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RESEARCH ARTICLE

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A familiar peer improves students' behavior patterns, attention, and performance when learning from video lectures

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Abstract

Synchronous online learning via technology has become a major trend in institutions of higher education, allowing students to learn from video lectures alongside their peers online. However, relatively little research has focused on the influence of these peers on students' learning during video lectures and even less on the effect of peer familiarity. The present study aimed to test the various effects of peer presence and peer familiarity on learning from video lectures. There were three experimental conditions: individual-learning, paired-learning with an unfamiliar peer, and paired-learning with a familiar peer. ANCOVA results found that students paired with a familiar peer reported higher motivation in learning and more self-monitoring behaviors than those paired with an unfamiliar peer or who learned alone. Furthermore, students paired with both unfamiliar or familiar peers demonstrated better learning transfer than those who learned alone. Together, these results confirm the benefits of and support learning alongside a familiar peer during video lectures.

Keywords: Video lectures, Peer presence, Motivation, Behavioral pattern, Attention

Introduction

Learning from video lectures has become a prevalent learning format in both formal and informal educational settings (Scagnoli et al., 2019). However, many students experience low levels of motivation and learning performance when learning from video lectures (Byun et al., 2020). A commonly-used approach to increase students' motivation is to provide them with peer presence via face-to-face video feeds or through online chats and forums, encouraging students to both engage simultaneously in the same online learning activities (Bayeck, 2016; Craig et al., 2009; Lytle et al., 2018), for example, both students watching the same video lecture simultaneously via Zoom. Studies on peer presence suggest that the mere presence of a peer and the student's awareness of that peer presence can facilitate or inhibit their learning performance (Belletier et al., 2019; Skuballa et al., 2019). However, relatively little research has focused on the social environment in which learning from video lectures occurs, and even less on the effects of peer familiarity.

The effects of peer presence on learning from video lectures

Peer presence is an integral component in the learning contexts of both the traditional classroom (Tricoche et al., 2021) and online learning (Byun et al., 2020; Skuballa et al., 2019). With the rapid increase in the use of video lectures, viewing them with peer presence has become a common experience, with students watching the same video lecture as their peer simultaneously, though generally without the two students interacting (Pi et al., 2021, 2022a). Exploration into how peer presence might facilitate or hinder learning is not new in social psychology (Zajonc, 1965). Social presence theory provides some explanation as to how peer presence while viewing video lectures might motivate a student to engage more deeply in the learning process, and thus enhance their learning performance. According to social presence theory, peer presence encourages students to adopt their peers' perspectives (Jouravlev et al., 2018; Lachner et al., 2021), thus, peer presence may trigger students' learning processes by causing them to consider whether and how their peers understand the incoming information. These processes help students self-monitor (e.g., evaluating their own knowledge and understanding of the material) and elaborate upon their mental models, and thus enhance their learning performance. Conversely, however, peer presence might also hinder a student's attentional engagement with the lecture content due to attention-capture effects of introducing a peer to the online lecture environment. The cognitive theory of multimedia learning postulates that students' cognitive resources are limited (Leahy & Sweller, 2011; Sweller et al., 2011), and the amount of cognitive processing required for learning at any one time cannot exceed one's cognitive capacity (Mayer, 2005). When learning from video lectures while a peer is present, students must pay attention to both the lecture and their peer simultaneously. This attentional conflict could lead to cognitive overload, resulting in a worse learning performance (Belletier et al., 2019; Skuballa et al., 2019).

Researchers have begun to focus on the role of peer presence in learning from video lectures (Byun et al., 2020; Lytle et al., 2018; Pi et al., 2021, 2022a). For example, Zhu et al. (2015) found that familiar, in-person peer presence (i.e., two friends) increased adult students' level of enjoyment and interest in video content (i.e., comedy, education, and sports YouTube videos) compared to when they watched the video content alone. Meanwhile, Pi et al. (2022a) explored how online peer presence moderated the effects of self-explanation and instructional explanation on behavioral patterns when viewing video lectures online (i.e., on an HTML-based webpage with embedded JavaScript) in a computer-based learning environment. They found that, compared to those in the no-peer condition, undergraduate and graduate students in the learning with peer presence condition exhibited more self-monitoring-related behavior sequences (e.g., pause → go backward and go backward → type explanation), but fewer "play → go forward" behavior sequences. In addition to affecting the quality of the learning experience and behavior patterns, peer presence has also been shown to influence learning outcomes. Recently, Pi et al. (2021) found that in-person peer presence led to increased comprehensive understanding of the material when learning from video lectures. Compared to students viewing video lectures alone, undergraduate and graduate students learning while paired with a peer felt greater motivation to try to understand the material themselves, invested more mental effort to do so, and ultimately demonstrated a better learning performance (Pi et al., 2021). Consistent with a higher use of mental effort, the students learning with a peer exhibited greater neural oscillations in the theta frequency (4–8 Hz) and alpha frequency (8–12 Hz) bands, suggesting higher working memory activity and cognitive load (Castro-Meneses et al., 2020; Wang et al., 2020).

However, other studies have shown no effect of peer presence on students' learning from video lectures (Samudra et al., 2019, 2020). For instance, Samudra et al. (2019) compared preschoolers' vocabulary learning from video lectures either with or without a researcher present, finding no significant differences between the two conditions. A later study conducted by Samudra et al. (2020) further tested the effect of in-person peer presence on preschoolers' attention when learning from a video lecture, again with a researcher either present or not while the child watched the video lecture. Interestingly, the finding showed that peer presence increased the preschoolers' percentage of dwell time on the video, which may have been motivated by the social benefits of peer presence. However, the increased dwell time on the video did not facilitate the students' learning performance. Furthermore, the study did not assess participants' dwell time on their peer while watching the video lecture, and the peer presence could have contributed to cognitive overload, as suggested earlier, offsetting the social benefits of peer presence (Mayer, 2005; Skuballa et al., 2019).

Existing findings on the impact of peer presence on learning from video lectures is clearly contradictory, which suggests that peer presence alone is not guaranteed to facilitate students' learning from video lectures. These mixed results could be due to students' familiarity with one another. Both Zhu et al. (2015) and Li et al. (2014) have demonstrated the positive effects of familiar peer presence, students who were either already friends, or who were paired together on a weekly basis for learning. Furthermore, in the studies of Pi et al., (2021, 2022a), some of the participants were classmates alongside their peer and some are not. However, Samudra et al., (2019) and Samudra et al. (2020) both found no effect of peer presence on learning in their studies, when the researcher—someone who was not familiar to the participants—played the role of the peer. To our knowledge, no study has yet investigated whether peer familiarity moderates the effect of peer presence on students' learning from video lectures. To address this gap in understanding how peer presence affects learning, the current study compared the effect of an unfamiliar peer presence with that of a familiar peer presence on the learning processes and outcomes of students when learning from video lectures.

