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Enhancing student memorisation through teacher webcam usage and the interplay of social presence

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Abstract
This study explores the impact of teachers' webcam activation on students' cognitive processes and learning outcomes within online education. It investigates how the presence of teachers' webcams influences visual attention, cognitive load, and memory retention in an online classroom setting, emphasising the role of social presence in enhancing the online learning experience. A laboratory experiment involving 132 participants gathered data through neurophysiological measurements and surveys, with analysis conducted via Macro PROCESS for SPSS. Findings indicate that an active webcam negatively affects students' lesson focus. Moreover, cognitive load positively influences students' memorisation. Social presence emerged as a key moderator in the relationship between teachers' webcam activation and students' lesson focus, underscoring its significance in improving online learning experiences. These insights provide valuable implications for optimising online teaching strategies, aiming to enhance student outcomes in online environments. By highlighting the effects of social presence, this research advocates for tailored approaches that encourage active participation and foster a sense of community in online classrooms.

Keywords Online learning, Webcam, Visual attention, Cognitive load, Memorisation, Social presence

Introduction

Online learning has become increasingly important in recent years, especially in education. Online educational platforms have emerged as critical components in modern educational contexts, increasing the use of tools such as Microsoft Teams, Zoom and Google Meet (Jung & Shin, 2021; Lange, 2024). This transition has sparked research into online teaching, which has highlighted its advantages, such as flexibility and convenience, and its challenges, which are generally related to the teachers' technical competencies, including how webcam usage impacts students' cognitive load (Kaminskienè et al., 2022; Li, 2022; Polat & Taslibeyaz, 2024). Furthermore, the proliferation of online education platforms has prompted discussions on educational quality, innovative learning approaches, content diversity and teachers and students´ perceptions of the methodology (Jung & Shin, 2021; Lee & Deale, 2021). As society continues to evolve at a rapid pace, online learning is gaining prominence by offering flexibility and access to learners globally, irrespective of their location or time constraints. This educational format is forecasted to grow annually by 8.61% in market revenue, achieving a total value of US$257.70 billion by 2028 (Statista, 2023).

With this increase in usage, it must be stressed that student learning must still be at the centre of online learning. This research asserts that there are three key factors that impact online learning: teacher cameras, social presence, and lesson focus. Understanding the factors influencing student engagement and outcomes in online classrooms is crucial. Recently, a factor that has attracted attention is the impact of whether the teacher's camera is activated/not activated (i.e. switched on/off) in video presentations in online classes (Williams & Pica-Smith, 2022; Xiaxia et al., 2025). When activated, it allows students to see the teacher's face, enhancing engagement, whereas a deactivated camera results in a blank space, potentially diminishing students' focus and cognitive load (Schwenck & Pryor, 2021). Furthermore, as students adapt to online learning, the concept of perceived social presence in the online classroom has also gained importance (Alemdag, 2022; Lim, 2023). Social presence relates to the degree to which individuals perceive and experience the presence of others in a communication environment (Barta et al., 2021). Therefore, perceived social presence in online education is essential to counteract the disconnection inherent in the format, given that it provides a sense of community and belonging that encourages students to participate actively. By facilitating more human and meaningful interactions between teachers and students, perceived social presence in online environments promotes more collaborative and enriched learning experiences (Richardson et al., 2017; Wang et al., 2024).

Previous research into cameras in online learning has primarily focused on students' experiences and preferences regarding their use during online classes (Trust & Goodman, 2023). Studies have revealed that students' decisions to turn their cameras on or off are influenced by a variety of factors, highlighting the concern for their appearance, for distracting their peers, and the need to manage their physical surroundings (Castelli & Sarvary, 2021; Schwenck & Pryor, 2021). While these findings shed light on students' preferences and anxieties, limited research examines how the teacher's camera activation may affect students' outcomes and cognitive load. Prior studies have shown that teacher webcam use can positively influence student engagement by fostering a more interactive and connected learning environment (Alemdag, 2022). However, limited research addresses how this practice impacts students' cognitive load and attention in online learning, which are crucial for effective learning (Skulmowski & Xu, 2022). Furthermore, from a methodological perspective, previous research in the field has generally used subjective measures, collected through questionnaires (Davidesco et al., 2021; Li, 2022). However, neuroscience measures, such as eye-tracking (ET) and electroencephalography (EEG), offer invaluable insights into cognitive processes that subjective measures alone cannot fully capture. ET provides real-time data on visual attention and gaze patterns, offering objective indicators of what individuals focus on during tasks/stimuli presentation. EEG records electrical activity in the brain, providing information about cognitive states, memorisation and neural responses to stimuli. Unlike subjective measures, which rely on self-reporting and introspection, neuroscientific techniques provide objective and quantifiable data that can help mitigate some of the biases and inaccuracies associated with self-reporting. However, as with any methodology, the interpretation of neuroscientific data requires careful and contextual analysis to ensure that conclusions accurately reflect the underlying cognitive processes. When combined with self-reported measures, these techniques enable a more holistic and enriched approach to studying online learning environments (Peng et al., 2021; Pi et al., 2024).

To bridge these gaps, this research analyses how camera activation/non-activation affects the attention students pay to class content and their cognitive load, ultimately affecting student outcomes, such as memorisation. While memorisation represents a foundational level within Bloom's taxonomy of learning objectives (Sosniak, 1994), it provides an important starting point for exploring how instructional strategies, such as webcam activation/non-activation, shape students' cognitive processes and retention of information. This focus on memorisation allows the study to establish a clear baseline for understanding the immediate effects of attention, cognitive load and perceived social presence on learning outcomes. Given that these factors influence memorisation, it provides an appropriate entry point for exploring how fundamental learning processes adapt to variations in instructional delivery. This approach addresses the initial stages of learning and lays the groundwork for future research to investigate higher-order cognitive skills, such as application, analysis, evaluation, and creation, which remain central to broader educational goals.

Furthermore, given the aforementioned importance of perceived social presence in the online learning context, this study aims to analyse how the degree of social presence perceived by students affects their cognitive processes and learning outcomes (i.e. memorisation) following future research lines proposed by Huang et al. (2023) and Yu et al. (2024). Consequently, the findings have significant implications for educators and instructional designers. Understanding how different instructional delivery modalities influence students' attention, cognitive load, and material retention can inform the design of more effective online learning experiences. Moreover, recognising the importance of perceived social presence sheds light on the interpersonal aspects of online education, guiding educators in fostering a sense of community in online classrooms.

Literature review and research model

Social presence in online education

Understanding how different dimensions of presence influence learning in online environments has become a key concern in recent educational research (Garrison, 2021; Martin et al., 2022; Richardson et al., 2017). Within this context, teaching presence has received particular attention through the lens of the Community of Inquiry (COI) model, which highlights its essential role in shaping student engagement and learning outcomes (Garrison et al., 2000). Numerous studies have confirmed the positive effects of teaching presence on learners' satisfaction and perceived learning (Caskurlu et al., 2020), and its interaction with social presence has also been shown to influence student persistence via satisfaction (Joo et al., 2011). However, more recent research has found no significant effect of teaching presence via webcam on students' learning performance or satisfaction (Xiaxia et al., 2025). These recent findings challenge earlier assumptions that visibility alone enhances instructional effectiveness, highlighting the relevance of the learning context.

