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EMPIRICAL ARTICLE

Attention Contagion Online: Attention Spreads Between Students in a Virtual Classroom

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(In)attentiveness can spread between students in the same learning environment, affecting their learning (Forrin et al., 2021). The present study is the first to investigate whether this phenomenon—*attention contagion*—extends to virtual classrooms when students have their webcams on. Undergraduate student participants ($n = 74$) watched a prerecorded lecture along with research confederates who were visible in "webcam video thumbnails." The confederates behaved either attentively or inattentively. Consistent with attention contagion, students who watched the lecture with attentive (vs. inattentive) confederates reported being more attentive and they learned more of the lecture content—performing 12% better on a postlecture quiz. They also perceived the lecture as more important, suggesting that social inferences (e.g., "this lecture is important") may undergird attention contagion. These novel findings indicate that the influence of webcams on students' learning depends, in part, on whether classmates are visibly attentive or inattentive. Attention is contagious online.

General Audience Summary

The COVID-19 pandemic has profoundly affected education systems worldwide by causing an abrupt transition to online learning. Following this transition, undergraduate students reported a decreased ability to pay attention to lectures (Hicks et al., 2021), highlighting the timeliness of research that elucidates factors influencing attention online. We investigated one potentially important factor: the (in)attentiveness of students' classmates. Specifically, we tested the hypothesis that (in)attentiveness spreads between students (i.e., "attention contagion") during an online lecture. In a simulated virtual classroom, undergraduate student research participants—who had their webcams on—watched a 30-min video lecture. Four of those students (seemingly other participants) visible in "webcam video thumbnails" during the lecture were, in fact, members of the research team trained to behave attentively or inattentively. When the four visible students were attentive (vs. inattentive), their classmates reported being more attentive, estimated engaging less often in inattentive behaviors (e.g., checking their phone), and performed 12% better on a subsequent lecture-content quiz. Thus, we found strong support for (in)attentiveness spreading in virtual classrooms—and that this "attention contagion" meaningfully affects learning. Moreover, students' impressions of the importance of the lecture content were affected by whether they could see attentive peers (higher importance) or inattentive peers (lower importance). Such impressions may drive attention contagion. These findings inform interventions that can boost learning online: For instance, if students are informed of the spreading of (in)attentiveness, they may be more likely to reduce any visible

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Our preregistration, study materials, data, and analysis files are on the Open Science Framework: https://osf.io/rch4q

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inattentive behaviors for the sake of their classmates. Our findings also contribute to the growing body of literature surrounding the effects of webcam usage in virtual classrooms: The effect of webcam use on learning depends, in part, on the (in)attentiveness of visible peers.

Keywords: attention, online learning, memory, simulated classroom, social inferences

The COVID-19 pandemic has precipitated a sweeping shift to online education. Undergraduate students whose classes transitioned online reported decreased motivation and ability to focus (Hicks et al., 2021), which underscores the timeliness of examining factors that contribute to students' (in)attention in virtual classrooms. Here, we tested the hypothesis that attentiveness and inattentiveness spread between students (i.e., *attention contagion*) visible via a webcam. Of current interest to educators and policymakers, support for this hypothesis would imply that the effect of webcams on students' attention and learning depends on the (in)attentiveness of their classmates.

Forrin et al. (2021) studied attention contagion in a simulated in-person classroom. Pairs of undergraduate students, consisting of a participant and a research confederate seated nearby, watched a video lecture together. Participants who watched the lecture with an attentive (vs. inattentive) confederate were more attentive and performed better on a lecture-content quiz. Distraction caused by inattentive confederates only partly accounted for attention contagion (i.e., by spreading inattentiveness). Mendoza and King (2020) similarly found evidence of *engagement contagion* between secondary school students. Student engagement is a multifaceted concept with behavioral, emotional, and cognitive components (Fredricks et al., 2004). Whereas Mendoza and King focused on the spread of behavioral and emotional components, we focused on a cognitive component—attention (i.e., the extent to which information is processed; e.g., Dijksterhuis & Aarts, 2010) as well as an important behavioral manifestation of inattention—media multitasking (e.g., see Wammes et al., 2019).

Extending Forrin et al. (2021), we had two main objectives: (a) to assess whether attention contagion occurs in virtual classrooms and (b) to explore potential mechanisms—distraction, goal contagion, and conformity—that may contribute to online attention contagion.

Distraction (Cognitive Load Theory)

Cognitive load theory proposes that people have finite attentional resources (Sweller, 2011). Students' distracting inattentive behaviors (e.g., phone checking) impose extraneous cognitive load on peers by (a) diverting peers' spatial attention away from ongoing learning material and/or (b) causing peers to activate top–down selective attention processes to ignore the distractions, leaving fewer attentional resources available to encode learning material (e.g., Sana et al., 2013). In either case, *distraction by peers spreads inattentiveness*.

Goal Contagion

People spontaneously infer the goals underlying others' behavior, which can result in unconscious goal activation. This process of goal contagion (Aarts et al., 2004) is strengthened when (a) the behavior is exhibited by *ingroup members* (Loersch et al., 2008) and (b) the inferred goal is *valued* by the observers (Aarts et al., 2004). Classrooms satisfy both conditions: For example, a learning or achievement goal (Eren, 2009; King & Mendoza, 2020) may spontaneously activate in a student who observes attentive peers, motivating goal pursuit (especially if the observer values that goal). Given that attention systems prioritize goal-relevant information (Dijksterhuis & Aarts, 2010), goal contagion ought to contribute to the spread of attentiveness between students.

