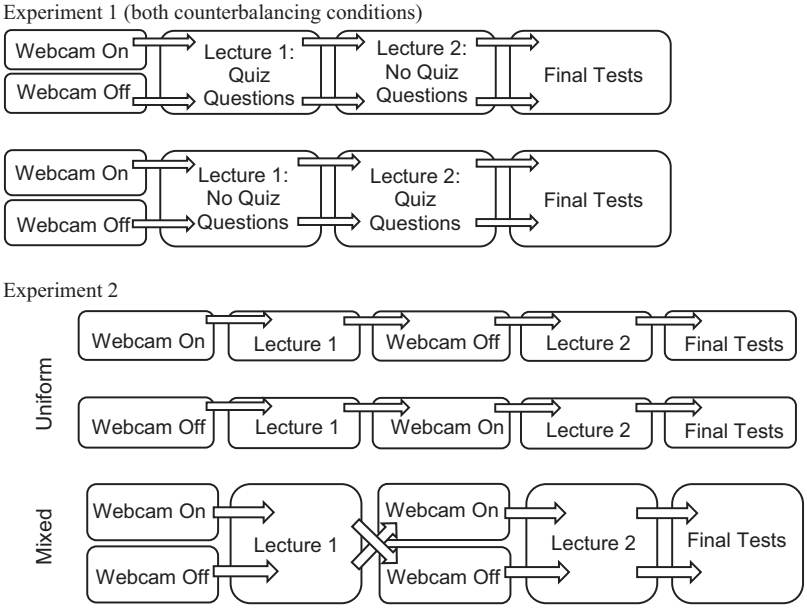
All participants were provided the Qualtrics link and instructed to read and sign the consent form. Conditions were assigned once the room was locked. Half of the participants were randomly assigned to the webcam-on condition and the other half assigned to the webcam-off condition. The experimenter checked that all participants complied with their webcam instructions and participants were instructed to report their condition code on their Qualtrics survey. The survey was password protected so that participants would not have premature access to later parts of the study.

Participants were told that they would watch two lectures and refrain from taking notes or using external resources during the study. They were informed that after the two lectures, which would take about half of the session time, they would leave the video conference and complete some additional activities, including a final test on what they had learned, using the same Qualtrics form. In half of the

[1] For both experiments, participant recruitment was mainly conducted at MSU and supplemented with participants from UCR when MSU's participant pool was closed (e.g., summer).

Figure 1

Schematic for Procedure and Counterbalancing of Experiments 1 and 2



Note. Experiment 1 used a 2 × 2 mixed design with webcam condition manipulated between-subjects and quiz condition manipulated within-subjects. Experiment 1 was counterbalanced by running two different types of sessions for participants; the session types for each counterbalancing condition are shown. Experiment 2 used a 2 × 2 mixed design with webcam condition manipulated within-subjects and class composition condition manipulated between-subjects. Experiment 2 was counterbalanced by running two different styles of sessions for the uniform condition (both are shown) and across participants in the mixed condition.

sessions, the experimenter administered the first lecture with no quiz questions by reading the script and using the conferencing software's built-in screen-sharing feature to show the slides. The second lecture contained the interpolated quiz questions (the quiz order was reversed in the other half of the sessions, counterbalancing quiz assignment to lecture and quiz condition order). Every third slide showed a quiz question about the material on the previous two slides. The experimenter read each question and answer options aloud twice before moving on. Participants reported their answer to each quiz question through the Qualtrics survey, which listed the question number and four answer options by letter. Lecture assignment to quiz condition was counterbalanced across participants, but the printmaking lecture always appeared first.

After the lectures, participants were instructed to complete the rest of the study through Qualtrics and that, unless they had questions, they should leave the video conference. After this, participants were dismissed from the video conference and completed the remainder of the study on their own through Qualtrics. Following a 5-min word search distractor, participants completed each final test in the order that the lectures were given and answered the self-presentational concern, multitasking, and compliance questions. The compliance questions confirmed that they had used their webcam as instructed (in case the experimenter failed to notice) and that they had completed the tests from memory. Finally, participants were debriefed and dismissed.