Given its potential to humanise digital learning environments, social presence is considered key in shaping how students perceive relationships with teachers and peers (Ratan et al., 2022). Although some studies question its cognitive impact (Annand, 2011), more recent research highlights several benefits: it can increase cognitive load (Costley, 2019), foster higher-order thinking (Lee, 2014), boost intrinsic motivation (Catyanadika, 2021), enhance perceived competence and enjoyment (Ratan et al., 2022), and support cognitive phases such as exploration and integration (Fathali, 2024). While social presence has been studied as a predictor of learning outcomes, its moderating role remains underexplored. Notable exceptions include Li and Yang (2025), who found no significant moderation between loneliness and burnout, and Li and Zhao (2024), who reported a significant moderating effect on learner satisfaction in massive open online courses. These results suggest its potential and the need for further research.

Despite limited evidence within education, other disciplines have recognised its moderating role in digital interactions. In tourism contexts, social presence has been shown to amplify the effect of source credibility on perceived information usefulness (Chung et al., 2015). Similarly, it moderates the relationship between personality traits and social media behaviour (Yang et al., 2023) and enhances the impact of face concern on behavioural responses such as word-of-mouth intentions and online reviews (Qiu et al., 2018). Therefore, these findings highlight the need to further explore the moderating role of social presence within educational settings, particularly in relation to how students respond to technological and instructional variables in online learning environments.

Student-centered interaction framework

Two key pedagogical models in online education are the COI model (Garrison et al., 2000) and the Student-centered Interaction models (Moore, 1989). The COI model posits that cognitive, social, and teaching presences jointly foster effective online learning. Cognitive presence refers to the extent to which learners can construct and confirm meaning through sustained reflection and discourse in a digital learning environment (Shea & Bidjerano, 2009). Social presence, reflecting one's projection in virtual environments and the feeling of a populated class, is reinforced by active participation and is foundational for supporting cognitive presence and facilitating community and critical thinking (Singh et al., 2022). Teaching presence, involving instructional design, facilitation, and direct instruction, guides and supports these processes to achieve meaningful learning outcomes (Ke, 2010). Teaching presence is crucial for guiding students through online interactions, ensuring that learning objectives are met (Garrison et al., 2000).

This evidence-based pedagogical framework is recognized for examining online learning dynamics, emphasizing how these three presences contribute to an enriched educational experience (Leem, 2023; Singh et al., 2022). Moore's Student-centered Interaction framework, a foundational model in online education, remains highly relevant in today's digital classrooms by focusing on core forms of interaction (Garrison et al., 2000). It complements the COI model by reinforcing cognitive, social, and teaching presences. Student-content interaction enhances understanding and critical thinking (Çakiroğlu & Kahyar, 2022; Leem, 2023), while student-student interaction strengthens social presence through meaningful peer connections (Çakiroğlu & Kahyar, 2022; Xiao, 2017). Student-teacher interaction, through personalised guidance, supports teaching presence and fosters a sense of community (Moore, 1989; Xiao, 2017). These essential, interdependent interactions underscore the importance of a supportive, inclusive online classroom atmosphere for successful learning outcomes (Leem, 2023).

In line with Moore's Student-centered Interaction framework, this study addresses the three interactions. First, it addresses student-content interaction by analysing the impact of the teacher's camera being activated (independent variable) on students' learning processes, such as the amount of time they spend visually focusing on the class content (hereafter, "lesson focus"), as measured by ET, cognitive load and, ultimately, degree of memorisation (measured through EEG). Second, it addresses student-student interactions by assessing whether the feeling of being in class with other students (self-reported measure) influences these learning variables. Third, student-teacher interaction is addressed by examining how the teacher´s camera being activated affects the online learning experience. Consequently, this study explores how different factors influence student's memorisation. While prior research has mostly examined the direct effects of camera use in virtual classrooms (Caskurlu et al., 2020; Martin et al., 2022), this study goes further by examining whether the perception of social presence, the feeling of connection and interpersonal closeness in online environments, can shape the impact that the camera use has on student outcomes. By introducing social presence as a moderating variable, the study moves beyond binary views of camera use and underscores the importance of relational and contextual dynamics in shaping online learning outcomes. This approach offers a more nuanced framework for understanding when and how camera use enhances or hinders student performance.

Hypotheses development

The Cognitive Theory of Multimedia Learning (CTML) highlights the need to minimize unnecessary cognitive load in online environments to improve information processing by managing attention to the teacher's face, peer interactions, and content (Mayer, 2014). While the CTML suggests teacher visibility can enhance learning by triggering social and cognitive responses (Gunawardena, 1995), evidence shows that merely seeing the teacher's image does not always lead to better outcomes and could distract from content focus due to humans' innate focus on faces (Mayer, 2014; Pi et al., 2024). Research indicates that direct eye contact with the teacher can further distract attention from learning materials (Kuang et al., 2023). This suggests that optimising students' focus may require limiting visual stimuli to just the lesson content.

H1a *The teacher's camera being activated (vs. non-activated) negatively influences students´ lesson focus.*

Cognitive load is a pivotal concept in learning; it affects cognitive processing in educational contexts (Çakiroğlu & Aksoy, 2017; Sweller, 1988). Cognitive load refers to the mental effort required to process and retain information in working memory (Sweller, 2020). In educational contexts, cognitive load is influenced by the cognitive processes elicited by stimuli, such as learning materials (Zhu et al., 2024). Activating the teacher's camera could significantly raise students' cognitive effort as they process lesson content and non-verbal cues. This simultaneous interaction between lesson content and non-verbal cues—gestures, facial expressions, eye contact—can increase cognitive load (Alim et al., 2023). While instructional videos featuring on-screen teachers are increasingly common in various educational settings, their impact has been questioned due to the mixed findings reported in the literature (Alemdag, 2022). On the one hand, some research has found that videos featuring teachers can reduce cognitive load, particularly when addressing challenging questions (Wang et al., 2020a). On the other, some studies have reported that students exposed to such videos experience higher cognitive load than those exposed to an interactive or text version of the work (mean difference = 0.475, $p = 0.025$; Wang et al., 2020b). Specifically, they demonstrated that students exposed to videos had significantly higher cognitive load than those exposed to the text version. These contrasting findings underscore the complexity of the relationship between the use of videos in education and their impact on the students´ cognitive load. To shed light on this issue, we measured students´ cognitive load using neuroscientific devices, and we propose the following:

H1b *The teacher's camera being activated (vs. non-activated) positively influences students´ cognitive load.*

