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RESEARCH ARTICLE

# Pedagogical Agent Emotional Design: The Effects of Emotional Cues and Model-Observer Similarity on Female Learners

**QINGTANG LIU[1,2], (Member, IEEE), TIANSHENG CAO[1,2], LINJING WU[1,2], FENGJUAN CHEN[1,2], AND RUIQIU YE[1,2]**

[1]Hubei Key Laboratory of Digital Education, Central China Normal University, Wuhan 430000, China
[2]Faculty of Artificial Intelligence in Education, Central China Normal University, Wuhan 430000, China

Corresponding author: Tiansheng Cao (1065489326@qq.com)

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**ABSTRACT** With growing recognition of the critical role of emotions, pedagogical agent (PA) emotional design has become an increasingly important research topic. In the realm of PA emotional design, investigating the effects of PA emotional cues on specific gender groups and exploring relevant moderating factors are crucial. This study investigated the effects of a PA's positive emotional cues on female learners' learning process experiences and outcomes compared to negative emotional cues. It also explored whether the similarity in clothing and grooming styles between female learners and PAs moderated these effects. This study employed a 2 (positive and negative emotional cues) × 2 (high and low similarity) between-subjects experimental design, with 128 female undergraduates randomly assigned to one group. The results indicated that a PA displaying positive emotional cues was perceived as having higher positive and lower negative emotions and being more likely to facilitate learning, more credible, and more engaging than a PA displaying negative cues. Female learners in the positive emotional cue condition showed higher positive emotions and motivation and lower negative emotions and extraneous cognitive load, with no significant differences in learning outcomes compared with those in the negative cue condition. Moreover, the results identified the boundary conditions of the moderating effect of the similarity in clothing and grooming styles between female learners and PAs. The similarity in clothing and grooming styles generally did not moderate these effects. An exception emerged under high similarity, where a PA displaying positive emotional cues was perceived as more human-like than one displaying negative emotional cues.

**INDEX TERMS** Pedagogical agent, emotional cues, model-observer similarity, similarity in clothing and grooming styles, female learners, emotions, motivation, cognitive load, learning outcomes.

## I. INTRODUCTION

A pedagogical agent (PA) is a computer-generated anthropomorphic visual representation designed to support instructional purposes [1]. Such agents represent a promising approach to educational development [2]. In recent years, researchers have emphasized the importance of integrating emotional design into PAs, focusing on the learning impact of PA emotional cues [3]. A PA's emotional cues are used to express its emotions, such as facial expressions. Recent research has compared the effects of positive and negative emotional cues from PAs [4], [5]. For example, differences in emotions, motivation, and learning outcomes between learners under PA-positive emotional cue conditions and those under PA-negative emotional cue conditions were examined [4]. Most of these studies used mixed-gender samples

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(male and female), but targeted exploration of specific groups (such as females) remained insufficient. The male group was also worthy of focused investigation, but this study primarily focused on the female group because some research showed that females might have had unique characteristics in processing emotional cues (such as facial expressions, tone, etc.): for example, studies demonstrated that females were more accurate in recognizing emotions conveyed through subtle facial expressions [6], and also more accurate in identifying emotions in voice [7]. Additionally, females exhibited stronger physiological responses (e.g., amygdala activation) to negative emotional stimuli [8], [9]. Since PA emotional cues include facial expressions, tone, and so forth, females may have more sensitive emotional perception and stronger emotional reactions when processing these emotional cues, which may profoundly influence their learning process experience and outcomes [10]. Therefore, clarifying the exact impact of PA emotional cues on female learners is of significant value. However, current empirical studies mostly involve mixed genders and have not yet fully elucidated how PA positive and negative emotional cues specifically affect female learner groups. This knowledge gap results in a lack of evidence-based guidance and recommendations for effectively utilizing PA emotional cues when designing personalized teaching scenarios for female learners.

Furthermore, there are inconsistent viewpoints in theoretical research regarding whether and how emotional PA cues influence learning outcomes [4], [10], [11], [12]. However, a synthesis of these differing perspectives reveals that the primary mechanism of influence occurs mainly through the impact on learning process experiences, such as the perception of emotions toward PAs, emotions, motivation, perceived social connection with PAs, and cognitive load, which subsequently affect learning outcomes. In empirical research, the effects of emotional cues on learning process experiences and outcomes are influenced by various factors [3], [13], with particular consideration given to the model-observer similarity between PAs and learners [14]. For example, recent research suggests that the impact of positive emotional cues from PAs on female learners may depend on the gender similarity between PAs and female learners [14]. Clothing and grooming styles are attributes that women pay high attention to [15] and [16]. However, studies on whether the effect of PA emotional cues on female learners depends on similarities in clothing and grooming styles between them are limited. For female learners, investigating how model-observer similarity moderates the effect of PA emotional cues enables a deeper investigation into their effectiveness while also shedding light on how PAs' social cues such as clothing and grooming styles and emotional cues jointly influence female learners' learning process experience and learning outcomes.

Overall, this study aimed to explore the impact of positive versus negative emotional cues from PAs on the learning process experiences and outcomes of female learners. Additionally, we examined whether the similarity in clothing and grooming style between female learners and PAs moderated these effects. This study differs from current research on PA emotional cues in the following ways: 1. This study combined current theoretical research and empirical findings, systematically summarized PA emotional cues might influence which learning process experiences and learning outcomes, and conducted a more comprehensive and integrated investigation. 2. This study only examined the effects of PA emotional cues from the perspective of female learners. The participants in this study were all female undergraduate students from Chinese universities, whereas prior similar studies have mostly used mixed-gender samples. 3. This study examined the moderating effect of similarities in clothing and grooming styles between PAs and female learners on the effects of PA emotional cues, which was different from the moderating factors examined in existing studies (for example, Wang et al. investigated the moderating effect of prior knowledge on the effects of PA emotional cues [13], while Beege et al. investigated the moderating effect of mental load in working memory on the effects of PA emotional cues [3]). Therefore, this study fills a gap in this field. The study contributes to the literature by providing empirical evidence on which aspects of female learners are influenced by PA emotional cues, examining whether model-observer similarity, specifically in clothing and grooming styles between female learners and PAs, moderates these effects, and offering empirical evidence and design recommendations for female-learner-oriented PA design to optimize female learners' learning in digital environments. Moreover, the analysis of the female group constitutes an important module for systematically deconstructing the impact of PA emotional cues on learners from different groups, and its methodology and findings will drive subsequent research targeting other characteristic groups (such as the male group, female groups with different traits), ultimately serving the development of inclusive intelligent education.

## II. LITERATURE REVIEW

### A. TYPES AND PRODUCTION METHODS OF PA EMOTIONAL CUES

According to previous studies, visual-emotional cues primarily include facial expressions and body posture. In the context of positive emotions, Pi et al. designed a PA that used a continuous smile to express happiness [17], and Lawson et al. designed a PA that expressed joy through an open-arm posture and a forward-leaning body position [11]. For negative emotions, Liew et al. designed a PA with wide-open eyes, furrowed brows, and a downturned mouth to convey anger [18]. Horovitz and Mayer designed a PA with crossed arms to express boredom [4]. Methods for creating visual emotional cues for PAs primarily include machine-synthesized animations (e.g., [14]) and recorded videos featuring teachers (e.g., [19]). Auditory emotional cues primarily focus on the vocal tone. For positive emotions, Beege et al. employed a greater dynamic pitch variation and higher pitch contour to express enthusiasm in PAs [3]. For negative emotions, Buttussi and Chittaro designed a sad vocal tone for PAs [20]. Methods for

creating auditory emotional cues for PAs primarily involve professional voice actor recordings (e.g., [13]) and speech synthesis engines (e.g., [21]). Therefore, this study utilized facial expressions, body postures, and vocal tones as PA emotional cues, with both positive and negative emotional cues entirely generated by machines.

### B. THE INFLUENCE OF PA EMOTIONAL CUES ON THE LEARNING PROCESS EXPERIENCES AND LEARNING OUTCOMES

#### 1) THEORETICAL RESEARCH

There are inconsistent theoretical perspectives on how PA emotional cues influence learning [3].

On the one hand, one perspective suggests that PAs' positive emotional cues could facilitate both learning process experiences and outcomes. The affective mediation hypothesis in the cognitive-affective theory of learning with media (CATLM) posits that affective and motivational factors may mediate learning by increasing or decreasing learners' cognitive engagement during the learning process [12]. Based on the CATLM, the cognitive-affective model of e-learning [11] assumes that when a PA exhibits positive emotional cues (presenting positive emotions), learners first recognize its emotional stance, then perceive a stronger social connection with it, and subsequently exert more effort to learn from it, leading to improved learning performance. Another version of the cognitive-affective model of e-learning indicates that when a PA expresses positive emotional cues, learners initially identify its emotional state and then feel the same positive emotions, which triggers positive changes in their motivational state, ultimately resulting in better learning outcomes [4]. When a PA displays negative emotional cues, these situations are reversed.

On the other hand, another perspective argues that both positive and negative emotional cues hinder learning. Emotional cues are information irrelevant to the learning task, leading to unrelated cognitive processing [10]. This can increase extraneous cognitive load [22], thereby obstructing learning.

