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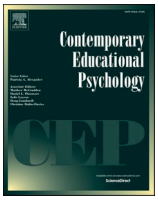

Does the emotional stance of human and virtual instructors in instructional videos affect learning processes and outcomes?

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ABSTRACT

This study investigates the *positivity principle* – the idea that people respond more positively and learn better from an instructor who displays positive emotion than from an instructor who displays negative emotion – and the *equivalence hypothesis* – the idea that learners respond similarly to the emotional tone displayed by both human and virtual instructors. In this between-subjects design experiment, participants viewed one of eight instructional videos on binomial probability, varying in the emotion portrayed by the voice and gestures of an onscreen instructor and varying in whether the instructor was human or virtual. Participants either saw a positive instructor (happy or content) or a negative instructor (bored or frustrated) and that instructor was either human or virtual. In support of the positivity principle, participants recognized the positive or negative emotional tone of the instructor, felt a similar emotion to the instructor, and had more favorable social connection ratings for positive instructors. However, the positivity of the instructor did not impact how well participants performed on a delayed posttest. In support of the equivalence hypotheses, all of these effects were found for both human and virtual instructors. Overall, this study provided support for three of the four links in the positivity principle, and showed that the principle applied to both human and virtual instructors as per the equivalence hypothesis.

1. Introduction

1.1. Objectives and rationale

Suppose an instructor has prepared a well-designed lesson consisting of clear slides along with a clear script. When the instructor goes into class to deliver this well-designed lesson, is there anything else she can do foster deep learning in her students? In the present study, we examine the idea that the emotional stance of the instructor during teaching can affect the way that students process the lesson and the quality of their learning outcomes. In particular, we examine the idea that students' learning processes and outcomes are improved when their instructor exhibits positive emotion in delivering a lecture, as reflected in positive emotional cues in the instructor's voice, gestures, facial expression, eye contact, and body movements. In short, we are interested in whether the emotional style of the instructor is an important ingredient in the teaching and learning.

Given the popularity of instructional video, we contextualize our study using instructional videos of an instructor–either a human or an animated character–standing next to a series of slides as she lectures. Instructional video has become a popular medium for delivering instruction, both in formal venues such as online, blended, or flipped classrooms and in informal venues such as Massive Open Online Courses (MOOCs), YouTube, or other online learning platforms (Fiorella, 2022). Although instructional films date back to the early 1900s, they had surprisingly little lasting impact on education during the 20th century (Cuban, 1986; Orgeron et al., 2012). In contrast, the 21st century has seen an increase in the popularity of instructional video, which may be attributed to advances in communication and video technology and the demands of remote learning (Kay, 2012; O'Callagan et al., 2017).

The goal of the present study is to examine techniques for improving the effectiveness of video lectures in which an instructor stands next to a series of slides as she lectures, such as exemplified in Fig. 1. Although researchers have discovered several evidence-based principles for how to design effective instructional video lectures (Fiorella, 2022; Mayer, 2021a; Mayer et al., 2020), there has been less research on how students respond to the emotional stance of human and virtual instructors (Horovitz & Mayer, 2021; Lawson et al., 2021a, 2021b, 2021c). Virtual instructors are onscreen animated, human-like agents, sometimes referred to as animated pedagogical agents (Johnson & Lester, 2016;

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Johnson et al., 2000; Lester et al., 1997; Schroeder et al., 2013; Wang et al., 2022).

In line with increasing interest in the role of emotion in academic learning (Pekrun & Linnenbrink-Garcia, 2012; Pekrun & Perry, 2014; Plass & Kaplan, 2016), we seek to expand the scope of inquiry to include the effects of human and virtual instructors' positive or negative emotional stance (Horovitz & Mayer, 2021; Lawson et al., 2021a, 2021b, 2021c). We draw on Russell's (1980, 2003) model of core affect, which distinguishes between positive and negative emotions as well as active and passive emotions. In our study we focus on an active positive emotion (e.g., happy) and a passive positive emotion (e.g., content) as the positive emotions displayed by our onscreen human and virtual instructors through voice and gesture, and we focus on an active negative emotion (e.g., frustrated) and a passive negative emotion (e.g., bored) as the negative emotions displayed by our human and virtual instructors.

In particular, we investigate two issues concerning the role of the instructor's emotional stance in instructional videos: (1) The *positivity principle* states that students respond more positively and learn better from instructors who display positive emotion (e.g. happiness or contentment) through their gesture and voice than from instructors who display negative emotion (e.g., boredom or frustration). (2) The *equivalence hypothesis* states that students respond to the emotional stance of human instructors and virtual instructors in the same way.

1.2. Literature review: the positivity principle

The positivity principle has been investigated by research on the effects of the instructor's emotional stance on students' affective and social processing during learning (based on self-report ratings) and learning outcomes (based on retention and transfer posttests). For example, Lawson et al. (2021b) asked students to view 16 short video clips from a statistics lecture in which an onscreen agent displayed positive emotion (e.g., happy or content) or negative emotion (e.g., frustrated or bored) through voice and gesture. Students rated the instructor as higher in positive emotion when they viewed a positive instructor than when they viewed a negative instructor, thereby demonstrating that people are sensitive to the emotional tone of virtual instructors. Using a similar methodology, Lawson et al. (2021a) found that people could perceive the positive or negative emotion displayed by both human and virtual instructors in short video clips.

Lawson et al. (2021b) asked students to view a short video lecture on statistics presented by an animated pedagogical agent who displayed positive or negative emotions as she lectures. Students who received a positive instructor gave higher ratings of the instructor's positive emotion and rated the instructor as better at facilitating learning, more credible, more human-like, and more engaging, but they did not perform better on a posttest than students who received a negative instructor. Lawson et al. (2021c) did the same experiment with a human instructor and found similar results for an immediate posttest but also found that students who received a positive instructor performed better on a delayed posttest than students who received a negative instructor. Horovitz and Mayer (2021) asked students to view the same video lecture with either a human or animated pedagogical agent who displayed either a positive or negative emotional stance based on voice and gesture. For both human and virtual instructors, students who received positive instructors gave higher ratings than students who received negative instructors on the instructor's positive emotion and their own experienced positive emotion, but they did not score higher on posttests given immediately after the lesson. The present study provides a broader and more comprehensive test of the positivity principle by comparing students who received positive and negative instructors on a delayed posttest (rather than an immediate test) and by using two types of positive emotion and two types of negative emotion (rather than one of each type).

