Effects of Pedagogical Agent's Personality and Emotional Feedback Strategy on Chinese Students' Learning Experiences and Performance: A Study Based on Virtual Tai Chi Training Studio

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Figure 1.Virtual Tai Chi training studio. Left: the animated trainer. Right: a learner in the actual studio.

ABSTRACT

In virtual learning environment, both personality and emotional features of animated pedagogical agents (APAs) may influence learning. To investigate this question, we developed four APAs with two distinct personality types and two sets of gestures expressing distinct emotional feedback. Effects of APAs' personality types and emotional feedback strategies on learning experiences and performance were assessed experimentally using a virtual Tai Chi training system. Fifty six participants completed the experiment. Results showed that positive emotional feedback strategy led to better learning experiences and performance than negative feedback strategy. Moreover, personality type had significant effect on learning. Choleric APAs led to better performance than Phlegmatic APAs.

Personality types moderated the effect of emotional feedback on learning satisfaction. Our study demonstrates that APAs with distinct personality types and emotional feedback are important design parameters for virtual learning environments.

Author Keywords

Personality; emotional feedback; pedagogical agent; virtual Tai Chi training; learning experience.

ACM Classification Keywords

J.4. [Computer Applications]: Social and Behavioral Sciences - Psychology.

INTRODUCTION

In recent years, there is an increased interest in the potential of animated pedagogical agents (APAs) in virtual learning environments. APAs are animated life-like characters designed to enhance learning performance and/or motivation by simulating social interaction with a learner [30]. They can provide instructional information to learners [35]. Moreover, they have significant potential to evoking social and emotional responses through verbal and nonverbal forms in human–computer interaction [30]. Previous studies revealed that the presence of an APA in a multimedia environment led to positive learning effects, which has been known as "persona effect" [16, 29, 47].

In order to maximize the potential of APA's, it is necessary to investigate the factors (e.g., the social-emotional factors) of APAs that can promote learning. Given that emotion influences an individual's rational thinking, social memory, judgments, and learning [22], emotional feedback is often considered as a key social-emotional factor for generating a "believable" agent. Emotional feedback is provided for learners to regulate their emotional states towards learning. Previous studies investigated the implementation and evaluation of emotional feedback strategies, as well as its effect on learners' behavioral intention and acceptance of E-learning system [7, 10, 15, 45, 50]. However, to the best of our knowledge, previous studies did not connect the use of emotional feedback with the flow-experience. Flow is a state in which an individual is completely immersed in an activity without reflective self-consciousness but with a deep sense of control. It represents a highly enjoyable mental state where the individual is fully immersed and engaged in the process of activity [12] [50]. It is a key component to evaluate user experience. Moreover, how different types of emotional feedback of APAs affect learning is not clear.

Another important social-emotional feature is personality. Agents are considered "believable" when they are perceived to possess the qualities and behaviors typical of different personality types [37]. Some researchers investigated the personality of APAs. Most of these papers describe ways to add personality to agents; few of them investigated how users respond to the personality of agents [2, 37, 43]. A recent study investigated the effect of agent's personality on user experience [13]. However, it is not in the context of a virtual learning environment thus the impact of this factor on learning was not investigated.

In the present study, we have constructed a virtual3D Tai Chi training studio (see Figure 1) in which APAs are used to provide instruction. The personality characteristics and emotional feedback of APAs were designed in detail. The APAs' appearance, behavioral and verbal features were designed to be related to a specific personality type. In addition, the APA's head and hand movements, as well as verbal contents were related to a defined emotional feedback. The potential effects of these properties on learning in virtual Tai Chi training system were systematically examined and assessed in the current study.

This paper makes the following contributions:

(1) We describe a set of methods for designing APAs with credible personalities and emotional feedback and a complete Tai Chi training studio employing such APAs.

(2) We carried out a systematic examination on the effects of APAs' personality types and emotional feedback strategies on learning experiences and learning performance. The outcome of this research can help designers of future virtual learning environments to parameterize APA characteristics.

The remainder of the paper is organized as follows: First, we briefly review related work. Secondly, we present the design, development and manipulation validation of agents with different personality types and emotional feedback. Thirdly, we describe the construction of a virtual Tai Chi training studio and a set of psychological experiments to examine the effects of our designs on learning. Finally, we discussed findings of the study, implications on virtual learning environments and future work.

RELATED WORK

APA's Physical Features and Personality

In daily life, people automatically make judgments on the stereotypical personality traits of others (i.e. zero-acquaintance [8]) based on visible characteristics. According to media equation hypothesis [44], people make the same kind of judgments on APAs as on human. Therefore, it is essential for believable agents to display physical appearance and behavioral characteristics, which allow users to make the same kind of inference about personality as they do in daily life [37].