In summary, these theoretical studies indicate that PA emotional cues may affect various aspects of learning process experiences, including the perception of PA emotions, emotions, motivation, perceived social connection with PA, and cognitive load, thereby influencing learning outcomes.

#### 2) EMPIRICAL FINDINGS

However, empirical research has yielded inconsistent conclusions. Some studies have found that, compared to negative emotional cues, positive emotional cues (e.g., smiling, open arms, and a positive tone) can enhance emotions and motivation but do not improve learning outcomes [4]. However, Liew et al. found that PAs' positive emotional cues significantly enhanced learning outcomes compared to neutral emotional PAs [23].

Additionally, positive emotional cues from PA do not necessarily enhance positive emotions. For instance, Beege et al. found that PAs with an enthusiastic voice did not enhance learners' positive emotions. Furthermore, regarding extraneous cognitive load [3], Liew et al. discovered that machine-generated low-enthusiasm voices reduced extraneous cognitive load compared with machine-generated neutral voices [21]. By contrast, Beege et al. found that, under conditions of high mental load, the extraneous cognitive load was higher in the enthusiastic voice condition than in the artificially recorded neutral voice [3]. Regarding the perception of PA emotions, a study indicated that learners perceived PAs displaying happy emotional cues as happier compared to PAs displaying bored emotional cues. However, this assessment was influenced by the type of instructor (human or animated) [4]. In terms of perceived social connection with PAs, a study suggested that PAs with positive emotional cues scored higher on facilitating learning and being credible, human-like, and engaging than PAs with negative emotional cues [24]. Conversely, Kraemer et al. found no significant differences in perceived social connection (rapport) between PA with positive emotional cues (e.g., nodding and smiling) and those without positive emotional cues [25].

These differences may be because the effectiveness of PA emotional cues depends on some moderating variables [13]. However, research on these moderating variables remains limited. Notably, the impact of PA emotional cues on female learners may depend on model-observer similarity. For example, Beege and Schneider found that for female learners, positive emotional cues only enhanced knowledge retention when the PA was female, compared to the neutral emotional cues [14]. However, few studies have explored the combined effects of model-observer similarity and emotional cues on female learners, particularly regarding which attributes' similarity may influence the effect of emotional cues for female learners.

### C. MODEL-OBSERVER SIMILARITY AND CLOTHING AND GROOMING STYLES

The concept of model-observer similarity indicates that the effectiveness of modeling depends on the degree to which observers perceive the model as similar to themselves. Furthermore, the similarity-attraction hypothesis posits that when learners observe a social model with high similarity to themselves in certain personal attributes, they are more likely to be attracted [26]. Notably, Baylor argues that in PA design, the similarity between the model and observer in appearance should be emphasized [27]. This is because the appearance of social models such as PAs can directly affect information reception and self-efficacy, potentially influencing learners' motivation, attitudes, and learning behaviors [28].

Researchers have explored the similarities in the appearance of PAs and learners. For example, Rosenberg-Kima et al. found that under the guidance of PAs similar to them, young women improved their stereotypes

about engineering and enhanced their self-efficacy [29]. Kim and Wei found that high school students were more willing to choose to learn under the guidance of PAs of the same gender and race [30]. However, some studies have not found benefits of model-observer similarity. For instance, Hoogerheide et al. found that in learning videos on circuit troubleshooting, regardless of whether the PA's gender was the same as that of the learner,

there were no differences in learners' test scores, self-efficacy, or other factors [31]. Nevertheless, studies have pointed out that because learners are easily influenced by PAs whose appearance is similar to their own [32], the similarity in appearance between PAs and learners should be considered when designing PAs [27], [33].

Existing research suggests that the similarity in appearance between the model and observer (e.g., whether the PA shares the same gender as female learners) may moderate the effects of emotional cues on female learners [14]. Hence, it was necessary to examine whether the influence of PA emotional cues on female learners also depended on the similarity of other appearance attributes, beyond gender. Clothing and grooming styles are notable appearance attributes that women value highly. Research has shown that female college students place great importance on others' appearance. For instance, a study involving 311 female college students found that 98.71% of them reported paying attention to others' appearances and comparing them with their own [15]. Clothing and grooming styles are critical components of appearance [16]. Female learners' focused attention on clothing and grooming styles may similarly transfer to PAs, potentially influencing their learning experiences. For example, Rosenberg-Kima et al. designed PAs with specific hairstyles and clothing to embody a ''cool'' style, finding that this approach enhanced female college students' self-efficacy [29]. This is because such clothing and grooming styles closely resembled their own [28].

Therefore, this study examined whether similarities in clothing and grooming styles between PAs and female learners moderated the effects of PA emotional cues on female learners. Additionally, because, unlike gender, clothing and grooming styles could not be distinctly categorized as similar or dissimilar, we treated the similarity of clothing and grooming styles as high or low.

### D. RESEARCH QUESTIONS

This study aimed to explore the impact of positive emotional cues compared with negative emotional cues from PA on the learning process experiences and outcomes of female learners. Additionally, we examined whether the degree of similarity in clothing and grooming styles between female learners and PAs moderated these effects. This study synthesized positive and negative emotional cues for PAs and designed PAs with both high and low similarities in clothing and grooming styles. Specifically, this study addressed the following research questions:

1. What differences exist in the learning process experiences (perception of emotions toward PAs, emotions, motivation, cognitive load, and perceived social connection with PAs) of female learners under conditions of positive and negative emotional cues from PAs?

2. What differences are observed in the learning outcomes of female learners under conditions of positive and negative emotional cues from PAs?

3. Does the similarity in clothing and grooming styles between the PAs and female learners moderate the effects of PA emotional cues on female learners' learning process experiences and outcomes?

## III. METHOD

### A. PARTICIPANTS AND DESIGN

The participants were 128 female undergraduate students recruited from a university in Wuhan, China. The experiment employed a 2 (emotional cues: positive or negative) $\times$ 2 (similarity in clothing and grooming styles: high or low) between-subject design. We assigned random numbers to each female learner using Microsoft Excel, sorted them in ascending order, and grouped them sequentially. Specifically, 32 learners were assigned to each of the following groups: the positive high-similarity (PH) group, the positive low-similarity (PL) group, the negative high-similarity (NH) group, and the negative low-similarity (NL) group.

### B. DESIGN OF MATERIALS

The teaching materials consisted of four versions of an instructional video, featuring a cartoon female character who taught the topic of ''Vertical Stratification of the Atmosphere'' alongside a series of slides. PAs exhibited tendencies to mimic real humans; they had natural blinking and head movements, and their lip movements synchronized with speech. This teaching topic was chosen because university students were generally perceived to have low prior knowledge of it. The instructional video had a duration of approximately 3 minutes and 15 seconds. For the duration setting of instructional videos, we referred to previously relatively mature cases [13]. For example, Wang et al.'s study on PA emotional cues employed a video length of 128 seconds [13]. The shorter durations might have served as a means to control confounding variables. For example, longer video times might have caused learner fatigue, which could have consequently affected factors such as emotion and motivation. The screenshot from the video is shown in Figure 1.

All video versions used the same script and slides, with the only difference being the PA. To address the research questions and effectively manipulate the independent variables, this study clearly separated different levels of ''PA emotional cues'' and the ''similarity in clothing and grooming styles between the PAs and female learners'' to ensure internal validity. We established features with distinct contrasts between these levels. This setup referred to previous studies [4], [17]. For example, Horovitz and Mayer designed

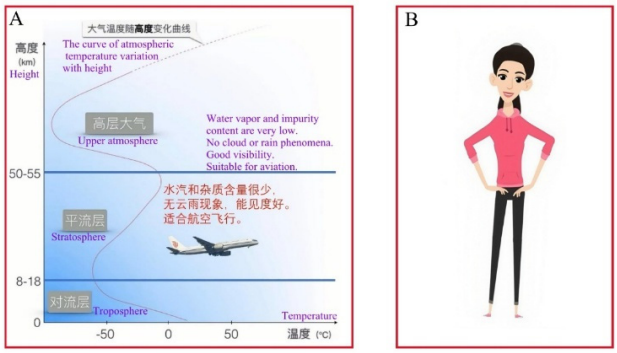


**FIGURE 1.** Screenshot from the video: A presents a slideshow on the topic of "Vertical Stratification of the Atmosphere." B demonstrates the PA that taught the knowledge.

two emotional cues for PAs, happiness and boredom, which have obvious and clear contrasting differences [4].

Emotional states were complex and diverse, such as excitement and enthusiasm. To address the research questions, we referred to the PA emotional framework and previous studies, selecting ''happiness'' as a typical positive emotion and ''frustration'' as a typical negative emotion. This was because Lawson et al. identified four quadrants of PA emotions based on two dimensions: valence (positive/negative) and arousal (active/passive). The four emotional quadrants were happiness (positive/active), contentment (positive/passive), frustration (negative/active), and boredom (negative/passive) [5]. Moreover, happiness was common in some studies on PA emotional cues [5], [19]. To avoid the influence of the emotional arousal dimension (active or passive), frustration [5], which was consistent with the emotional arousal of happiness (active), was chosen as the negative emotion.