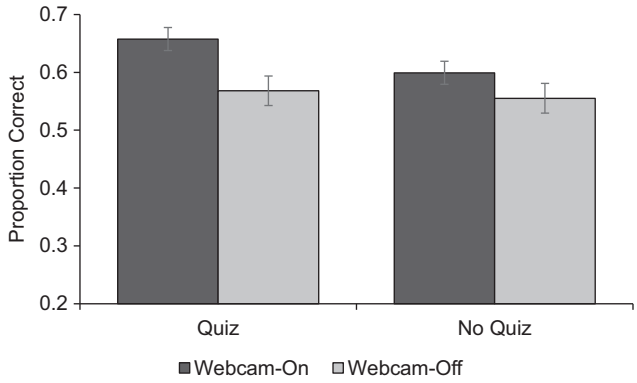
Results

Test Performance

Full data sets are available online (Ramirez Perez et al., 2023). Test performance, calculated as proportion of questions correct, was analyzed using a 2 (webcam condition) × 2 (quiz condition) mixed analysis of variance (ANOVA; see Figure 2). A main effect of

Figure 2

Proportion Questions Correct on Final Test in Experiment 1



Note. Error bars indicate standard error of the mean.

the webcam condition was detected such that participants in the webcam-on condition (M = .63, SD = 0.13) outperformed participants in the webcam-off condition (M = .56, SD = 0.18), $F(1, 115) = 5.19$, $p = .025$, $\eta^2_{partial} = .04$, $d = 0.42$, 95% CI_d [0.05, 0.79]. There was also a main effect of quiz condition such that performance was higher in the quiz condition ($M = .61$, $SD = 0.18$) compared to the no quiz condition ($M = .58$, $SD = 0.17$), $F(1, 115) = 6.61$, $p = .011$, $\eta^2_{partial} = 05$, $d = 0.24$, 95% CI_d [0.05, 0.42]. There was no evidence of an interaction between the webcam condition and the quiz condition, $F(1, 115) = 2.69$, $p = .104$, $\eta^2_{partial} = .02$.

Survey Questions

Reliability statistics were calculated for the multitasking and self-presentational concern measures. The five multitasking questions had questionable reliability ($\alpha = .60$), so those questions were tested independently, while the three self-presentational concern questions had good reliability ($\alpha = .88$) and were therefore averaged together for the analysis. The results of the survey questions were analyzed using independent-samples t tests comparing the two webcam conditions. Participants in the webcam-on condition reported higher levels of self-presentational concern ($M = 2.7$, $SD = 1.2$) compared to participants in the webcam-off condition (M = 1.8, SD = 0.9), $t(115) = 4.59$, $p < .001$, $d = 0.85$, 95% CI_d [0.47, 1.23]. Participants did not report a significant difference in how frequently they looked at the videos of other participants (webcam on: $M = 2.4$, $SD = 1.1$, webcam off: $M = 2.4$, $SD = 1.1$), $t(115) = 0.12$, $p = .905$, $d = 0.02$, 95% CI_d [−0.34, 0.38], how frequently they thought about other things during lecture (webcam on: $M = 3.3$, $SD = 0.9$, webcam off: M = 3.4, SD = 1.0), $t(115) = 0.61$, $p = .542$, $d = 0.11$, 95% CI_d [−0.25, 0.48], or how frequently they multitasked during the lecture (webcam on: $M = 2.3$, $SD = 1.3$, webcam off: $M = 2.4$, $SD = 1.2$), $t(115) = 0.48$, $p = .631$, $d = 0.09$, 95% CI_d [−0.27, 0.45] between the two conditions. However, participants in the webcam-off condition ($M = 2.1$, $SD = 1.2$) reported browsing the web, checking email, and using social media significantly more frequently than participants in the webcam-on condition (M = 1.6, SD = 0.9), $t(115) = 2.27$, $p = .025$, $d = 0.42$, 95% CI_d [0.05, 0.78]. This discrepancy in the multitasking results may have occurred because participants did not sufficiently consider or failed to notice their own multitasking behavior, specifically media multitasking, unless they were given specific examples of such behaviors.