Potential effects of peer familiarity on learning from video lectures

In the context of group learning, students' familiarity with one another in the classroom has been shown to affect their learning processes (Cao & Philp, 2006; Pastushenkov et al., 2021). Learning processes, in the context of peer presence, include how students interact with the video lectures, how they generate responses, and how much attention they pay to both the video lecture and their peer (Pi et al., 2022a). Specifically, students demonstrate different behavioral patterns and performance when paired with a familiar peer as opposed to when paired with an unfamiliar peer (Cao & Philp, 2006; Dao et al., 2021; Pastushenkov et al., 2021). For example, Dao et al. (2021) found that in second language learning, compared to the unfamiliar dyad condition, those in the familiar dyad condition showed a higher engagement with the material (e.g., taking part in more task-related generative learning activities, increased attention), which positively predicted the students' subsequent learning performance. This suggests that, unlike unfamiliar peers, familiar peers will facilitate the quality of students' learning process (in task-related contexts), as well as their learning performance (Dao et al., 2021; Pastushenkov et al., 2021).

Meanwhile, unfamiliar peers appear to have a negative effect on students' learning. For instance, students feel less comfortable in the presence of strangers than friends, creating an unfavorable generative learning environment (Cao & Philp, 2006). Other studies on group learning have also shown that the presence of unfamiliar peers inhibits students' learning performance (i.e., retention and transfer; Cholewka, 1997; Poteau, 2011). Furthermore, some psychological studies have shown that individuals' attention allocation to the faces of others varies according to the familiarity of the face (Gobbini et al., 2013; Jackson & Raymond, 2006). Jackson and Raymond (2006) found that, compared to familiar faces, unfamiliar faces attracted more attention to get awareness. Therefore, it is reasonable to assume that peer familiarity influence students' learning processes and performance in the context of viewing synchronized video lectures with peer presence. Learning processes in the context of peer presence include how students operate video lectures, generate, and pay attention to video lectures and the peer (Pi et al., 2022a).

The present study

Despite the increased use of video lectures and the ubiquity of the phenomenon of peer presence during learning, little research has explored the impact of peer presence on students' learning performance, nor its effect on students' learning processes (i.e., attention, behavior patterns). There are also few studies examining whether the familiarity of a peer (i.e., familiar vs. unfamiliar) will impact learning from video lectures. Thus, the current study aimed to test the effects of peer presence and peer familiarity on student learning from video lectures.

Social presence theory (Jouravlev et al., 2018; Lachner et al., 2021) suggests that students peer presence may motivate students to invest more attention on video lectures than when they view the video lectures independently. In contrast, the cognitive theory of multimedia learning (Mayer, 2005) suggests that peer presence can impair students' learning performance due to the extra working memory load imposed by the students' need to distribute their attention between the lecture material and their peer before mentally processing and integrating their awareness of both into a single experience. In other words, when paired with a peer, students could be motivated by the peer presence to invest more mental effort into learning, however they may also split their attention between their peer and the video lecture simultaneously, leading to the two information sources creating an overload, causing the student to perceive the learning experience as being more difficult than it would be without the peer presence. The positive or negative effect of peer presence on learning performance may thus depend on whether the social benefits outweigh the cognitive losses involved when learning from video lectures.

The present study examined the impact of peer presence (i.e., learning alone vs. learning alongside a peer) and peer familiarity (i.e., familiar vs. unfamiliar) on students' motivation, behavioral patterns, attention, and learning performance (i.e., retention and transfer). There were three conditions: individual-learning, paired-learning with an unfamiliar peer, and paired-learning with a familiar peer. In the individual-learning condition, the student was alone while viewing the video lecture and engaging in generative learning activities. In the two paired-learning conditions, the student viewed the video lecture and engaged in generative learning activities together with a peer, who participated and engaged with the student through an on-screen video chat window; the peer was either a stranger to the student, or someone the student was already familiar with. Participants' eye movements and log data were recorded as they watched the video lecture, and their learning performance was measured after they had finished viewing the video lecture.

Social presence theory and the cognitive theory of multimedia learning both informed our hypotheses regarding the effects of peer presence on learning (Jouravlev et al., 2018; Lachner et al., 2021; Mayer, 2005; Skuballa et al., 2019). Specifically, we hypothesized that a familiar peer would trigger a higher level of motivation and a higher cognitive load in students than an unfamiliar peer, while both level of motivation and cognitive would be lowest in the individual-learning condition.

Empirical evidence related to group learning was also used to inform our hypotheses about the effects of peer familiarity (Cao & Philp, 2006; Pastushenkov et al., 2021). Specifically, studies have documented the positive impact that pairing students with someone familiar has on learning, compared to when the student is paired with an unfamiliar peer (Cao & Philp, 2006; Pastushenkov et al., 2021; Poteau, 2011)—although at the current time no study has explored this effect on learning from video lectures. Based on existing relevant results, however, we expected that a familiar peer presence would enhance students' motivation, self-monitoring behaviors, attention, cognitive load, and learning performance compared to those of the students in the individual-learning and paired-with-an-unfamiliar-peer-learning conditions. Our hypotheses were thus as follows:

Motivation hypothesis (H1): Students paired with a familiar peer while learning from a video lecture will report the highest level of motivation, followed by those paired with an unfamiliar peer, and finally by those learning individually.

Behavioral pattern hypothesis (H2): Students paired with a familiar peer while learning from a video lecture will show increased self-monitoring behaviors (as measured by log data in the video area; e.g., pause → go backward and go backward → type explanation), followed by those paired with an unfamiliar peer, and finally by those learning individual.

Attention hypothesis (H3): Students paired with a familiar peer while learning from a video lecture will pay greater attention to the video lecture and the explanation areas (as measured by percentage dwell time), followed by those paired learning with an unfamiliar peer, and finally by those learning individual. Additionally, students paired with an unfamiliar peer will pay greater attention to the peer area than those who are paired with a familiar peer.

