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Exploring Persona Characteristics in Learning: A Review Study of Pedagogical Agents

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Abstract

In digital interactive learning environments, pedagogical agents are digital characters that assist instruction, providing learners with coaching, feedback, as well as emotional and social support. Recently, increased work has explored how animated, actual, or artificial pedagogical agents impact learning. Some studies found that agents promote learning, while some revealed that agents increased the workload and caused learners to lose focus. Especially poorly designed pedagogical agents would aggravate learners' external cognitive load, negatively affecting learning performance and experience. This work reviewed how features of pedagogical agent roles affect learners' retention and transfer performance, as well as the learning experience. It extracted five features, including appearance, gender, facial expression, sound, and movements, then discussed their impact. The survey concludes with the implications for designing effective agents.

Keywords: Pedagogical agent; Agent persona characteristic; Agent design; Learning

1. Introduction

In digital interactive learning environments, pedagogical agents (see Figure 1) are digital characters that assist instruction, providing learners with coaching, feedback, as well as emotional and social support [42]. These characters can be animated, actual, or some image between animated and actual. There is no unified definition of pedagogical agents. For example, Johnson et al. [18] defined pedagogical agents as "vivid and lifelike autonomous roles existing in the learning environment and having rich face-to-face interaction with learners". Terzidou et al. [45] pointed out that "a pedagogical agent is an intelligent agent, which automatically supports the educational process in a synchronous interactive learning environment to achieve better learning". With the development of virtual reality and other tech-

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nologies, the current pedagogical agent has not only 2D form but also 3D form, and the degree of anthropomorphism is also improving. According to the role of agents in teaching, they can be divided into tutors [44], assistants [23], motivators [3], learning partners [19], competitors [38], and trouble makers [14].

Due to the separation of teachers and students in online learning, it is hard for teachers to offer instruction support in person. The existence of a pedagogical agent can provide personalized guidance and support for learners. Schroeder et al. [42] reported a meta-analysis showing that the use of pedagogical agents in learning has a small and significant impact on learning. Compared with college students, pedagogical agents promoted the learning greater for students in the K-12 stage. The language cues (such as oral and written texts) and visual cues (such as gaze, gesture, emotion, etc.) provided by pedagogical agents in multimedia materials can enhance students' cognitive and emotional participation in the learning process [28]. However, pedagogical agents may interfere with learners' learning, because they can distract students as "seductive details" [12]. Poorly designed pedagogical agents will increase learners' external cognitive load and have a negative impact on learning performance and experience. In total, some studies found that agents promote learning, while some revealed that agents increased the workload and caused learners to lose focus. Especially poorly designed pedagogical agents would aggravate learners' external cognitive load, negatively affecting learning performance and experience.
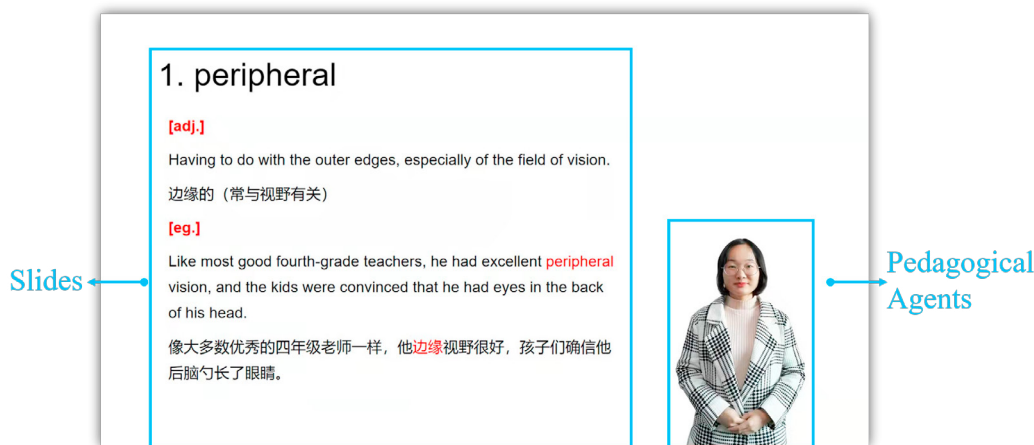

Fig. 1. An example of pedagogical agent in a lecture video.