Afterwards, we mainly referred to previous research cases and considered using dual channels to enhance emotional representation, and for ease of control, we selected 2D animated PA and designed the combinations of emotional cues (several typical cues) in the visual (facial expressions and postures) and auditory (vocal tone) aspects. Previous studies showed that a single 2D animated PA with typical emotional cues set in facial expressions, postures, and vocal tone could effectively express PA emotions [3], [13], [14]. For example, Beege and Schneider designed 2D animated PA with a smiling face and enthusiastic vocal tone. Through participants' evaluations of PA emotions, they found that these designs could effectively express PA's positive emotions [14]. Moreover, different studies often included typical emotional cues. For instance, in various studies, researchers frequently used ''smiling'' to express PA's positive emotions [14], [19], [23]. Additionally, Ba et al. pointed out that setting emotional cues in dual channels (visual and auditory) could more effectively convey the expresser's emotions by enhancing viewers' emotional perception [34].

Specifically, in terms of PA facial expressions, research showed that the eyes and mouth were the key areas for expressing emotions on the human face [35]. This study used a ''smile (corners of the mouth raised, eyes open and relaxed, eyebrows raised)'' as the facial expression of happiness. This referred to the research design of Pi et al. [19], who used a ''smile'' as the facial expression of PA happiness. This study used ''corners of the mouth drooping, eyes half-open, eyebrows furrowed and tightly pressed against the eyes'' as the facial expression of frustration. In terms of PA body posture, this study used ''both hands placed on the waist and body opened'' as the happy body posture, and ''arms crossed and body closed'' as the frustrated body posture. This referred to the studies of Lawson et al. on PA emotional cues [5], [11], who pointed out that happy body postures had open characteristics, while frustrated body postures had closed characteristics. Additionally, in Chinese culture, ''both hands placed on the waist and body opened'' represented confidence and happiness. The 2D animated PA and its facial expressions and body postures were created using an animation production tool, for example, selecting the happy facial expression labeled ''happy,'' which had the characteristic of a smile. In terms of PA vocal tone, Lawson and Mayer found that voice effectively conveyed PA emotions [36]. Moreover, Ba et al. synthesized PA's positive voice using a speech synthesis platform [34]. Referring to these studies, this study used a speech synthesis platform. The same female character was used, only changing the tone (respectively selecting the emotional options of ''happy'' and ''frustrated''), producing two different voices.

Additionally, because previous studies had relatively few design references regarding the similarities in clothing and grooming styles between PAs and female learners, we mainly referred to the opinions of the target group (female undergraduates from China). We engaged in discussions with female undergraduate students to design PAs with high and low similarity to the clothing and grooming styles of female learners. They had not participated in any experiments of this study. The PA with high similarity had a black, straight high ponytail, a pink hoodie, black pants, and pink sneakers. By contrast, the PA with low similarity had brown, wavy long hair, pearl stud earrings, a black scarf adorned with yellow hexagonal stars, a purple professional suit, and red high heels. We used an animation production tool to create the effects of these clothing and grooming styles. All visual effects are shown in Figure 2.

We recruited 20 female undergraduate students from a university in Wuhan, China, to test the effectiveness of PA emotional cues and similarity. These 20 participants were intended to validate the design of the PAs; they did not participate in the formal experiment. The total sample size of the formal experiment was 128 participants, and these 20 participants were not a subset of the 128 formal experiment participants. Referring to the experimental manipulation test by Pi et al. [19], each participant viewed each of the four videos in random order and subsequently rated the emotions of the PA as well as the perceived similarity. For the emotional assessment of the PA, each instructional video included two

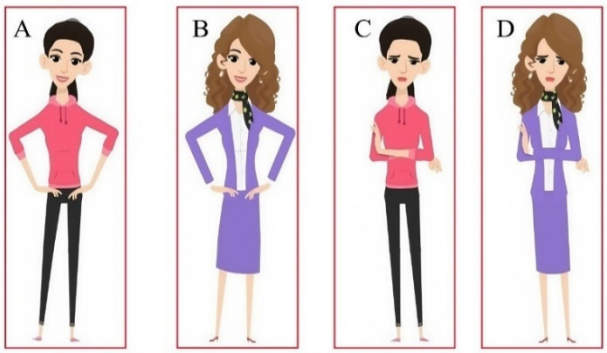


**FIGURE 2.** Examples of visual effects for different PAs: A showcases a PA with positive emotional cues and high similarity in clothing and grooming style; B exhibits a PA with positive emotional cues and low similarity in clothing and grooming style; C shows a PA with negative emotional cues and high similarity in clothing and grooming style; D displays a PA with negative emotional cues and low similarity in clothing and grooming style.

9-point Likert scale items: ''How happy was the PA in the video?'' and ''How frustrated was the PA in the video?''

There have been different perspectives regarding the applicability of parametric tests to ordinal data from Likert scales, each supported by its own theoretical basis and practical examples. This study used some parametric test methods (such as t-tests and ANOVA) on the ordinal data produced by Likert scales, mainly referring to relevant statistical theories and common research practices. First, in terms of statistics, Norman argues that when the sample size per group is sufficient (greater than 5 in the original text), t-tests and ANOVA can be used for ordinal data produced by Likert scales [37]. Norman's reason is as follows: First, t-tests and ANOVA are based on the assumption of normality of the distribution of means, not the normality of the data itself. The central limit theorem states that when the sample size per group is sufficient, regardless of the original distribution, the means are approximately normally distributed. Norman demonstrates through theory and cases that when the sample size is sufficient, t-tests and ANOVA do not require the normality assumption and produce nearly correct results even for obviously non-normal and asymmetric distributions (such as exponential distributions). Afterwards, Norman points out that the general belief that ordinal data produced by Likert scales cannot be used for t-tests and ANOVA mainly stems from the inability to assume normality of the data. However, analysis of variance, t-tests, and other tests of central tendency are highly robust to non-normality. The distribution shape of ordinal data observed from Likert scales often follows a non-normal distribution. Therefore, when the sample size per group is sufficient, ANOVA and t-test methods remain robust for the ordinal data produced by Likert scales. In our study, each group had a sufficient sample size (far greater than 5). Therefore, this study was applicable to such a situation. Second, regarding research cases, in relevant PA emotional cue studies, using t-tests and ANOVA on data produced by Likert scales was a relatively common method. Some studies similar to ours, for example, Pi et al. used ANOVA to analyze intergroup differences among different PA emotional cue groups [17]; Horovitz and Mayer also used ANOVA to analyze intergroup differences [4]; Pi et al. used t-tests to verify the validity of the PA emotional cue design [19]. We referred to these studies.

The results of the paired-sample t-tests indicated that the happiness ratings for the two PAs manipulated as happy were significantly higher than their frustration ratings ($t(19) = 13.709$, $p < .001$, 95% CI [4.787, 6.513]; $t(19) = 22.584$, $p < .001$, 95% CI [5.036, 6.064]). Conversely, the frustration ratings for the two PAs manipulated as frustrated were significantly higher than their happiness ratings ($t(19) = 10.903$, $p < .001$, 95% CI [4.404, 6.496]; $t(19) = 5.295$, $p < .001$, 95% CI [2.207, 5.093]). Therefore, the manipulation of the PAs' positive (happy) and negative (frustrated) emotional cues was successful. For the similarity assessment of PA clothing and grooming styles, each instructional video included a 9-point Likert scale item inquiring about similarity. The results of the paired-sample t-tests indicated that under the happy PA condition, the similarity ratings for the PA manipulated with high similarity were significantly higher than those for the PA manipulated with low similarity ($t(19) = 2.629$, $p = .017$, 95% CI [0.326, 2.874]). Under the frustrated PA condition, the similarity ratings for PA manipulated with high similarity were also significantly higher than those for PA manipulated with low similarity ($t(19) = 2.247$, $p = .037$, 95% CI [0.072, 2.028]). Therefore, the manipulation of the similarity between PAs and female learners in terms of clothing and grooming styles was successful. Overall, the manipulation of independent variables was considered successful.

### C. INSTRUMENTS

#### 1) PERCEPTION OF EMOTIONS TOWARD PAS

The measurement items for perceptions of emotions toward PAs were adapted from the Positive and Negative Affect Scale (PANAS; [38]). We added ''PA'' to the front of each word in the positive and negative affect scales, resulting in 10 items for perceived positive emotions of the PA (Cronbach's alpha = 0.905) and 10 items for perceived negative emotions of the PA (Cronbach's alpha = 0.917). Each item was rated on a 5-point Likert scale ranging from 1 (not at all) to 5 (very much). The average value of each type of item represented the perceived positive and negative emotion scores of the PA, respectively. For example, each participant's score for perception of positive emotions toward PAs was the average of the 10 items it contained, and this average was used for data analysis. In research practice, there were different methodological approaches to operationalizing latent variables, such as the use of Structural Equation Modeling (SEM) or the calculation of item means. In this study, the reasons for selecting the method of mean values to operationalize latent variables (e.g., perception of positive emotions toward PAs) included research conventions, reliability support, and goal fit. First, this approach was a relatively common

method in related PA emotional cue studies. For example, in Wang et al.'s study [13], each person's extraneous cognitive load (ECL) score was the average of the scores of items ECL contained, and the average was used for data analysis. Second, both types reported high Cronbach's alpha coefficients, indicating high consistency among items. This meant that using the mean to operationalize the latent variable had relatively sufficient reliability support. Moreover, our latent variable structure was simple, and the goal was to compare group differences rather than complex effects (e.g., mediation effects). Using the mean fitted the current objective. Therefore, employing the mean method was a reasonable operational choice in this study.