Existing studies showed that the reference of development of agents' personalities was psychological knowledge about the links between physical appearance, behavior and personality judgment [11, 37]. On the one hand, different components of physical appearance are related to different personality traits. For example, style of dress is a valid indicator of conscientiousness [1, 8, 39]; facial feature is another effective cue in personality judgment [40] and facial expression has been connected to extraversion [28]. Verbal behavior is also a common way of presenting personality. Some researchers suggested that users were able to recognize the personality of digital voice [27, 34, 38]. These studies showed verbal cues of an agent could influence users' perception of its personality. Therefore, although many elements of physical appearance may influence the process of accurate personality judgment, we only focus on facial features and verbal behaviors as personality cues in current study.

Theoretical Model to Generate Personality

If we want to design agents possessing psychologically plausible personality features, a credit theoretical approach is required [37].Psychological research on personality attribution has to two main theories: five-factor model (the Big 5) or Eysenck's trait model [46].

Previous studies compared the two models to determine which one is more theoretically appropriate for generating believable agent [37, 46]. The Big 5 describes a personality by five stable dimensions. Although the model was preferred by researchers to understanding and developing personalities of virtual agents [2, 13, 43], this model is not able to classify personalities into types. In contrast, Eysenck's model can classify personalities into types, allowing the generation of virtual characters with different personality types. In Eysenck's model, four distinct personality types (melancholic, choleric, phlegmatic and sanguine temperaments) result from different quadrantal combinations of the super factors Extraversion (E) and Neuroticism (N) (see Figure 2). Therefore, Eysenck's

model can provide parameters which are more easily controlled.

Moreover, Eysenck' theory provided not only an operationalized method for classifying human personalities into different types but also a description of each type [19]. Eysenck provided eight descriptors for each of these personality types as shown in Figure 2 [19]. The descriptors include both traits and states, which make it easier to generate corresponding personality types.
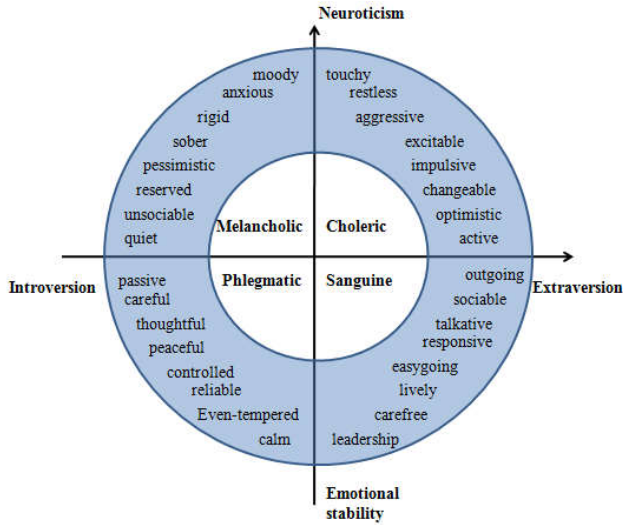

Figure 2. Eysenck'strait theory mode

The availability of Eysenck's theory in constructing personality of virtual agent has been verified by McRorie et al [37]. In their study, four agents with distinct personalities were built based on Eysenck's theory and evaluated as having high credibility. Therefore, Eysenck's theory model can provide an available basis for building personality types of virtual agents.

For the above reasons, we have designed our APAs based on Eysenck's theoretical model. According to media equation hypothesis, people make judgments on APAs in the same way on human of zero-acquaintance. Therefore, what we need to do next is to build the stereotypical features (appearance, behavior, etc.) consistent with descriptions of a defined personality type [9, 39]. In this way, perceivers can make the corresponding personality judgment from these visible physical features.

Emotional Feedback and Bodily Expression
In a virtual learning environment, APAs equipped with emotional feedbacks play influential role. Kim et al. indicated that the learners' social judgments on the instructional functionality of the APAs varied according to APAs' emotional states [30]. Later, Terzis et al. designed an agent with empathetic encouragement behavior as emotional feedback, and found a significant effect on learning intention [51]. Therefore, it is necessary to add effective emotional feedback to APAs.