Experiment 2

Experiment 1 replicated the testing effect shown in prior literature but did not find a significant interaction with webcam use. For this reason, interpolated quizzing was not further examined. Critically, a webcam effect was observed such that participants who attended a lecture with their webcam on outperformed participants who attended with their webcams off on a final test. This webcam effect could be caused by several mechanisms. Participants who had their webcams on might have felt more socially present, for example, making them feel more connected to the lecturer and engaged compared to participants with their webcams off. Alternatively, webcam-on participants may have felt more accountable to stay on-task during the lecture compared to webcam-off participants. Interestingly, though webcam-off participants did not report reliably elevated levels of multitasking compared to webcam-on participants, they did report checking email or web browsing more frequently than their webcam-on counterparts. So, participants may have multitasked but failed to notice their multitasking behavior without being directed to specific examples of such behaviors. Experiment 2 was designed to differentiate between these two accounts (social presence vs. accountability) and examine webcam effects in classrooms in which all students have their webcams on, as in classes with webcam mandates. Specifically, Experiment 2 sought to replicate the webcam effect and investigate whether class-wide patterns of webcam use influenced the size of the webcam effect on learning.

In Experiment 2, both individual and class webcam use were manipulated. All participants attended one lecture with their webcam on and one with their webcam off, but half of the participants attended uniform classrooms where all participants had their webcams on or off at the same time, or mixed classrooms where half of participants had their webcams on at any given time. Experiment 1 used a mixed class format, so we expected to replicate the webcam effect in this condition such that webcam-on participants would outperform webcam-off participants on a final test. Both accounts predict a replication of the webcam effect in this mixed condition because having a webcam on should increase both social presence and accountability relative to attending webcam off. However, the two accounts make different predictions for the uniform condition. According to the social presence hypothesis, webcam-on participants will feel the most social presence in uniform classes because they will be able to see and be seen by all their classmates, leading to a similar or even larger webcam effect in the uniform condition compared to the mixed condition. The accountability hypothesis predicts the opposite pattern of results in the uniform condition; the effect might be attenuated in uniform classes because webcam-on participants feel less accountable among the crowd of other webcam-on participants.

Method

Participants

For Experiment 2, 131 participants were recruited from MSU and eight from UCR; one was excluded for reporting that they did not follow directions ($N = 138$). A power analysis indicated that at least 64 participants per condition would be needed to observe the webcam effect with a similar effect size as was observed in Experiment 1 ($d = 0.50$), for a total of 128 participants. Some additional participants were run to account for noncompliance. Participants ranged from 18 to 44 years old ($M = 20.1$, $SD = 3.5$).

Design

Experiment 2 used a 2 (webcam use: webcam on vs. webcam off; within-subjects) × 2 (class composition: uniform vs. mixed; between-subjects) mixed design. Webcam condition was manipulated within-subjects; participants changed their webcam setting between lectures. Class composition condition was manipulated between-subjects with each session designated as either uniform, in which all participants had their webcams on or off at the same time, or mixed with participants split half-and-half into the two webcam conditions during each lecture. The order in which participants participated in each webcam condition was counterbalanced across participants. In the mixed condition, half of participants were randomly assigned to

attend the first lecture with their webcam on (and the other half with their webcam off) and counterbalancing groups switched their webcam settings for the second lecture. To counterbalance the uniform condition, in half of the sessions, all participants were assigned to the webcam-on condition for the first lecture and told to turn their webcams off for the second lecture, and in the other half, all participants were assigned to the webcam-off condition for the first lecture and told to turn their webcams on for the second lecture (see Figure 1).