Conformity

Deutsch and Gerard (1955) distinguished between two types of conformity (Asch, 1951)—informational social influence (privately accepting information from others as evidence about reality) and normative social influence (adhering to social norms to gain acceptance and/or avoid disapproval). In line with informational social influence, the attentive behavior of visible classmates provides information that attentiveness is appropriate (perhaps because the lecture content is important), thereby facilitating the spread of attentiveness. Regarding normative social influence, students may tend to refrain from engaging in visibly inattentive behaviors (e.g., media multitasking) to avoid social disapproval. Visibly inattentive peers, however, may weaken attentiveness norms and foster the spread of inattentiveness.

The Present Study

Undergraduate student research participants attended a simulated virtual classroom, with their webcams on, and watched a video lecture. Four other students (ostensibly participants, but actually research confederates) were visible in "video thumbnails" above the video lecture. We manipulated (between sessions) whether confederates behaved attentively or inattentively. Sessions were conducted "live" and with participants' webcams on (i.e., not asynchronously with prerecorded visible confederates) because the proposed mechanism of conformity ought to exert a stronger influence when participants believe that they are visible to their peers (e.g., Laporte et al., 2010).

We predicted, in accord with our attention contagion hypothesis, that participants who watched the lecture with attentive (vs. inattentive) confederates would report having been more attentive during the lecture and would estimate having spent less time on their phones and visiting unrelated websites—two forms of *media multitasking* (i.e., processing lecture-unrelated content on electronic devices). Wammes et al. (2019) defined media multitasking as a mode of attentional disengagement during lectures and found that it was more frequent than mind wandering. We focused on media multitasking here due to its prevalence during online lectures (e.g., Lepp et al., 2019) and its negative association with learning outcomes (Wammes et al., 2019)—consistent with the broader finding that attentional disengagement hinders learning (e.g., Chun & Turk-Browne, 2007; Samuels & Turnure, 1974; Szpunar et al., 2013).[1] We, therefore, predicted that students who watched our lecture with

[1] We acknowledge that attentional disengagement can be measured by switch costs in the cognitive literature (e.g., Monsell, 2003). We treated attentional disengagement and inattention as synonymous constructs for our research question.

attentive (vs. inattentive) confederates would perform better on a lecture-content quiz.

Our secondary measures explored whether distraction, goal contagion, and conformity (i.e., informational and normative social influence) may contribute to attention contagion. We predicted that students who watched the lecture with attentive (vs. inattentive) confederates would retrospectively report: (a) being less distracted by confederates (consistent with distraction contributing to attention contagion), (b) having higher levels of motivation (consistent with goal contagion), and (c) perceiving the lecture as more important (consistent with informational social influence). Last, in line with prior research demonstrating that feelings of *publicness* (Lapinski et al., 2014) strengthen normative social influence, we predicted that students who experienced greater feelings of publicness during the lecture would report having spent less time media multitasking (because media multitasking would contradict norms of attentiveness in the classroom).

The results of these secondary measures were intended to elucidate potential mechanisms warranting more rigorous testing in future research. We did not intend to test for causality (i.e., via mediation models) because that would entail measuring these factors during the lecture (before attentiveness is measured), which would distract from the lecture and diminish ecological validity. Thus, to maximize the validity of our primary measures, we grouped our secondary measures in a postlecture survey.

To foreshadow, we found robust attention contagion effects in our virtual classroom that meaningfully affected quiz performance, regardless of prelecture motivation (a preregistered covariate in our main analyses). Our results elucidate the attentional dynamics in online learning environments, informing both online teaching practices and the development of interventions.

Method

Participants

Seventy-four introductory psychology students from McMaster University participated in the study in exchange for partial course credit. Two students did not consent to our using their data; of the remaining 72 who gave informed consent ($M_{age} = 19.15$, $SD = 2.81$), 57 identified as female. All participants lived in the same geographic region as the institution, which minimized the likelihood of connectivity and/or bandwidth issues during the study. To increase recruitment and motivation to learn, we advertised a lottery that awarded $100 Amazon gift certificates to four participants (two who scored between 50 and 80% on the quiz and two who scored over 80%). The study was approved by McMaster's Research Ethics Board.

Study Design

In each session, a group of 3–19 participants watched a video lecture along with four confederates who posed as participants. All participants and confederates had their webcams on, but each participant could see only themself and four confederates (see Figure 1). Confederates consistently behaved either attentively (attentive-confederates condition) or inattentively (inattentive-confederates condition) throughout the lecture. Afterward, participants answered a multiple-choice quiz that assessed their memory for the lecture content, and then completed a survey regarding their experience while watching the lecture. (See https://osf.io/rch4q for our preregistration and a Supplemental Method section that provides additional details to facilitate direct replication of this study.)

Confederate Characteristics and Behaviors

Six undergraduate research assistants (three male, three female) posed as participants. These confederates were 19–22 years old ($M = 20.33$, $SD = 1.37$) and were of diverse ethnic backgrounds (three East Asian, two South Asian, one Indigenous). The experimenter randomly selected four confederates to be visible in webcam "video thumbnails" above the video lecture. (Our protocol for making confederates visible is outlined in the Supplemental Method section.) Prior to launching the study, the confederates attended a training session in which they were given detailed instructions on the attentive and inattentive behaviors to engage in during the lecture. Table 1 lists those behaviors. Video clips from two experimental sessions (one of each condition) showing the confederates and the video lecture have been posted at https://osf.io/rch4q

Materials and Measures

We encourage readers to view our study materials on OSF (https://osf.io/rch4q). We describe each measure (and its purpose) below.

Prelecture Survey

Participants first read a letter of information and clicked a box to indicate their agreement to participate. Next, participants rated their motivation to learn the lecture content on an 11-point Likert scale from 0 (*not at all*) to 10 (*extremely*); we preregistered this measure as a covariate because it would likely be correlated with our main dependent measures.