Cognitive load hypothesis (H4): Students paired with an unfamiliar peer while learning from a video lecture will report a higher cognitive load (as measured by mental effort and perceived difficulty), followed by those paired with a familiar peer, and finally by those learning individual.

Learning performance hypothesis (H5): Students paired with a familiar peer while learning from a video lecture will demonstrate better learning performance (as measured by retention and transfer), followed by those paired with an unfamiliar peer, and finally by those learning individually.

Materials and method

Participants and study design

We randomly recruited 58 students unknown to the experimenter (i.e., the third author), who acted as their peers during the video lectures. An additional 29 participants who were classmates of the experimenter and familiar with each other, were also recruited for the study. All students were attending a Chinese university (74 female, 13 male). Their mean age was 22.46 years ($SD = 2.13$). To ensure a balanced study design, we strived to maintain a similar gender ratio across the three experimental groups. The resulting gender distribution did not show a significant difference between the groups, confirmed by a Pearson Chi-Square test value of 4.25 ($p = 0.119$). This result indicated that the gender distribution was equal among the three conditions. All participants were unfamiliar with the video lecture topic used in the study, which was by having each participant complete a knowledge pre-test which was administered at the very start of the experiment. After completing the experiment, each participant received 20 RMB for their participation. The current study procedures were approved by the ethics committee of the experimenter's university.

The experiment used a between-subjects design. There were three conditions. Participants who did not know the experimenter beforehand were assigned randomly into one of the following two conditions: (a) individual-learning ($n = 28$); (b) paired-learning with an unfamiliar peer ($n = 30$). The remaining participants, all of whom knew the experimenter before participating in this study, were all assigned to the paired-learning with a familiar peer condition ($n = 29$).

Learning system and video lecture

The online learning system used in this study was developed by the authors' research team, and consisted of a video lecture module, a peer module, and a generation module. The video lecture module was used to present the video lecture. The peer module was used to present the peer visually. The generation module allowed the students to type, send, and display messages to their peer (i.e., explanations). Figure 1 shows the interface of the online learning system. The video lecture used in the current study focused on infectious diseases and lasted 5:36 min. In the video lecture, a female instructor discussed infectious diseases in detail, covering five subtopics: definition, characteristics, pathogenesis, the epidemic process, and prevention.

Each participant watched the video independently. They could pause, advance/rewind, or restart the lecture as they wished. In the individual-learning condition, participants watched the lecture alone. After each subtopic, participants were required to pause the video lecture and engage with the topic through a generated explaining prompt. In the paired-learning with an unfamiliar peer condition, participants were also required to pause the video lecture after each subtopic, but instead of summarizing it for themselves, they were told to explain the subtopic to the unfamiliar peer. The paired-learning with a familiar peer condition followed the same procedure as for the unfamiliar peer, except that the participants explained the subtopic to a familiar peer.

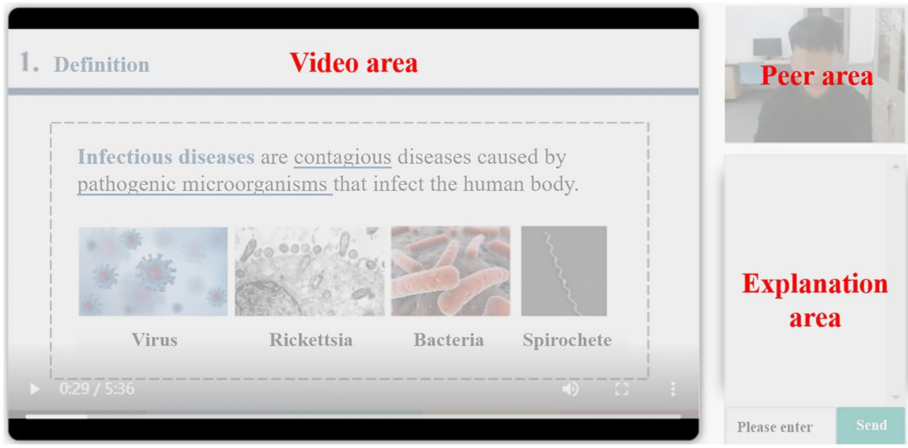

Fig. 1 Interface of the Learning System (translated from Chinese)

In the paired-learning conditions, the peer was visible in the peer area onscreen, played by the experimenter (i.e., the same peer for every participant), who was male and of a similar age as the participant. The peer kept his focus on the video lecture during the whole learning process. To manipulate the peer familiarity in the paired-learning with a familiar peer condition, we recruited 29 participants who already knew the experimenter (fellow-participant) to view the lecture concurrently, though both participants were seated in separate rooms.

Measurements

Inclusion of other in the self scale (IOS)

The Inclusion of other in the self scale (IOS), developed by Aron et al. (1992), comprises one item which measures respondents' degree of familiarity between themselves and a peer. It is rated using a seven-point scale ranging from 1 ("Not familiar at all") to 7 ("Very familiar"). The IOS scale uses seven pairs of circles, one labelled "self" and the other labelled "peer", whose overlap varies from none to almost all. Higher IOS scores reflect a more familiar relationship between individuals (Aron et al., 1997; Myers & Hodges, 2012). The scale has been used widely in interpersonal closeness studies to measure the closeness of relationships (Baber, 2021; Herrera et al., 2018; Taillon et al., 2020).

Prior knowledge test

The prior knowledge test was developed by the instructor presenting the video lecture, which was used to evaluate participants' general knowledge related to infectious diseases. The test had one open-answer item: "How can we prevent infectious diseases?" Two trained raters assessed each response for its reference to and correct usage of the six possible idea units. The final score was measured by tallying up the number of main idea units referenced, with each idea unit valued at one point. The highest possible score on the prior knowledge test was six points (Cronbach's $\alpha = 0.82$), and the two trained raters showed excellent inter-rater agreement in scoring the open-answer items ($r = 0.96$, $p < 0.001$).

Motivation questionnaire

Motivation was measured using the motivation dimension from the Learning Experience Questionnaire (Stull et al., 2018), and has been used widely in studies on video lectures to measure students' motivation to learn (Pi et al., 2021, 2023). The scale consists of six subjective items: (1) "I enjoyed learning in this way." (2) "I would like to learn this way in the future." (3) "I feel like I have a good understanding of the material." (4) "After this lesson, I would be interested in learning more about the material." (5) "I found the lesson to be useful to me." (6) "I felt motivated to try to understand the material." Participants used a seven-point scale to rate their level of motivation from 1 ("Strongly disagree") to 7 ("Strongly agree"). The motivation score was the total sum of the six items. The questionnaire had high internal consistency in the current study (Cronbach's $\alpha = 0.90$).