Researchers have considered that facial expressions and speech are important modalities of emotional feedback. By contrast, bodily expressions were relatively neglected in existing literatures. Actually, bodily expression conveys important emotion information. Differing from other emotional indicators such as speech or facial expression, it is simple visual stimulus produced by combinations of parts of the human body [42, 49]. Neuroscientific and psychological studies have revealed that body movement is an important modality of emotion expression [24, 36]. Upper-body movements are of particular important functions. Specifically, head and hands movements are actually most often employed to express one's affection, and hand illustrator is one of the most frequent, regularly occurring quantifiable bits of overt behavior accessible for expressivity study [23]. Human observers focus attention spontaneously around this body region when tempting to infer others' emotions [25].
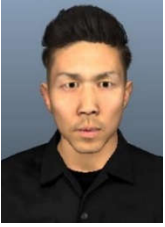
In virtual reality environments, bodily expression can be an important emotional expressive mode of virtual characters. On the basis of hands position and trajectory patterns, Balomenos et al. defined four classes of gesture for a human-computer interaction system, including hands clapping, hands over the head, "Italianate" gestures, and lift of the hand [5]. The combinations of these gestures were proved successful for the classification of six prototypical emotions. Later, Glowinski et al. defined postural and dynamic expressive gesture features, and developed a 4D model of emotion expression [25]. The model effectively classified emotions according to valence (positive, negative) and arousal (high, low). This predominance of upper-body movements in emotional communication is reinforced by current computer interfaces and practice. Yet, these expressive gestures have not been thoroughly applied in virtual learning environment.

BUILDING PERSONALITY

Design of Personality Parameters
Based on Eysenck's model, we created two sets APAs of distinct personality types. Lee (male) and Lin (female) are more choleric, Chen (male) and Cheng (female) are more phlegmatic. The reason for selecting these two types is that they have significant differences both in Extraversion and Neuroticism. The two types can be operationalized and defined by a combination of Eysenck's factors (shown in Figure 2), and measured by his test.

Personality types were constructed by manipulating physical appearance, behavioral features and verbal features. The features are associated with specified personality stereotypes, which are defined as beliefs about the characteristics of groups of individuals [14]. They are stored in the brain as schemata, which automatically and instantaneously lead perceivers to form expectations about others' personality [18]. Based on previous study results, we associated sets of physical appearance, behavioral and verbal features to each APA with its own personality (see Table1).

Agent	Personality	Characteristics	Appearance manipulation	Verbal features	Behavioral features
Lee Lin	Choleric (neurotic extravert): high E score and high N score	Active, restless, aggressive, impulsive, hot-tempered, touchy	Asymmetrical faces, frowning eyebrows, staring eyes, prolonged direct eye gaze, wide eyes	Strong, confident, powerful words and phrasing	Higher movement speed, larger movement range
Chen Cheng	Phlegmatic (stable introvert): low E score and low N score	Passive, peaceful, controlled, careful, even-tempered, calm	Symmetrical face, peaceful face, no facial expression, formal clothes	Calm, less direct and confident phrasing	Lower movement speed, smaller movement range

Table 1. Personality parameters of each agent

Defining physical appearance of APAs

The traits of Lee and Lin were defined as active, restless, aggressive, impulsive, hot-tempered and angry [19, 26]. Their facial features were set in a permanently angry configuration or a serious facial appearance because they need to exhibit angry and aggressive behavior frequently. Facial features of anger are demonstrated with frowning eyebrows and staring eyes [52], and facial threat are typified via prolonged direct eye gaze and wide eyes. These features are associated with neuroticism [20]. Moreover, given that asymmetrical faces were rated as being more neurotic, less agreeable and less conscientious [21], this feature was also added to the agents.

The choleric quadrant of the chart included other terms such as optimistic which might suggest different facial features. In this study, however, we designed the choleric personality types to exhibit constant anger in their facial expressions, because we wanted to start with a stereotypical extreme. This gives us a baseline for future research and represents an important beginning.

Chen and Cheng were defined as passive, peaceful, controlled, careful, even-tempered and calm [19, 26]. They were given symmetrical facial appearances, because faces with symmetry were generally rated for less neurotic, conscientiousness and agreeableness [20]. At the same time, they were given a peaceful face without any obvious facial expression. Besides, they were given formal clothes to have business-like manner. These features were designed to appear practical and pragmatic, indicating they were controlled and careful person with low impulsivity and high conscientiousness [55].

Defining behavior of agents

Lee and Lin are extroversive. Studies have shown extraverts tend to demonstrate more body movements and greater levels of facial activities [33]. Extraversion is also associated with higher levels of gesturing and more frequent head movements [9]. In addition, Lee and Lin have high neuroticism and low emotional stability. Taken these into consideration, we defined their behavioral features in two dimensions: movement speed and movement range. Finally, the facial activity, gestures and movements of Lee and Lin were defined as higher speed and larger movement range.

By contrast, the facial activity, gestures and movements of Chen and Cheng were defined as lower speed and smaller movement range.

Defining voice of agents
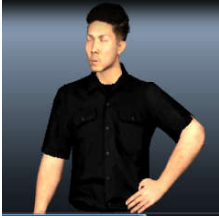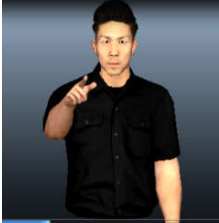
Considering that extraversion is correlated with a loud and powerful voice [9], Lee and Lin were given this kind of voice consistent with their tempers [37].