When students exert more focus in class sessions, they are exposed to more information, which challenges their finite cognitive capacities. Prolonged exposure requires processing a larger volume of data and concepts, potentially increasing cognitive load (Sweller, 1988). Class content, especially when dense/complex, increases cognitive load as it requires more time for comprehension (Mayer & Moreno, 2003). According to cognitive load theory and in line with previous ET-based studies (e.g. Zheng et al., 2022), it is posited that increased attention on the slide in the video can affect cognitive load. By spending more time on lesson content, students are more likely to be more analytical, raise questions and seek clarification, which can increase cognitive load. Thus:

H2 *The student´s lesson focus positively influences the cognitive load.*

Greater lesson focus may be associated with deeper understanding and enhanced retention of the presented information. Memorisation is pivotal in learning; it is the cognitive process by which information is actively paid attention to and encoded in long-term memory (Klimesch et al., 1996). Deactivating the teacher's camera can reduce visual distractions, allowing students to concentrate on the class content fully. This approach aligns with individual learning preferences and can improve memorisation by minimising potential visual interruptions (Mayer & Moreno, 2003). Therefore, as with other student outcomes (e.g., learning effect; Leem, 2023), increasing the time students spend focused on lesson content should improve student memorisation through increased exposure and reinforcement.

H3a *The student´s lesson focus positively influences the students´ memorisation.*

Information retention may be affected by amount of information processed. Intensified cognitive effort may contribute positively to an enhanced level of retention as students grapple more fully with the information presented during classes (Wang et al., 2020a). Cognitive load can activate memory consolidation processes. When students are experiencing increased cognitive load, relevant information is more likely to be retained effectively in long-term memory (Sisakhti et al., 2021). Sustained attention and active thinking, which are associated with a balanced cognitive load, create stronger synaptic connections, which can improve information retention and enhance memorisation (Brame, 2016). Thus:

H3b *The student´s cognitive load positively influences the students´ memorisation.*

The moderating effect of perceived social presence

The effectiveness of technological features in online environments, such as webcam activation, depends not only on their functional role but also on the social and psychological context in which they are embedded (Barta et al., 2025). Although prior studies have shown that having the teacher's camera activated can lead to increased distractions (Castelli & Sarvary, 2021), such negative effect may be buffered when students perceive a high degree of social presence. Social presence is a psychological concept related to the sense of connection, closeness and immediacy experienced in social interactions, including in online environments (Barta et al., 2021). Social presence enhances interpersonal connections in online classrooms, offsets isolation, and fosters the sense that students and teachers share the classroom with others (Weidlich et al., 2024). Given its role in 'humanising' interactions, social presence is instrumental for understanding student-teacher and student-student interactions and learning dynamics, making it a vital moderating variable in the context of online learning (Li & Zhao, 2024). Social presence underpins Garrison's COI framework and Moore's interaction theories, which propose that enhanced social presence positively impacts academic achievement. Moreover, CTML laid the foundation for social agency theory (Henderson & Schroeder, 2021), which interprets online classes as social events. Thus, social agency theory suggests that students can engage in social interaction processes that influence their perception and behaviour of the learning process (Beege et al., 2023).

Perceived social presence acts as a motivational cue that enhances focus and learning outcomes (Pi et al., 2024). Perceived social presence creates a more interactive and human environment, which can affect the impact of the stimuli presented in the online classroom. When students perceive greater social presence in an online class, it can increase their sense of belonging and commitment to the learning environment, increasing their participation, attention, and perceived importance of class information (Daliri et al., 2014). Furthermore, when social presence is high, the teacher's camera is interpreted not as a distraction, but as a relational cue of presence and attentiveness, reducing the potential distracting effect of the camera on the student's focus (Xie & Derakhshan, 2021). Consequently, in conditions of high social presence, the negative impact of camera activation on attention is attenuated, as students interpret the teacher's visibility not as an extraneous demand, but as a relational sign which increases the attention on the content lesson. Thus, high levels of perceived social presence reduce the negative impact of other classroom stimuli on attention. In contrast, when perceived social presence is low, the teacher's camera is more likely to be interpreted as a distracting or intrusive visual stimulus, rather than as a relational cue, thereby reinforcing its negative impact on students' ability to maintain focus during the lesson.

H4 *The negative impact of the teacher's camera being activated (vs. non-activated) on students´ lesson focus is weaker when perceived social presence increases.*

Camera activation increases perceptual and interpersonal complexity, which can elevate student's cognitive load, particularly when social presence is heightened. According to cognitive load theory, instructional environments require simultaneous processing of content, visuals, and social cues, which demands more cognitive resources (Zheng et al., 2022). Perceived social presence can create a sense of responsibility and emotional connections (teacher-students and student-student), reinforcing students´ commitment to the learning process and improving their concentration during class. When students perceive a high degree of social presence, they feel they are participating in an enjoyable educational activity where they feel connected to others (Ratan et al., 2022). In such contexts, students do not passively observe the teacher's image but actively interpret paralinguistic cues —such as facial expressions and gaze—which, while socially enriching, contribute to increased cognitive demands.

Moreover, the students' sense of community and belonging in the online classroom makes them feel more emotionally connected to the teacher and their classmates, intensifying their affective engagement with the learning process (Phirangee & Malec, 2017). While such engagement is often viewed as positive, it also implies that students are more likely to attend to social cues and maintain interpersonal responsiveness during the lesson. These processes require the simultaneous allocation of attentional and emotional resources, thereby increasing the internal and external cognitive load (Fan et al., 2020). As proposed in H1b, the teacher's camera being activated already increases the amount of perceptual information students must manage. However, this input is more cognitively demanding when students interpret it as socially meaningful, which is more likely under high levels of perceived social presence (Costley, 2019). By contrast, when social presence is low, the students do not perceive they are part of a live, interactive, and relationally rich environment (Ratan et al., 2022). In such cases, teacher's camera may remain a peripheral stimulus—noticed but not deeply processed—and therefore has a weaker impact on students' cognitive load. This suggests that higher social presence may amplify the cognitive effort required to navigate the visual and interpersonal dynamics of the online class, thus intensifying the effect of the activated camera on cognitive load.

H5 *The positive impact of the teacher's camera being activated (vs. non-activated) on the student´s cognitive load is stronger when perceived social presence increases.*
Figure 1 depicts the conceptual framework and the proposed hypotheses.