Video Lecture

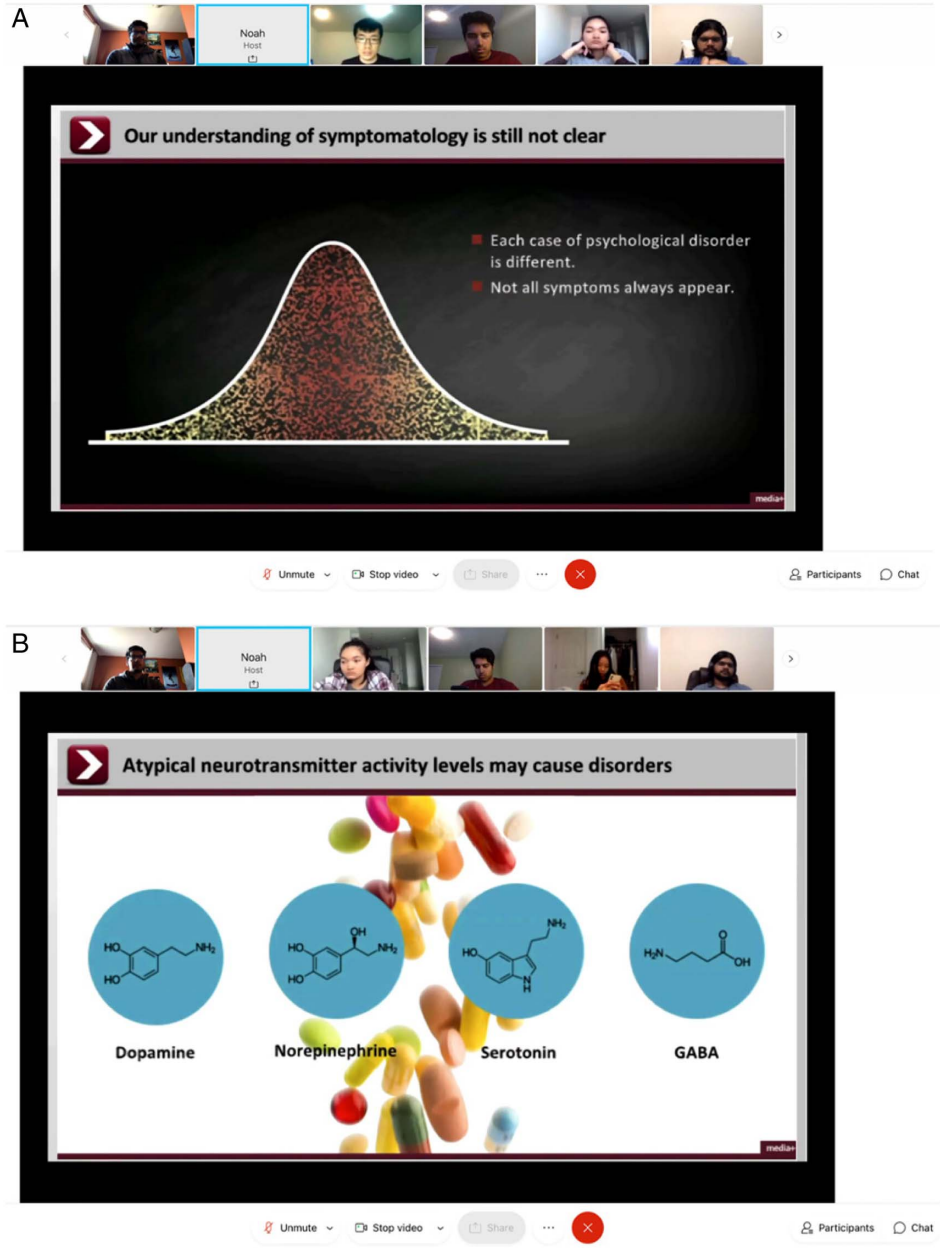
The video lecture presented to participants was an edited version of a "web module" scheduled to be released later in the semester in their introductory psychology course. (Web modules are essentially weekly video lectures on the course website that features the instructors' narration over PowerPoint slides, interspersed with practice questions.) We edited the prior year's web module on psychological disorders (which included content on the Diagnostic and Statistical Manual of Mental Disorders (Fifth Edition), classification and various disorders, including depression, generalized anxiety, and schizophrenia) by cropping out the instructor from parts of the video and removing practice questions and transition slides. The final product was a 30-min lecture that consisted of the instructor's narration over PowerPoint slides. We selected real course content for the sake of ecological validity and so that students would be motivated to learn the material.

Quiz

Immediately after the lecture, participants had 10 min to complete a 23-item four-alternative multiple-choice quiz on LimeSurvey that assessed their retention of lecture content. There were 19 factual questions (e.g., What does it mean if a mental disorder is "chronic"?) and four inferential questions (e.g., Which of the following would be considered a negative symptom of schizophrenia?).

Figure 1

Screenshots Taken During an Attentive-Confederate Session (A) and an Inattentive-Confederate Session (B)



Note. Above the video lecture, the participant appears in the far-left video thumbnail (the researcher who took these screenshots, for illustrative purposes, therefore appears in this spot). Next is a gray thumbnail containing the experimenter's first name (the experimenter's webcam was off), and then the four confederates. See the online article for the color version of this figure.

Survey

After participants completed the quiz (or time expired), they had 5 min to complete a final survey on LimeSurvey. Unless stated otherwise, ratings were made on 11-point Likert scales with the scale labels *not at all* at 0 and *extremely* at 10. The survey can be viewed at https://osf.io/rch4q). The key self-report measures, corresponding to our primary and secondary predictions (outlined in the Introduction), are summarized in Table 2.