In the interactive learning environment, there is a phenomenon called "persona effect" [25], which have revealed that "lifelike animation characters, even the least expressive characters, will positively impact students' learning experience". Although there is no definite conclusion about the effect of a pedagogical agent in teaching, well-designed pedagogical agents are more likely to promote deep learning. How to design effective pedagogical agents has been widely concerned by educational researchers. Many studies have shown that the specific characteristics of pedagogical agent persona, including appearance, gender, facial expression, speech, and posture, will impact learning performance. Therefore, researchers have paid increased attention to the design and development of pedagogical agents and studied how different features affect learning.

Literature for this review was conducted by searching the online databases of Science Direct, Google Scholar, and Web of Science. Keywords used in the database search included the descriptors "agent persona AND pedagogical agent" and "agent persona AND virtual human". This study analyzed the existing research on the characteristics of the pedagogical agent persona. Its aims at understanding which characteristics of agent persona contribute to learning results and how to design pedagogical agent persona to promote learning.

2. Characteristics of Pedagogical Agent Persona

This section discussed how pedagogical agents impact learning according to five moderating variables: appearance, gender, facial expression, voice and motion. We listed and summarized the related work in Table 1.

Table 1. Agent persona moderating variables

Study	Appearance	Gender	Facial expression	Voice	Motion
Hong et al. (2014) [15]	Human, Animated human,Animated parrot	Male	Happy,sad	Computer	Gesture
Li et al. (2016) [26]	Human, Human animation, Robot, Robot animation	Male	Absent	Human, Computer	Absent
Ahmadi et al. (2017) [1]	Human animation, Animated hand	Male	Various facial expressions	Human	Gesture, Nod
Muniady et al. (2020) [37]	Realistic agent, Aemi-realistic agent, Stylized agent, Cartoon-like agent	Female	Absent	Human	Absent
Mohamad et al. (2017) [35]	Human, Realistic 3D agent, Non-realistic 3D agent, 2D agent	Male	Absent	Human	Absent
Makransky et al. (2019) [31]	3D human animation, Drone	Female	Absent	Computer	Absent
Schroeder et al. (2015) [41]	Human animation	Male, Female	Absent	Computer	Gesture
Krämer et al. (2016) [21]	3D human animation	Male, Female	Smile	Computer	Nod
Bringula et al. (2018) [7]	Human animation	Female	Happy, Sad, Surprise, Neutral	Absent	Gesture
Horovitz et al. (2021) [16]	Human, Human animation	Female	Happy, Bored	Human	Gesture, Body stance, Eye gaze
Liew et al. (2016) [29]	3D human animation	Female	Happy, Neutral	Computer	Absent
Chiou et al. (2020) [9]	Human animation	Female	Absent	Human, Computer	Absent
Lawson et al. (2021) [22]	Human animation	Female	Happy, Content, Frustrated, Bored	Human	Gesture, Body movement, Eye movement
Beege et al. (2020) [6]	Human animation	Male	Absent	Human	Absent
Cook et al. (2017) [10]	Human animation	Male	Absent	Human	Gesture
Beege et al. (2020) [5]	Human animation	Female	Absent	Human	Gesture, Eye gaze
Anasingaraju et al. (2020) [2]	Human animation	Male	Happiness, Sadness, Anger, Fear, Surprise	Computer	Gesture, Eye gaze

2.1. Appearance

Concerning realism and humanization, pedagogical agents are more or less human-like. But not all of them are anthropomorphic characters. Hong et al. [15] studies the effects of the presence (humanoid agents, non humanoid agents such as parrots) and absence of pedagogical agents on primary school students' English learning. The results show that with the support of agents, students' English learning effect is improved.