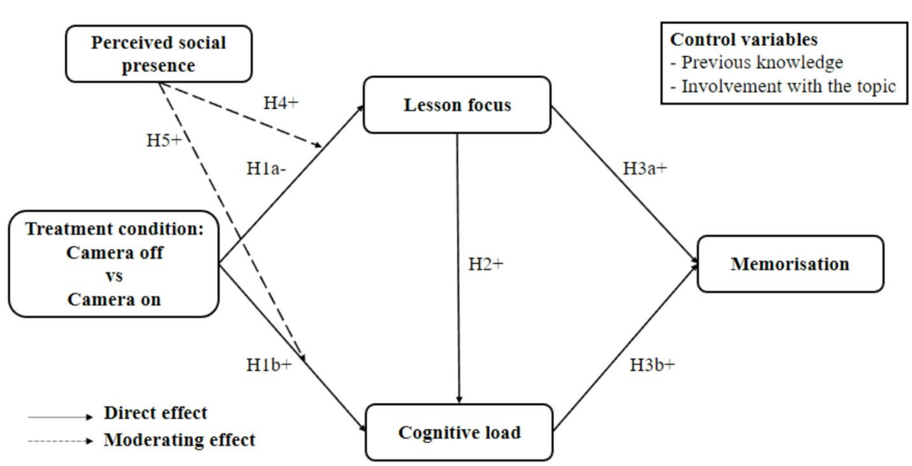

Fig. 1 Proposed model

Method

The study was conducted in a large public university in Spain. The participants engaged in the study, conducted in a manner consistent with the Declaration of Helsinki guidelines, voluntarily after the university granted ethical approval. The participants were students belonging to Generation Z; that is, they were born between 1995 and 2005. This cohort represents a significant proportion of the higher education population (Gitnux, 2023). Generation Z, often described as digital natives, is highly proficient in online learning environments due to their extensive exposure to digital technologies, including mobile devices and the web (Bagdi et al., 2023). This familiarity was further amplified, and in many cases necessitated, by the COVID-19 pandemic, which accelerated the global shift to online learning. Familiarity with online classes was measured using a 7-point Likert scale. 75% of respondents reported a familiarity level of 5 or higher, indicating a strong familiarity with online environments (average value = 5.28; standard deviation = 1.74). A two-scenario experiment was conducted; the neurophysiological data was collected through two neuroscientific, physiological tools (eye-tracking and electroencephalography). Moreover, the participants answered a survey for collecting self-reported data. Therefore, ET and EEG measurements are complemented by the participant's perceptions, which allows for a deeper understanding of the processing and memorisation of the information presented (Hyönä, 2010).

Participants and experimental design

The participants were recruited via email and social media; ensuring they were Generation Z. They were incentivised though a raffle for a service worth €300. Some 143 subjects initially took part; however, due to issues that arose in the data recording during the fieldwork (lacking normal or corrected-to-normal vision, and/or corrupted data) the final sample was 132 participants. This sample is much larger than is usual in ET and EEG studies. Furthermore, based on the power analysis conducted using the G*Power software (Erdfelder et al., 1996), the sample size used in the hypothesis testing exceeded the minimum required to achieve a statistical power of 80%, assuming a medium effect size (0.15) and a significance level of 5%.

The study employed a between-subjects experimental design in which participants were randomly assigned to one of two experimental conditions. In both scenarios, a Google Meet platform-based video simulated an online classroom featuring a teacher and other students. In the online classroom, a slide/content was displayed, which the teacher discussed. The video lasted 110 s, and the concept discussed was the metaverse. This topic was chosen due to the younger population´s interest in new technologies and the growing importance it was acquiring when the study was conducted (Deloitte, 2023). Figure 2 depicts both scenarios, the same stimuli except for the experimental condition. The teacher´s webcam was switched off for the first group, while it was switched on for the second group. The first group comprised 67 participants (35 females and 32 males), while the second group included 65 participants (34 females and 31 males). The mean age for this study was 23.18 years. The age groups are composed as follows. The most represented age group was 20 years old (15.2%), followed by ages 23 and 25 (10.6% each). Ages 21, 22, 24, 26, and 27 each accounted for 9.1%, while age 28 represented 8.3%. The least represented groups were 18 (5.3%) and 19 years old (4.5%).

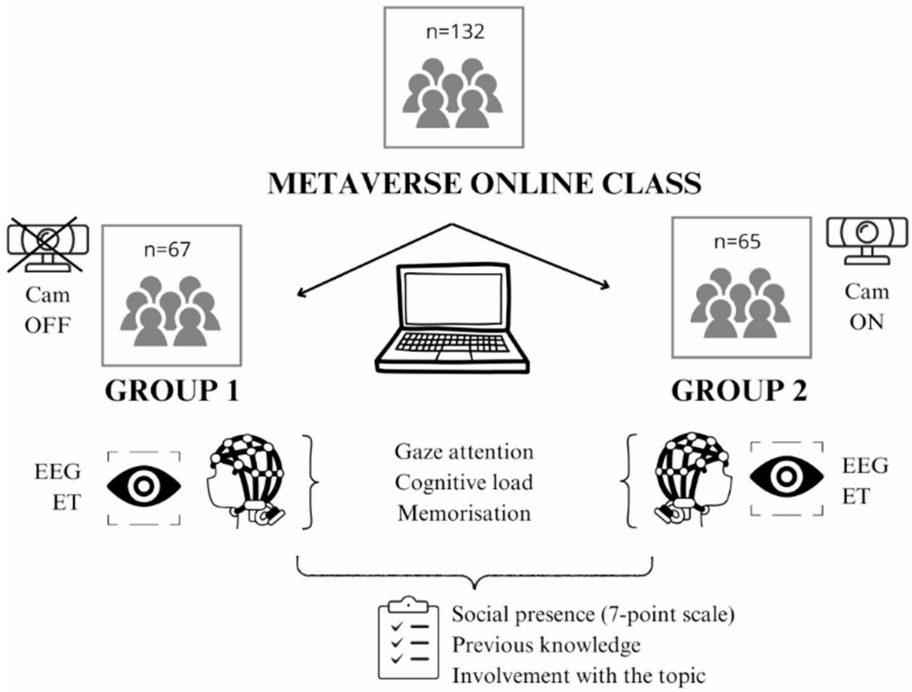

Fig. 2 Diagram of the study's experimental design. Notes: EEG: electroencephalography; ET: eye-tracking