Demographic Questions. Participants reported their age and gender.

Manipulation Checks. Participants were asked "On average, how attentive to the lecture were the four other participants whom you could see?" (which referred to the visible confederates) and "On

Table 1
Attentive and Inattentive Behaviors That Confederates Were Trained to Display

Type of behavior	Attentive	Inattentive
Expressions	Periodically nodding head Interested and surprised facial expressions (emotions consistent with the lecture content)	Blank and bored facial expressions
Body posture	Slight forward lean (alert) Pensive posture ("the thinker")	Slouching
Gaze	Gaze focused on the video lecture	Periodically looking away from the video lecture
Movement	Infrequent movement	Restless/uncomfortable Fidgeting (e.g., playing with hair or examining nails)
Media multitasking	No checking phone or other websites	Periodically checking phone and other websites

average, how motivated to learn the lecture content were the four other participants whom you could see?" Statistically significant differences between conditions would verify (a) that participants could perceive the confederates' behaviors (which was not guaranteed given the small size of the webcam video thumbnails; see Figure 1) and (b) that confederates behaved in line with their training—a *treatment fidelity check*. As a further check of treatment fidelity, the two researchers who attended each session checked and verified that four confederates (and no participants) were visible and that the confederates displayed the trained attentive/inattentive behaviors.

Primary Measures. These measures tested the attention contagion hypothesis. Participants retrospectively rated their attentiveness during the lecture and estimated how many minutes they spent on their phone and on other websites on their computer. The latter two measures assessed media-multitasking frequency.

Secondary Measures. These measures explored mechanisms that plausibly drive attention contagion in virtual classrooms. Participants retrospectively rated how *distracted* they were by the "other visible participants" (i.e., the confederates), how *motivated* they were to learn the lecture content while watching the video lecture, and how *important* the lecture content was. Participants were then asked, "Would you like to receive an email, to your McMaster email account, containing more information on the lecture content (psychological disorders and treatments)?" (yes/no response). A higher proportion responding "yes" in the attentive-confederates condition would support both the informational social influence mechanism (participants with attentive confederates perceived the lecture content as more important) and would also arguably support the goal contagion mechanism (participants wanted the additional information to make further progress toward their learning goal).

The survey also measured participants' subjective experience of *publicness* (i.e., openness to public scrutiny; Lapinski et al., 2014) by asking them to rate the extent to which they (dis)agreed with the statement "sometimes I thought about the fact that some participants could see me" (coded as 1 = *strongly disagree*, 2 = *disagree*, 3 = *agree*, 4 = *strongly agree*). We probed for this association more directly by asking participants the extent to which they (dis)agreed with the statement "I paid more attention because other participants could me." Last, we asked participants the extent to which they (dis)agreed with the statement that "I paid more attention because the *experimenter* could see me." We had hoped to minimize the effect of the experimenter's presence on participants' attentiveness by having the experimenter's webcam off during the session and by presenting instruction slides in lieu of the experimenter speaking. This question explored whether the presence of the experimenter nevertheless affected participants' attentiveness and, if so, whether the effect might have differed between conditions.

Measures Pertaining to Exclusion Criteria

Participants were also asked, "During the lecture video, how many 'thumbnail videos' of other participants did you see on your screen at the same time?" This measure was used to exclude any participants who did not see any thumbnails and therefore could not have seen our confederates. We assessed whether participants were suspicious of the confederates by asking whether they thought that

Table 2
Survey Self-Report Measures That Tested Our Primary and Secondary Predictions

Measure/prediction	Survey item	Response scale
Primary	How attentive to the lecture were you?	0 (*not at all*) to 10 (*extremely*)
	During the lecture, approximately how many minutes did you spend on other websites on your computer (including checking your email)?	0–30
	During the lecture, approximately how many minutes did you spend on your phone?	0–30
Secondary	How distracted were you by the other participants whom you could see?	0 (*not at all*) to 10 (*extremely*)
	While watching the lecture video, how motivated were you to learn the content?	0 (*not at all*) to 10 (*extremely*)
	How important was the lecture content?	0 (*not at all*) to 10 (*extremely*)
	Sometimes I thought about the fact that some participants could see me	1 (*strongly disagree*), 2 (*disagree*), 3 (*agree*), 4 (*strongly agree*)

any important details about the purpose of the study were left out of the letter of information (participants were reminded that the purpose was stated as "to advance knowledge of factors that influence students' learning during lectures in online classrooms").

We also asked participants, "Did you experience any issues during the study (e.g., technical issues, unexpected distractions in your home environment) that prevented you from watching or hearing the lecture for more than 5 minutes?" (yes/no response). We preregistered excluding participants who responded "yes" to this question to reduce noise in our data.

Procedure

The study was conducted using Webex Events videoconferencing software across nine sessions (five with attentive confederates and four with inattentive confederates) during the Winter 2021 semester. To preclude time of day potentially confounding our results (see Smith et al., 2018, for evidence that time of day affects attentiveness), a similar number of participants in each condition participated on each day and at each time. On average, 8.22 students ($SD = 4.63$) participated in each session.[2] Additionally, four to six confederates (depending on availability) attended each session.

An experimenter (who was the "host" of the event) controlled the procedure. A second researcher attended each session (with webcam on) and noted: (a) how many confederates were visible in thumbnails, (b) whether the confederates were behaving in line with their training, and (c) any irregularities pertinent to our preregistered exclusion criteria (e.g., a participant having their webcam off).

On the evening before each session, the experimenter emailed the prelecture survey to participants and requested that they complete the survey prior to the scheduled start time of the study. To ensure that participants were visible on webcam and could see the four confederates, they were asked to join the session via their computer rather than their phone.