The positivity principle focuses on the way students are influenced to feel because of the instructor. Some prior literature has demonstrated that emotions can negatively impact student learning as they add to the learner's extraneous load (Fraser et al., 2014; Knörzer et al., 2016; Plass & Kalyuga, 2019). Knörzer et al. (2016) found that when students were induced with positive emotions before the lesson, they performed worse on posttests than when the students were induced with negative emotions. The Knörzer et al. (2016) study differs from the focus of the present paper in the way the emotions are induced; our paper focuses on how an instructor's emotion displayed while teaching influences the students' emotion and learning whereas the focus of the Knörzer et al. (2016) study was on induced emotions unrelated to the content of the material.

1.3. Literature review: the equivalence hypothesis

The equivalence hypothesis posits that students respond to the instructor's emotional stance in the same way for human and virtual instructors, including how they perceive the instructor's emotion, how they experience emotion during learning, how they build rapport with the instructor, and how they perform on posttests. Thus, the equivalence hypothesis predicts the same pattern for both human and virtual instructors on each measure of affective and cognitive processing. Specifically, students who learn with positive instructors should have higher

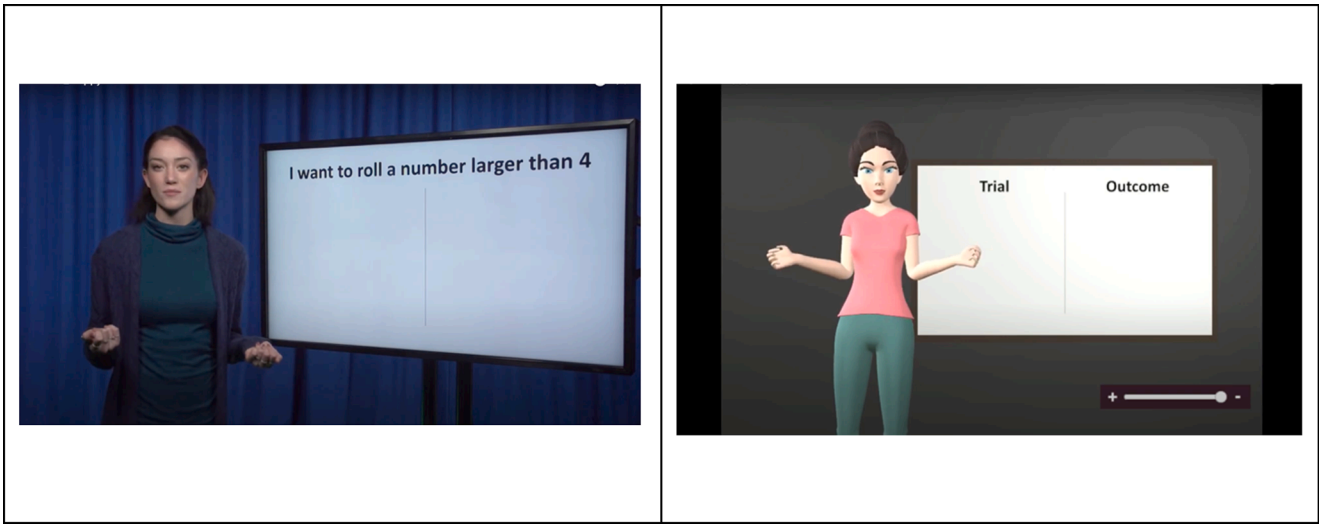

Fig. 1. Images of Human and Virtual Instructor.

scores than students who learn with negative instructors on ratings of perceived positive emotion, ratings of experienced positive emotion, ratings of rapport with the instructor, and posttest performance.

The equivalence hypothesis is based on Reeves and Nass's (1996) media equation theory, in which people treat computers like they are real people. The media equation theory is based on a diverse set of research findings such as people treat computers with female voices differently than computers with male voices, people treat large faces on the computer screen as more invasive of their personal space than small faces on the computer screen, and people are more polite to computers they have worked with previously. The overall conclusion is that people treat media not as machines but rather as social beings, and that social rules that apply to interactions with humans also apply to interactions with computers. The media equation has been updated with more recent work that supports the same conclusion but focuses on features such as voice (Nass & Brave, 2005; Nass & Yen, 2010).

The equivalence hypothesis is also grounded in the persona effect which holds that onscreen agents can display distinct personalities that people recognize and respond to (Baylor et al., 2003; Johnson & Lester, 2016; Johnson et al., 2000; Lester et al., 1997). The persona effect has been explored by research on animated pedagogical agents showing the conditions under which people build relationships with onscreen characters in the same way they would with actual humans (Castro-Alonso et al., 2021; Clarebout et al., 2002; Guo & Goh, 2015; Schroeder et al., 2013). Overall, research shows that gesture and voice are strong social cues that promote the persona effect (Mayer, 2021b; Wang et al., 2022). However, Horovitz and Mayer (2021) and Lawson et al. (2021a) reported that the persona effect was present for both human and virtual instructors, but for some measures the effect was stronger with human instructors than with virtual instructors. The present study examines the equivalence hypothesis in the context of learning from a video lecture with either a human or virtual instructor who displays either positive or negative emotion, in order to determine whether students respond to the emotion displayed by a human instructor in the same way they respond to the emotion displayed by a virtual instructor.

1.4. Theory and predictions

In the present study, students viewed a video lecture on a statistical concept in which the instructor was either a human or virtual agent who displayed either a positive emotion (i.e., happiness or contentment) or a negative emotion (i.e., boredom or frustration). After the lesson, students rated the level of positive emotion (i.e., happiness and contentment) and the level of negative emotion (e.g., boredom or frustration) displayed by the instructor; rated their own level of experienced positive and negative emotion; rated their social perception of the instructor; and took a delayed posttest on the lesson.

This study tests the positivity principle, which posits that students respond more positively and learn better from positive instructors than from negative instructors. The positivity principle is derived from the cognitive-affective model of e-learning (Lawson et al., 2021c, Mayer, 2020), as represented in modified form in Fig. 2. The first step is to present an instructional video in which the instructor displays positive emotion (e.g., happiness or contentment) or negative emotion (e.g., boredom or frustration) through gesture and/or voice. Next, the learner perceives the emotion displayed by the instructor (link 1), experiences the emotion displayed by the instructor (link 2), and builds a social connection with the instructor based on the instructor's emotional stance (link 3). Finally, the instructor's emotional stance influences the learner's efforts to build a learning outcome, which is reflected in posttest performance (link 4). This model yields the following predictions concerning main effects of the instructor's emotional stance (i.e., positive versus negative) that are tested in the present experiment.