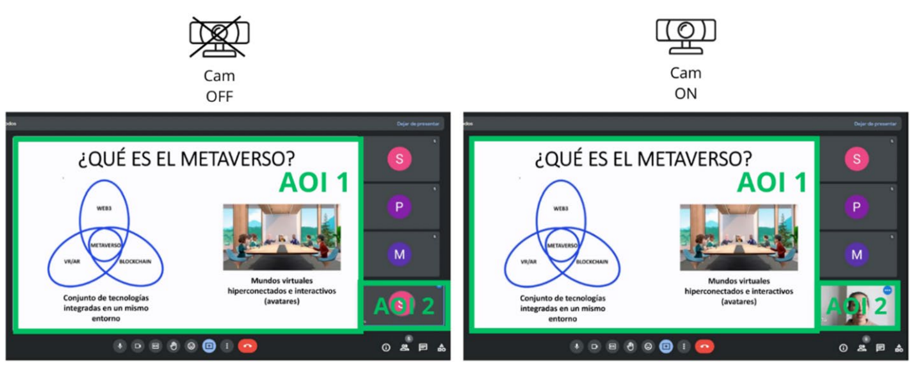

Fig. 3 AOI experimental conditions

The analysis was based on two Areas of Interest (AOI) (see Fig. 3). The first was the lesson content (AOI 1), and the second was the image shown by the teacher's webcam, visible only to Group 2 (AOI 2). The participants´ eye movements related to the AOIs were recorded on the Tobii Pro Nano eye-tracking device. This device samples corneal reflection and pupil dilation at a rate of 60 hertz (Hz). The system features a spatial tracking accuracy of 0.2º of visual angle, and it is integrated into a 21.5" monitor, with a screen with 47,60 × 26,70 full HD resolution. Calibration was performed at nine points to optimise spatial tracking accuracy. The Tobii Fixation Filter (default) was applied, with the velocity threshold parameter set to 100 degrees per second and a minimum fixation duration of 60 milliseconds. This filter detects quick changes in the gaze point signal by using sliding averaging, thus distinguishing between fixations and saccades. The eyes of the participants were situated approximately 60 cm from the screen. The data were processed using Tobii Pro Lab software.

Data collection: procedure and measures

The participants were placed individually in a quiet room, isolated from external noise, with ambient light set at 200 lx to replicate a home environment (Holmqvist et al., 2011; Permana & Ningtias, 2024). This level of lux has been recently used in recent studies based on eye-tracking research to approximate typical indoor lighting conditions in a home setting (see Ezer et al., 2023; García-Carrión et al., 2023). Furthermore, a recent study has further validated these parameters, employing an ambient lux level of 200 (Permana & Ningtias, 2024). After the participants were welcomed, they were given an overview of the steps they would undertake during the study, including a preliminary explanation of the experimental phases. They were then briefed on the informed consent process and signed the necessary documentation. The session continued with data collection calibration. Calibration involved viewing a non-educational video, closing eyes for EEG rhythm identification, fixating on a screen cross to gauge attention and cognitive load, and viewing various videos for EEG calibration. Each video was followed by a relaxation prompt to prevent signal overlap. Calibration continued until successful, followed by brief eye closure and refocusing before the experimental video presentation. The calibration process is depicted in Fig. 4. After the successful calibration process, the video was viewed, and then, the participants completed the survey.

The study involved collecting objective information based on the participants´ biometric responses, and subjective information through a survey. The biometric responses were visual attention measured by an eye-tracking device, and brain activity areas were recorded through EEG. These devices are depicted in Appendix A.

EEG records the electrical activity of the brain in five brain waves, each characterised by different frequencies and amplitudes: delta (0–4 Hz), theta (3–7 Hz), alpha (8–12 Hz), beta (13–30 Hz) and gamma (30–40 Hz); these reflect different cognitive and affective

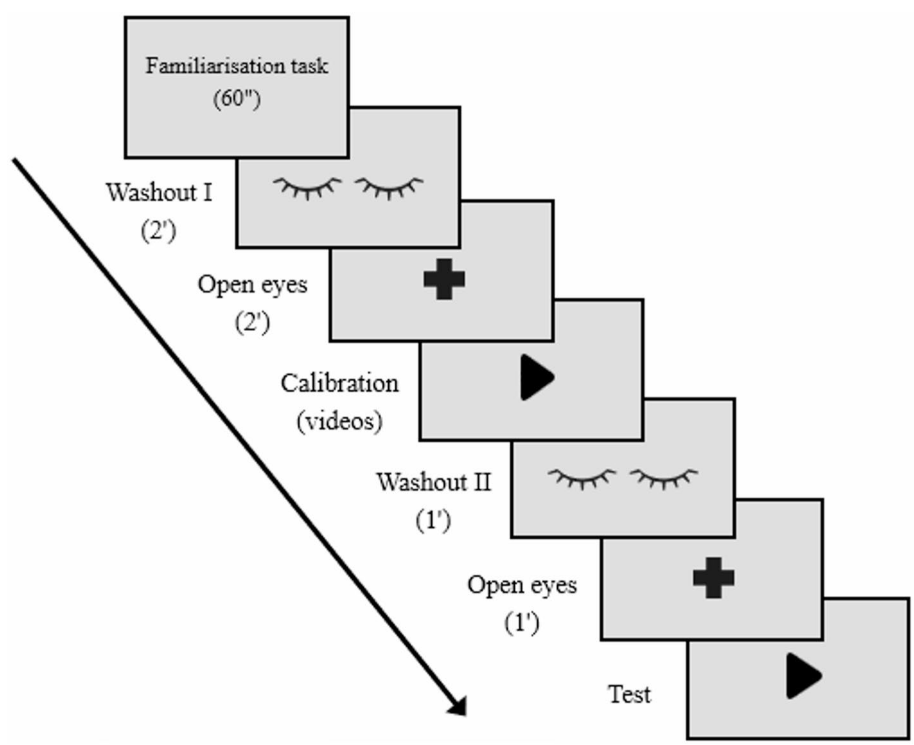

Fig. 4 Calibration process. Note: washout: the participants close their eyes; they are not exposed to stimuli

states (Khushaba et al., 2013). EEG activity was collected at a sampling rate of 256 Hz using twelve sensor sites, following the 10–20 system (Jasper et al., 1958). SennsMetrics software was, thereafter, used for artefact decontamination purposes, for example, eye blinks, muscle movements and environmental/electrical interference, such as spikes and saturations (Fernandez-Lores et al., 2024; Saavedra et al., 2025).

Before the experiment, participants reported their prior knowledge and involvement with the topic of the metaverse, as these factors could influence the dependent variables (Baber, 2020). Therefore, the data analysis included previous knowledge and involvement as covariates, ensuring that the experiment provided more accurate and reliable conclusions. By controlling for these variables, we aimed to isolate the effects of the key variables in the proposed research model and reduce the impact of external influences (Maier et al., 2023). Following the experiment, the participants reported the degree of social presence they perceived in the online classroom. To measure these variables, we used 7-point Likert scales (from 1 = "strongly disagree", to 7 = "strongly agree") adapted from previous literature to the study context. Appendix B lists the items used and their corresponding sources.

Data analysis

The data analysis began with the filtering of the EEG signal. The EEG data were put through a bandpass filter (ranging from 0.5 to 30 Hz), using a fourth-order Butterworth filter. Channels exhibiting poor signal quality were rectified through spherical interpolation. To eliminate high amplitude disturbances, the Artifact Subspace Reconstruction (ASR) method was implemented (Mullen et al., 2015). In addition, Independent Component Analysis (ICA) (Hyvarinen, 1999) and Multiple Artifact Rejection Algorithm (MARA) techniques were applied to discard artifact-laden independent components (Winkler et al., 2011). Furthermore, the Individualised Alpha Frequency (IAF) metric was calculated to accommodate variations in the alpha band in the different subjects (Klimesch, 1999).