#### 2) EMOTIONS

This study used the PANAS [38] to measure participants' emotions. In this survey, participants were asked to rate the extent of 10 positive emotions (before watching: Cronbach's alpha = 0.854; after watching: Cronbach's alpha = 0.893) and 10 negative emotions on a five-point Likert scale (before watching: Cronbach's alpha = 0.872; after watching: Cronbach's alpha = 0.850), with each item rated from 1 (not at all) to 5 (very much). The scale was administered before and after watching the instructional videos. The average value of each item type represented their positive and negative emotion scores, respectively. For example, each participant's score for positive emotions was the average of the scores of the 10 items positive emotions contained. This average was used for subsequent data analysis.

#### 3) MOTIVATION

The Motivation Scale [39] was used to measure participants' motivation. It consisted of eight items (Cronbach's alpha = 0.954), with each item rated from 1 (strongly disagree) to 7 (strongly agree). Each participant's score for motivation was the average of the scores of the 8 items motivation contained. This average was used for subsequent data analysis.

#### 4) COGNITIVE LOAD

We used Leppink et al.'s 11-point Likert scale [40] to measure the cognitive load. The scale consisted of three components: Intrinsic Cognitive Load (ICL, three items, Cronbach's alpha = 0.884), Extraneous Cognitive Load (ECL, three items, Cronbach's alpha = 0.870), and Germane Cognitive Load (GCL, four items, Cronbach's alpha = 0.924). Each item was rated on a scale from 0 (not at all the case) to 10 (completely the case). The average score of each subscale was used as the cognitive load score for that subscale for each participant. For example, each participant's score for ICL was the average of the scores of the 3 items ICL contained. This average was used for subsequent data analysis.

#### 5) PERCEIVED SOCIAL CONNECTIONS WITH PA

The Agent Persona Instrument (API; [41]) was used to assess participants' perceived social connections with the PA [24]. It consisted of four subscales: facilitating learning (10 items, Cronbach's alpha = 0.917), credible (5 items, Cronbach's alpha = 0.862), human-like (5 items, Cronbach's alpha = 0.749), and engaging (5 items, Cronbach's alpha = 0.882). The score for each item ranged from 1 (strongly disagree) to 5 (strongly agree). The average score of each subscale was used as the assessment score for that subscale for each participant. For example, each participant's score for "credible" was the average of the scores of the 5 items "credible" contained. This average was used for subsequent data analysis.

#### 6) PRIOR KNOWLEDGE ASSESSMENT

We developed a prior knowledge test (Cronbach's alpha = 0.736) based on the instructional content to assess participants' prior knowledge. Specifically, it consisted of 14 open-ended questions with each question worth 1 point, and the answers were derived from the instructional content. Participants were informed that if they did not know the answer, they could respond with "I don't know." The maximum possible score was 14 points.

#### 7) LEARNING ASSESSMENT

The learning assessment consisted of 20 questions. Based on the tests conducted by Lawson and Mayer regarding the effects of PA guidance [24], our learning assessment included remembering, understanding, applying, and evaluating.

The test consisted of 14 multiple-choice questions and six open-ended questions, with each multiple-choice question having only one correct option. We included an "I don't know" option for multiple-choice questions and instructions to write "I don't know" for open-ended questions to prevent participants from guessing the answers. Each question was worth 1 point, with a maximum total score of 20 points. Cronbach's alpha for this assessment was 0.61, and the reason for the lower coefficient was consistent with previous research [5], [11], [24]. The test evaluated different levels of learning objectives, including remembering, understanding, applying, and evaluating. The test comprised various types of questions to gain a deeper understanding of the participants' learning of materials. This diversity of items might have provided a broader assessment, leading to a lower alpha.

### D. PROCEDURE

The survey was administered online. Participants accessed materials such as videos and scales through a link provided by Wenjuanxing (a website for online surveys). Once they indicated their readiness for the experiment and reported their voluntary participation, the experiment commenced. First, they completed their age, pretest PANAS, and prior knowledge assessment. Subsequently, they received a link to the video and were required to watch the instructional video in its entirety. Afterward, they completed the following scales or assessments: perception of PA emotions, post-test PANAS, motivation, cognitive load, perceived social connection with the PA, and learning assessment. The total duration of the experiment was approximately 30 minutes. In order to minimize participants' tendency to respond in ways they

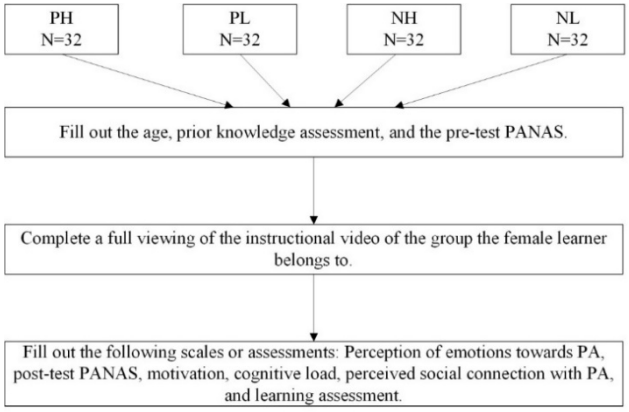


**FIGURE 3.** Procedure of the experiment.

believed aligned with the researchers' hypotheses and to obtain authentic responses from participants, we took several precautions. First, since the experiment was a between-subjects design, each participant only received the video link for their own group and did not receive video links for other groups. For example, participants in the PH group received the teaching video link for the PH group but did not receive the teaching video links for the PL, NH, or NL groups. This approach ensured that each group's participants could only watch the videos of their own group, thereby minimizing participants' awareness of the stark contrasts between the teaching videos of different groups. Second, neutral language was used in the relevant experimental instructions, and no labels such as ''emotion'' or ''similarity'' were present. This measure aimed to minimize participants' awareness of the design purposes of each group. Additionally, we explicitly informed participants that there were no right or wrong answers in all scales, and that they should answer truthfully. This approach aimed to obtain learners' genuine responses as much as possible. The experimental procedure is illustrated in Figure 3.

## IV. RESULTS

### A. DATA PROCESSING RESULTS

Table 1 presents the descriptive statistics for all variables under the four conditions. To ensure that the differences in the experimental results were not due to variations in the participants' ages, pre-test emotional states, or prior knowledge, we conducted a one-way analysis of variance (ANOVA) on these factors [17]. The results indicated no significant differences in age, pre-test positive and negative emotional states, and prior knowledge across the four conditions ($F(3, 124) = 0.804$, $p = .494$, $\eta_p^2 = 0.019$; $F(3, 124) = 0.100$, $p = .960$, $\eta_p^2 = 0.002$; $F(3, 124) = 2.397$, $p = .071$, $\eta_p^2 = 0.055$; $F(3, 124) = 0.155$, $p = .926$, $\eta_p^2 = 0.004$), suggesting that covariates were not necessary for analysis. Next, we conducted a two-way ANOVA on the other dependent variables. The results are summarized in Table 2 .

### B. PERCEPTION OF EMOTION TOWARD THE PA

Female learners who viewed positive emotional cues from the PA ($M = 3.206$, $SD = 0.696$) reported significantly higher scores in terms of perceiving positive emotions toward the PA compared to those who viewed negative emotional cues ($M = 2.081$, $SD = 0.807$) ($F(1, 124) = 71.270$, $p < .001$, $\eta_p^2 = 0.365$). Female learners who viewed positive emotional cues in the PA ($M = 1.136$, $SD = 0.334$) had significantly lower levels of perceived negative emotions toward the PA than those who viewed negative emotional cues ($M = 2.136$, $SD = 0.836$) ($F(1,124) = 78.659$, $p < .001$, $\eta_p^2 = 0.388$). Regarding female learners' perceptions of positive and negative emotions toward the PA, the main effect of similarity and its interaction effect with emotional cues were not significant.

### C. EMOTIONS

Regarding post-test positive emotions, female learners who viewed the PA's positive emotional cues had significantly higher positive emotions ($M = 2.848$, $SD = 0.838$) than those who viewed the PA's negative emotional cues ($M = 2.409$, $SD = 0.768$) ($F(1,124) = 9.483$, $p = .003$, $\eta_p^2 = 0.071$). Regarding post-test negative emotions, female learners who viewed the PA's positive emotional cues had significantly lower negative emotions ($M = 1.291$, $SD = 0.471$) than those who viewed the PA's negative emotional cues ($M = 1.513$, $SD = 0.564$) ($F(1,124) = 5.744$, $p = .018$, $\eta_p^2 = 0.044$). Regarding post-test positive and negative emotions, the main effect of the similarity and its interaction effect with the PA's emotional cues were not significant.