Hypothesis 1a (Perceive positive emotion): Students who learn with positive instructors will rate their instructor higher in positive emotion than students who learn with negative instructors.
Hypothesis 1b (Perceive negative emotion): Students who learn with negative instructors will rate their instructor higher in negative emotion than students who learn with positive instructors.
Hypothesis 2a: (Feel positive emotion): Students who learn with positive instructors will rate their own experienced positive emotion higher than students who learn with negative instructors.
Hypothesis 2b: (Feel negative emotion): Students who learn with negative instructors will rate their own experienced negative emotion higher than students who learn with positive instructors.
Hypothesis 3: (Feel social connection): Students who learn with positive instructors will rate the instructor higher on positive social dimensions (such as being supportive, engaging, credible, and human-like) than students who learn with negative instructors.
Hypothesis 4: (Understand information): Students who learn with a positive instructor will score higher on a transfer posttest than students who learn with a negative instructor.

This study also tests the equivalence hypothesis, which posits that students react to the emotional stance of virtual instructors and human instructors in the same way. The equivalence hypothesis yields the following predictions concerning a lack of disordinal interaction between the instructor's emotion (i.e., positive vs. negative) and the instructor's format (i.e., human versus virtual).

Hypothesis 5a (Same pattern in perceiving positive emotion with human and virtual instructors): Hypothesis 1a holds for human and virtual instructors, with no disordinal interaction between instructor emotion and instructor format.
Hypothesis 5b: (Same pattern in perceiving negative emotion with human and virtual instructors): Hypothesis 1b holds for human and virtual instructors, with no disordinal interaction between instructor emotion and instructor format.
Hypothesis 6a: (Same pattern in experiencing positive emotion with human and virtual instructors): Hypothesis 2a holds for human and virtual instructors, with no disordinal interaction between instructor emotion and instructor format.
Hypothesis 6b: (Same pattern in experiencing negative emotion with human and virtual instructors): Hypothesis 2b holds for human and virtual instructors, with no disordinal interaction between instructor emotion and instructor format.
Hypothesis 7: (Same pattern in building social connection with human and virtual instructors): Hypothesis 3 holds for human and virtual instructors, with no disordinal interaction between instructor emotion and instructor format.
Hypothesis 8: (Same pattern on posttest score with human and virtual instructors): Hypothesis 4 holds for human and virtual instructors, with no disordinal interaction between instructor emotion and instructor format.

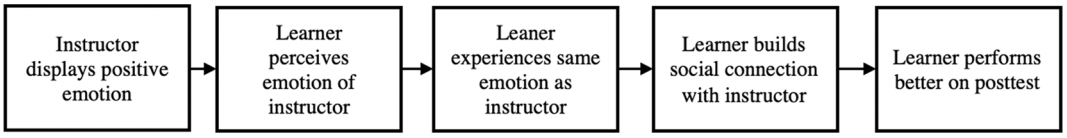

Fig. 2. Cognitive Affective Model of E-Learning.

2. Method

2.1. Participants and design

The participants were 167 students recruited from a paid psychology subject pool at a university in southern California, who participated in both sessions of a two-part experiment. Their mean age was 21.62 years ($SD = 3.60$); 99 were women, 65 were men, and 3 did not indicate their gender. The experiment used a 2 (instructor type: human or virtual) × 2 (valence of instructors' emotion: positive or negative) × 2 (activity of instructor's emotion: active or passive) between-subjects design. This created 8 groups: 16 participants saw a happy (i.e., positive and active) human instructor (link to video: https://youtu.be/zay6w1tSjQc), 24 participants saw a content (i.e., positive and passive) human instructor (link: https://youtu.be/grGdY-7ZmGg), 21 participants saw a frustrated (i.e., negative and active) human instructor (link: https://youtu.be/0Kph7ZWDOtk), 25 participants saw a bored (i.e., negative and passive) human instructor (link: https://youtu.be/bvkrCerByWI), 19 participants saw a happy virtual instructor (link: https://youtu.be/1M_IPXuvF0c), 20 participants saw a content virtual instructor (link: https://youtu.be/h2lGC55st_g), 21 participants saw a frustrated virtual instructor (link: https://youtu.be/J5DujABMQqs), and 21 participants saw a bored virtual instructor (link: https://youtu.be/T6Mp7BL4k_w). Participants received a $15 Amazon gift card for their participation.

2.2. Materials

The materials were all computer-based and presented on Qualtrics. The materials consisted of a prequestionnaire, 8 versions of an instructional video on binomial probability, a posttest consisting of 12 questions, and a postquestionnaire.

2.2.1. Prequestionnaire

The prequestionnaire collected demographic information from the participants, soliciting their age and gender. Additionally, it collected information on participants' prior knowledge of statistics by asking them to rate their knowledge of statistics on a 5-point scale ranging from "Very Low" to "Very High." Lastly, the prequestionnaire collected information on participants' prior and current math courses by providing a list of 6 math courses and asking participants to select which courses they had completed or were taking as well as indicating at what level they completed or were taking it (e.g., "high school" or "currently enrolled").

2.2.2. Video lessons

The instructional materials consisted of eight versions of a recorded video displaying a young woman instructor teaching about binomial probability while standing next to a series of slides. The lesson script was adapted from Mayer and Greeno (1972) and described how to solve binomial probability problems. The lesson lasted approximately 10 min, varying slightly depending on the emotional tone of the instructor. All versions of the lesson showed a young woman, either a human woman or a virtual woman, and all used the same script along with the same slides.

Of the 8 videos, 4 of the lessons were taught by a human instructor and 4 of the lessons were taught by a virtual instructor. The 4 versions of the lesson for both the human instructor and the virtual instructor varied in the emotion that was displayed: happy, content, frustrated, or bored. To create the human videos, a 21-year-old female actor from a university's Theater Department was recorded while delivering the lecture for each of the four different emotions. While reading the script from the teleprompter in front of the camera, she was directed by the experimenters to vary her gestures, facial expression, body stance, and voice according to the target emotion. While doing this, the experimenters monitored the tapings and asked for a retake when the script was not followed exactly or the emotional tone was not appropriate. The same human instructor videos were used in previous studies, which helped validate that the emotions the human instructor portrayed were accurate (Lawson et al., 2021a, 2021b).

Once the videos with the human instructor were recorded, they were turned into the videos with a virtual instructor, which also were used in previous studies (Lawson et al., 2021a, 2021b, 2021c). The virtual instructor resembled the human instructor, had the same voice, and exhibited some similar gestures, facial expressions, and body stances as the human instructor in the corresponding emotion video. The videos of the human instructor were turned into the videos with the virtual instructors through a custom Unity 3D platform, as described in Adamo et al. (2021). The agents are commercially available 3D character rigs whose joint structure was modified to be compatible with Unity's character animator feature. The gestures were motion captured and blended together. Facial deformations were produced using joint deformers and the agents' facial animations were manually keyframed.