As the study addresses memorisation and cognitive load, the alpha (8–12 Hz) and theta (3–7 Hz) bands were selected as predictors of these constructs (Klimesch, 1999). Memorisation quantifies the intensity of cognitive activities associated with the creation of memories during stimulus exposure. Participant memorisation was assessed using global field power in the theta frequency band (Klimesch et al., 1996). This signal undergoes a max-min normalisation process (scaled from 0 to 100) based on the data obtained during each individual's calibration and testing phases. Although there is no direct method to estimate cognitive load based on EEG electrical signals, a widely used approach is the Theta–Alpha Ratio (TAR) (Fernandez-Lores et al., 2024). While individual differences in baseline neural activity can introduce variability in TAR values, normalization techniques, such as min-max normalization, are commonly employed to mitigate inter-individual differences and enhance participant comparability (see other studies on the topic over the years: Dan & Reiner, 2017; Klimesch et al., 1996, 1997; Sederberg et al., 2003; Trammell et al., 2017). It is important to note that EEG-based cognitive load estimation is not intended to serve as a direct diagnostic tool but rather as an indicator of relative cognitive effort within experimental conditions.

Results

Prior to hypotheses testing, the scales were validated in a multivariate analysis (Hair et al., 2010). Specifically, the reliability and validity of the scales were checked. Appendix B contains the results of the analysis of reliability and convergent validity. Discriminant validity was assessed through the Fornell and Larcker (1981) criteria. Table 1 shows these results. After the scales were validated, the average values of the items were calculated to create the measures used in the analysis.

Prior to the analyses, a check was made to ensure all the participants had understood the experimental manipulation correctly. In the first part of the survey, the respondents had to confirm whether the teacher´s camera had been on or off. All the participants gave the correct answer based on their randomly assigned group.

PROCESS macro for SPSS was used to test the effects proposed in the research model (Hayes et al., 2017). One model was designed to analyse the direct effects of the teacher´s camera being activated on lesson focus and student cognitive load. In addition, the effects of these variables on student memorisation were tested. Consequently, camera status (on vs. off) was used as the independent variable (X). Lesson focus and student cognitive load were the mediators (M), and student memorisation was the dependent variable (Y). Perceived social presence was included as a moderator variable (W). The model also included previous knowledge and involvement with the topic as covariables.

Table 2 shows the results of the analyses. Camera on (vs. off) negatively affected lesson focus (H1a supported). Camera on (vs. off) did not significantly increase student cognitive load (H1b not supported). Moreover, lesson focus significantly increased student cognitive load (H2 supported), but it did not increase student memorisation (H3a not supported). Finally, student cognitive load positively affected student memorisation (H3b supported).

Regarding the moderating effects of perceived social presence, the negative effect of camera (on vs. off) on lesson focus was weaker when social presence increased, supporting H4. However, the positive effect of camera (on vs. off) on student cognitive load was not stronger with increased perceived social presence, not supporting H5. Figures 5 and 6 show the moderating effects of perceived social presence on the relationships between camera status, lesson focus, and student cognitive load. As to the control variables, previous knowledge and involvement with the topic did not affect the dependent variables (lesson focus, student cognitive load and student memorisation).

As social presence is a continuous variable, a more detailed analysis of the moderating effect found for the relationship between camera (on vs. off) on lesson focus was carried out. Specifically, the Johnson-Neymann procedure was conducted. This statistical

Table 1 Inter-construct correlations

Variable	(1)	(2)	(3)	(4)	(5)	(6)
(1) CAMERA						
(2) LESFOC	-0.371					
(3) COGLOAD	-0.096	0.097				
(4) MEMO	-0.093	-0.054	0.258			
(5) SOCPRES	0.105	-0.100	0.098	0.041		
(6) KNOW	0.245	-0.070	-0.005	0.096	0.097	
(7) INV	-0.238	-0.140	-0.070	0.049	0.211	0.544

Notes: CAMERA = Camera on (vs. off); LESFOC = Student lesson focus; COGLOAD = Student cognitive load; MEMO = Student memorisation; SOCPRES = Perceived social presence; KNOW = Previous knowledge; INV = Involvement with the topic

Table 2 Results of the analysis

Predictor	Coeff.	SE	t	*p*	LLCI	ULCI
Student lesson focus						
Constant	94.005	4.692	20.036	< 0.001	84.720	103.290
Camera*	-44.923	6.687	-6.718	< 0.001	-58.158	-31.689
Social presence	-2.963	1.324	-2.238	0.027	-5.583	-0.343
Camera* x social presence	5.403	2.124	2.544	0.012	1.199	9.607
Previous knowledge	0.047	0.901	0.052	0.959	-1.736	1.829
Involvement with the topic	1.085	1.009	1.075	0.284	-0.912	3.083
Model Summary	**$R^2 = 0.464$; $F_{(5,126)} = 21.776$, $p < 0.001$**					
Student cognitive load						
Constant	15.335	4.949	3.098	0.002	5.540	25.130
Camera*	4.973	4.018	1.238	0.218	-2.979	12.926
Student lesson focus	0.129	0.046	2.806	0.006	0.038	0.220
Social presence	1.313	0.696	1.886	0.062	-0.065	2.690
Camera* x social presence	-0.587	1.123	-0.523	0.602	-2.809	1.636
Previous knowledge	-0.469	0.464	-1.011	0.314	-1.388	0.450
Involvement with the topic	-0.565	0.523	-1.081	0.282	-1.600	0.470
Model Summary	**$R^2 = 0.105$; $F_{(6,125)} = 2.433$, $p = 0.029$**					
Student memorisation						
Constant	21.563	3.090	6.978	< 0.001	15.449	27.678
Student lesson focus	-0.072	0.027	-2.666	0.009	-0.126	-0.019
Student cognitive load	0.464	0.068	6.780	< 0.001	0.328	0.599
Previous knowledge	0.543	0.362	1.501	0.136	-0.173	1.260
Involvement with the topic	-0.243	0.399	-0.609	0.544	-1.032	0.546
Model Summary	**$R^2 = 0.280$; $F_{(4,127)} = 12.3291$, $p < 0.001$**					

Notes: $N = 132$; Confidence interval calculated at 95% significance; LLCI = lower limit confidence interval; ULCI = upper limit confidence interval; * Camera off = 0, Camera on = 1