Additionally, considering that emotional stability are correlated with calm speaking [9], Chen and Cheng were given a kind of soft voice and calm speaking consistent with their temper.

DESIGNING EMOTIONAL FEEDBACK

Postural and dynamic motion features are considered relevant to the communication of emotional content. They can be extracted from low-level kinematic features of head and hands. Therefore, we mainly designed head and upper-body movements to express emotional feedback in this study.

Emotion	Gesture
Baseline	 No obvious movement
Positive	 Nodding head Thumb up Two thumbs up Clapping hands and nodding
Negative	 Shaking head Waving hands Pointing finger at others Crossing hands and shaking head

Table 2. Different upper-body gestures of expressing emotions

We enrolled 8 people and asked them to pose gestures usually used to express positive emotion (happiness, approval, and encouragement) and negative emotion (anger, disapproval, and impatience). In total, 11 upper-body gestures expressing positive emotions and 10 upper-body gestures expressing negative emotions were collected. We selected 4 positive gestures with highest frequency, including nodding, clapping hands, thumb up and two thumbs up. Meanwhile, we selected 4 negative gestures with highest frequency, including shaking head, waving hands, crossing hands and pointing finger at others.

These gestures were showed in Table 2. According to different personality types, the speed and range of the action is different. In addition, each gesture was accompanied with verbal content that is consistent with the type of gesture invoked.

EVALUATION OF OUR DESIGNS BY HUMAN VIEWERS

We constructed virtual characters varying in visual appearance, voice quality, vocal content and nonverbal behavior. To ensure the accuracy and emotional effectiveness of our designs, we evaluated APAs' personalities and emotional feedback perceived by human viewers. Specifically, we examined whether viewers' perception of APAs' personalities were consistent with their "actual" personalities as we had intended. We also examined whether viewers' perception of emotional gestures were consistent with their "actual" emotions as we had intended. This is an effective method, which has been verified in [37].

Fifty-six college students, including 28 undergraduates and 28 postgraduates, were recruited from a university in China to complete the evaluation (26 males, 30 females, mean age = 21.35).

Materials and Measures

In order to make it convenient for perceivers to assess each agent's personality, two kinds of material were made to show the appearance, behavior and verbal characteristics of each APA: Static images of each agent and short video clips. The static images are consisted of three pictures of each agent, including full face, three-quarter right and three-quarter left profiles. The short video clips include self-introduction of each agent. For instance, Lee said the word "Hi, I am Lee. Now, I will be your coach in the next training" accompanied with some natural movements. External conditions of these materials such as lighting were identical.

Similarly, in order to assess the emotional feedback designed by us, video materials were made to show the gestures of each APA. Including baseline state, each gesture was recorded as a video. Each video was edited into a six-second video clip. A total of nine video clips of each agent were to be rated. External conditions of these materials such as lighting were identical.

In order to evaluate the effectiveness of constructed personalities, Extraversion (E) subscale and neuroticism (N) subscale taken from the Eysenck Personality Questionnaire Revised (EPQ-RSC) [41] were used to measure personality. This is a forced-choice questionnaire with items rated as "yes" or "no." The EPQ-RSC was proved to be a reliable and valid tool of measuring Eysenck's model [41].

Emotional feedback perceived by raters was measured with an adjective-based scale. The scale was designed specifically to evaluate emotional feedback gestures in two dimensions named emotional valence and arousal [3]. The

scale consisted of two bipolar opposites (negative/positive and calm/excited), which were rated on a five point Likert scale.

Results

The E score and N score of each agent were shown in Table 3. Referring to the norm of Chinese sample [41], these original scores were turned into T standard scores. Based on the T scores, it could be concluded that the scores of Lee and Lin lied in first quadrant of Eysenck's model (choleric); the scores of Chen and Cheng lied in third quadrant of Eysenck's model (phlegmatic). The results showed that the perceived personality features of these agents were consistent with our expectancy.

The intended categories of emotional feedback (positive, baseline and negative) were tested with one-way ANOVAs on valence and arousal ratings. Figure 3 showed the descriptive statistics results. Higher score indicates a higher negative valence. Results revealed a significant main effect of category on valence, $F_{(1, 26)}=45.326$, $p<0.01$, $\eta_P^2=0.660$.