Cognitive load questionnaire

Cognitive load was measured using two items that were each rated on a Likert scale ranging from 1 to 9: (a) "How much mental effort have you spent in the learning just now?" (b) "How difficult did you find the material just now?" (Deleeuw & Mayer, 2008; Paas & Van Merriënboer, 1994). While mental effort focuses on the amount of cognitive resources utilized during a task, perceived difficulty reflects students' perception of task difficulty, which can be influenced by their level of motivation. Combining mental effort with perceived difficulty can provide a more comprehensive understanding of cognitive load in various learning situations. This scale has been widely used to measure students' cognitive load in video lectures (Hong, Pi, & Yang, 2018; Sweller et al., 2019). We used the sum of the two item ratings as the cognitive load scores (Cronbach's $\alpha = 0.38$).

Retention test

The retention test was developed to test how much the students remembered the learning topic taught in the video in the current study. It consisted of five fill-in-the-blank items (e.g., "Whether a pathogen can cause disease after invading the human body depends on the following two factors: ______ and ______"). Each blank was worth one point, with a total possible test score of eight points (Cronbach's $\alpha = 0.60$).

Transfer test

The transfer test consisted of one open-answer item in which participants were asked to apply what they had learned in the video lecture to a new situation. The specific question asked was, "What are the characteristics of COVID-19 transmission? According to the epidemic characteristics of infectious diseases, how can we effectively control and prevent COVID-19?" Participants' answers were assessed by two trained raters. The test was scored by tallying up the number of main idea units correctly addressed by the participant, with each idea unit valued at one point, and a total possible score of nine (Cronbach's $\alpha = 0.78$). The two trained raters showed excellent inter-rater agreement in scoring ($r = 0.98$, $p < 0.001$).

Coding scheme

A coding scheme was developed to document the study participants' clickstream, and tracked the following six behaviors: Play (Pl), Pause (Pa), Go forward (GF), Go backward (GB), Type explanation (TE), and Send explanation (SE), see Table 1 (Li, 2019; Pi et al., 2022a; Sinha et al., 2014). To ensure the validity of the coding scheme, two professors proficient in video learning behavior analysis were asked to verify the feasibility of the coding scheme. Two trained coders worked separately to code all behaviors, and showed high inter-rater consistency (*Kappa* > 0.99 based on 20% of the data).

Lag sequential analysis (LSA)

To examine the statistical significance of certain behavioral patterns in each condition group, we recorded participants' learning behaviors as they viewed the video lecture using screen capture. We coded their learning behaviors in a timeline format, an example of which could be: "Pl → Pa, Pa → TE, TE → GF". We then performed lag sequential analysis (LSA) using GSEQ 5.1 to identify the behavioral patterns across the different conditions (Bakeman & Gottman, 1997). The LSA was done in three steps. First, the coded behavior sequences of each group were imported into GSEQ 5.1 and saved as a separate document. Second, the frequency of each behavior was compiled, along with the adjusted residual results of the transitions between the various behaviors. Third, behavior transition diagrams were created visually for each sequence that reached statistical significance.

Apparatus and eye movement data analysis

Eye tracking was done using a Tobii T120 eye tracker, which allows for participants' eye movements (e.g., fixation) to be recorded in real-time. Participants sat in front of a 17-inch monitor at a distance of about 60 cm, and a nine-point calibration and validation procedure was performed before the participant began watching the video lecture. The three areas tracked corresponding to the three areas of interest (AOIs; see Fig. 1) were created: (a) video lecture area; (b) generation area; (c) peer area. The eye-tracking device provided data on the participant's dwell time on each AOI, that is, the time spent the participant spent watching each specific AOI, which can be used to indicate how much visual attention the viewer pays to each specific area on the screen (van Wermeskerken et al., 2018; Pi et al., 2022a, 2022b; Yang et al., 2021). Due to differences between the participants in total time spent learning, we calculated the percentage of dwell time on each AOI rather than using the total dwell times. The percentage of dwell time was calculated

Table 1 Log data coding scheme

Code	Behavior	Description
Pl	Play	Clicked the video area to play the video
Pa	Pause	Clicked the video area to pause the video
GF	Go forward	Clicked the progress bar to jump to a later time point
GB	Go backward	Clicked the progress bar to jump to a previous time point
TE	Type explanation	Clicked on the text box to type an explanation
SE	Send explanation	Clicked on the send button to send an explanation

by dividing the total dwell time a participant spent on a particular AOI by the total fixation duration for watching the entire video lecture (Pi et al., 2019, 2020).

Procedure

The entire experiment procedure lasted approximately 40 min (see Fig. 2). The experimental procedure consisted of three phases. (1) In the pre-learning phase, the experimental procedure was explained to the participants and they signed the informed consent form, after which they completed the IOS and the prior knowledge test. (2) In the learning phase, depending on their IOS score in the first step, participants were assigned randomly into one of the three different conditions. While learning from the video lecture, participants' eye movements and click behaviors were recorded synchronously. (3) In the post-test phase, the participants completed the cognitive load questionnaire, the retention test, and the transfer test.

Results

The descriptive results, including means and standard deviations, are reported for all variables in Table 2. ANCOVAs or ranked ANCOVAs tests were used to compare the three groups with the prior knowledge as the covariance. One-way ANCOVA was used with the dependent variables that met the normality assumption, while the ranked ANCOVA was used as a nonparametric test of ANCOVA when the variables did not meet the normality assumption (Cangür et al., 2018) based on the skewness and kurtosis (>1.00): Percentage dwell time on video lecture area, generation area, and peer area.

Manipulation check, prior knowledge and learning time

To check the manipulation of peer familiarity, we conducted an independent-samples *t*-test. The results showed that those in the paired-learning with a familiar peer condition reported significantly higher IOS results than those in the paired-learning with an unfamiliar peer condition: $t(57) = -10.10$, $p < 0.001$, $d = 0.80$. Therefore, the manipulation of peer familiarity was effective.