Li et al. [26] studied the impact of different appearance designs of teachers inserted in video courses on learning. The embedded video of the online course is composed of images and human sounds or synthetic sounds. Four experimental conditions were explored, including real human, cartoon human, robot, and cartoon robot. Results showed that the knowledge retention test performance was equally good for learners in real human and cartoon robot groups. For cartoon human and robot groups, learners have a poor retention performance. The authors explained that novel presentation forms of cartoon humans distracted learners' attention and then hindered information retention. Ahmadi et al. [1] studied the influence of agent appearance on knowledge retention of English idioms in multimedia environments. There are two experimental groups: the cartoon humanoid image agent group and the non-humanoid image cartoon agent (animator) group. The control group received the traditional teaching form. Results showed that learners' knowledge retention was better in the presence of pedagogical agents, especially in the case of the non-humanoid agent group. Findings from interviews showed that learners' attention is distracted due to the attractive expression and appearance of human-like agents. According to the redundancy principle of multimedia learning, human-like agents may cause learners' more significant external cognitive load. Furthermore, Johnson et al. [17] found that students tend to choose pedagogical agents looking similar to themselves. In this way, agents would promote their understanding of knowledge.

Muniady et al. [37] developed four virtual pedagogical agents with different degrees of realism (real, semi-real, stylized and cartoon). The appearance of the pedagogical agent adopts the image of typical Malaysian local women to study the impact of different appearance designs on learners' emotions. The results show that there are significant

differences between the four conditions in the two dimensions of emotional valence and arousal. Semi-realistic agents have the highest valence and arousal degree for students' emotions, and there are significant differences with the other three groups, followed by realistic agent and stylized agent. There is no significant difference between them, and the cartoon-like agent has the worst influence on emotion.

The difference between 2D and 3D rendering will lead to different effects of pedagogical agents on learning. Castro et al. [8] did a meta-analysis and found that 2D is more effective than 3D pedagogical agents in a multimedia teaching environment. The finding is consistent with the redundancy effect of cognitive load theory and the coherence principle of cognitive theory of multimedia learning. In the multimedia teaching environment, Mohamad et al. [35] developed and tested four agents with different realistic levels: cartoon 2D agent, nonrealistic 3D agent, realistic 3D agent, and an actual human agent. The results showed that the nonrealistic 3D agent had the highest emotional impact, followed by cartoon 2D and human agents. There was no significant difference in emotional scores under these three conditions, and the effect of the realistic 3D agent was the worst, which was significantly different from the other three conditions. The findings can be explained by the "uncanny valley" phenomenon [36]. An agent that is too real will make the learners feel uneasy and uncomfortable when watching it. The high humanness of 3D agents may induce more obvious feeling of eeriness and aversive response, then affect people's processing of information [43].

In the virtual reality teaching environment, the interaction between learners and pedagogical agents can increase learners' sense of existence and presence, and enhance learners' learning experience and engagement. Grivokostopoulou et al. [13] studied the impact of pedagogical agents in virtual reality on students' learning experience, engagement, and knowledge construction. The results showed that the existence of virtual agents could improve learners' interest and motivation, then increase their participation and learning efficiency, and improve their understanding of knowledge. Terzidou et al. [46] found that although the presence of agents did not affect students' attitude towards the curriculum, it supported and helped the development of collaborative learning, and improved the cohesion and learning performance of the team. Recently, the humanoid degree of agent persona in the virtual platform has become increasingly higher. Therefore, people should consider the influence of the "uncanny valley" phenomenon in agent design.

2.2. Gender

Another factor involved in humanoid agent design is the agent's gender choice. Lee et al. [24] reported that the gender of agents affected people's decision of the agent's ability and credibility. People believe more in the suggestions made by male agents in the fields that men are good at (such as electronic technology and sports), and more in the suggestions made by female agents in the areas that women are good at (such as beauty and fashion). Makransky et al. [31] reported the impact of gender matching of pedagogical agents on middle school students' learning effect in immersive virtual reality environments. The results showed that when girls used a female agent and boys used a robot agent, students performed better in knowledge retention and transfer tests. Kim et al. [20] studied the influence of students' attributes (gender and race) on their choice of pedagogical agents. The study found that the gender and ethnic consistency between agents and learners affected agents' credibility and learners' learning attitude. Students tended to choose agents consistent with their gender and race. But different agents do not affect students' learning results. Schroeder et al. [41] studied whether the gender of pedagogical agent affects learners' cognitive and emotional results. They found that the learning effect had nothing to do with the gender of pedagogical agents. Krämer et al. [21] reported the impact of the gender and rapport behavior (nodding and smiling) of 3D pedagogical agents on learners' learning. The research found that the goodwill behavior of the agent had a moderate impact on learners' performance and a small impact on learners' efforts. Learners' performance and efforts increased significantly when interacting with opposite-sex agents who showed rapport behavior. However, there is still no unified conclusion on the impact of gender design of pedagogical agents on learning results.