Agent	Personality	*Mean(S.D)*	T score	Quadrant
Lee	Extraversion	8.61(2.22)	53.5	First quadrant
	Neuroticism	6.52(1.62)	57.1	
Lin	Extraversion	7.60(2.83)	51.0	First quadrant
	Neuroticism	5.25(1.97)	53.8	
Chen	Extraversion	5.71(1.78)	41.7	Third quadrant
	Neuroticism	4.11(1.21)	48.4	
Cheng	Extraversion	5.21(2.08)	42.1	Third quadrant
	Neuroticism	4.37(1.44)	48.7	

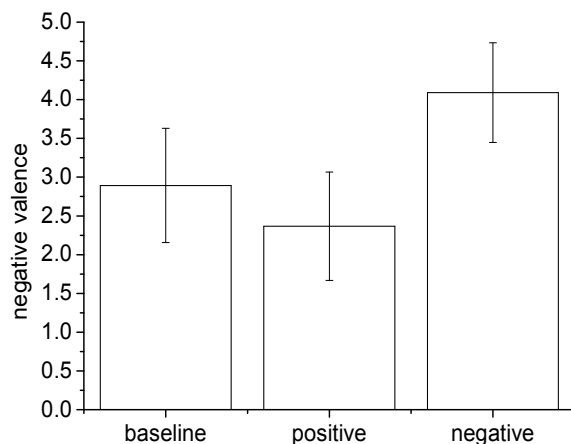**Table 3. E and N scores of each agent**

Figure 3. Mean valence ratings for different gestures

Post hoc comparisons showed that valence ratings were higher for negative than baseline (t = 6.355, p < 0.001) and positive gestures (t=9.375, p<0.001). Valence ratings were higher for baseline than positive gestures (t = 3.719, p < 0.01).

Results did not show significant main effect of category on arouse rating, F (1, 26) =1.732, p=0.185, η_P^2 =0.058. The ideal result is that there is significant difference in valence, but no difference in arousal level. Our results are indeed in line with this expectation.

Overall, the evaluation suggested our designs of personalities and emotions were successful and can be used to investigate learning in virtual environments.

VIRTUAL TAI CHITRAINING STUDIO

In order to investigate whether our designed APAs influence learning in virtual learning environment, we constructed a virtual Tai Chi training studio. The studio includes a 3D animation demonstrate unit, a Smartphone user interface and an instruction unit.

In the 3D animation demonstrate unit, learners can watch 3D Tai Chi demonstration, which contains the entire 24-Style Tai Chi popular in China. Each style has a characteristic protocol that differs from the other styles (Such as Yang-Style Tai Chi and Chen-Style Tai Chi) in the postures or forms. The set of actions are demonstrated by one additional virtual character called "demonstrator", who has no facial expression, personality or feedback traits. In the process of learning and practicing, the user may need to watch demonstration from different view angles. Moreover, to observe the demonstration clearly, learners may need to control demonstration process such as fast forward/backward and repeat. In order to solve these problems, we designed a Smartphone-based user interface, which provided more natural interactive experience. With a Smartphone fixed on forearm, learner can rotate/scale the demonstration scene and control the demonstration speed. As to the instruction unit, one of the four APAs was arranged to be present on a screen to the left side of the main screen (showed in figure 1), and played the role of "coach" in training. The APA was manipulated by a director familiar with Tai Chi. A camera in front of the learner was used to capture his/her practice movements. Live images were viewed by the director in real-time. According to the learner's practice, the director gave instructional information about the Tai Chi and emotional feedback about the performance by clicking some buttons to control the APA.

Furthermore, APAs provided emotional feedback to learners based on their practice. After the system recognized the starting of learning, the "coach" began to use positive feedback strategy or negative feedback strategy to instruct the learner. The positive feedback strategy was that the coach mainly gave positive feedback to the learner according to his/her learning, expressing happiness and encouragement. The ratio of positive emotional feedback/negative emotional feedback was approximately

4:1. As to the negative feedback strategy, the coach mainly gave negative feedback to the learner, and expressed anger, impatience and harshness. The ratio of negative emotional feedback/positive emotional feedback was approximately 4:1.

The reason why feedback was controlled by a realperson instead of a computer program was for avoiding possible inappropriate feedback and therefore improving the APAs' "believability". For instance, if a computer controlled agent gives feedback to a learner when the learner was not doing any effective exercise (e.g., moving around for other reasons), the APA would be perceived as less "believable" and this could in turn affect the learning outcome. In contrast, a real person could avoid this problem. In essence, the human coach was a well-trained experimenter. Although the feedback was controlled by a real person, we systematically controlled the number of times and ratio of the two kinds of feedback. Specifically, the coach was asked to provide emotional feedback every two minutes during each 20minuteslearning. The ratio of positive emotional feedback/ negative emotional feedback was 4:1in positive emotional feedback strategy. According to the ratio, the coach provided eight times of positive emotional feedback and two times of negative emotional feedback. The position of negative feedback was random. Accordingly, the positive feedback strategy was used in the same way.

The ideal design for future APA would be an intelligent interaction system, which could automatically and correctly give feedback. This is the ultimate goal of our overall research while it is beyond the scope of the current study.