### D. MOTIVATION

Female learners who viewed the PA's positive emotional cues exhibited significantly higher motivation ($M = 4.719$, $SD = 1.294$) than those who viewed the PA's negative emotional cues ($M = 3.328$, $SD = 1.568$) ($F(1,124) = 29.803$, $p < .001$, $\eta_p^2 = 0.194$). The main effect of the similarity and its interaction effect with PA emotional cues were not significant.

### E. COGNITIVE LOAD

The results of the two-way ANOVA for the ICL and GCL indicated that the main effects of emotional cues and the similarity and their interaction effects were not significant. The results of the two-way ANOVA for ECL revealed that female learners who viewed the PA's positive emotional cues had significantly lower ECL scores ($M = 1.755$, $SD = 0.984$) than those who viewed the PA's negative emotional cues ($M = 2.698$, $SD = 1.664$) ($F(1,124) = 15.197$, $p < .001$, $\eta_p^2 = 0.109$). The main effect of the similarity and its interaction effect with the PA's emotional cues were not significant.

### F. PERCEIVED SOCIAL CONNECTIONS WITH PA

In terms of facilitating learning, female learners who viewed the PA's positive emotional cues had significantly higher facilitating learning scores ($M = 3.395$, $SD = 0.812$) than those who viewed the PA's negative emotional cues

**TABLE 1.** Mean and standard deviation of all variables under the four conditions.

| Variable | Positive emotional cues | | Negative emotional cues | |
|---|---|---|---|---|
| | High similarity (M±SD) | Low similarity (M±SD) | High similarity (M±SD) | Low similarity (M±SD) |
| Age | 19.188±1.091 | 19.188±1.091 | 19.500±1.078 | 19.469±1.077 |
| Pre-test positive emotions | 2.938±0.807 | 2.881±0.643 | 2.841±0.771 | 2.881±0.610 |
| Pre-test negative emotions | 1.659±0.692 | 1.688±0.716 | 1.363±0.402 | 1.716±0.534 |
| Prior knowledge | 2.656±1.945 | 2.312±2.055 | 2.188±2.070 | 2.250±2.140 |
| Perceived positive emotions of the PA | 3.309±0.688 | 3.103±0.700 | 1.994±0.693 | 2.169±0.910 |
| Perceived negative emotions of the PA | 1.194±0.425 | 1.078±0.198 | 2.213±0.895 | 2.059±0.779 |
| Post-test positive emotions | 2.931±0.899 | 2.766±0.777 | 2.344±0.759 | 2.475±0.784 |
| Post-test negative emotions | 1.275±0.398 | 1.306±0.540 | 1.494±0.589 | 1.531±0.548 |
| Motivation | 4.789±1.390 | 4.648±1.209 | 3.129±1.531 | 3.527±1.603 |
| ICL | 4.042±1.726 | 3.635±2.093 | 3.250±1.657 | 4.104±2.095 |
| ECL | 1.667±0.943 | 1.844±1.030 | 2.490±1.760 | 2.906±1.562 |
| GCL | 8.805±1.577 | 8.641±1.555 | 8.492±1.586 | 8.406±1.604 |
| Facilitating learning | 3.441±0.902 | 3.350±0.724 | 2.569±0.934 | 2.803±0.905 |
| Credible | 3.419±1.013 | 3.075±0.780 | 2.569±0.900 | 2.738±0.991 |
| Human-like | 2.338±1.085 | 1.944±0.945 | 1.825±0.507 | 2.063±0.684 |
| Engaging | 2.994±1.133 | 2.669±0.940 | 1.894±0.913 | 1.931±0.755 |
| Learning outcomes | 14.344±2.801 | 14.594±2.326 | 14.875±2.121 | 14.750±3.005 |

($M = 2.686$, $SD = 0.920$) ($F(1,124) = 21.279$, $p < .001$, $\eta_p^2 = 0.146$). In terms of credibility, female learners who viewed the PA's positive emotional cues had significantly higher scores ($M = 3.247$, $SD = 0.913$) than those who viewed the PA's negative emotional cues ($M = 2.653$, $SD = 0.943$) ($F(1,124) = 13.171$, $p < .001$, $\eta_p^2 = 0.096$). In terms of being engaging, female learners who viewed the PA's positive emotional cues had significantly higher scores ($M = 2.831$, $SD = 1.046$) than those who viewed the PA's negative emotional cues ($M = 1.913$, $SD = 0.831$) ($F(1,124) = 30.258$, $p < .001$, $\eta_p^2 = 0.196$). Regarding each of the three terms mentioned above, the main effect of the similarity and its interaction effect with the PA's emotional cues were not significant.

In terms of human-like characteristics, the results of the two-way ANOVA indicated that the main effects of emotional cues and similarities were not significant. However, the interaction effect was significant ($F(1,124) = 4.559$, $p = .035$, $\eta_p^2 = 0.035$). The simple effects analysis showed that under conditions of high similarity, the human-like scores for the PA displaying positive emotional cues were significantly higher than those for the PA displaying negative emotional cues ($F(1,124) = 6.010$, $p = .016$, $\eta_p^2 = 0.046$). By contrast, under low similarity conditions, there was no significant difference between the two groups ($F(1,124) = 0.323$, $p = .571$, $\eta_p^2 = 0.003$).

### G. LEARNING OUTCOMES

The main effects of emotional cues, the main effect of similarity, and the interaction effect were not significant.

## V. DISCUSSION

Based on the research results, the following discussion targeted the research questions.

As for learning process experiences (RQ1), our research indicated that compared to viewing the PA's negative emotional cues, female learners who viewed positive emotional cues perceived higher levels of positive emotions and lower levels of negative emotions, experienced higher positive emotions and lower negative emotions, exhibited higher motivation, experienced lower extraneous cognitive load, and had a stronger social connection with the PA (facilitating learning, credibility, and being engaging), resulting in a better learning process experience. The findings related to female learners' perceptions of the PA's emotions are consistent with those of some previous studies (with mixed-gender samples) [4], [5], [24]. This suggests that female learners can identify a PA's emotional stance. Furthermore, similar to the theory of emotional contagion in interpersonal communication [42], the PA's positive emotions can lead to an increase in positive emotions among female learners, whereas negative emotions can lead to an increase in negative emotions among female learners. These findings regarding the emotional aspects of female learners are consistent with those of some previous studies (with mixed-gender samples) [4], [24]. Positive emotional cues from the PA can enhance positive emotions, and research had shown that positive emotions promoted motivation [10], [39]. Regarding the cognitive load, this study indicated that positive emotional cues reduced the ECL of female learners, supporting the findings of Beege and Schneider [14]. A possible explanation is derived from the positive emotion as a facilitator hypothesis [10], which suggests that

**TABLE 2.** Results of two-way analysis of variance.

| Dependent variables | Independent variables | Main effect | | Interaction effect | |
|---|---|---|---|---|---|
| | | F | $\eta_P^2$ | F | $\eta_P^2$ |
| Perceived positive emotions of the PA | Emotional cues | 71.270*** | 0.365 | 2.046 | 0.016 |
| | Similarity | 0.014 | 0.000 | | |
| Perceived negative emotions of the PA | Emotional cues | 78.659*** | 0.388 | 0.028 | 0.000 |
| | Similarity | 1.420 | 0.011 | | |
| Post-test Positive emotions | Emotional cues | 9.483** | 0.071 | 1.084 | 0.009 |
| | Similarity | 0.015 | 0.000 | | |
| Post-test Negative emotions | Emotional cues | 5.744* | 0.044 | 0.001 | 0.000 |
| | Similarity | 0.138 | 0.001 | | |
| Motivation | Emotional cues | 29.803*** | 0.194 | 1.120 | 0.009 |
| | Similarity | 0.256 | 0.002 | | |
| ICL | Emotional cues | 0.230 | 0.002 | 3.506 | 0.027 |
| | Similarity | 0.443 | 0.004 | | |
| ECL | Emotional cues | 15.197*** | 0.109 | 0.245 | 0.002 |
| | Similarity | 1.507 | 0.012 | | |
| GCL | Emotional cues | 0.958 | 0.008 | 0.020 | 0.000 |
| | Similarity | 0.200 | 0.002 | | |
| Facilitating learning | Emotional cues | 21.279*** | 0.146 | 1.117 | 0.009 |
| | Similarity | 0.218 | 0.002 | | |
| Credible | Emotional cues | 13.171*** | 0.096 | 2.453 | 0.019 |
| | Similarity | 0.286 | 0.002 | | |
| Human-like | Emotional cues | 1.774 | 0.014 | 4.559* | 0.035 |
| | Similarity | 0.279 | 0.002 | | |
| Engaging | Emotional cues | 30.258*** | 0.196 | 1.178 | 0.009 |
| | Similarity | 0.741 | 0.006 | | |
| Learning outcomes | Emotional cues | 0.565 | 0.005 | 0.168 | 0.001 |
| | Similarity | 0.019 | 0.000 | | |

Note. Statistics are unstandardized coefficients. * $p < .05$, ** $p < .01$, *** $p < .001$.

positive emotions, rather than negative ones, enhance the task execution process [10], leading to fewer distractions and reducing adverse effects on learning [14], thereby resulting in lower ECL. Regarding the perception of social connection with the PA, female learners who viewed positive emotional cues from the PA provided higher ratings in terms of facilitating learning, credibility, and being engaging than those who viewed negative emotional cues. The findings for female learners in these three aspects are consistent with those of some previous studies (with mixed-gender samples) [5], [11]. Overall, the survey results of these learning process experiences support the CATLM [12] and the cognitive-affective model of e-learning [4], [5].