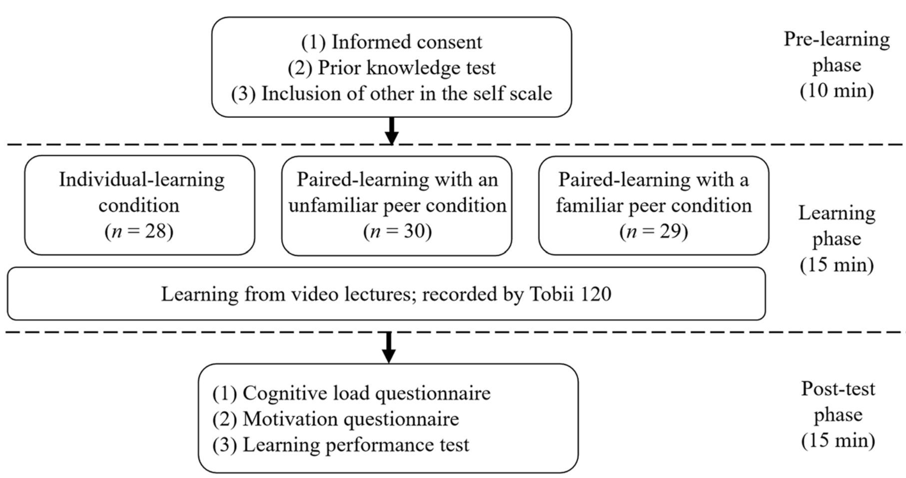

Fig. 2 Experimental procedure

Table 2 Means (M) and Standard Deviations (SD) for all variables, possible range noted in brackets

Variable	Individual-learning condition (*n* = 28)		Unfamiliar peer condition (*n* = 30)		Familiar peer condition (*n* = 29)	
	M	*SD*	*M*	*SD*	*M*	*SD*
IOS (1, 7)	/	/	1.17	0.38	4.00	1.49
Prior knowledge (0, 6)	1.66	0.69	1.42	0.68	1.43	0.78
Learning time (s)	623.61	99.185	603.73	93.52	572.76	88.66
Motivation (7, 42)	27.04	6.95	26.37	6.34	31.31	4.57
Percentage dwell time (%)						
Video lecture area	88.23	6.21	87.28	6.63	88.42	6.21
Generation area	11.77	6.21	11.26	6.48	10.33	5.91
Peer area	/	/	1.46	1.30	1.25	1.18
Cognitive load (2, 18)	12.57	1.64	11.90	2.80	12.93	2.09
Learning outcomes						
Retention (0, 8)	4.03	2.10	4.00	2.08	5.28	1.41
Transfer (0, 9)	4.75	2.04	5.50	1.79	5.69	1.42

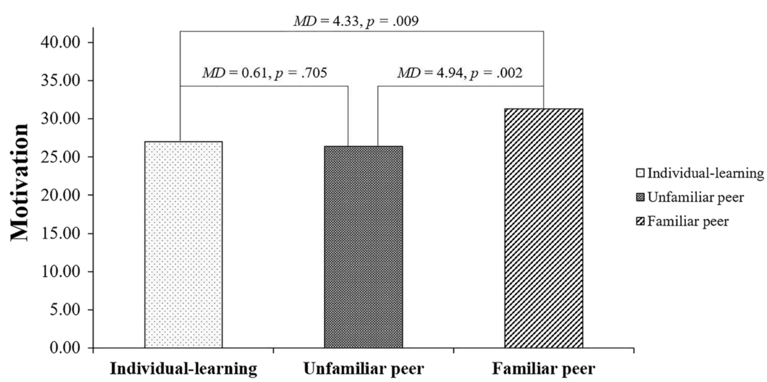

Fig. 3 Differences in motivation across the three conditions 3.3. behavioral patterns

We then checked whether there was a difference in prior knowledge. No significant difference was found among the three conditions: $F(2, 84) = 1.03$, $p = 0.360$, $\eta^2 = 0.02$. This result suggested that we could exclude the effects of learners' prior knowledge on learning performance. Similarly for the learning time, no significant difference was found among the three conditions: $F(2, 84) = 2.13$, $p = 0.125$, $\eta^2 = 0.05$. This result suggested that we could exclude the effects of learning time on learning performance.

Motivation

We found significant differences in motivation scores across the three conditions: F (2, 83) = 5.73, $p = 0.005$, $\eta_p^2 = 0.12$. The statistical power (1-β) for this effect was 0.82. Partially consistent with our motivation hypothesis (H1), the post hoc tests (LSD) revealed that participants in the paired-learning with a familiar peer condition reported significantly higher motivation than those in the paired-learning with an unfamiliar peer and the individual-learning conditions (see Fig. 3).

To test the behavioral pattern hypothesis (H2), we conducted LSAs of the log data for each condition. Appendix Tables 3, 4, 5 show the results of the frequency transition across the three conditions. Appendix Tables 6, 7, 8 show the adjusted residual results of the sequential analysis, with a *Z*-score > 1.96 indicating that the behavior path was significant. We found six significant behavioral sequences in the individual-learning condition (i.e., Pl → Pa, Pa → TE, TE → SE, SE → Pl, GB → GB, and GF → GF). The paired-learning with an unfamiliar peer condition had six significant behavioral sequences (i.e., Pl → Pa, Pa → TE, TE → SE, SE → Pl, GB → GB, and GF → GF). Finally, eight significant behavioral sequences were seen in the paired-learning with a familiar peer condition (i.e., Pl → Pa, Pa → TE, TE → SE, SE → Pl, GB → GB, GF → GF, GB → GF, and GF → GB). Diagrams representing the sequences found in each condition are showing in Fig. 4.

As shown in the behavioral transition diagrams, some common transitions were identified across all three conditions, specifically, Pl → Pa, Pa → TE, TE → SE, and SE → Pl. All indicated that participants in all three conditions were fully engaged in the explanation part of the experiment. As partially H2 expected, we also identified the distinctive transitions of GB → GB and GF → GF in the paired-learning with a familiar peer condition. These transitions indicated that participants quickly reviewed and scanned the video lecture. These results suggested that students might have been looking for specific pieces of information to compensate for missing learned information, which is related to self-monitoring.