EXPERIMENTAL TEST

We assessed the effects of APAs' personality types and emotional feedback strategies on Tai Chi learning. Fifty six undergraduates (46 males and 10 females) were recruited to participate in the test. The age of the sample ranged from 17 to 21 years old (M= 19.20years, SD=0.86years). All of them had no previous experience of learning Tai Chi.

Design

We conducted a psychological experiment involving a 2 (personality types: choleric/ phlegmatic) × 2 (emotional feedback strategies: positive/ negative) factorial mixed design. Emotional feedback strategy was within-subject factor, that is, every subject experienced both strategies. Learner characteristics remain constant in the two conditions. Personality type was between-subject factor, and thus there might be individual participant differences between the two personality conditions, such as the personality of the participant or their initial capability. We adopted the methods of expanding the sample size and randomly assigning subjects to each condition to ensure the validity of learning outcome. The dependent variables included several indicators of learning experiences and learning performance. The presentation order of two emotional feedback strategies was counterbalanced.

Procedure

The participant was invited into a quiet room equipped with the virtual Tai Chi training studio for self-regulated learning.

Upon logging in the system, each participant was immediately assigned to one of the four agents.

In the first 20minutes, the participant was asked to learn 1-4 forms of Tai Chi. In the course of learning, the "coach" used one of the two emotional feedback strategies to instruct the participant. After that, the participant showed what they studied in front of a camera, and their performance was recorded as videos. Then, the participant completed a questionnaire. In a second 20 minute session, the participant learned 5-8 forms of Tai Chi in the same environment. The only difference was that the agent used a different emotional feedback strategy to instruct learners. The rest of procedures were the same as described above.

Measures

We evaluated learning experiences and Tai Chi performance. Subjective learning experiences were evaluated from 4 aspects including flow-experience, intrinsic interest, task-specific self-efficacy and satisfaction. Specifically, flow represented a highly enjoyable mental state where the individual is fully immersed and engaged in the process of activity [12, 50]. Intrinsic interest referred to how the learner felt interested in the learning by intrinsic motivations. Task-specific self-efficacy referred to ones' belief in their capability to successfully learn in the learning environment. Satisfaction in this study referred to how satisfied the learner felt with the learning process. All the questionnaire items were showed in detail in Table 4. Participants rated them on a five point Likert scale from "1" (totally disagree) to "5" (totally agree).

Learning performance was determined with the method of expert evaluation. According to Shi et al. [48] and the advice of experts in Tai Chi, five appraisal criteria of 24 -form Tai Chi were identified, including high technical quality, good coordination, appropriate strength, good spiritual state and appropriate rhythm. Weighed distribution of these criteria was also presented in their study [48].Three experts were invited to watch the recorded videos and evaluate each stroke according to the five appraisal criteria on a five point rating scale. The rating results of the three experts had a high consistency (alpha = 0.912).

Results

To explore the effect of personality type and emotional feedback strategy on learning experiences and learning outcome, a series of 2×2 mixed-model repeated measurement analysis of variance were performed. The results of descriptive statistics were shown in Table 5.

Learning experiences

Results showed that there were significant main effects of emotional feedback strategy on flow-experience [$F_{(2, 54)}$ = 7.367, p = 0.009, η_P^2 =0.120], self-efficacy in learning [$F_{(1, 38)}$ =5.429, p=0.025, η_P^2=0.125] and learning satisfaction [$F_{(1, 54)}$ =15.160, p<0.001, η_P^2= 0.219]. Compared with negative emotional feedback strategy, positive strategy led to higher level of flow-experience, self-efficacy and satisfaction in learning (see Table 5).

The results also revealed a significant interaction effect of emotional feedback strategy × personality type [F (2, 54) = 4.510, p = 0.038, η_P^2 =0.077]. In order to further understand the interaction effect clearly, a simple effect analysis was conducted. The result showed that learners assigned to phlegmatic coaches showed more learning satisfaction in positive emotional feedback condition than in negative condition (F=15.86, p<0.001). But similar difference was not found in learners assigned to choleric coaches. Figure4 illustrated this interaction effect.