2.3. Facial Expression

Another essential character related to the humanoid degree of pedagogical agents is the design of its facial expression. People's emotions can be expressed not only through language, but also through nonverbal cues such as facial expressions, gestures and body posture. In social communication, people's emotions are often affected by the people around them. People perceive and respond to others' emotions, and vice versa, impact others. This phenomenon also

exists in the process of human-computer interaction. People's emotions would also be affected by different emotions shown by virtual agents, which affect people's cognition and behavior [39]. The emotional state generated in the learning process will affect the learning experience, so as to promote or inhibit learning. Facial expression is one of the most important ways to reflect emotion.

Bringula et al. [7] studied the effects of the animation agent with switching dynamic facial expressions and with only a neutral expression on the mathematics performance of Grade seven students in an intelligent teaching system. The facial expression of the former included happy, sad, surprised, and neutral, and the expression can change according to students' performance. The results showed that the learners' mathematics performance of the group with dynamic facial expression agent was significantly improved. The facial expression and text feedback of pedagogical agents can enhance students' emotion after solving problems, so as to promote them to solve mathematical problems. Horovitz et al. [16] reported whether the emotional state (happiness or boredom) of human or 3D animation virtual teachers will produce different learning results in teaching videos. The study found that the emotional state of pedagogical agents affected learners' emotional state and motivation. Human teachers make students have a stronger emotional experience. However, there is no significant difference between human teachers and animation virtual teachers. Different agent persona and expressions do not affect learning results.

Liew et al. [29] studied the impact of neutral expression and smiling expression of 3D virtual agents on college students' programming learning in the virtual learning environment. The study found that learners experience lower positive emotion, pleasure, and confidence under smiling faces. There is no significant difference in learning test results between the two groups. This may be due to the mismatch between the agent's smile expression and the computer-generated neutral voice emotion, which affected learners' perception of the agent's emotion. Learners also thought the agent's smile was very hypocritical, which resulted in negative emotions. Facial expression is one of the crucial ways to express one's feelings. Therefore, it is natural for learners to pay attention to the facial emotions of pedagogical agents in the learning process. Natural and realistic facial expression design plays a vital role in learners' perception of emotions.

2.4. Sound and Speech

Voice is another essential feature of agent persona design. Adding manual recording voice to the pedagogical agent requires careful production to ensure the synchronization between the agent and the voice. The matching program is complex, and the cost is high, so it is not easy to make it on a large scale. Therefore, people began to study the application of synthesized speech for pedagogical agents. Mayer et al. [32] reported that real recorded human voice is more helpful for students' in-depth learning than synthesized speech. Chiou et al. [9] studied the computer-generated low-quality and high-quality voice, human recorded voice, which can affect learners' learning results and their trust and perception of pedagogical agents. The results showed that although learners' trust and perception of human pedagogical agents are better than agents with a synthesized voice, voice quality has no impact on learning results.