Materials

The materials were the same as those used in Experiment 1, with two changes. First, no quiz questions were used, so lectures were completed slightly more quickly: in approximately 20 min. Second, posttest survey questions were constructed to gauge feelings of social presence in the classroom. The social presence survey was adapted from a scale designed to measure social presence in a computer-mediated conferencing environment (Gunawardena & Zittle, 1997). The survey questions asked about participants' views on online lectures as a medium for social interaction, their sense of community and connection with other "students," and how personal the lectures felt, and were answered using a 5-point Likert scale ranging from *strongly disagree* to *strongly agree*.

Procedure

The procedure of Experiment 2 was the same as the procedure of Experiment 1 except where noted. Because Experiment 2 included a factor that depended on the presence of other participants, no session was run with fewer than seven participants. If fewer than seven signed up, the session was canceled; if no-shows pushed attendance below seven, those who attended were dismissed with credit. Sessions ranged from 7 to 25 participants with an average session size of 14.3 participants ($SD = 5.9$). Half of the sessions were assigned to be uniform and the other half to be mixed. In uniform sessions, participants were all in the same webcam condition, while in mixed sessions, participants were split into separate groups of webcam conditions. Before the lectures began, participants gave consent and were assigned to a webcam condition. After each lecture, participants completed the social presence survey. Once the first lecture was complete, participants toggled their webcam setting before moving forward: those who initially had their webcam on turned it off, and those who initially had their webcam off turned it on.

In both uniform webcam on and both the webcam-off and webcam-on mixed conditions, it is likely that participants had a similar view on their screens since conferencing platforms prioritize showing webcam-on participants. So, participants in these conditions likely saw the videos of webcam-on participants above or next to the slides that were shared by the experimenter, while participants in the uniform webcam-off condition saw black boxes indicating the presence of other webcam-off participants.

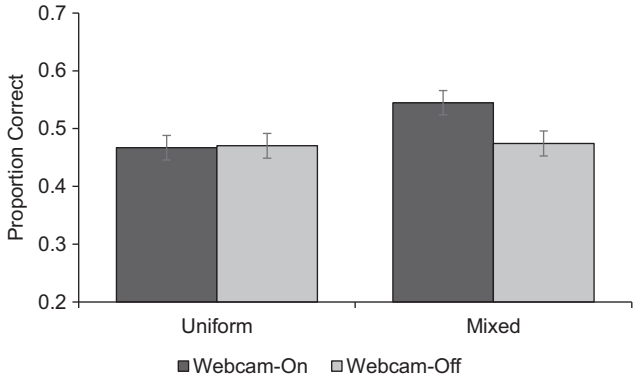
Results

Test Performance

Proportions of correct test answers were analyzed using a 2 (webcam condition) × 2 (class composition) mixed ANOVA (see Figure 3). There was a significant main effect of webcam use; specifically, performance was significantly higher in the webcam-on condition ($M = .51$, $SD = 0.18$) than in the webcam-off condition ($M = .47$, $SD = 0.18$), $F(1, 136) = 4.83$, $p = .030$, $\eta^2_{partial} = .03$, $d = 0.21$, 95% CI_d [0.04, 0.37]. The main effect of class composition was not significant (mixed: $M = .51$, $SD = 0.15$, uniform: $M = .47$, $SD = 0.15$), $F(1, 136) = 2.48$, $p = .117$, $\eta^2_{partial} = .02$, $d = 0.27$, 95% CI_d [−0.07, 0.61]. However, both main effects were qualified by a significant interaction between webcam condition and class composition condition, $F(1, 136) = 5.81$, $p = .017$, $\eta^2_{partial} = .04$. Performance was significantly higher in the webcam-on condition than the webcam-off condition for participants in the mixed condition (webcam on: $M = .54$, $SD = 0.17$, webcam off: $M = .47$, $SD = 0.18$), $t(75) = 3.50$, $p < .001$, $d = 0.40$, 95% CI_d [0.16, 0.63], but the webcam effect was not reliably observed in the uniform condition (webcam on: $M = .47$, $SD = 0.18$; webcam off: $M = .47$, $SD = 0.17$), $t(61) = 0.14$, $p = .890$, $d = 0.02$, 95% CI_d [−0.23, 0.27].