However, no main effect of personality type or other interaction effect on learning experiences was found.

| Dependent variables	Descriptions	Alpha
Flow-experience [17]	I feel just the right amount of challenge	0.879
	My thoughts/activities run fluidly and smoothly	
	I do not notice time passing	
	I have no difficulty concentrating	
	My mind is completely clear	
	I am totally absorbed in what I am doing	
	The right thoughts/movements occur of their own accord	
	I know what I have to do each step of the way	
	I feel that I have everything under control	
	I am completely lost in thought	
Intrinsic interest [53]	I enjoy learning in this environment	0.852
	Using this training environment excites my curiosity	
	Learning in this studio is intrinsically interesting	
Task-specific self-efficacy [32]	I am confident in learning	0.931
	I can achieve high grades in this learning	
	I am confident in acquiring learning contents	
Satisfaction	I am satisfied with the overall experience of learning	

Table 4. Measures of learning experiences

Learning performance
Results revealed a significant main effect of emotional feedback strategy on learning performance [F (2, 54) =12.241, p = 0.001, η_P^2 =0.185]. Positive strategy led to better performance (see Table 5). Moreover, a significant main effect of personality types was also found [F (2, 54) =5.597, p = 0.022, η_P^2 =0.094]. Specifically, learners assigned to choleric coaches showed better learning performance than learners assigned to phlegmatic coaches. The interaction effect of emotional feedback strategy with personality type was not significant.

Dependent variables	Personality	Positive Mean(S.D)	Negative Mean(S.D)
Flow-experience	choleric	35.44(8.54)	34.70(8.37)
	phlegmatic	38.16(6.86)	35.52(7.99)
Intrinsic interest	choleric	11.29(3.24)	11.18(2.45)
	phlegmatic	11.48(2.49)	11.57(2.89)
Efficacy	choleric	9.54(3.28)	9.32(3.39)
	phlegmatic	10.11(3.13)	9.39(3.50
Satisfaction	choleric	3.89(1.03)	3.71(1.01)
	phlegmatic	4.21(0.79)	3.50(0.86)
Learning performance	choleric	64.26(14.29)	59.51(15.80
	phlegmatic	56.12(17.73)	48.32(18.62)

Table 5. Mean rating of learning experiences and performance in different conditions
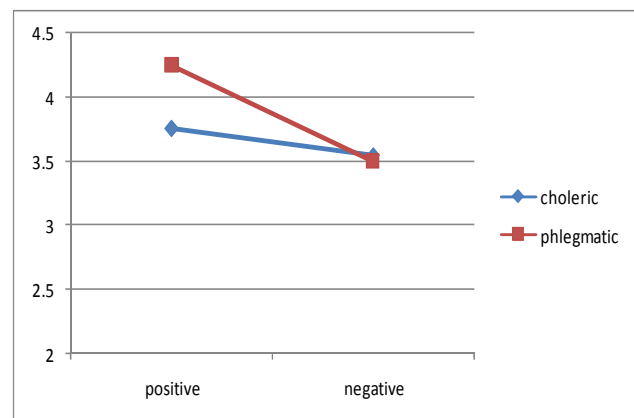
Figure 4. Interaction effect of emotional feedback strategy with personality type

Overall, these results suggested that positive emotional feedback led to better learning experiences and learning performance. Although results revealed an interaction effect of emotional feedback strategy × personality type, almost no significant effect of personality type on learning experience was found. By contrast, personality type had a significant effect on learning performance, indicating its role in influencing learning.

DISCUSSION

Designs of APAs

In this study, we built two sets of APAs with distinct personalities based on the personality classifications and descriptors of Eysenck' theory, as well as previous studies on relationships between appearance and personality. Evaluation results showed that our designs of appearances, behavioral and verbal features activated specified personality stereotypes and effectively guided perceivers' personality judgments. These results verified that Eysenck's psychological theory could be used to design personality of APAs.

We designed two sets of upper-body gestures expressing distinct emotional feedback. The effectiveness of these gestures in guiding perceivers' emotion judgments was also verified by a manipulation check. We embedded these APAs and emotional feedback into a virtual Tai Chi training system. The system contained a social-emotional modality, and its interactivity was improved. Based on this system implementation, the role of APAs' personality types and emotional feedback strategies on learning was examined.

Effect of Emotional Feedback Strategy on Learning

It is more commonly known that positive feedback strategies can promote learning while the question of whether stress caused by negative feedback can also possibly promote learning has not been well studied. In addition, as far as we know, the relationship between APA's emotional feedback and flow experience has not been investigated before. This study expanded previous studies in these aspects. The present study revealed that the emotional feedback strategies of APAs had significant effects on both learning experience and learning performance. Positive emotional feedback strategy led to more positive experiences (higher level of flow-experience, self-efficacy and satisfaction in learning) and better learning performance than negative emotional feedback strategy. As shown by previous studies, APAs' affective behaviors had positive impact on learners' affective states and perception in multimedia environments [4, 6, 30, 31]. By contrast, stress caused by negative feedback did not effectively promote learning. These results are meaningful for enhancing APAs' emotional feedback design to improve learners' flow state, confidence and satisfaction in virtual learning environment. Finally, appropriate emotional feedback strategy might contribute to a better learning process.