Regarding learning outcomes (RQ2), no significant differences in the learning outcomes of female learners who viewed negative emotional cues from PA compared to those who viewed positive emotional cues were observed. However, based on prior knowledge and learning outcomes, they achieved an improvement in their mastery of this part of their knowledge. The findings regarding female learners' learning outcomes were consistent with those of several previous studies (with mixed-gender samples) [4], [13], [24]. One possible explanation is that we employed immediate testing, whereas the effect of the PA's positive emotional cues on learning outcomes was more likely to manifest in delayed testing [5]. Another possible explanation is that our instructional videos were relatively short, whereas the PA's positive emotional cues were more likely to benefit long-term learning outcomes [43]. Another is the cultural influence. In Chinese educational culture, a belief that one should avoid allowing emotions to affect cognitive processing is common. For example, one should not lose control and act out of the ordinary because of happiness, and even when feeling depressed or down, one should maintain a firm will and ambition. Similar sentiments frequently appear in Chinese education, serving as a reminder to learners that they should not have let positive or negative emotions interfere with rational cognitive processing. Under the influence of this culture, these female learners might not have allowed fluctuations in positive or negative emotions to affect their learning outcomes.

Regarding RQ3, the impact of positive and negative emotional cues from the PA on the learning process experiences and outcomes of female learners typically did not depend on similarities in clothing and grooming styles between female learners and the PA. The PA with positive emotional cues was perceived as more human-like than the PA with negative emotional cues only when the similarity was high. This indicates that when considering the effects of the PA's positive and negative emotional cues on female learners, the similarity in clothing and grooming styles between female learners and PAs might not have played a moderating role in most aspects (e.g., females' positive emotions, motivation, learning outcomes), but it possibly exerted a moderating effect in certain specific aspects (e.g., females' evaluation of the human-like degree of PAs).

The possible reason for these results was that, for factors where no moderating effect of similarity was found (e.g., positive emotions, motivation), females' more sensitive perception and stronger reactions for emotional cues [6], [7], [8], [9] led to emotional cues having a deeper and more dominant impact. The main difference between the human-like degree of PA and factors without moderating effects was that the human-like degree of PA might have more easily prompted female learners to compare the female PA with themselves [15]. A high similarity in clothing and grooming styles might have led female learners to perceive the PA as more like themselves [28]. Therefore, they used themselves as the standard to evaluate ''human-like.'' Compared with negative emotional cues, the PA displaying positive emotional cues was closer to their usual or ideal state, resulting in higher scores in the ''human-like'' aspect.

## VI. CONCLUSION

In the field of PA emotional design, exploring the impact of a PA's emotional cues on specific gender groups and exploring the related regulatory factors is of great significance. This study investigated the effects of the PA's positive emotional cues on female learners' learning process experiences and outcomes compared to negative emotional cues, as well as whether the similarity in clothing and grooming styles between female learners and PAs moderated these effects. This study provided new insights by clarifying the differences in the effects of positive and negative emotional cues from PAs on female learners, and by identifying the boundary conditions under which the similarity in clothing and grooming styles between female learners and PAs moderated the influence of PA emotional cues on female learners.

First, previous studies had not fully clarified the precise differences in the effects of positive and negative emotional cues from PAs on female learners. Based on prior theoretical and empirical research, this study conducted a more comprehensive and integrated investigation into the influence of PA emotional cues on female learners. Although the conclusions drawn in this study (with a female-only sample) might be fundamentally consistent with some prior studies (with mixed-gender samples) [4], [11], [24], this study indeed revealed the differential impacts of positive and negative emotional cues from PAs on female learners' learning experience and outcomes. Specifically, this study indicated that the PA displaying positive emotional cues was perceived as having higher positive emotions and lower negative emotions and being more likely to facilitate learning, more credible, and more engaging compared to the PA displaying negative cues. Female learners in the positive emotional cue condition showed higher positive emotions and motivation and lower negative emotions and extraneous cognitive load, with no significant differences in learning outcomes compared with those in the negative cue condition.

Secondly, regarding the moderating factors of PA emotional cues on female learners, this study examined model-observer similarity, selecting the similarity in clothing and grooming styles between female learners and PAs. Since previous research had rarely investigated this moderating factor, the conclusions drawn from our experiment also added new insights. Specifically, in terms of the influence of PA emotional cues on female learners, the similarity in clothing and grooming styles between female learners and PAs did not moderate the following factors: perception of emotions toward PAs, emotions, motivation, cognitive load, learning outcomes, and evaluations of PAs in facilitating learning, being credible and engaging aspects. However, it had a moderating effect on the human-like degree of PAs. When the similarity in clothing and grooming styles was high, a PA displaying positive emotional cues was perceived by female learners as more human-like than a PA displaying negative emotional cues.

The theoretical or knowledge contribution of this study is that this study verified the applicability of previous findings on the influence of PA emotional cues within a specific gender group (female learners) and identified the boundary conditions of the moderating effect of the similarity in clothing and grooming styles between female learners and PAs. Regarding the influence of PA emotional cues, this study provided refined and direct knowledge targeted at the specific gender group (female learners), enriching the knowledge system of PA emotional cues directed at female learners. This also confirmed the basic applicability of some previous research conclusions [4], [11], [24] within the specific gender group (female learners) and further substantiated the findings of prior studies. This serves broader research objectives. First, it provides a research foundation for future studies to further explore the precise impact of PA emotional cues on female learners with different characteristics (such as varying personality traits). Second, it lays the groundwork for future research investigating the influence of PA emotional cues from a gender perspective, helping to examine whether gender is a key variable in the impact of PA emotional cues or to verify whether the effects of PA emotional cues are consistent across genders. Furthermore, this study identified the boundary conditions of the moderating effect of the similarity in clothing and grooming styles between female learners and PAs, specifying the exact range of when it is

effective or ineffective. Specifically, regarding the influence of PA emotional cues on female learners, the similarity in clothing and grooming styles did not exert a moderating effect on most factors (such as emotions and motivation). In these aspects, female learners were more likely influenced directly by the PA emotional cues themselves. However, PA emotional cues and the similarity in clothing and grooming styles jointly influenced female learners' evaluations of the human-like degree of PA. Positive emotional cues combined with high similarity were rated more favorably than negative emotional cues combined with high similarity.

The research conclusions have practical guiding value. These conclusions provide direct evidence and reference cases for the design of PAs aimed at female learners. For example, when designers aim to enhance female learners' positive emotions and motivation, designing PAs with positive emotional cues in facial expressions, body posture, and tone of voice may be more effective than using negative emotional cues. In addition, when designers focus on the learning outcomes of female learners, they may need to pay more attention to factors such as instructional strategies and knowledge presentation methods. Moreover, when designers consider female learners' emotions and motivation, they may not need to invest excessive resources in finely adjusting the PA's clothing and grooming styles to match female learners. This may provide design directions that avoid wasting resources and effort, reduce costs, and improve efficiency. Furthermore, PA appearance is recommended to be similar to the target user group [27], [33]. Therefore, designers may easily design PAs to be more similar to female learners in clothing and grooming styles, but it is necessary to note that in this case, PAs should display positive emotional cues rather than negative emotional cues. This is because it may affect female learners' perceived social connections with PA (for example, the human-like degree of PA). Perceived social connections with PA are an important factor because, according to the cognitive-affective model of e-learning [11], perceived social connections with PA may influence the level of effort put into learning.

This study acknowledges several limitations and outlines potential directions for future research. In terms of the design of PAs and their emotional cues, this study mainly referred to existing research to design a two-dimensional animated single PA with a combination of emotional cues in visual aspects (facial expressions, posture) and auditory aspects (tone of voice). The experimental results showed that these emotional cues effectively expressed the PA's happiness and frustration emotions and influenced learners' emotions. This indicates that these emotional cues capture part of the emotional communication. However, it needs to be emphasized that emotional expression in real environments has complexity and subtlety. For example, in real environments, regarding the types of emotional cues, real teachers express the same emotion in various ways; regarding the switching of emotional cues, real teachers often switch between different emotional cues; regarding subtlety, real teachers often show certain emotions through slight changes in facial muscles and eye gaze. Therefore, in future research, emotional cues can be designed to better fit real environments, such as realistic 3D PAs that switch among more types and more subtle emotional cues.