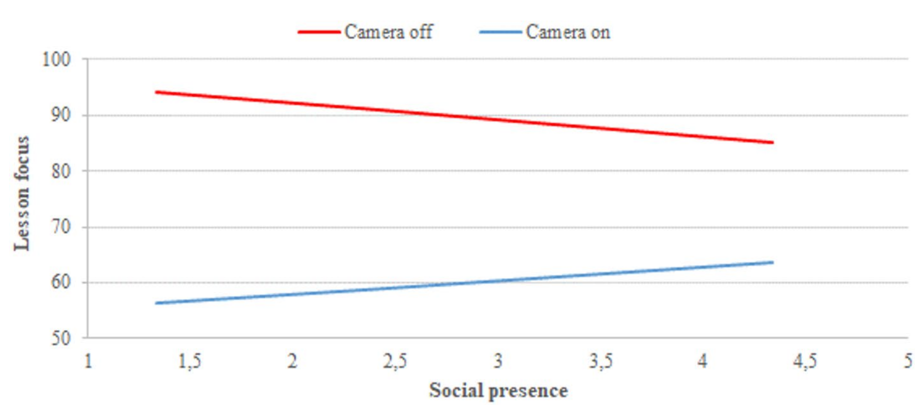

Fig. 5 Camera on (vs. off) x perceived social presence on lesson focus

method identifies the values of the moderator variable at which point the relationship between the predictor variable and the criterion variable becomes significant/non-significant. By determining the precise cut-off points of the moderator variable, the Johnson-Neymann test provides a more detailed and specific understanding of the interaction between the variables involved (Lin, 2020). This information is essential to avoid simplistic interpretations and to identify complex patterns that may influence the study results. Table 3 shows these values.

The results in Table 3 show that activating the teacher´s camera is associated with less lesson focus at all levels of perceived social presence below 5.763. However, for high

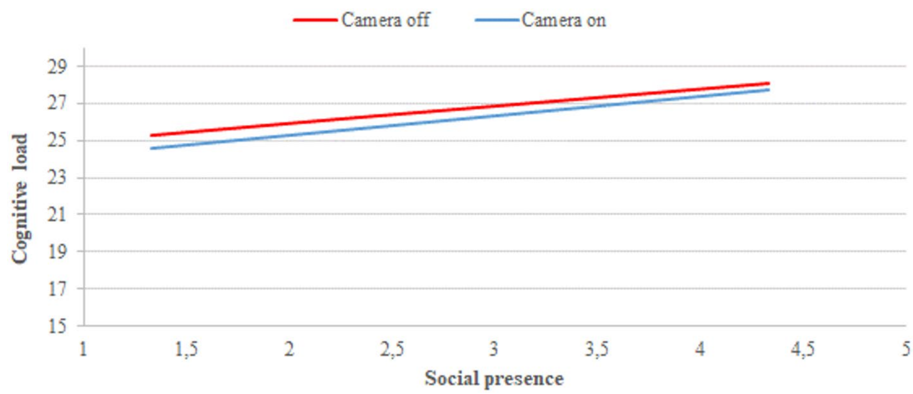

Fig. 6 Camera on (vs. off) x social presence on cognitive load

Table 3 Results of Johnson-Neymann procedure

Conditional effect of camera on (vs. off) on lesson focus at values of perceived social presence			
Social presence	**Effect**	**t**	***p*-value**
1.000	-39.520	-8.086	< 0.001
1.267	-38.080	-8.545	< 0.001
1.533	-36.639	-9.028	< 0.001
1.800	-35.198	-9.502	< 0.001
2.067	-33.757	-9.905	< 0.001
2.333	-32.316	-10.143	< 0.001
2.600	-30.875	-10.109	< 0.001
2.867	-29.435	-9.732	< 0.001
3.133	-27.994	-9.031	< 0.001
3.400	-26.553	-8.113	< 0.001
3.667	-25.112	-7.115	< 0.001
3.933	-23.671	-6.144	< 0.001
4.200	-22.230	-5.259	< 0.001
4.467	-20.790	-4.480	< 0.001
4.733	-19.349	-3.806	< 0.001
5.000	-17.908	-3.227	0.002
5.267	-16.467	-2.730	0.007
5.533	-15.026	-2.301	0.023
5.763	-13.785	-1.979	0.050
5.800	-13.585	-1.931	0.056
6.067	-12.143	-1.608	0.110
6.333	-10.703	-1.326	0.187

values of social presence (5.763 or above), whether the teacher's camera was activated or not had no statistically significant effect on lesson focus.

Discussion and conclusions

This study addresses a pivotal aspect of online learning: the impact of having the teacher's camera activated on students' behaviours and learning outcomes, noting the status of the camera´s potential to enhance students' memorisation through improved student-student, student-content and student-teacher interactions. The findings contribute significantly to the understanding of online learning, particularly in the rapidly evolving landscape of synchronous videoconference-based instruction, and extend knowledge of previously identified cognitive processes and learning outcomes (Chernikova et al., 2020).

Our result indicating that the teacher's camera being on reduces the time students spend focusing on lesson content aligns with Mayer's Cognitive Theory of Multimedia Learning (2014). This theory suggests that extraneous visual elements can detract from essential processing, thus reducing learning efficiency. Our findings also echo the concerns Brame (2016) raised, who noted the potential for cognitive overload in multimedia learning environments. They are also in line with previous studies, which found that the teacher´s presence may reduce students´ time spent fixating on learning materials (Kuang et al., 2023; Wang et al., 2020a).

However, this study does not provide evidence to confirm that the teacher's camera being on increases cognitive load. Sweller (1988) argued that the design of instructional materials plays a pivotal role in influencing students' cognitive load. In this context, the appearance of the teacher in a video could be perceived as an additional element that increases cognitive load. However, this effect is not uniform and can vary significantly depending on the specific context and complexity of the learning material (Schüler et al., 2015). A recent meta-analysis suggested that the teacher´s camera being activated increased students´ cognitive load (Alemdag, 2022); however, some studies have argued that this increase may be due to the class content and/or characteristics of the sample (e.g. age; Alemdag, 2022). In this regard, studies have returned contrasting results that reflect the inherent complexity in establishing whether and how the teacher´s face being displayed in videos affects cognitive load (Wang et al., 2020a). This divergence in findings suggests that factors such as video design, the type of content presented, and students´ characteristics are significant determinants.

Contrary to our expectations, lesson focus had no significant positive effect on student memorisation. This may be because looking at class content does not necessarily translate into enhanced memorisation. While attention is a critical factor in learning, other cognitive processes, such as encoding, consolidation and retrieval are equally important for effective memorisation. For instance, if information is not encoded adequately during the learning process, it may not be effectively stored in long-term memory. Moreover, individuals prioritise certain information through selective attention, while ignoring other information, influenced by factors such as relevance, novelty and personal interests (Sondermann et al., 2024). Consequently, even if students focus on a particular piece of information, they may not necessarily retain it if they do not perceive it to be important or meaningful. In addition, this discrepancy between our results and those obtained in previous literature might be explained from a methodological point of view. Collecting biometric data from participants to measure attention and memorisation makes it possible to avoid potential biases, such as social desirability bias in responses (Nederhof, 1985), which may have affected previous research in the field. In any case, the evidence of the present study indicates that an increase in students' cognitive load positively affects their memorisation. This finding aligns with cognitive load theory, which emphasises the necessity of maintaining a balance in cognitive load for efficient information processing (Sweller, 1988). Our findings are consistent with earlier empirical studies that demonstrated that balanced cognitive load is important for effective information retention (Polat & Taslibeyaz, 2024).