2.2.3. Posttest

The posttest consisted of 12 items, each presented on a different page. These included questions requiring the participants to recall definitions ("What does N symbolize in the binomial probability equation?"), solve problems using formulas ("P = 1/2, N = 8, R = 5, What is C(N,R)?"), solve word problems ("One-tenth of the peanuts in a barrel are rotten. If you take five peanuts, what is the probability that the first four are good and the fifth one is rotten?"), and recognize impossible problems ("N = 5, R = 2, P = 3/2, What is $P^R \times (1\text{-}P)^{N-R}$?"). The posttest was shown one question at a time on Qualtrics, allowing participants to take as much time as they wanted per question. Participants could not go back to previous questions. Cronbach's alpha for the posttest was 0.69. A reason for the low internal consistency is that the test is assessing different levels of learning objectives (Anderson et al., 2001), including remembering (i.e., defining symbols), understanding (i.e., solving word problems), applying (i.e., solving formula problems), and evaluating (i.e., recognizing impossible situations).

2.2.4. Postquestionnaire

The postquestionnaire contained 36 items that assessed participants' experience with the lesson. The first 6 questions assessed how well participants could perceive the emotion displayed by the instructor in the video. The six items assessing perceived emotion were: "The instructor was happy." "The instructor was content." "The instructor was frustrated." "The instructor was bored." "The instructor was active." and "The instructor was pleasant." Each item was rated on a 5-point Likert scale, ranging from "Strongly Disagree" (which was scored as 1) to "Strongly Agree" (which was scored as 5). We did not use the data for "active" and "pleasant" ratings because the other four items were more specific.

The next 5 items assessed participants' cognitive and affective reaction to the video: "I was motivated to pay attention to the lesson I just watched." "The information in the lesson was difficult for me." "I put in a lot of effort to understand the information in the lesson." "I enjoyed learning about this information." and "I would like more lessons like this one." The same 5-point Likert scale was used for these questions as for the previous ones.

The next 20 items came from the Agent Persona Instrument (API; Baylor & Ryu, 2003), which consisted of four subscales assessing students' perceptions of how well the instructor facilitated learning ($n = 10$, $\alpha = 0.95$), the credibility of the instructor ($n = 3$, $\alpha = 0.82$), how human-like the instructor was ($n = 5$, $\alpha = 0.89$), and how engaging the instructor was ($n = 4$, $\alpha = 0.92$). Items were rated on a 5-point Likert scale ranging from "1-Strongly Disagree" to "5-Strongly Agree.".

The last 5 item assessed how the instructor made the participants feel. The first item was an open-ended question asking, "What emotion did you experience while watching the video?" After that, participants were asked to rate their felt emotion on a 5-point Likert scale for four items: "The instructor made me feel happy." "The instructor made me feel content." "The instructor made me feel frustrated." and "The

instructor made me feel bored.".

2.3. Procedure

Participants signed up for this two-part online study on the SONA platform through the paid psychology subject pool at a university in southern California. The study consisted of two sessions. In the first session, participants joined a Zoom call at their assigned experiment time and were instructed in how to complete the study. Once participants were given the instructions, the experimenter put each participant in their own individual breakout room to complete the study. They were sent a link for the study in Qualtrics. Once they opened the Qualtrics link, they were taken to the informed consent form, where they agreed to participate. After that, they were taken to the prequestionnaire page. After they filled out the prequestionnaire, participants were randomly assigned to one of the eight conditions and instructed to watch the corresponding video. They were required to stay on the video page for the length of the video. Once they finished the video, they were asked "Did you take notes?" and "Did everything work?" Once done with that, the participants were instructed to rejoin the main room of the Zoom call where the experimenter let them know they were done for the day and to come back the following week to complete the rest of the experiment.

A week later, the participants joined the Zoom call at their assigned experiment time and were instructed in how to complete the second part of the study. Once they were given the instructions, they were put into their own breakout rooms to complete the study. They were sent the link to the second part of the study in Qualtrics. Once they opened the Qualtrics link, they were given the instructions on how to complete the posttest. Then, they went through the posttest at their own pace, one question at a time, without being able to go back to previous questions. Once they completed the posttest, they rated the postquestionnaire items. Next, were asked: "Did you use notes to complete the test?" and "Did everything work?" Finally, they were asked to upload pictures of any scratch paper they worked on. We obtained IRB approval and followed guidelines for ethical treatment of human subjects. The data and study materials will be available upon request by contacting the corresponding author.

3. Results

The following analyses focus on the positivity principle and the equivalence hypothesis, as these were the hypotheses we aimed to test in this study. We focus on the valence of the instructor's emotion (i.e., positive or negative) and the type of instructor (i.e., human or virtual). The statistics for the activity dimension (i.e., active or passive) are not reported below as we do not have predictions about these, and the activity dimension is not our focus. The activity dimension was included in the study design to round out all four quadrants of Russell's model of core emotion and to provide two instances of positive emotion (i.e., happy and content) and negative emotion (i.e., bored and frustrated).

3.1. Do the groups differ in their basic characteristics?

To check that random assignment was successful in creating equivalent groups, we conducted analyses to assess whether the groups were equivalent on basic characteristics. Means and standard deviations on basic characteristics are displayed in Table 1. Concerning rating of prior knowledge, there was no statistically significant differences between the groups based on valence of instructors' emotion, $F(1, 159) = 0.04$, $p = .849$, or based on instructor type, $F(1, 159) = 0.09$, $p = .764$, and there was no significant interaction, $F(1, 159) = 0.22$, $p = .640$. Concerning age, there also was no statistically significant difference between the groups based on valence, $F(1,159) = 0.52$, $p = .472$, or based on instructor type, $F(1, 159) = 1.46$, $p = .228$, and there was no significant interaction, $F(1, 159) = 0.32$, $p = .570$. Concerning number of math courses taken, there was no statistically significant difference between the groups based on valence, $F(1, 159) = 0.63$, $p = .429$, or based on instructor type, $F(1, 159) = 0.32$, $p = .572$, and there was no significant interaction, $F(1, 159) = 0.04$, $p = .845$. Concerning gender, there was no statistically significant difference between the groups, $X^2(14, N = 167) = 13.42$, $p = .494$. We conclude that the groups were equivalent in these basic characteristics.

3.2. Testing the positivity principle

3.2.1. Hypothesis 1: Can learners perceive the emotion of their instructor?

The first link in the cognitive affective model of e-learning is that learners can perceive the emotion displayed by the instructor. We are particularly interested in whether instructors displaying positive emotions (happy and content) were perceived as more positive by learners (hypothesis 1a) and whether instructors displaying negative emotions (frustrated and bored) were perceived as more negative by learners (hypothesis 1b), in line with the positivity principle. Perceived emotion rating means and standard deviations are reported in Table 2. A 2 (valence: positive and negative) × 2 (instructor type: human and virtual) × 2 (activity: active and passive) ANOVA was used for each of the four perceived emotion ratings (happy, content, frustrated, and bored).