Moreover, we designed minimal, stylized cues (e.g., the PA's smile and clothing) aimed at female undergraduates from China in order to effectively manipulate the independent variables. This study clearly separated different levels of "PA emotional cues" and "the similarity in clothing and grooming styles between female learners and the PAs" to ensure internal validity, thereby examining their effects on emotions, motivation, and other factors. However, there are some potential limitations and directions for future research: although we took some precautions (e.g., explicitly informing participants that there were no right or wrong answers and encouraging honest responses), participants might still have guessed the researchers' hypotheses based on the characteristics of the current videos. As a result, they may have chosen to respond in self-reports in ways they thought aligned with the researchers' hypotheses rather than reflecting their true emotions, motivation, and other factors. In relevant research on PA emotional cues, many studies have used distinct and contrasting features [4], [17] to clearly separate different levels of PA emotions. In addition, self-report methods are also common data collection approaches in related PA emotional cue studies [4], [11]. In future research, to obtain participants' authentic emotional responses as much as possible, physiological indicators can be used as supplements or alternatives to self-report methods. For example, eye-tracking technology can be used to measure cognitive load, and electrodermal activity (EDA) can be used to measure emotional arousal.

Furthermore, to address the research questions, this study used a $2 \times 2$ between-subjects design and adopted binary contrasting emotional expressions and the similarity in clothing and grooming styles between female learners and PAs to draw conclusions. However, in this regard, the experimental design of this study has methodological limitations. In real teaching scenarios, emotional expression and perceived similarity exist on nuanced continua (for example, emotional valence such as from very unhappy to very happy, and emotional arousal such as from very slight to very intense; degrees of similarity such as 30%, 50%, 80%, etc.) and interact with learners' cultural backgrounds, individual differences (for example, different age groups and personalities), and other related factors. These limitations may affect the richness and depth of the research. First, the binary contrasting design may reduce the richness of the study. Dichotomous classification ignores intermediate states and

subtle variations, resulting in findings that cannot reflect possible gradient changes, intensity differences, or threshold effects in influences of emotion and similarity. Second, due to the lack of consideration for female learners' cultural backgrounds, individual differences, and other related factors, the depth of the research is limited. For example, the results cannot reflect the different effects of PA emotional cues

on female learners with different cultural backgrounds, age groups, or personality traits. Future research would benefit from employing more fine-grained, dimensional approaches that capture the complexity of these affective and perceptual processes. For example, multiple groups of PAs expressing different types of emotions and varying levels of perceived similarity will be designed, along with moderator variables such as age groups and other individual differences for analysis.

In addition, this study referred to relatively mature research cases [13], designed the duration of PA usage, and was conducted in a laboratory environment. The laboratory setting has limited ecological validity. In natural educational contexts, time is long-term and continuous, social interactions are highly complex (including teacher-student and peer interactions), and natural education is embedded within complex socio-cultural settings [5]. Therefore, our research conclusions need to be restricted to a narrow range of specific artificial settings, specifically those involving videos that are short, highly controlled, stylized, and non-interactive. This type of short video still has its applicable scope, such as brief explanatory videos targeting a small knowledge point on online platforms for female learners. The findings of this study provide theoretical knowledge or practical guidance for this type of educational scenario. Moreover, this study was conducted in a laboratory setting and was not used in natural teaching contexts. This also constitutes an important research topic for further exploration using other research methods in the future.

## REFERENCES


[1] S. Schneider, M. Beege, S. Nebel, L. Schnaubert, and G. D. Rey, "The cognitive-affective-social theory of learning in digital environments (CASTLE)," *Educ. Psychol. Rev.*, vol. 34, no. 1, pp. 1–38, Mar. 2022, doi: 10.1007/s10648-021-09626-5.

[2] U. C. Apoki, A. M. A. Hussein, H. K. M. Al-Chalabi, C. Badica, and M. L. Mocanu, "The role of pedagogical agents in personalised adaptive learning: A review," *Sustainability*, vol. 14, no. 11, p. 6442, May 2022, doi: 10.3390/su14116442.

[3] M. Beege, S. Schneider, S. Nebel, and G. D. Rey, "Does the effect of enthusiasm in a pedagogical agent's voice depend on mental load in the learner's working memory?" *Comput. Hum. Behav.*, vol. 112, Nov. 2020, Art. no. 106483, doi: 10.1016/j.chb.2020.106483.

[4] T. Horovitz and R. E. Mayer, "Learning with human and virtual instructors who display happy or bored emotions in video lectures," *Comput. Hum. Behav.*, vol. 119, Jun. 2021, Art. no. 106724, doi: 10.1016/j.chb.2021.106724.

[5] A. P. Lawson, R. E. Mayer, N. Adamo-Villani, B. Benes, X. Lei, and J. Cheng, "The positivity principle: Do positive instructors improve learning from video lectures?" *Educ. Technol. Res. Develop.*, vol. 69, no. 6, pp. 3101–3129, Oct. 2021, doi: 10.1007/s11423-021-10057-w.

[6] H. Hoffmann, H. Kessler, T. Eppel, S. Rukavina, and H. C. Traue, "Expression intensity, gender and facial emotion recognition: Women recognize only subtle facial emotions better than men," *Acta Psychol.*, vol. 135, no. 3, pp. 278–283, Nov. 2010, doi: 10.1016/j.actpsy.2010.07.012.

[7] R.-T. Sinvani, H. Fogel-Grinvald, and S. Sapir, "Self-rated confidence in vocal emotion recognition ability: The role of gender," *J. Speech, Lang., Hearing Res.*, vol. 67, no. 5, pp. 1413–1423, May 2024, doi: 10.1044/2024_jslhr-23-00373.

[8] P. Ohrmann, A. Pedersen, M. Braun, J. Bauer, H. Kugel, A. Kersting, K. Domschke, J. Deckert, and T. Suslow, "Effect of gender on processing threat-related stimuli in patients with panic disorder: Sex does matter," *Depression Anxiety*, vol. 27, no. 11, pp. 1034–1043, Nov. 2010, doi: 10.1002/da.20721.

[9] J. S. Stevens and S. Hamann, "Sex differences in brain activation to emotional stimuli: A meta-analysis of neuroimaging studies," *Neuropsychologia*, vol. 50, no. 7, pp. 1578–1593, Jun. 2012, doi: 10.1016/j.neuropsychologia.2012.03.011.

[10] J. L. Plass and S. Kalyuga, "Four ways of considering emotion in cognitive load theory," *Educ. Psychol. Rev.*, vol. 31, no. 2, pp. 339–359, Mar. 2019, doi: 10.1007/s10648-019-09473-5.

[11] A. P. Lawson, R. E. Mayer, N. Adamo-Villani, B. Benes, X. Lei, and J. Cheng, "Do learners recognize and relate to the emotions displayed by virtual instructors?" *Int. J. Artif. Intell. Educ.*, vol. 31, no. 1, pp. 134–153, Jan. 2021, doi: 10.1007/s40593-021-00238-2.

[12] R. Moreno and R. Mayer, "Interactive multimodal learning environments," *Educ. Psychol. Rev.*, vol. 19, no. 3, pp. 309–326, Jun. 2007, doi: 10.1007/s10648-007-9047-2.

[13] Y. Wang, X. Feng, J. Guo, S. Gong, Y. Wu, and J. Wang, "Benefits of affective pedagogical agents in multimedia instruction," *Frontiers Psychol.*, vol. 12, Feb. 2022, Art. no. 797236, doi: 10.3389/fpsyg.2021.797236.

[14] M. Beege and S. Schneider, "Emotional design of pedagogical agents: The influence of enthusiasm and model-observer similarity," *Educ. Technol. Res. Develop.*, vol. 71, no. 3, pp. 859–880, Mar. 2023, doi: 10.1007/s11423-023-10213-4.

[15] C. Coelho, P. Machado, B. Machado, and S. Gonçalves, "Appearance comparisons, affect, body dissatisfaction and eating pathology in Portuguese female university students," *Nutrients*, vol. 15, no. 11, p. 2484, May 2023, doi: 10.3390/nu15112484.

[16] T. Stolovy, "Befriending the body through clothes: The role of clothing in secular and religious women's body appreciation," *Frontiers Psychol.*, vol. 15, May 2024, Art. no. 1297663, doi: 10.3389/fpsyg.2024.1297663.

[17] Z. Pi, W. Liu, H. Ling, X. Zhang, and X. Li, "Does an instructor's facial expressions override their body gestures in video lectures?" *Comput. Educ.*, vol. 193, Feb. 2023, Art. no. 104679, doi: 10.1016/j.compedu.2022.104679.

[18] T. W. Liew, S.-M. Tan, and S. N. Kew, "Can an angry pedagogical agent enhance mental effort and learning performance in a multimedia learning environment?" *Inf. Learn. Sci.*, vol. 123, no. 9, pp. 555–576, May 2022, doi: 10.1108/ils-09-2021-0079.

[19] Z. Pi, R. Liu, H. Ling, X. Zhang, S. Wang, and X. Li, "The emotional design of an instructor: Body gestures do not boost the effects of facial expressions in video lectures," *Interact. Learn. Environ.*, vol. 32, no. 3, pp. 952–971, Mar. 2024, doi: 10.1080/10494820.2022.2105898.