Figure 3

Proportion Questions Correct on Final Test in Experiment 2



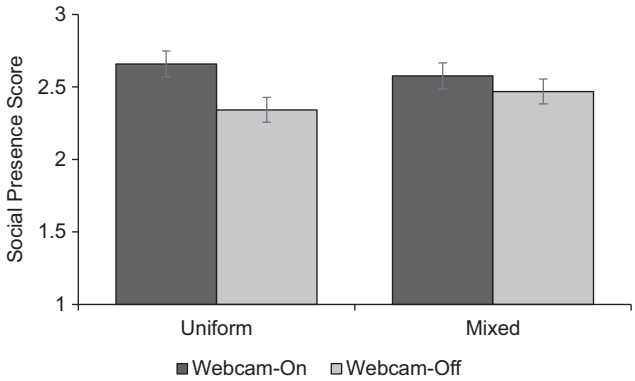
Note. Error bars indicate standard error of the mean.

Social Presence

The five social presence survey questions had good reliability ($\alpha = .83$). The social presence survey results were analyzed using the same mixed factorial ANOVA as the test results (see Figure 4).

Figure 4

Social Presence Ratings by Condition in Experiment 2



Note. Social presence ratings ranged from 1 = *low social presence* to 5 = *high social presence*. Error bars report standard error of the mean.

There was a significant main effect of the webcam condition; specifically, reported social presence was significantly higher in the webcam-on condition ($M = 2.6$, $SD = 0.7$) than in the webcam-off condition ($M = 2.4$, $SD = 0.7$), $F(1, 136) = 25.09$, $p < .001$, $\eta^2_{partial} = .16$, $d = 0.40$, 95% CI_d [0.23, 0.57]. The effect of class composition was not significant (mixed: $M = 2.5$, $SD = 0.7$, uniform: $M = 2.5$, $SD = 0.7$), $F(1, 136) = 0.04$, $p = .848$, $\eta^2_{partial} < .001$, $d = 0.03$, 95% CI_d [−0.30, 0.37]. Critically, there was a significant interaction between class composition and webcam use, $F(1, 136) = 6.05$, $p = .015$, $\eta^2_{partial} = .04$. Social presence was significantly higher in the webcam-on condition compared to webcam off, but this effect was larger in the uniform condition (webcam on: $M = 2.7$, $SD = 0.8$, webcam off: $M = 2.3$, $SD = 0.7$), $t(61) = 4.24$, $p < .001$, $d = 0.54$, 95% CI_d [0.27, 0.80], than in the mixed condition (webcam on: $M = 2.6$, $SD = 0.7$, webcam off: $M = 2.5$, $SD = 0.7$), $t(75) = 2.33$, $p = .023$, $d = 0.27$, 95% CI_d [0.04, 0.50]. Bivariate correlations also revealed some evidence of a negative correlation between social presence ratings and test scores in the webcam on, $r(138) = -.17$, $p = .046$, $CI_{95\%}$ of $r = [-.33, -.003]$ but not the webcam-off condition, $r(138) = -.12$, $p = .162$, $CI_{95\%}$ of $r = [-.28, .05]$. We will refrain from strongly interpreting these weak negative correlations, but the 95% confidence intervals indicate that, at most, only a very weak positive correlation between social presence and test performance would likely be observed in the population sampled. This finding does not align with prior work showing positive associations between social presence and learning in other online classroom settings.[2]