For the rating of happy emotion of the instructor, there was a statistically significant effect of valence of the instructor's emotion, with positive instructors ($M = 3.80$, $SD = 0.98$) being rated as more happy than negative instructors ($M = 1.77$, $SD = 1.10$), $F(1, 159) = 174.20$, $p < .001$, $d = 1.95$. For the rating of content emotion of the instructor, there was also a statistically significant effect of valence, with positive instructors ($M = 3.97$, $SD = 0.89$) being rated as more content than negative instructors ($M = 2.08$, $SD = 1.15$), $F(1, 159) = 150.58$, $p < .001$, $d = 1.84$. These findings are both in line with the positivity principle and provide support for hypothesis 1a, demonstrating that positive instructors are perceived as more positive.

For the rating of frustrated emotion of the instructor, there was a statistically significant effect of valence, such that negative instructors ($M = 3.53$, $SD = 1.24$) were rated as more frustrated than positive instructors ($M = 1.62$, $SD = 0.91$), $F(1, 159) = 128.34$, $p < .001$, $d = 1.76$. Additionally, for the rating of bored emotion of the instructor, there was a statistically significant effect of valence, such that negative instructors ($M = 4.18$, $SD = 1.22$) were rated as significantly more bored than positive instructors ($M = 2.19$, $SD = 1.19$), $F(1, 159) = 9.63$, $p < .001$, $d = 1.65$. These findings are both in line with the positivity principle and provide support for hypothesis 1b, demonstrating that negative

Table 1
Means and standard deviations of participant characteristics.

		Human Instructors				Virtual Instructors			
		Happy	Content	Frustrated	Bored	Happy	Content	Frustrated	Bored
Prior Knowledge	*M*	2.69	2.75	2.86	2.76	2.95	2.70	2.57	2.82
	SD	0.60	0.94	0.91	0.78	1.03	0.80	1.03	0.91
Age	*M*	21.38	21.13	21.19	21.48	22.37	20.85	23.24	21.43
	SD	2.50	4.14	2.27	3.55	4.04	3.84	4.11	3.53
Math	*M*	5.19	5.21	5.38	5.28	5.21	5.35	5.00	6.00
	SD	1.68	1.59	1.02	1.72	1.32	1.46	1.38	1.00

Table 2
Means and standard deviations of ratings of instructors' emotions.

		Human Instructors				Virtual Instructors			
		Happy	Content	Frustrated	Bored	Happy	Content	Frustrated	Bored
Happy Rating	*M*	4.19	3.38	1.43	1.52	4.16	3.65	2.38	1.81
	SD	1.17	0.71	0.98	1.05	1.02	0.88	1.20	0.98
Content Rating	*M*	4.19	3.83	1.71	1.64	4.21	3.75	2.71	2.33
	SD	0.98	0.82	1.10	0.91	0.92	0.85	1.15	1.16
Frustrated Rating	*M*	1.69	1.71	4.10	4.32	1.79	2.45	3.62	4.48
	SD	1.14	1.00	1.19	1.25	0.98	1.19	1.24	1.08
Bored Rating	*M*	1.81	2.54	4.29	4.32	1.79	2.45	3.62	4.48
	SD	1.11	1.29	1.19	1.25	0.98	1.19	1.24	1.08

instructors are perceived as more negative.

Consistent with hypotheses 1a and 1b, these analyses demonstrate that learners are able to perceive whether an instructor's emotion is positive or negative. Thus, we have evidence for the first link in the cognitive affective model of e-learning, which reflects affective processing.

3.2.2. Hypothesis 2: Do learners respond emotionally to instructor's emotions?

The second link in the cognitive affective model of e-learning is that learners experience an emotional response to the emotion displayed by the instructor. In this study, we measured this response by asking participants to rate the emotions they experienced while watching the instructional video. Based on the positivity principle, participants who see positive instructors should have higher ratings of positive felt emotions (happy and content) than those who see negative instructors (hypothesis 2a). Additionally, participants who see negative instructors should have higher ratings of negative felt emotions (frustrated and bored) than those who see positive instructors (hypothesis 2b). Felt emotion rating means and standard deviations are reported in Table 3. A 2 (valence: positive and negative) × 2 (instructor type: human and virtual) × 2 (activity: active and passive) ANOVA was conducted for each of the four felt emotion ratings (happy, content, frustrated, and bored).

For ratings of how happy the participants were while watching the video, there was a statistically significant effect of valence with positive instructors ($M = 1.87$, $SD = 0.76$) inspiring more happy feelings than negative instructors ($M = 1.28$, $SD = 0.57$), $F(1, 159) = 37.59$, $p < .001$, $d = 0.88$. Additionally, for ratings of how content the participants were while watching the video, there was a statistically significant effect of valence, in which positive instructors ($M = 2.13$, $SD = 0.79$) inspired more content feelings than negative instructors ($M = 1.43$, $SD = 0.71$), $F(1, 159) = 37.36$, $p < .001$, $d = 0.93$. These results are consistent with hypothesis 2a and show support for the positivity principle.

For ratings of how frustrated the participants were while watching the video, there was a statistically significant effect of valence with negative instructors ($M = 2.31$, $SD = 0.81$) priming more negative felt emotions than did positive instructors ($M = 1.67$, $SD = 0.81$), $F(1, 159) = 26.70$, $p < .001$, $d = 0.79$. Additionally, for ratings of how bored the participants felt while watching the video, there was a statistically significant effect of valence with negative instructors ($M = 2.57$, $SD = 0.77$) priming more negative felt emotions than did positive instructors ($M = 2.14$, $SD = 0.87$), $F(1, 159) = 11.98$, $p < .001$, $d = 0.52$. These results show support for hypothesis 2b and the positivity principle.

Overall, consistent with hypotheses 2a and 2b, learners' feelings of positive or negative emotion during learning was influenced by the instructor's displayed emotion. This gives us evidence for the second link in the cognitive affective model of e-learning, which reflects affective processing.

3.2.3. Hypothesis 3: Does the emotion of an instructor impact the way in which learners view instructors?

The third link in the cognitive affective model of e-learning is that learners develop a social connection with their instructor depending on the instructor's emotional impact. In this study, we measured social partnership by using the API to assess how students viewed their instructors on four dimensions: how well the instructor facilitated learning, how credible the instructor was, how human-like the instructor was, and how engaging the instructor was. Based on the positivity principle, participants who see positive instructors should have higher ratings of these API categories that those who see negative instructors (hypothesis 3). Rating means and standard deviations for each API dimension are reported in Table 4. A 2 (valence: positive and negative) × 2 (instructor type: human and virtual) × 2 (activity: active and passive) ANOVA was conducted for each of the four API dimensions.