Attention

Inconsistent with our attention hypothesis (H3), we did not observe any significant differences in percentage dwell time on the video lecture or generation areas across the three conditions: $F(2, 83) = 0.22$, $p = 0.803$, $\eta_p^2 = 0.01$; $F(2, 83) = 0.19$, $p = 0.826$, $\eta_p^2 = 0.01$. In addition, we did not find any significant differences in percentage dwell time on the peer area between the paired-learning with an unfamiliar peer condition and the paired-learning with a familiar peer condition: $F(1, 56) = 1.15$, $p = 0.388$, $\eta_p^2 = 0.02$. These results suggest that peer presence did not affect participants' attention to the video lecture, generation, or peer areas.

Cognitive load

Inconsistent with our cognitive load hypothesis (H4), we did not observe significant differences in reported cognitive load across the three conditions: $F(2, 83) = 1.57$, $p = 0.214$, $\eta_p^2 = 0.04$. These results suggest that peer presence did not increase participants' cognitive load during learning from the video lecture.

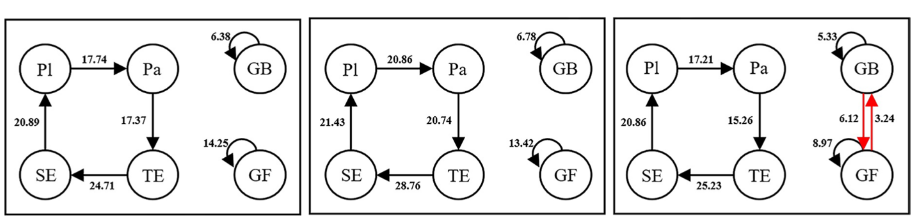

Fig. 4 Behavior transition diagrams for each of the three conditions

Learning performance

Concerning retention, we found significant differences between the three conditions: $F(2, 83) = 4.91$, $p = 0.010$, $\eta_p^2 = 0.11$. The statistical power (1-β) for this effect was 0.70. Furthermore, the post hoc tests revealed that participants in the paired-learning with a familiar peer condition showed significantly better retention than participants in the paired-learning with an unfamiliar peer and the individual-learning conditions. Significant differences in retention were not evident between participants in the paired-learning with an unfamiliar peer and the individual-learning conditions. Concerning transfer, we also observed significant difference across the three conditions: $F(2, 83) = 3.11$, $p = 0.049$, $\eta_p^2 = 0.07$. The statistical power (1-β) for this effect was 0.44. The post hoc tests showed that participants in the paired-learning conditions gained significantly better transfer than those in the individual-learning condition (see Fig. 5). No significant difference was seen between the two paired-learning conditions.

To summarize, the analysis results on retention and transfer partially supported our learning performance hypothesis (H5), showing that paired-learning with a familiar peer enhanced both retention and transfer, while paired-learning with an unfamiliar peer enhanced transfer only.

Discussion

Empirical contributions

This study examined the effects of peer presence and peer familiarity on learning from video lectures with consideration of students' motivation, behavioral patterns, attention, cognitive load, and learning performance (i.e., retention and transfer). The results confirm the benefits of peer presence, and particularly the benefit of learning with a familiar peer, on students' motivation, self-monitoring behaviors, and learning performance. This study contributes in several ways to the wider understanding of the effects of peer presence on learning from video lectures from both social and cognitive perspectives.

First, the current study used LSA and eye-tracking technology to examine the effects of peer presence during video lectures on students' learning performance. LSA found that students paired with a familiar peer demonstrated more self-monitoring behavioral transitions (i.e., GB → GB and GF → GF) than those paired with an unfamiliar peer or learning alone. These enhanced self-monitoring behaviors might provide a possible explanation for the superior role of a familiar peer as compared to an unfamiliar peer.

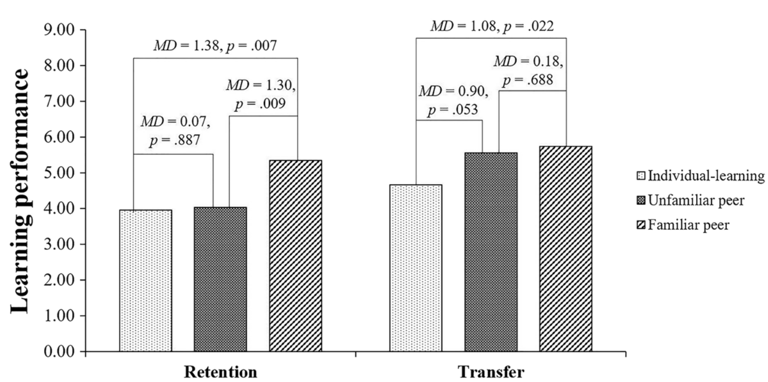

Fig. 5 Differences in learning performance across the three conditions

These results were consistent with existing studies on peer familiarity (Dao et al., 2021; Pastushenkov et al., 2021), which have shown that learning with a familiar peer increases students' engagement, as evidenced by increased task-related generative activities, attention, and thinking. The significant transitions of GB → GB and GF → GF suggest that students were more engaged in recognizing what information they had missed after generating their explanations and inferences. To be aware of this, the students needed to be able to relate the newly-learned information to their prior knowledge, and to identify and correct the information received (Chi, 2000).

The eye movement results showed no significant differences in students' percentage dwell time on the video lecture area between the individual-learning and paired-learning conditions. Furthermore, students' percentage dwell time on the peer did not differ significantly between the unfamiliar and familiar peer conditions. These results are not consistent with those of Samudra et al. (2020), nor of Jackson and Raymond (2006). Samudra et al. (2020) found that students in the peer presence condition paid greater attention to the video than those in the no peer presence condition. Meanwhile, Jackson and Roymond (2006) found that, compared to familiar faces, unfamiliar faces attracted more attention. These results in current study suggest that although students paid some attention to their peer regardless of their familiarity, this did not decrease the attention they paid to the video lecture. Pi et al. (2022a) showed that a peer without praise cues (e.g., nodding their head or smiling) attracted students' attention to the peer area more than to the video lecture or generation area. Thus, one possible explanation for the contrasting results in the current study could be due to the fact that peer presence in our study was unaccompanied by numerous non-verbal cues, and was therefore not a strong enough distraction to draw students' attention away from the video lecture.

The current study results also showed no significant difference in the reported cognitive load by students across all three conditions. Nevertheless, the null results on attention to the video and cognitive load may explain why the students paired with an unfamiliar peer demonstrated better transfer than those learning alone. According to social presence theory (Jouravlev et al., 2018; Lachner et al., 2021), peer presence does have social benefits. We found that students paired with a familiar peer reported higher motivation than those learning alone. More importantly, peer presence did not lead to cognitive loss in the present study. The eye movement evidence in the current study also extends the findings of previous studies which have focused on interaction behaviors (Basterrechea & Gallardo-del-Puerto, 2020; Dao et al., 2021; Mozaffari, 2017) by providing information about the attentional processes involved in learning from video lectures with peer presence.