It was noted that the emotional feedback had no significant influence on intrinsic interest. Both studies of Kim et al.[30] and Wang [54] suggested similar results. One possible explanation could be that intrinsic interest in learning mainly depended on the content and form of learning. For instance, learning in virtual reality environment might stimulate more interests than learning in real world; virtual learning environment with an APA might stimulate more interests than the one without an APA. In the present study, although the appearance and feedback of APAs were different, the learning content and form are the same, so no significant difference was found on learning interest.

Effect of APA's Personality on Learning

As far as we know, this study is the first study examining the impact of personality on learning, specifically for Tai Chi. One of our interesting findings was that personality type moderated the effect of emotional feedback on learning satisfaction. For phlegmatic coaches (Chen and Cheng), positive emotional feedback strategy led to more satisfaction than negative strategy. But for choleric coaches (Lee and Lin), the effect of emotional feedback strategy was not significant. If designers want to maximize the role of emotional feedback, an APA with phlegmatic temperament would be a better choice than one with choleric temperament. The interaction effect between APAs' personality types and emotional feedback on learning might be an important design guideline for further study,

In addition, although personality type almost had no significant influence on learning experience, it had a significant effect on learning performance. For learners assigned to a choleric coach, their learning performances are better than that of learners assigned to a phlegmatic coach. A possible explanation is that learners experienced more pressure when facing a choleric coach. Although the pressure did not make learners feel better, it motivated them to learn better. Another possible reason is that the participants in this study were all students who are young Chinese and maybe used to strict teachers in colleges.

However, whether these results are also applicable to Western students require further investigation. On the one hand, there could be cultural differences between students in Chinese colleges and students in Western colleges. Chinese students might have faced more strict teachers since their childhood, resulting in the pressures from a strict coach serving as a helpful impetus for them. We knew from educational psychology research that some stress could be good for learning, but the level of stress appropriate for learning might be quite different between Chinese students and Western students. These differences point to the importance of studying culturally appropriate HCI techniques rather than trying to fit and generalize impractical and problematic 'one-size-fits-all' model across all cultures. Our research is taking steps in this direction. On the other hand, it is too early to conclude similar preferences could not be found in Western learners, as it has not been investigated previously and today's Chinese children are raised by more and more western educated teachers and parents. Therefore, whether this finding

applies to the general population needs to be further researched.

Interestingly, phlegmatic APAs were helpful to promote the effect of emotional feedback on learning satisfaction. Nevertheless, choleric APAs could contribute to better learning performance. These seemingly controversial results may mean that there is no perfect personality of APA fitting all the requirements, and users may need to choose different coach according to different needs.

An Expanded Discussion
In order to investigate whether APAs designed in this study will instruct learners as a real person, we conducted an extended test. Users were asked to learn Tai Chi in two conditions of APA. In one condition, the behavior of the APA was predesigned in the study (Lee). In another condition, the APA immediately reflects the action and verbal contents of a real person. The presence of APAs, learning experience and performance were measured.

After comparison, we found the APA manipulated by real person was perceived as a more real social presence than our designed APA (t=2.557, p<0.05). However, no other difference was found. These results suggested that our designed APA can instruct users to learn as well as a real coach. However, the believability of our APA still needs to be improved.

Overall, emotional feedback and personality of an APA are both important impact factors of learning. It is important to note that this study is for Tai Chi learning--a physical exercise, which has never been investigated before. Therefore, current study expanded the range of APA-based learning domains. These results also suggest that our virtual Tai Chi training studio could be effectively applied for Tai Chi learning.

CONCLUSIONS AND FUTURE WORK
The present study offers several important outcomes. Firstly, our study supported that Eysenck's theoretical model is an effective theoretical basis which can be used to generate APAs with different personality types. Secondly, upper-body movement can be an effective modality for APAs to express emotions. Thirdly, emotional feedback of an APA can influence both learning experience and performance. Positive feedback can be designed to improve learning. Fourthly, personality of an APA mainly influences the learning performance. Compared with a phlegmatic APA, a choleric APA can lead to better performance. However, phlegmatic APAs are helpful to promote the effect of emotional feedback on learning satisfaction. Our results point to the need of designing different APAs with different personality types to fulfill different learning needs. Finally, although learners might feel that our APA is not a real social presence, their learning experience and performance have been shown to be as good as that of learners learning with a real coach in our testing environment. This might imply that learners treat our designed APA as a real person to some extent.

From the results of this study, we propose several future research directions. Firstly, different learning environments for learning different contents are needed to test hypothesis about APA characteristics. Secondly, more emotion elements, especially emotional feedback should be added to training environments to improve learning. Thirdly, more personality types could be built and tested to understand their effects on learning. Fourthly, cultural differences in facing different APAs between Chinese learners and Western learners need to be further studied. Finally, we will develop new types of believable APAs and intelligent interactive systems in order to further improve our understanding of the role of APAs in learning environments.

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