One of the most remarkable findings of this research relates to the moderating role of perceived social presence. The importance of interactions in the classroom for the development of relationships among students, student-teacher and student-educational institutions are being increasingly recognised (Xiao, 2017). Our findings shed light on the complicated dynamics of perceived social presence in online learning and underscore its crucial importance in this educational context. This study demonstrates that the adverse effect of a teacher's camera being on (versus off) on the student´s lesson focus is mitigated by degree of perceived social presence. As highlighted by Weidlich et al. (2024), perceived social presence can mitigate the feelings of isolation common in these environments. This concept aligns with COI theory (Garrison et al., 2000), emphasising the significance of social interaction in enriching the learning experience.

Moreover, other studies have confirmed that social presence emanates not just from the teacher but is also based on active student-student and student-content engagement: taken together these elements have a critical impact on the effectiveness and students´ perceptions of online courses (Lee & Deale, 2021). Thus, higher perceived social presence can weaken the negative impact of the teacher's camera being activated on lesson focus (with no significant impact at high perceived social presence values). Furthermore, the anticipated stronger impact of the teacher's camera being activated (vs. off) on the student´s cognitive load in scenarios of heightened perceived social presence was not supported in our findings. This finding aligns with recent research that demonstrates no effects on cognitive load in different conditions in which the perceived social presence may differ. The cognitive load remained stable when students were paired with a peer rather than learning alone (Pi et al., 2023). Therefore, while enhanced perceived social presence is generally seen as beneficial (Lee & Deale, 2021), its interaction with visual elements, such as an activated teacher's camera, may not directly translate into increased cognitive load. These findings contribute to the literature by shifting the focus from the direct effects of social presence, which have been widely studied in prior research, to the conditional processes that shape students' outcomes in online learning environments. The moderating role of social presence underscores the importance of contextual and relational dynamics in online education. Instructors should not only consider whether cameras are on or off, but also actively cultivate a sense of social presence to mitigate potential negative effects and enhance learning effectiveness in terms of memorisation.

Implications, limitations and future directions

When teachers kept their cameras on during online lessons, the students paid less attention to the lesson content. In addition, the students' cognitive load increased when the attention they paid to the lesson content was higher. This result suggests that mental effort increases when students are more attentive to lessons, ultimately leading to a high degree of long-term memorisation of their content. Therefore, teachers should be aware of the cognitive load imposed on students during online lessons and adopt strategies to keep it at an appropriate value. This could be done by providing students with clear and concise instructions and offering additional learning support resources. Furthermore, when students are more involved, and exert more mental effort, they are better able to retain information (Zheng et al., 2022). Educators should develop strategies promoting student attention and increased cognitive load, as these factors can enhance students' memorisation and learning. This could involve developing interactive activities, providing the students with opportunities to apply their knowledge and by offering timely feedback.

Furthermore, teachers should balance the benefits of switching their cameras on (e.g., increased student cognitive load) with the potential drawbacks (e.g., reduced lesson focus). Educators should carefully consider the trade-offs of camera usage in their online classrooms and tailor their approach to their students' specific needs and preferences. When deciding whether to activate the teacher's camera, consideration should be given to the degree of perceived social presence in the classroom. For high degrees of perceived social presence, the negative effect of the camera being activated on student attention to class content is not relevant. This underscores the emphasis on the importance of fostering a rich social atmosphere in virtual environments if the use of cameras is expected to contribute positively to learning. Therefore, teachers activating their cameras during online classes should feel connected with their students. To do so, several actions might be undertaken. First, teachers should encourage active participation through regular engagement with students via discussion forums and interactive activities. Providing opportunities for group collaboration on projects/assignments promotes a sense of community among learners. Second, using icebreaker activities at the beginning of each session can create a more comfortable environment for students and encourage them to interact. In addition, incorporating multimedia elements, such as videos, podcasts and interactive presentations, can stimulate discussion. Third, establishing clear communication channels and expectations, along with providing timely feedback, can further strengthen social bonds and foster a sense of community in online learning environments.

Moreover, the results of the research provide implications for the proper integration of short-form educational content (e.g. videos between 30 and 120 s explaining a concept), which presents a promising avenue for engaging modern learners, particularly Generation Z. Given that high cognitive load can be detrimental to sustained attention, the adoption of concise, audiovisual-based materials aligns with the learning preferences of Generation Z students, who are accustomed to immediate and interactive digital content consumption (Giray, 2022). As camera-on conditions negatively affect lesson focus, designing learning materials that encourage sustained engagement without requiring excessive visual effort is crucial. These materials allow students to engage with focused microlearning experiences that prioritise clarity and conciseness, preventing attention fatigue while maximizing lesson effectiveness.

Finally, this study has some limitations that open avenues for future research. Laboratory experiments are a valid methodology because they allow better isolation of the effects of the experimental manipulations conducted, which provides a high degree of internal validity. However, future studies might conduct field experiments to increase external validity over a more extended period of time. Additionally, the intriguing results returned in this study about the moderating role of social presence and the emergence of new online environments with features that can enhance perceptions of social presence suggest that further research in this area is needed. New online environments (e.g. the metaverse), where participants are represented through avatars and can share a common virtual space, may increase the degree of perceived social presence (Mele et al., 2025). Therefore, future studies should analyse the role that these emerging platforms can have in learning and memorisation in online education. Furthermore, in this research, perceived social presence in the classroom environment was assessed using a broad approach, without differentiating between the agents that participate in the classroom (teacher or peers; Ratan et al., 2022). Future research could explore higher-order cognitive skills—such as application, analysis, evaluation, and creation—which are fundamental to broader educational objectives, as outlined in Bloom's Taxonomy. Future studies might analyse the moderating role the degree of social presence perceived by the teacher and other students have on these cognitive skills.

Appendix, A. Neuroscientific devices used

Appendix B. Scale items

Social presence (Lu et al., 2016; α = 0.731; CR = 0.840; AVE = 0.638)
During the online class I just attended, I felt…
SOCPRES1. like I was with other people
SOCPRES2. there were other people in the same class
SOCPRES3. there was close personal contact
Previous knowledge of the topic (Barta et al., 2023; α = 0.957; CR = 0.875; AVE = 0.713)
KNOW1. I know what the metaverse is
KNOW2. I have information about the metaverse
KNOW3. *I do not need more information to know what the metaverse is*
Involvement with the topic (Keaveney & Parthasarathy, 2001; α = 0.937; CR = 0.960; AVE = 0.890)
INV1. I am interested in learning about the metaverse
INV2. I am interested in finding out more about the metaverse
INV3. I am very committed to knowing more about the metaverse
Gender
Age

Note: the item in italics was deleted during the validation process

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Author contributions

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Data availability

Data can only be made available according to the Declaration of Helsinki.

Declarations

Competing interests

There are no competing interests to disclose.

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