Finally, previous studies on video lectures do not have consistent conclusions regarding the effects of peer presence, in that some studies have shown benefits to peer presence on learning (Craig et al., 2009; Lytle et al., 2018; Zhu et al., 2015), while others have shown no effect (Samudra et al., 2019, 2020). Studies on group learning, meanwhile, have shown that peer familiarity influences students' learning processes and performance (Dao et al., 2021; Pastushenkov et al., 2021). The present study compared individual-learning with paired-learning with either an unfamiliar or a familiar peer. We found that peer presence (both familiar or unfamiliar) enhanced students' transfer, and a familiar peer also enhanced their retention. These results provide support for the benefits of peer presence from both social and cognitive perspectives. Researchers have argued that peer presence motivates students and primes their evaluation and self-monitoring behaviors, thereby enhancing their learning performance (Figueira & Garcia-Marques, 2019; Lytle et al., 2018; Roscoe, 2014; Tricoche et al., 2021). Furthermore, the results of the present study are consistent with those of studies on group learning which have shown that a familiar peer presence is superior to an unfamiliar peer presence in enhancing learning (Cao & Philp, 2006; Dao et al., 2021; Pastushenkov et al., 2021).

Theoretical contributions

The current study extends the findings of prior research by showing the peer benefits on learning from video lectures. Although the relevant theories do explain the role of peer presence in learning from video lectures, few studies have addressed this directly with consideration of social and cognitive perspectives (Byun et al., 2020; Lytle et al., 2018; Pi et al., 2022a, 2022b). The current findings thus advance our understanding of the underlying mechanism of the effects of peer presence on learning in a video lecture context by analyzing the motivation and learning behavior patterns of students. Although the current study may not provide groundbreaking theoretical advancements, it does contribute to the ongoing discussion in the field by providing new empirical evidence regarding peer presence and peer familiarity, as well as by shedding light on potential areas for further research and development in both theory and practice.

According to social presence theory (Jouravlev et al., 2018; Lachner et al., 2021), peer presence does have some social benefits, and students may be motivated by their peer to increase their awareness in terms of evaluation and self-monitoring. In line with social presence theory, we found that students paired with a familiar peer reported higher motivation and exhibited more self-monitoring behavioral transitions. These results suggest that learning with a familiar peer has numerous social benefits on learning.

Meanwhile, according to the cognitive theory of multimedia learning (Mayer, 2005), when learning with a peer, students must divide their attention between the video lecture and their peer, which may result in cognitive overload (Skuballa et al., 2019). This could depend upon how strongly a peer attracts the students' attention, however, as a recent study by Pi et al. (2022a) found that, compared to the peer without praise cues condition, the peer with praise cues condition did attract students' attention more to the peer area, increasing their cognitive load as indicated by mental effort. In the current study, however, our findings showed that although the students did fixate some time on their peer, they reported only a moderate cognitive load (roughly 66%).

Limitations and future directions

There are three limitations to the current study that should be considered. First, the reliabilities of the cognitive load questionnaire and the retention test were low in the current study. The cognitive load scale measured two items, students' mental effort and their perception of task difficulty. Previous studies have shown that these two items are related, but sensitive to different types of cognitive load (DeLeeuw & Mayer, 2008; Vandewaetere & Clarebout, 2013). Specifically, the mental effort rating is most sensitive to changes in intrinsic load, while the difficulty rating is most sensitive to changes in germane load (DeLeeuw & Mayer, 2008; Haji et al., 2015). However, it's important to note that the triarchic theory of cognitive load, distinguishing between intrinsic, extraneous, and germane cognitive load, and measures of these three types of cognitive load are still contentious within the field. Consequently, interpretations based on these constructs should be made with caution. In the current study, the students in the paired-learning conditions had to process the video lecture as well as the presence of the peer while learning. The peer introduced a change to the students' learning situation, even if task difficulty and germane processing remained the same. Therefore, the extraneous process of the peer presence is likely to have increased the students' extraneous load rather than their intrinsic and germane loads. This might explain why we did not find a significant difference in cognitive load between the conditions. Further research is encouraged to adopt a cognitive load questionnaire which can measure different kinds of cognitive load (i.e., intrinsic, extraneous, and germane cognitive load). Furthermore, regarding the low reliability of the retention test, each item tested one subtopic of the video lecture (i.e., definition, characteristics, pathogenesis, epidemic process, and prevention). Future studies should attempt to test the effects of peer presence on students' extraneous load.

In addition, one of the unforeseen yet prevalent challenges in the educational sector during the COVID-19 pandemic was that students frequently opted not to activate their cameras during online sessions. The presence or absence of visual images can significantly alter the dynamics of virtual interactions and could conceivably impact the cognitive load (Lauricella et al., 2022). The peer presence in our study was assumed to be perceived uniformly by all students; however, variations in camera usage could potentially introduce additional variability in perceived peer presence. Therefore, future research should consider the effects of camera usage on cognitive load and the overall learning experience in a remote learning context.

Second, the sample size in the present study was relatively small as choosing a familiar or unfamiliar peer can be difficult in real-world settings. Although the statistical power is still acceptable, the small sample size does limit the generalizability of our research findings. Increasing the sample size in future studies would likely strengthen the reliability and generalizability of findings. Nevertheless, our study provides valuable preliminary insight into the effect of peer presence on learning from video lectures. Therefore, future research should examine the effects of peer presence on learning from video lectures by using a larger sample to allow for further generalization of the main findings of the present study.

Third, collaborative learning is complex, and is influenced not only peer presence, but also by peer interaction, such as idea sharing, peer assessment, and uptake (Nokes-Malach et al., 2015; Pi et al., 2022b; Zhang et al. 2021a, 2021b). The current study focused only on peer presence without taking peer interaction into account, which might also limit the generalization of the findings. Moreover, the fact that the peer in the study was a graduate student but also a research team member (being aware of the study's objectives) could potentially introduce a bias. Although the 'peer' had no authoritative or influential role over the other participants, their dual role might have subtly influenced the dynamics of the paired-learning conditions. Therefore, further research should examine how students collaborate and interact with a naïve peer who does not know the research purpose when learning from video lectures to minimize potential biases. The effects of peer dynamics, such as power relationships and perceived peer expertise, should also be scrutinized, as these could potentially impact learning (Storch, 2002).