The first dimension of the API had learners report how well the instructor facilitated learning. There was a statistically significant effect of valence, such that learners who had positive instructors ($M = 3.18$, $SD = 0.97$) gave higher ratings on facilitated learning than did those who had negative instructors ($M = 2.08$, $SD = 0.90$), $F(1, 159) = 65.77$, $p < .001$, $d = 1.18$. The second dimension of the API had learners report how credible the instructor was. There was a statistically significant effect of valence, such that learners who had positive instructors gave higher credibility ratings ($M = 3.93$, $SD = 0.77$) than did learners who had negative instructors ($M = 3.18$, $SD = 0.92$), $F(1, 159) = 33.46$, $p < .001$, $d = 0.88$. The third dimension of the API had learners report how human-like the instructor seemed to them. There was a statistically significant effect of valence in which learners who had positive instructors gave higher human-like ratings ($M = 3.19$, $SD = 1.01$) than did learners who had negative instructors ($M = 2.38$, $SD = 0.97$), $F(1, 159)$

Table 3
Means and standard deviations of participants' felt emotions.

		Human Instructors				Virtual Instructors			
		Happy	Content	Frustrated	Bored	Happy	Content	Frustrated	Bored
Happy Rating	*M*	2.19	1.79	1.14	1.20	2.16	1.45	1.48	1.33
	SD	0.91	0.72	0.36	0.41	0.60	0.60	0.75	0.66
Content Rating	*M*	2.31	2.25	1.14	1.36	2.16	1.80	1.81	1.43
	SD	0.79	0.79	0.36	0.64	0.69	0.83	0.87	0.75
Frustrated Rating	*M*	1.44	1.70	2.52	2.36	1.84	1.65	2.19	2.19
	SD	0.73	0.81	0.75	0.81	0.90	0.81	0.87	0.81
Bored Rating	*M*	1.94	2.20	2.76	2.48	2.21	2.15	2.38	2.67
	SD	0.93	0.83	0.54	0.87	0.85	0.93	0.86	0.73

Table 4
Means and standard deviations of the API dimensions.

		Human Instructors				Virtual Instructors			
		Happy	Content	Frustrated	Bored	Happy	Content	Frustrated	Bored
Facilitate learning	*M*	3.54	2.96	1.71	2.00	3.60	2.74	2.56	2.05
	SD	0.93	0.91	0.60	0.87	0.81	1.02	1.02	0.93
Credible	*M*	4.06	3.88	2.79	3.13	4.11	3.73	3.52	3.29
	SD	0.78	0.80	0.67	0.98	0.68	0.82	1.03	0.86
Human-like	*M*	3.93	3.16	2.48	2.37	3.24	2.59	2.60	2.17
	SD	0.78	0.92	0.74	0.91	0.84	1.07	1.13	0.91
Engaging	*M*	3.78	2.94	1.39	1.58	3.61	2.80	2.14	1.61
	SD	0.96	0.89	0.50	0.69	0.86	1.08	1.12	0.83

$= 32.81$, $p < .001$, $d = 0.82$. The last dimension of the API had learners report how engaging the instructor's teaching was for them. There was a statistically significant effect of valence in which the engagement rating was higher for positive instructors ($M = 3.23$, $SD = 1.02$) than for negative instructors ($M = 1.68$, $SD = 0.84$), $F(1, 159) = 135.87$, $p < .001$, $d = 1.66$. These findings provide consistent support hypothesis 3 of the positivity principle, and for link three in the cognitive affective model of e-learning, which reflects social processing.

3.2.4. Hypothesis 4: Does the emotion of an instructor influence learning outcomes?

The final link in the cognitive affective model of e-learning is that learners learn better from instructors who are positive. In this study, we measured learning outcome with a delayed posttest. Based on the positivity principle, participants who learn from positive instructors should have higher posttest scores than those who learn from negative instructors (hypothesis 4). Posttest score means and standard deviations are reported in Table 5. A 2 (valence: positive and negative) × 2 (instructor type: human and virtual) × 2 (activity: active and passive) ANOVA was conducted for posttest score. The AVOVA showed that there was not a significant effect of valence on posttest score such that those who saw positive instructors ($M = 5.24$, $SD = 2.61$) scored about the same as those who saw negative instructors ($M = 5.38$, $SD = 2.45$), $F(1, 159) = 0.12$, $p = .729$. This finding was not in line with the positivity principle or hypothesis 4. Unlike the first three links involving affective and social processing during learning, we do not have evidence for the fourth link in the cognitive affective model of e-learning, which reflects cognitive processing.

3.3. Testing the equivalence hypothesis

Along with the positivity principle, we were interested in testing the equivalence hypothesis, which asserts that people accept virtual instructors in the same way as human instructors. To understand if there are differences between the way learners are affected by the emotions displayed by human and virtual instructors for each of the steps of the cognitive affective model of e-learning, the main effect of instructor type and interaction of valence and instructor type were investigated in the above ANOVAs.

3.3.1. Hypothesis 5: Are perceived emotion ratings of instructors similar for human and virtual instructors?

According to the equivalence hypothesis, in the first step of the cognitive affective model of e-learning, learners should be able to perceive the emotions displayed by virtual instructors similarly to how they perceive the same emotions displayed by human instructors. Thus, positive instructors should be seen similarly as more positive (i.e., happy and content) than the negative instructors for both human and virtual instructors, as indicated by no significant disordinal interaction between valence and type of instructor (hypothesis 5a). Additionally, negative instructors should be seen similarly as more negative (i.e., frustrated and bored) than the positive instructors for both human and virtual instructors, as indicated by no significant disordinal interaction between valence and type of instructor (hypothesis 5b).

In line with the equivalence hypothesis, there was not a statistically significant interaction between the valence and instructor type for ratings of how happy was, $F(1, 159) = 2.55$, $p = .112$. Additionally, there was a statistically significant ordinal interaction for ratings of how content the instructor was, $F(1, 159) = 8.06$, $p = .005$. *T*-test analyses revealed that for human instructors, positive instructors ($M = 3.98$, $SD = 0.89$) were rated as significantly more content than negative instructors ($M = 1.67$, $SD = 0.99$), $t(84) = 11.26$, $p < .001$, $d = 2.45$. Similarly, for virtual instructors, positive instructors ($M = 3.97$, $SD = 0.90$) were rated as significantly more content than negative instructors ($M = 2.52$, $SD = 1.15$), but to a lesser extent, $t(79) = 6.27$, $p < .001$, $d = 1.40$. These findings are generally consistent with the equivalence hypothesis and support hypothesis 5a in that positive instructors were seen as more positive than negative instructors for both human and virtual instructors, although the effect concerning content ratings was stronger for human instructors.