When participants joined the session, they saw an instruction screen requesting that they turn on their webcam and then close Webex's "Chat" and "Participant" panels. This resulted in six "webcam video thumbnails" being visible to participants (see Figure 1). Participants could see themselves in the leftmost thumbnail. The next thumbnail was of the experimenter, whose webcam was kept off to minimize any possible effect of experimenter presence on participants' attentiveness (allowing us to better isolate the hypothesized attention contagion effects). The final four webcam thumbnails initially showed other participants and/or confederates as they arrived (in alphabetical order).

A few minutes after the scheduled start time for each session, the experimenter restricted access to the session and showed a second instruction screen informing participants that the video lecture would start shortly and that there would be a quiz afterward. Participants were instructed to "please learn the lecture content without writing/typing any notes," because we would have no way to prevent students from checking their notes during the quiz (which would have made the quiz too easy). It is possible that some participants did not comply with this instruction, which would have added noise to our data. Participants were also instructed "do not adjust any settings in Webex during the lecture, and do not adjust any visual features (e.g., adjusting the video size or the thumbnail videos of other participants). This will help us ensure that participants have a consistent experience."

While participants read the instructions, the experimenter briefly unmuted and then remuted the microphones of *four* confederates, one at a time, to make their webcam video thumbnails appear in the four right-most positions (see the Supplemental Method for technical details). We presumed that participants would either be too busy reading the study instructions to notice this or, if they did notice, that they would assume that the confederates were participants who had arrived late to the session and/or had accidentally unmuted themselves.

Next, participants watched the 30-min video lecture, shared from the experimenter's laptop. We used a video lecture instead of a live lecture to tightly control the experiment (i.e., the lecture would be identical across sessions and between conditions). For the duration of the video, participants could see the six webcam video thumbnails, including the four videos of confederates (Figure 1). Based on our testing of Webex, we assume that participants who had not followed the earlier instruction to close the chat and participant panels would have seen only three confederates during the lecture. We also cannot rule out the possibility that some participants disregarded our study instructions and scrolled through the webcam videos (a feature that cannot be disabled), which would have putatively weakened our manipulation. For experimental control, participants remained muted during the lecture. Although we cannot confirm that participants closed the chat panel as instructed, no participant used the chat.

Immediately following the video lecture, the experimenter displayed an instruction slide asking participants to turn off their webcams and to complete the quiz and survey using the LimeSurvey link that the experimenter posted in the chat (participants could readily reopen the chat panel to access the link). Participants had 10 min to complete the quiz, which was immediately followed by the survey (5-min time limit). Shortly thereafter, the experimenter or the second researcher (who took notes regarding the session) debriefed participants, revealing and explaining the deceptive element of using research confederates, and answered any questions that participants had. Participants then read a postdebriefing consent form on LimeSurvey and were asked for their consent to use their data. All participants were awarded course credit.

Results

Participant Exclusion

First, we deleted the data of two participants (one in each condition) who declined consent. Adhering to our preregistered exclusion criteria, we then excluded participants as follows: seven (two in the attentive-confederates condition and five in the inattentive-confederates condition) who experienced technical issues or unexpected distractions that prevented them from attending the video lecture for at least 5 min; one (inattentive-confederate condition) who reported not having seen any other participants while watching the video lecture; two (both in the inattentive-confederates condition) who had their webcams off, and one (inattentive-confederates condition) who was not visible on camera.

[2] Sessions with attentive confederates tended to have fewer participants ($M = 6.40$, $SD = 2.97$) than those with inattentive confederates ($M = 10.50$, $SD = 5.74$), but this difference was statistically nonsignificant, $t(7) = 1.40$, $p = .205$.

These exclusions resulted in a *final sample of 61 participants* (29 in the attentive-confederates condition and 32 in the inattentive-confederates condition), 50 of whom identified as female. More participants identified as female in the attentive-confederates condition (89.66%) than in the inattentive-confederates condition (75.00%), but this difference was statistically nonsignificant, $\chi^2(1) = 2.21$, $p = .137$. The ages of participants in the attentive-confederates condition ($M = 18.69$ years, $SD = 1.42$) and in the inattentive-confederates condition ($M = 19.06$, $SD = 2.59$) also differed nonsignificantly, $t(59) = 0.69$, $p = .495$.

Missing Data

Participants with missing data (six participants did not answer the prelecture motivation question, one did not rate how attentive they were during the lecture, and one did not rate how much they thought about the fact that other participants could see them) were not excluded from our final sample; however, the six participants with missing prelecture motivation measures could not be included in our preregistered analysis of covariance (ANCOVA) analyses that included prelecture motivation as a covariate.[3]

Suspicion

Ten participants responded "yes" to Item 10 of the survey ("Do you think that the above description leaves out any important details about the purpose of this study?").[4] Importantly, no participants responded that they were suspicious of confederates; likewise, during the Debriefing session, no one said (or typed in the chat) that they had been suspicious.

Descriptive and Inferential Statistics

Table 3 shows means (with SDs) for our dependent measures and analysis of variance (ANOVA)/ANCOVA test statistics. In line with our preregistration (https://osf.io/rch4q), prelecture motivation was included as a covariate for our primary measures and for two secondary measures (motivation to learn during the lecture and importance of lecture content).

Manipulation Check

Number of Visible Webcam Thumbnails and Confederates' Behavior

Both the experimenter and the second researcher who attended each experimental session noted that four confederates were visible above the video lecture in each session. Although they did not code confederates' behavior, they did confirm that the confederates adhered to their training and displayed the attentive/inattentive behaviors listed in Table 1.