Practical implications

One of the significant findings of the current study is the recognition of the positive effects of peer presence, especially a familiar peer, when learning from video lectures. These findings contribute to our understanding of learning processes and performance associated with the social environment, enabling us to identify optimal potential strategies for enhancing learning from video lectures. By building upon the existing literature and exploring the role of familiarity in peer presence when learning from video lectures, this study offers valuable insight for educators and researchers seeking to optimize learning processes and performance across various educational settings. The findings of this study demonstrates that learning with a peer, regardless of their familiarity, enhances students' learning motivation. Therefore, if students experience a lack of motivation when learning from video lectures, they should be encouraged to learn with a peer, whether they are familiar or not. Second, the findings of the present study also indicate that learning with a familiar peer increases students' self-monitoring behaviors (i.e., GB → GB and GF → GF). Consequently, if students are unaccustomed to self-monitoring while learning from video lectures, they should be encouraged to learn alongside a familiar peer. Third, the current study shows that learning alongside a familiar peer enhances students' retention. Therefore, if students are required to memorize information conveyed through video lectures, they should be encouraged to learn alongside a familiar peer. Finally, the current study does identify advantages of learning with a peer, regardless of their familiarity, on students' transfer. Therefore, if students are required to transfer knowledge learned via video lectures to novel situations, they should be encouraged to learn alongside an unfamiliar or familiar peer.

Appendix

See Tables 3, 4, 5, 6, 7, 8.

Table 3 Results of frequency transition in the individual-learning condition

N	Pa	Pl	GF	GB	TE	SE
Pa	0	37	6	24	128	0
Pl	131	0	15	21	29	2
GF	13	7	47	15	7	1
GB	27	19	14	40	26	0
TE	20	7	1	27	0	140
SE	4	117	9	1	5	0

Pa: Pause; Pl: Play; GF: Go forward; GB: Go backward; TE: Type explanation; SE: Send explanation. Each row represents an initial behavior and each column represents a follow-up behavior. For example, the frequency of Pl → Pa in the individual learning condition is 131

Table 4 Results of frequency transition in the paired-learning with an unfamiliar peer condition

N	Pa	Pl	GF	GB	TE	SE
Pa	0	18	3	23	138	0
Pl	139	1	19	23	4	0
GF	12	10	48	13	12	0
GB	25	17	15	29	9	0
TE	6	1	0	6	1	172
SE	1	133	11	1	22	0

Pa: Pause; Pl: Play; GF: Go forward; GB: Go backward; TE: Type explanation; SE: Send explanation

Table 5 Results of frequency transition in the paired-learning with a familiar peer condition

N	Pa	Pl	GF	GB	TE	SE
Pa	0	12	4	25	118	0
Pl	103	0	16	14	31	0
GF	12	1	29	20	18	0
GB	21	14	29	35	24	0
TE	22	5	1	28	8	179
SE	2	119	5	3	45	0

Pa: Pause; Pl: Play; GF: Go forward; GB: Go backward; TE: Type explanation; SE: Send explanation

Table 6 Results of sequential analysis of log data in the individual-learning condition

Z-score	Pa	Pl	GF	GB	TE	SE
Pa	− 8.02	− 0.36	− 3.54	− 0.60	**17.37**	− 6.64
Pl	**17.74**	− 7.89	− 1.18	− 1.39	− 2.38	− 6.26
GF	− 1.55	− 3.03	**14.25**	0.89	− 3.19	− 3.92
GB	0.20	− 1.45	0.54	**6.38**	− 0.03	− 5.11
TE	− 4.06	− 6.41	− 4.90	0.10	− 8.02	**24.71**
SE	− 5.54	**20.89**	− 1.35	− 4.74	− 5.31	− 5.34

Pa: Pause; Pl: Play; GF: Go forward; GB: Go backward; TE: Type explanation; SE: Send explanation. Values in bold indicate that the behavior path is significant ($p < 0.05$)

Table 7 Results of sequential analysis of log data in the paired-learning with an unfamiliar peer condition

Z-score	Pa	Pl	GF	GB	TE	SE
Pa	− 7.55	− 3.73	− 4.36	1.10	**20.74**	− 7.27
Pl	**20.86**	− 7.37	− 0.16	0.98	− 6.92	− 7.37
GF	− 1.91	− 2.38	**13.42**	1.10	− 1.98	− 4.96
GB	1.61	− 0.48	1.77	**6.78**	− 2.79	− 4.96
TE	− 6.43	− 7.37	− 5.24	− 3.60	− 7.53	**28.76**
SE	− 6.98	**21.43**	− 1.86	− 4.61	− 2.60	− 6.92

Pa: Pause; Pl: Play; GF: Go forward; GB: Go backward; TE: Type explanation; SE: Send explanation. Values in bold indicate that the behavior path is significant ($p < 0.05$)

Table 8 Results of sequential analysis of log data in the paired-learning with a familiar peer condition

Z-score	Pa	Pl	GF	GB	TE	SE
Pa	− 6.25	− 3.19	− 3.1	1.01	**15.26**	− 6.69
Pl	**17.21**	− 6.15	0.42	− 1.96	− 2.24	− 6.82
GF	− 0.49	− 3.76	**8.97**	**3.24**	− 0.72	− 4.53
GB	0.03	− 1.5	**6.12**	**5.33**	− 1.73	− 5.76
TE	− 3.81	− 6.88	− 5.4	− 0.92	− 9.33	**25.23**
SE	− 6.16	**20.86**	− 3.09	− 4.97	0	− 7.07

Pa: Pause; Pl: Play; GF: Go forward; GB: Go backward; TE: Type explanation; SE: Send explanation. Values in bold indicate that the behavior path is significant ($p < 0.05$)

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Author contributions
ZP: Conceptualization, Methodology, Writing - Original Draft and Revising; YZ: Software, Methodology, Writing - Original Draft and Revising; QY: Investigation, Data Curation, Visualization; JY: Conceptualization, Supervision, Funding acquisition.

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Availability of data and materials
The data used to support the findings of this study are available from the corresponding author upon request.

Declarations

Competing interests
There is no conflict of interest, as we conducted this study only as part of our research program.

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