In addition to the difference between the human voice and synthesized speech, the agent's intonation and tone will also convey different emotions to learners. Lawson et al. [22] studied the influence of pedagogical agent's voice on learners' emotional perception in multimedia environments. One group contains pedagogical agents, and the other group only includes the sound of agents. The research showed that learners could judge the emotional state of teachers only through the voice of pedagogical agents. Agents with intonation changes (pause, raise voice from time to time, etc.) in speech expression can better convey knowledge than agents with poor speech expression [47]. Beege et al. [6] studied the influence of sound enthusiasm on learners' learning effect. A professional dubbing actor recorded the sound. One group of subjects received enthusiastic voice explanation (with large dynamic change of tone and high tone), and the other group received neutral voice explanation (with calm, pleasant, and low tone). The results showed that the neutral voice agent performs better for learners with high cognitive load and the enthusiastic voice agent performs better for learners with low cognitive load. However, there is no significant difference between the two groups in open-ended questions. Therefore, different emotions conveyed by pronunciation and intonation can affect learners' short-term memory as an external cognitive load, but it does not affect learners' understanding and knowledge transfer. Although human voice is better for emotional expression, synthesized sound may also achieve the same teaching purpose. There is no consistent view on the impact of sound design on learning.

2.5. Motions

Just as people often express their emotions through various actions in the communication process, the action of pedagogical agents also impacts students' learning. The movement characteristics of pedagogical agents mainly include head movement (micro change of facial expression, nod, eye guidance) and body movement (mainly hand movement). Lusk et al. [30] have shown that dynamic agents can better promote learning than static agents. These body movements can be used as emotional clues to affect students' organizing and understanding of knowledge.

Gestures can be used to convey nonverbal information. There are four key gesture types in teaching: iconic gestures (actions used to show specific information), metaphorical gestures (explaining abstract information in speech), deictic gestures (guiding the interlocutor's attention), beat gestures (rhythmic movement with hands) [34]. Cook et al. [10] compared the effects of agents with and without gestures on primary school students' mathematics learning. They found that pedagogical agents with gestures can better promote learners' understanding and mathematics knowledge transfer. Davis et al.[11] reported a meta-analysis of the impact of pedagogical agent gestures on learning in the multimedia learning environment. They found that pedagogical agent gestures have a weak impact on students' short-term knowledge transfer and knowledge retention, but they have little impact on students' cognitive load. Generally speaking, in the multimedia teaching environment, the gestures of pedagogical agents can promote learning. The research of Beege et al. [5] shows that deictic gestures rather than beat gestures could improve learners' attention and social presence,, so as to improve learning effect. Li et al. [27] also found that to promote learning more effectively, specific pointing gestures with clear goals need to be used, beat gestures and pointing gestures without clear goals do not promote learning results. Schneider et al. [40] found that the existence of pedagogical agents with metaphorical gestures improves its humanity and promotes students' learning transfer.

Pedagogical agents' deictic gestures were commonly accompanied by eye guidance. Mayer et al. [33] found that The agents with gestures, eye gaze and body movement can promote the performance of students' transfer test better than those without movements. Anasingaraju et al. [2] investigated the effects of three body channels (trunk/limbs/head, face, and voice) and five emotional expressions (happiness, sadness, anger, fear, and surprise) of pedagogical agents on agent credibility. They found that gestures (trunk/limbs/head) had the most significant impact on agent credibility, followed by face and voice. Happiness, anger, fear, and surprise have the most significant impact on the agent's emotional credibility among the five emotions. Baylor et al. [4] found that the facial expression of agent is more conducive to attitude instruction, and gesture movement of agent is more conducive to procedural instruction. Therefore, the influence of the motion characteristics of pedagogical agents on students' learning can not be ignored.

3. Conclusion

In this survey, we reviewed the features of pedagogical agents that might impact learning. Pedagogical agents are frequently used in multimedia environments. It is undeniable that the emergence of pedagogical agents plays an increasingly important role in attracting and retaining students in online learning and promoting the realization of life-long learning. Literature research showed that the ability and attractiveness of agents might affect learning positively. However, to date there is no consensus about their impact. Therefore, we believe that the design of pedagogical agents should consider the target users, learning objectives, and what they would convey.

Furthermore, the development cost and difficulty might hinder the use of agents. In 3D virtual environments, the design of 3D pedagogical agents costs more to achieve an excellent humanoid degree. Developers or instructors might spend more time, energy, and money to complete a pedagogical agent. Therefore, finding a plan that would reach a good learning effect and save costs simultaneously needs to be considered when designing.

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