General Discussion

Experiment 1 revealed a webcam effect such that participants assigned to attend a lecture with their webcams on outperformed participants assigned to keep their webcams off on a test of the lectured content. While including quiz questions in a lecture improved performance, it was not an effective intervention for the webcam effect, which was observed regardless of quiz condition. Experiment 2 further investigated the webcam effect by manipulating class-wide webcam use. Participants either attended a lecture that was uniform (all participants in the same webcam condition at once) or mixed (half of participants in each webcam condition at once). The webcam effect replicated in the mixed condition but was attenuated in the uniform condition such that no significant difference was detected between webcam-on and webcam-off participants. Interestingly, Zoom and Webex prioritize showing webcam-on participants on screen when a session host is sharing their screen, as the experimenter did in both studies to show slides to participants. So, it is likely that most participants in the mixed and uniform webcam-on conditions saw a similar view on their screens, with the main difference between both conditions being participants' knowledge of the proportion of people in the session that had their webcams on. Furthermore, the interaction seemed to be driven primarily by enhanced performance in the webcam-on mixed classroom condition relative to both the webcam-off conditions and the webcam-on uniform condition.

We proposed two mechanisms to explain the webcam effect: social presence and accountability. According to the social presence hypothesis, webcam-on participants feel more socially connected to the lecturer and other participants, and this increased social presence improves engagement and learning as reflected by test performance. An accountability hypothesis argues, instead, that webcam-on participants felt more accountable and were therefore more resilient against attentional disengagement and media multitasking.

Experiment 2 was designed to differentiate between theoretical accounts by creating a realistic situation that could boost social presence but reduce accountability for webcam-on participants—a lecture in which all participants used their webcams uniformly. A social presence account predicts particularly high social presence in a uniform webcam-on classroom, since participants can see and be seen by all their classmates. Though our measure of social presence confirmed this to be the case—webcam-on participants reported higher social presence than webcam off, particularly in the uniform class composition—the webcam effect was attenuated in the uniform condition. Further, we found no evidence that social presence positively covaries with test performance, with 95% confidence intervals on the correlations between test performance and social presence ratings indicating, at most, negligible positive correlations.

The accountability hypothesis can explain this pattern of results more compellingly. According to the accountability hypothesis, webcam-on participants outperformed webcam-off participants to a greater extent in mixed than uniform classes because webcam-on participants felt more likely to be caught multitasking or disengaged when they were part of a proportionately smaller group. So, participants in the mixed condition stayed more engaged and on-task when they had their webcams on than off. When all participants had their webcams on in the uniform condition, they may have felt more likely to be lost among the crowd and therefore safer to disengage, thus attenuating the webcam benefit. Participants with their webcams off would not necessarily make the same calculation with respect to class composition, since they could not be observed multitasking regardless of class-wide webcam use.

Consistent with this accountability hypothesis, in Experiment 1, webcam-on participants reported checking external websites and emails less frequently than webcam-off participants, but self-reported general multitasking or off-task thoughts did not reliably vary with webcam condition. It is possible that participants may not have considered specific media multitasking behaviors like web browsing when asked about multitasking generally because such behaviors are so common. Future work might examine a wider array of behaviors or differentiate between different types of multitasking. For example, students might be more prone to multitasking on a computer compared to using smartphones when they have their webcams on. Future inquiry could also measure multitasking behaviors directly through direct observation in the lab or through screen recording.