Ratings of Confederates' Attentiveness and Motivation to Learn

The critical measure checking our manipulation was participants' retrospective ratings of the confederates' attentiveness. Relative to participants in the inattentive-confederates condition, those in the attentive-confederates condition rated the "other participants" whom they could see as having been significantly more attentive to the lecture. Participants also rated the attentive confederates as having been significantly more motivated to learn the lecture content. The robust effect sizes (ds = 2.57 and 1.95, respectively) indicate that our manipulation was strong.

Primary Measures

These measures tested our hypothesis that (in)attention spreads between students in online learning environments (i.e., attention contagion).

Self-Reported Attentiveness

As predicted, participants who watched the lecture with attentive confederates rated themselves as having been more attentive than did participants who watched the lecture with inattentive confederates.

Estimated Time on Phone and on Other Websites

Relative to participants who watched the lecture with inattentive confederates, those who watched the lecture with attentive confederates estimated having spent significantly less time on their phone and marginally less time on other websites.

Quiz Performance

Participants who watched the lecture with attentive (vs. inattentive) confederates performed significantly better on the postlecture quiz, a meaningful 12% difference (see Table 3). Participants' quiz performance was significantly positively correlated with their retrospective attentiveness ratings (Table 4), consistent with the idea that greater attentiveness resulted in deeper encoding of the lecture content.

Secondary Measures

These measures were used to explore the extent to which the three viable mechanisms outlined in the Introduction contributed to attention contagion in our experiment. As preregistered, we included prelecture motivation as a covariate in our analyses of the "motivation to learn during the lecture" and the "importance of the lecture content" measures.

Distraction

Distracted by Confederates. There was a nonsignificant difference between conditions in participants' ratings of how distracted they were by the "other participants" who they could see (Table 3). Moreover, distraction ratings were nonsignificantly correlated with

[3] These six participants did not submit the prelecture survey, which included an informed consent question; however, they still voluntarily attended the experimental session and, after the debriefing session, consented to our using their data. We reported this issue to our institutional ethics board, who approved our use of their data.

[4] Of those 10, seven—three in the attentive-confederates condition and four in the inattentive-confederates condition—indicated in their subsequent open-ended response (Item 11) that they thought that the study had something to do with being able to see others and/or that others could see them (e.g., "How having the cameras be on influence online learning specifically memory recall."). See https://osf.io/rch4q for all responses.

Table 3
Means (With Standard Deviation) in the Attentive- and Inattentive-Confederate Conditions, and Inferential Statistics for Each Measure

Measure	Attentive M (SD)	Inattentive M (SD)	F (df1, df2)	MSE	p	η_p^2
Manipulation checks						
Confederates' attentiveness (0–10)	8.76 (1.12)	4.34 (2.15)	98.00 (1, 59)	3.03	**<.001**	.62
Confederates' motivation (0–10)	8.07 (1.65)	4.50 (2.00)	57.20 (1, 59)	3.39	**<.001**	.49
Prelecture motivation to learn (0–10)	7.03 (1.52)	7.58 (1.58)	1.68 (1, 53)	2.40	.20	.03
Primary measures						
Self-reported attentiveness (0–10)	7.45 (1.76)	6.68 (1.68)	8.17 (1, 51)	2.48	**.006**	.14
Estimated phone use (min)	0.21 (0.49)	1.75 (3.65)	7.07 (1, 52)	7.59	**.010**	.12
Estimated other website use (min)	0.31 (0.81)	1.25 (2.99)	3.41 (1, 52)	5.41	.070	.06
Quiz performance (%)	79.01 (12.08)	66.85 (17.87)	5.09 (1, 52)	248.92	**.028**	.09
Secondary measures						
Distracted by confederates (0–10)	4.72 (2.74)	4.72 (2.84)	<0.01 (1, 59)	7.80	.99	<.001
Motivation to learn during lecture (0–10)	7.41 (1.70)	6.63 (2.30)	11.61 (1, 52)	2.59	**.001**	.18
Importance of lecture content (0–10)	8.24 (1.24)	7.41 (1.56)	13.33 (1, 52)	1.62	**<.001**	0.20
Thought about participants seeing them	3.14 (0.59)	3.13 (0.66)	0.01 (1, 59)	0.40	.91	<.001
Attentive due to participants seeing them	2.45 (0.91)	2.41 (0.80)	0.04 (1, 59)	0.73	.85	.001
Attentive due to experimenter seeing them	2.45 (0.91)	2.50 (0.95)	0.05 (1, 59)	0.87	.83	.001

Note. Statistically significant p values are in bold. Prelecture motivation was a statistically significant covariate ($p < .02$) for self-reported attentiveness to learn, motivation to learn during lecture, and importance of lecture content, but was nonsignificant ($p > .21$) for quiz performance, estimated phone use, and estimated website use. Removing the covariate from the latter analyses did not affect their statistical significance (quiz performance: $p = .003$; estimated phone use: $p = .028$, estimated website use: $p = .107$). Responses to the final three measures in this table were coded as 1 = *strongly disagree*, 2 = *disagree*, 3 = *agree*, 4 = *strongly agree*.

both attentiveness ratings and quiz performance (Table 4), suggesting that distraction did not contribute to the spread of inattentiveness.

Goal Contagion

Prelecture Motivation to Learn. Prior to watching the video lecture, there was a statistically nonsignificant difference in participants' motivation to learn the lecture content.

Self-Reported Motivation to Learn During the Lecture. Participants who watched the lecture with attentive (vs. inattentive) confederates retrospectively rated themselves as having been significantly more motivated to learn the lecture content while watching the video.