[20] F. Buttussi and L. Chittaro, "Humor and fear appeals in animated pedagogical agents: An evaluation in aviation safety education," *IEEE Trans. Learn. Technol.*, vol. 13, no. 1, pp. 63–76, Jan. 2020, doi: 10.1109/TLT.2019.2902401.

[21] T. W. Liew, S.-M. Tan, W. M. Pang, M. T. I. Khan, and S. N. Kew, "I am Alexa, your virtual tutor!: The effects of Amazon Alexa's text-to-speech voice enthusiasm in a multimedia learning environment," *Educ. Inf. Technol.*, vol. 28, no. 2, pp. 1455–1489, Feb. 2023, doi: 10.1007/s10639-022-11255-6.

[22] J. Sweller, "Element interactivity and intrinsic, extraneous, and germane cognitive load," *Educ. Psychol. Rev.*, vol. 22, no. 2, pp. 123–138, Apr. 2010, doi: 10.1007/s10648-010-9128-5.

[23] T. W. Liew, N. A. M. Zin, and N. Sahari, "Exploring the affective, motivational and cognitive effects of pedagogical agent enthusiasm in a multimedia learning environment," *Human-centric Comput. Inf. Sci.*, vol. 7, no. 1, pp. 1–21, May 2017, doi: 10.1186/s13673-017-0089-2.

[24] A. P. Lawson and R. E. Mayer, "Does the emotional stance of human and virtual instructors in instructional videos affect learning processes and outcomes?" *Contemp. Educ. Psychol.*, vol. 70, Jul. 2022, Art. no. 102080, doi: 10.1016/j.cedpsych.2022.102080.

[25] N. C. Kraemer, B. Karacora, G. Lucas, M. Dehghani, G. Ruether, and J. Gratch, "Closing the gender gap in STEM with friendly male instructors? On the effects of rapport behavior and gender of a virtual agent in an instructional interaction," *Comput. Educ.*, vol. 99, pp. 1–13, Aug. 2016, doi: 10.1016/j.compedu.2016.04.002.

[26] D. H. Schunk, A. R. Hanson, and P. D. Cox, "Peer-model attributes and children's achievement behaviors," *J. Educ. Psychol.*, vol. 79, no. 1, pp. 54–61, Mar. 1987, doi: 10.1037/0022-0663.79.1.54.

[27] A. L. Baylor, "The design of motivational agents and avatars," *Educ. Technol. Res. Develop.*, vol. 59, no. 2, pp. 291–300, Feb. 2011, doi: 10.1007/s11423-011-9196-3.

[28] A. L. Baylor, "Promoting motivation with virtual agents and avatars: Role of visual presence and appearance," *Phil. Trans. Roy. Soc. B, Biol. Sci.*, vol. 364, no. 1535, pp. 3559–3565, Dec. 2009, doi: 10.1098/rstb.2009.0148.
[29] R. B. Rosenberg-Kima, A. L. Baylor, E. A. Plant, and C. E. Doerr, "Interface agents as social models for female students: The effects of agent visual presence and appearance on female students' attitudes and beliefs," *Comput. Hum. Behav.*, vol. 24, no. 6, pp. 2741–2756, Sep. 2008, doi: 10.1016/j.chb.2008.03.017.
[30] Y. Kim and Q. Wei, "The impact of learner attributes and learner choice in an agent-based environment," *Comput. Educ.*, vol. 56, no. 2, pp. 505–514, Feb. 2011, doi: 10.1016/j.compedu.2010.09.016.
[31] V. Hoogerheide, M. van Wermeskerken, H. van Nassau, and T. van Gog, "Model-observer similarity and task-appropriateness in learning from video modeling examples: Do model and student gender affect test performance, self-efficacy, and perceived competence?" *Comput. Hum. Behav.*, vol. 89, pp. 457–464, Dec. 2018, doi: 10.1016/j.chb.2017.11.012.
[32] J. N. Bailenson, J. Blascovich, and R. E. Guadagno, "Self-representations in immersive virtual environments," *J. Appl. Social Psychol.*, vol. 38, no. 11, pp. 2673–2690, Oct. 2008, doi: 10.1111/j.1559-1816.2008.00409.x.
[33] Y. Kim and A. L. Baylor, "Research-based design of pedagogical agent roles: A review, progress, and recommendations," *Int. J. Artif. Intell. Educ.*, vol. 26, no. 1, pp. 160–169, Mar. 2016, doi: 10.1007/s40593-015-0055-y.
[34] S. Ba, D. Stein, Q. Liu, T. Long, K. Xie, and L. Wu, "Examining the effects of a pedagogical agent with dual-channel emotional cues on learner emotions, cognitive load, and knowledge transfer performance," *J. Educ. Comput. Res.*, vol. 59, no. 6, pp. 1114–1134, Oct. 2021.
[35] C. Qi, M. Li, Q. Wang, H. Zhang, J. Xing, Z. Gao, and H. Zhang, "Facial expressions recognition based on cognition and mapped binary patterns," *IEEE Access*, vol. 6, pp. 18795–18803, 2018, doi: 10.1109/ACCESS.2018.2816044.
[36] A. P. Lawson and R. E. Mayer, "The power of voice to convey emotion in multimedia instructional messages," *Int. J. Artif. Intell. Educ.*, vol. 32, no. 4, pp. 971–990, Oct. 2021, doi: 10.1007/s40593-021-00282-y.
[37] G. Norman, "Likert scales, levels of measurement and the 'laws' of statistics," *Adv. Health Sci. Educ.*, vol. 15, no. 5, pp. 625–632, Feb. 2010, doi: 10.1007/s10459-010-9222-y.
[38] D. Watson, L. A. Clark, and A. Tellegen, "Development and validation of brief measures of positive and negative affect: The PANAS scales," *J. Personality Social Psychol.*, vol. 54, no. 6, pp. 1063–1070, 1988, doi: 10.1037//0022-3514.54.6.1063.
[39] A. M. Isen and J. Reeve, "The influence of positive affect on intrinsic and extrinsic motivation: Facilitating enjoyment of play, responsible work behavior, and self-control," *Motivat. Emotion*, vol. 29, no. 4, pp. 295–323, Dec. 2005, doi: 10.1007/s11031-006-9019-8.
[40] J. Leppink, F. Paas, C. P. M. Van der Vleuten, T. Van Gog, and J. J. G. Van Merriënboer, "Development of an instrument for measuring different types of cognitive load," *Behav. Res. Methods*, vol. 45, no. 4, pp. 1058–1072, Apr. 2013, doi: 10.3758/s13428-013-0334-1.
[41] A. L. Baylor and J. Ryu, "The API (Agent persona instrument) for assessing pedagogical agent persona," in *Proc. Media Innovate Learn.*, Honolulu, HI, USA, 2003, pp. 448–451.
[42] E. Hatfield, J. T. Cacioppo, and R. L. Rapson, "Emotional contagion," *Curr. Dir. Psychol. Sci.*, vol. 2, no. 3, pp. 96–100, 1993.
[43] T. Endres, S. Weyreter, A. Renkl, and A. Eitel, "When and why does emotional design foster learning? Evidence for situational interest as a mediator of increased persistence," *J. Comput. Assist. Learn.*, vol. 36, no. 4, pp. 514–525, Feb. 2020, doi: 10.1111/jcal.12418.

**QINGTANG LIU** (Member, IEEE) was born in Hubei, China, in 1969. He received the Ph.D. degree in electronic information engineering from Huazhong University of Science and Technology, Wuhan, in 2005.

He is currently a Professor with Central China Normal University. His current research interests include pedagogical agent and digital learning. He is a member of ISO/IEC JTC1 SC36, AVS Standard Organization, the National Beacon Committee Education Technology Sub-Technical Committee (CELTSC), and ACM.

**TIANSHENG CAO** was born in Xinyang, Henan, China, in 1994. He received the master's degree in educational technology from Henan Normal University, Xinxiang, China, in 2020. He is currently pursuing the Ph.D. degree with Central China Normal University, Wuhan, China. His research interest includes pedagogical agent.

**LINJING WU** was born in Hubei, China, in 1987. She received the Bachelor of Science degree from Hubei University, China, in June 2007, and the Ph.D. degree in science from the Education Information Technology Research Center, Central China Normal University, China, in June 2013. She is currently teaching with Central China Normal University, as an Associate Professor and a Doctoral Supervisor. She has published over 60 papers in domestic and foreign journals and international academic conferences and applied for four national invention patents and obtained four software copyrights. Her research interests include artificial intelligence and educational applications.

**FENGJUAN CHEN** was born in Xuchang, Henan, China, in 1990. She received the master's degree in educational technology from Central China Normal University, Wuhan, China, in 2016, where she is currently pursuing the Ph.D. degree. Her research interest includes intelligent tutoring.

**RUIQIU YE** was born in Xiaogan, Hubei, China, in 2000. She received the bachelor's degree in intelligent science and technology from Wuhan Institute of Technology, Wuhan, China, in 2022. She is currently pursuing the Ph.D. degree with Central China Normal University, Wuhan. Her research interest includes virtual mentor.