Previous work investigating webcam effects on learning has produced mixed results. Austin et al. (2022) found a similar effect of webcam use as observed in this study; however, the webcam benefit was only statistically significant when comparing a webcam-off condition to a condition in which participants used webcams with self-view and when outliers were excluded. We did not instruct participants on the use of self-view, so participants with webcams on in the present study could have turned self-view off. The accountability hypothesis

[2] The same multitasking ($\alpha = .62$) and self-presentational concern ($\alpha = .80$) questions were presented to participants as in Experiment 1 at the end of the study. Because webcams were manipulated within-subjects, comparisons between webcam condition are not possible, and these comparisons could only be made between class composition conditions. No predictions were made about differences in the results of the surveys between uniform and mixed participants. Analyses were conducted using independent-samples t tests; no significant differences were observed (all $p > .26$).

does not make clear predictions concerning video self-view, and instead focuses on whether a student expects their video to be seen by others. However, camera self-view could draw attention toward the fact that a student could be seen and increase the size of the webcam-on benefit. Future work could differentiate between the effects of what students see on their own screens like other participants and self-view, and the mindset brought on by being seen through a webcam.

Our findings did not align with those of Tien et al. (2023), who found no effect of webcam use directly on test performance. We did not measure appearance anxiety or participant self-view behaviors, so a direct comparison is not possible. However, consistent with Tien et al.'s findings, Experiment 1 found that webcam-on participants reported more self-presentational concern than webcam-off participants. Tien et al. also shifted between uniform (Experiment 1A) and mixed webcam use (Experiment 1B) throughout their investigation, which could contribute to the mixed findings. It is, however, interesting to compare increased awareness of being viewed, which Tien et al. referred to as the "spotlight effect," with the construct of accountability. Indeed, Tien et al. argued that the spotlight effect would grow in mixed webcam classrooms by drawing participants' attention to the fact that they could be seen. The construct of appearance anxiety and student accountability may overlap considerably, and instructors might consider differences in students' responses to webcams when weighing how to improve accountability while limiting appearance anxiety. Individual differences in proneness to appearance anxiety, for example, may contribute to performance impairments for some students who use webcams, while others may need to keep their webcam on to maintain accountability.

Future work might more closely emulate real-world classroom conditions by investigating the webcam effect across multiple sessions, in longer lectures, and with larger groups. Participants in the present study met once and were limited in their ability to connect with their fellow "classmates" or the "instructor." Though differences in social presence ratings were observed across both webcam and class composition conditions in Experiment 2, social presence likely plays a more substantial role in student success than implied by our findings. Participants also saw relatively short lectures compared to many real classes, and prior work has shown that attention to online lectures tends to wane across time (Guo et al., 2014; Risko et al., 2012). It is possible that differences in attention or acclimation to having one's webcam on could change the magnitude of the webcam effect across a longer class period. Session sizes were also relatively small due to limited participant availability. Students in synchronous online classes frequently report class size as a determining factor for when they turn their webcams on (Bedenlier et al., 2021; Händel et al., 2022), and class size is relevant to establishing both social presence and accountability. As such, class size will be important to investigate further.

The applied implications of the current results suggest that it may be worthwhile for instructors to encourage students in synchronous online classrooms to turn their webcams on, given that webcam-on participants consistently outperformed webcam-off participants. It is worth noting, however, that not all students can use their webcams in class due to issues like limited private space or weak internet connections. Because these concerns disproportionately affect underrepresented minority students (Castelli & Sarvary, 2021), developing interventions against the webcam effect that improve overall learning would be a worthwhile avenue for future work. Though quizzing did not attenuate the webcam effect in Experiment 1, it is possible that practice testing implemented differently could be an effective intervention. Other interventions designed to foster accountability like cold-calling students or encouraging check-ins through chat could also be worthwhile. Because the detrimental effects of webcam use could disproportionately impact underrepresented and minority students, future research would benefit from the collection of additional demographics and diverse samples.

In sum, the present study indicates that webcam-on students might indeed learn more than their webcam-off classmates. This effect was, however, attenuated when everyone turned their webcam on, indicating that attending class with webcams on might not provide a benefit to students under all circumstances. Webcam use may improve student learning by helping students stay accountable and avoid multitasking in their online courses, so strategies that improve accountability might bring about similar improvements, including for students who cannot or prefer not to attend class with their webcams on.

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