Self-Reported Motivation Before Versus During the Lecture. To further assess the extent to which confederates affected participants' motivation to learn the lecture content, we conducted a Time (before vs. during lecture) × Condition (attentive-confederates vs. inattentive-confederates) mixed ANOVA. The main effect of time was marginal, $F(1, 53) = 3.78$, $MSE = 1.32$, $p = .057$, $\eta_p^2 = .07$, driven by a decrease in motivation in the inattentive-confederates condition, and the main effect of condition was nonsignificant, $F < 1$. Of main interest, the interaction was statistically significant, $F(1, 53) = 13.51$, $MSE = 1.32$, $p < .001$, $\eta_p^2 = .20$. In the attentive-confederates condition, there was a statistically nonsignificant increase in self-reported motivation to learn during the lecture ($M = 7.41$, $SD = 1.70$) compared to before the lecture ($M = 7.03$, $SD = 1.52$), $t(28) = 1.49$, $p = .148$, $d = 0.28$. In the inattentive-confederate condition, there was a statistically significant decrease in self-reported motivation to learn during the lecture ($M = 6.35$, $SD = 2.33$) compared to before the lecture ($M = 7.58$, $SD = 1.58$), $t(25) = 3.37$, $p = .002$, $d = 0.66$.

A "motivational ceiling effect" for some participants may have attenuated evidence of increasing motivation in the attentive-confederates condition (e.g., two participants rated their prelecture

Table 4
Bivariate Correlation Coefficients (Pearson's r) Between Dependent Measures

Measure	1	2	3	4	5	6	7	8	9	10	11
1. Confederates' attentiveness	—	.83***	.37**	−.25*	−.25*	.32*	−.01	.02	.38**	.36**	.09
2. Confederates' motivation		—	.34**	−.31*	−.26*	.40**	−.02	.03	.37**	.33**	.29*
3. Self-reported attentiveness			—	−.37**	−.28*	.36**	.08	.39**	.87***	.48***	.06
4. Estimated phone use				—	.40**	−.23†	−.13	−.04	−.31*	−.31*	−.30*
5. Estimated other website use					—	−.37**	.13	−.13	−.35**	−.38**	−.15
6. Quiz performance (%)						—	−.13	−.11	.34**	.15	−.01
7. Distracted by confederates							—	.15	.02	.08	.25†
8. Prelecture motivation to learn								—	.54***	.22	.07
9. Motivation to learn during lecture									—	.47***	.04
10. Importance of lecture content										—	.18
11. Thought about participants seeing them											—

† $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

motivation a "10"). As a more targeted analysis of goal contagion, we focused on a subset of 18 participants who rated the confederates as being more motivated during the lecture than they rated themselves *before* the lecture. Presumably, goal contagion ought to have exerted a stronger influence on these participants, who perceived themselves as less motivated than their peers. Indeed, these participants rated their motivation as significantly higher during the lecture ($M = 7.56$, $SD = 1.79$) than before the lecture ($M = 6.61$, $SD = 1.33$), $t(17) = 3.31$, $p = .004$. Moreover, participants who perceived larger differences between their prelecture motivation and confederates' motivation reported larger increases in their own motivation, $r(16) = .49$, $p = .038$, suggesting that goal contagion exerted a larger influence when there was a larger gap in motivation between participants and confederates.

Informational Social Influence

Importance of the Lecture Content. Participants who watched the lecture with attentive (vs. inattentive) confederates rated the content as significantly more important.

Requested More Information on the Lecture Topic. 79.31% of participants who watched the lecture with attentive confederates indicated that they wanted to receive an email with more information regarding the lecture topic, compared to 65.63% of students who watched the lecture with inattentive confederates. This difference was, however, statistically nonsignificant, $\chi^2(1) = 1.42$, $p = .234$.

Normative Social Influence

Thought About Participants Seeing Them. Participants in both conditions tended to agree with the statement "Sometimes I thought about the fact that some participants could see me," and responses were nonsignificantly different between conditions. Contrary to our prediction, the extent to which participants agreed with this statement was nonsignificantly correlated with participants' self-reported attentiveness and their estimated time spent on other websites. However, participants who expressed greater agreement did tend to estimate having spent less time on their phones (see Table 4).

Paying More Attention Because Other Participants Could See Them. The extent to which participants (dis)agreed with the statement "I paid more attention because other participants could see me" was nonsignificantly different between conditions. In each condition, participants' responses tended to be about midway between "agree" and "disagree."

Paying More Attention Because the Experimenter Could See Them. The extent to which participants (dis)agreed with the statement "I paid more attention because the experimenter could see me" was nonsignificantly different between conditions, and again tended to be about midway between "agree" and "disagree." Responses to this measure were also nonsignificantly correlated with our other measures ($p > .05$). Thus, as intended, the experimenter (who was not visible on webcam and did not interact with participants) did not meaningfully affect participants' attentiveness.

Correlations

Table 4 shows correlations between our main dependent measures. Notably, there was a robust positive correlation between participants' ratings of the confederates' attentiveness and their own attentiveness, $r(58) = .37$, $p = .004$, supporting the attention contagion hypothesis. There also was a robust positive correlation between participants' ratings of confederates' motivation during the lecture and their own motivation during the lecture, $r(59) = .37$, $p = .003$, consistent with the proposed goal contagion mechanism.

Discussion

We tested the hypothesis that (in)attentiveness spreads between students who have their webcams on (i.e., *attention contagion*). We found consistent evidence of attention contagion in simulated online psychology lectures in which four research confederates were visible (via "webcam video thumbnails") and behaved either attentively or inattentively. Students who watched the lecture with attentive (vs. inattentive) confederates were more attentive, spent less time media multitasking (i.e., checking other websites and their phone), and, importantly, performed meaningfully better on a lecture-content quiz (by over one letter grade: 79% vs. 67%).