In line with the equivalence hypothesis, there was no statistically significant interaction between the valence and instructor type for ratings of how frustrated the instructor was, $F(1, 159) = 1.28$, $p = .259$, or for ratings of how bored the instructor was, $F(1, 159) = 0.29$, $p = .591$. Both of these findings support hypothesis 5b as the negative instructors were seen as more negative than the positive instructors similarly across both human instructors and virtual instructors.

3.3.2. Hypothesis 6: Do learners respond emotionally to instructor's emotions similarly for human and virtual instructors?

The second step of the cognitive affective model of e-learning is that learners respond to the emotions of an instructor. Based on the equivalence hypothesis, participants who see positive instructors should report higher ratings of feeling positive emotions (happy and content) similarly for the human and virtual instructors, as indicated by no significant disordinal interaction between valence and type of instructor (hypothesis 6a). Additionally, participants who see negative instructors should report higher ratings of feeling negative emotions (frustrated and

Table 5
Means and standard deviations of delayed posttest performance.

		Human Instructors				Virtual Instructors			
		Happy	Content	Frustrated	Bored	Happy	Content	Frustrated	Bored
Posttest score	*M*	5.50	5.19	5.10	5.12	4.66	5.65	5.50	5.83
	SD	2.42	3.02	2.26	2.46	2.32	2.60	2.87	2.27

bored) similarly for human and virtual instructors, as indicated by no significant disordinal interaction between valence and type of instructors (hypothesis 6b).

There was a statistically significant ordinal interaction between valence and instructor type for ratings of felt happy emotion, $F(1, 159) = 4.45$, $p = .036$. Follow up t-tests demonstrated that for human instructors, positive instructors ($M = 2.93$, $SD = 1.10$) inspired more happy feelings in learners than negative instructors ($M = 1.63$, $SD = 0.77$), $t(84) = 6.40$, $p < .001$, $d = 1.37$. Similarly, for virtual instructors, positive instructors ($M = 2.82$, $SD = 0.94$) inspired more positive emotions than negative instructors ($M = 2.02$, $SD = 1.09$), but to a lesser extent, $t(79) = 3.50$, $p < .001$, $d = 0.79$. Similarly, there was a statistically significant ordinal interaction for ratings of felt content emotion, $F(1, 159) = 8.61$, $p = .004$. Follow up t-tests demonstrated that for human instructors, positive instructors ($M = 3.38$, $SD = 1.21$) inspired more happy feelings in learners than negative instructors ($M = 1.80$, $SD = 0.89$), $t(84) = 6.92$, $p < .001$, $d = 1.49$. Similarly, for virtual instructors, positive instructors ($M = 3.08$, $SD = 0.96$) inspired more positive emotions than negative instructors ($M = 2.31$, $SD = 1.26$), but to a lesser extent, $t(79) = 3.07$, $p = .003$, $d = 0.69$. Generally, hypothesis 6a was supported from these analyses; however, the effects were stronger for human instructors than virtual instructors.

In line with predictions, there was not a significant interaction between valence and instructor type for ratings of how frustrated the participants felt, $F(1, 159) = 2.79$, $p = .097$, or for how bored the participants felt, $F(1, 159) = 0.63$, $p = .428$. Hypothesis 6b was supported here as participants felt more negative with negative instructors than positive instructors regardless of whether the instructor was human or virtual.

3.3.3. Hypothesis 7: Does the emotion of an instructor impact the way in which learners view instructors similarly for human and virtual instructors?

The third step of the cognitive affective model of e-learning is that learners develop a social connection with their instructor depending on the instructor's emotional impact. Based on the equivalence hypothesis, participants who see positive instructors should have higher ratings on the four API categories similarly for both human and virtual instructors, as indicated by a lack of disordinal interaction (hypothesis 7).

There was no significant interaction between valence and instructor type on ratings of how well the instructor facilitated learning, $F(1, 159) = 3.67$, $p = .057$; or ratings of how credible the instructor was, $F(1, 159) = 3.49$, $p = .064$. There was a significant ordinal interaction on ratings of how human-like the instructor was, $F(1, 159) = 4.55$, $p = .034$. Follow up t-tests revealed that for the human instructors, the positive instructors ($M = 3.47$, $SD = 0.94$) were rated as more human-like than negative instructors ($M = 2.37$, $SD = 0.91$), $t(84) = 5.48$, $p < .001$, $d = 1.19$. Additionally, for the virtual instructors, the positive instructors ($M = 2.91$, $SD = 1.01$) were rated as more human-like than negative instructors ($M = 2.39$, $SD = 1.04$) but to a smaller extent, $t(79) = 2.29$, $p = .025$, $d = 0.51$. There also was a significant ordinal interaction for ratings of how engaging the instructor was, $F(1, 159) = 3.94$, $p = .049$. Follow up t-tests demonstrated that for human instructors, positive instructors ($M = 3.28$, $SD = 1.00$) were rated as more engaging than negative instructors ($M = 1.49$, $p = .61$), $t(62.88) = 9.78$, $p < .001$, $d = 2.16$. Similarly, for virtual instructors, positive instructors ($M = 3.19$, $SD = 1.05$) were rated as more engaging than negative instructors ($M = 1.88$, $SD = 1.01$) but to a lesser extent, $t(79) = 5.76$, $p < .001$, $d = 1.27$. Overall, these findings generally support the equivalence hypothesis as reflected in hypothesis 7. For both human and virtual instructors, positive instructors are rated as better at facilitating learning, more credible, more human-like, and more engaging, but the effects on the last two scales were stronger for human instructors than virtual instructors.

3.3.4. Hypothesis 8: Does the emotion of an instructor influence learning outcomes similarly for human and virtual instructors?

The final step of the cognitive affective model of e-learning is that learners learn better from instructors who are positive. Based on the equivalence hypothesis, participants who learn from positive instructors should have higher posttest scores than those who learn from negative instructors similarly for human and virtual instructors, as indicated by a lack of disordinal interaction between valence and type of instructor (hypothesis 8). For the posttest, there was not a significant interaction between valence and instructor type, $F(1, 159) = 0.88$, $p = .349$. These results are consistent with hypothesis 8 and the equivalence hypothesis as there were no differences in posttest performance based on whether the instructor was human or virtual.