Distraction

Participants reported similarly moderate distraction from both attentive and inattentive confederates.[5] Moreover, ratings of confederates' distractingness were nonsignificantly correlated with participants' self-reported attentiveness and their quiz performance, whereas ratings of confederates' attentiveness were significantly positively correlated with those measures (see Table 4). These results are inconsistent with the possibility that peer distraction spread inattention in our virtual classroom, and instead suggest that *perceptions of peers' attentiveness* are related to attention contagion.

Goal Contagion

Students paired with inattentive confederates reported decreased motivation from before to during the lecture, consistent with inattentiveness spreading. For students who watched the lecture with attentive confederates, a corresponding increase in motivation was observed in a subset of students—those who perceived confederates as more motivated to learn than they themselves had been before the lecture. Thus, a motivational ceiling effect may have obscured evidence of attention contagion in students who were initially highly motivated to learn (though goal contagion may have helped *sustain* their high motivation). To avoid a motivational ceiling effect, future research could use a less relevant video lecture (e.g., content unrelated to their academic major) and not offer financial incentives for good quiz performance.[6]

[5] Attentive confederates may have been moderately distracting because they frequently leaned forward and looked directly at the video lecture: Given that eyes attract visual attention (e.g., Itier et al., 2007), we suspect that some participants reflexively glanced at confederates' eyes, which may have increased their sense of distraction.

[6] It is worth noting that emerging research on motivational contagion in educational settings (Burgess et al., 2018, 2020; Radel et al., 2010) has proposed different theoretical frameworks, including mimicry (Chartrand & Dalton, 2009) and self-determination theory (Deci et al., 1991). Those theories are germane to *social interactions* between students and therefore may not account for the results of our study (in which students only *observed* their peers), which are better explained by goal contagion: Goal contagion theory (Aarts et al., 2004) posits that the observation of goal-directed behavior is sufficient to unconsciously activate that goal in the observer and motivate goal pursuit.

Conformity

In line with *informational social influence*, participants paired with attentive (vs. inattentive) confederates rated the lecture content as significantly more important. They also spent significantly less time on their phones, consistent with *normative social influence*: Unlike attentive confederates, inattentive confederates occasionally checked their phones, possibly weakening the social norm of refraining from phone use during the lecture. Moreover, the subjective experience of being seen by others (*publicness*; Lapinski et al., 2014) was negatively associated with participants' time spent phone checking, suggesting that fear of public scrutiny discouraged this behavior. Future research could examine whether students are more likely to engage in inattentive behaviors when their webcams are off (thereby eliminating publicness).

Theoretical Implications

To summarize, our results are consistent with the possibility that goal contagion and conformity contribute to attention contagion, although further research is needed to establish causality. These potential mechanisms—which are interrelated and may operate in tandem—are rooted in students' ability to draw inferences from their classmates' (in)attentive cues—for example, inferring from classmates' engaged facial expressions that they have learning goals (goal contagion), that the lecture content is important (informational social influence), and that attentiveness norms are present (normative social influence).

Our confederates displayed strong (in)attentive cues, which may have heightened attention contagion. Specifically, cues were: (a) *unambiguous* in signaling attentiveness (e.g., head nodding) or inattentiveness (e.g., phone checking); (b) *consistent* throughout the lecture; and (c) *salient* due to webcams giving participants a close-up view of confederates' faces during the lecture. Future research could examine whether attention contagion is stronger in virtual (vs. in-person) classrooms due to more salient (in)attentive cues.

Educational Implications

Our results have several key implications for online learning. First, students readily perceive (in)attentive cues from classmates, despite the diminutive size of webcam "video thumbnails." Second, attention may be highly contagious in virtual classrooms. The effect of webcams on students' learning therefore depends, in part, on the (in)attentiveness of visible students. Third, a feature allowing students to hide webcam videos of inattentive peers would be a useful addition to videoconferencing software, helping to minimize the spread of inattentiveness. And fourth, instructors should consider encouraging teaching assistants to be visible in their virtual classrooms because their attentiveness may spread to students. Future research could examine whether informing students of attention contagion motivates them to curtail their visibly inattentive behaviors (for the sake of their classmates).

Limitations

First, the *generalizability* of our results was constrained by using a single lecture and sample of students. Students were in an unfamiliar context (a research study) which may have strengthened informational social influence (see Deutsch & Gerard, 1955). Moreover, relative to our confederates, students in real classrooms may typically display weaker (in)attentive cues, producing smaller attention contagion effects. These challenges to generalizability call for further research in real online classrooms. Second, our retrospective attentiveness measures were susceptible to memory and self-report biases (e.g., social desirability). Reassuringly, these measures were significantly correlated with quiz performance (Table 4), which also differed significantly between conditions (mirroring the results of our attention measures); together, these results strongly support attention contagion.

Third, our other single-item self-report measures (motivation, importance, distraction) had similar problems (e.g., see Anmarkrud et al., 2019, for issues with using single-item self-report measures of cognitive load). Due to the timing of our measures, we could not properly test whether these factors mediated the relation between our confederate-attentiveness manipulation and quiz performance. Future research could measure these variables during the video lecture (although such concurrent measures can themselves be distracting). Fourth, our results do not differentiate whether attentiveness or inattentiveness (or both) spreads between students. Future research could add a control/baseline condition with no confederates/peers visible on webcam.

Conclusion

Our experiment strongly supports the hypothesis that (in)attention spreads in virtual classrooms, affecting students' learning. The effect of webcams on attentiveness, therefore, depends on the (in)attentiveness of those visible. Further, evidence suggests that two social contagion mechanisms—goal contagion and conformity—may contribute to this phenomenon. Classrooms, even virtual ones, are social settings in which social contagion occurs and influences attention. The net effect is that attention is contagious online.

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