4. Discussion

4.1. Empirical contributions

4.1.1. Positivity principle

This study provided support for the positivity principle in three of the four links of the modified cognitive affective model of e-learning. First, learners who saw positive instructors indicated that these instructors were more positive than those who saw negative instructors as well as learners who saw negative instructors indicated that these instructors were more negative than those who saw positive instructors. Second, learners who saw positive instructors reported more positive emotions than those who saw negative instructors. Additionally, learners who saw negative instructors reported more negative emotions than those who saw positive instructors. Third, participants who saw positive instructors rated their instructors as better at facilitating learning, more credible, more human-like, and more engaging than those who saw negative instructors. However, learners performed similarly on the delayed posttest whether they had a positive instructor or a negative instructor. Thus, we found support for hypotheses 1, 2, and 3, but not for hypothesis 4.

4.1.2. Equivalence hypothesis

Concerning the equivalence hypothesis, this study helped demonstrate that learners generally treat virtual instructors in the same way as they treat human instructors. First, there were no disordinal interactions for how well learners could recognize the instructor's emotion, indicating that learners were able to tell the emotions of the instructor, regardless of whether the instructor was human or virtual. Second, there were also no disordinal interactions for the types of emotions that participants felt in response to the instructor's emotions, indicating that learners responded similarly to human and virtual instructors' emotions. Third, learners indicated similar social relations with the instructor, regardless of whether the instructor was virtual or human, seen through the lack of disordinal interactions. Lastly, there wasn't a disordinal interaction for learning performance, indicating that human and virtual instructors were equivalent in their ability to teach students information.

4.2. Theoretical implications

This paper provides partial support for the positivity principle, as represented in the cognitive affective model of e-learning summarized in Fig. 2. Throughout the findings of this study, positive instructors were rated as more positive, induced more positive emotions in students, and created more positive social connections between instructor and learner. These findings support the idea that positive emotions being displayed by an instructor can act as a motivator in terms of activating affective and social processing (Plass & Kalyuga, 2019). However, this research failed to find that the emotion of an instructor influences posttest score, which reflects cognitive processing. Apparently, there was a disconnect between affective/social processing (which were influenced by the instructor's emotional stance) and cognitive processing (which was not influenced by the instructor's emotional stance). This could indicate one of two things. First, there may not be a direct relationship between the instructor's emotion and a student's learning outcome, even though it

can influence how the student feels about the instructor. Second, there could be an indirect relationship in that the emotional tone of an instructor influences a students' view of that teacher which then influences how likely that student is to attend class, pay attention, and work hard, which may then impact learning in the long-term. The short-term nature of this study precluded an effective test of this idea.

This paper also provides evidence for the equivalence hypothesis and the media equation theory (Reeves & Nass, 1996) from which it is derived in that participants treated both human instructors and virtual instructors in similar ways. Participants were able to recognize the emotion displayed by human and virtual instructors, and thus responded in similar ways, depending on the emotion portrayed by the instructor.

4.3. Practical implications

An important implication for teaching is that even if an instructor has prepared a well-designed lesson consisting of clear slides and a clear script, there is more she can do to improve student learning. This study suggests that instructors should consider their emotional stance in how they deliver their lecture. In particular, they should strive to convey positive emotion as they teach through their voice, gestures, facial expression, eye contact, and body movement. Giving an effective lecture depends both on the content of lecture and on way that the instructor delivers it, so the instructor's positive emotional stance is an important ingredient in teaching and learning.

This research provides further reason for instructors and designers of instructional videos to consider what kinds of emotions the instructor is displaying to learners. This study shows how the emotions displayed by an instructor can be picked up by learners and then used to influence learners' emotions and the connection the learner feels with the instructor. It follows then that those designing instructional material should make sure that video lectures display an instructor with positive emotions rather than negative emotions. Additionally, the results of this study demonstrate that it is important to design virtual instructors to have positive emotions as well, as learners respond more positively when their instructor is positive, regardless of if their instructor is human or virtual.

4.4. Limitations and future directions

One limitation to the study presented here is that the study was short and didn't follow students along a real learning scenario. Our study did not find any impact of an instructor's emotion on learning outcome; however, we did find that the instructor's emotion influenced the learner's emotion and their connection with the instructor. It may be the case that these factors are what influences learning in the long run, as students who are happier with the course as well as feel a stronger connection with the instructor may attend class more often, put more effort into learning the material and thus learn more. As this study only involved one short lesson, it is hard to know if the above mentioned scenario occurs or if there really is no connection between an instructor's emotion and the student's learning outcome. Future research should focus on how an instructor's emotion influences a student's behavior over a longer amount of time to understand the impact on learning.

Additionally, it is challenging to precisely equate the human instructor's and virtual instructor's gestures and facial expressions. Although there was an attempt at trying to make the virtual instructor match up to the human instructor as much as possible, they are not completely the same. This could have some effects on how well learners were able to recognize the emotions of the instructor, how the instructor made the leaner feel, and how the learner developed a social connection with the instructor. Future research should investigate how different ways of matching the gestures of virtual and human instructors can influence how well learners respond to the virtual instructors.

Furthermore, the subject of the lesson in this study, statistics, is often seen demotivating or threatening to many students and this may have played a role in how students felt watching the video and connecting to the instructor. It may be the case that in subjects that students find less motivating, the emotion of an instructor is highly important in students developing a connection and responding to the instructor compared to more exciting subjects where the information is motivating in itself. Alternatively, it could be that the demotivating nature of statistics dampened the effect of an instructor's emotion on learning and a more motivating lesson topic would have shown greater effects. Future research should investigate how the positivity principle and equivalence hypothesis play a role in learning of more exciting or motivating subject material.

Lastly, participants were not asked if they studied the material between part 1 and part 2 of the experiment. Because of this, there may have been some participants who chose to look into binomial probability on their own between the two sessions, and thus part of their learning would not be due to the instructor. Random assignment should address this problem by randomly placing people who do study between sessions at similar rates into the eight groups, but we cannot assess that this was the case since participants did not report if they studied between sessions. Future research should investigate: 1) if positive instructors influence students to want to study more in the time gaps during delayed posttest studies and 2) if studying during this time impacts participants' further understanding of the material.

4.5. Conclusion

This research investigated the positivity principle and the equivalence hypothesis by examining how the emotions displayed by human and virtual instructors influenced (1) how well learners could recognize the emotions of the instructor, (2) the emotions the learner felt while watching the video lecture, (3) what kind of social connection the learner developed with the instructor, and (4) how well learners performed on a delayed test. There was support for both the positivity hypothesis for the first three steps, and support for the equivalence hypothesis in all four steps of the cognitive-affective model of e-learning.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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