

Can Humans Be Pedagogical Agents?

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Since the late 1990s, computer-generated images, known as pedagogical agents, have been a medium of interaction within computer-based environments. Whether the interaction is reciprocal or one-way, pedagogical agents require the user to anthropomorphize the image as an entity that is lifelike and possesses a persona. With the advancement of technology, researchers have had the opportunity to design agents that perform or interact with humans in various ways. However, these advancing features of today's pedagogical agents are different from human instructors and require specialized design considerations in theory and principle. This article will examine the various types of pedagogical agents and the key theoretical underpinnings of agents in computer-based environments.

Keywords: Pedagogical agent, embodiment, agent person, gestures, human instructors

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What is a pedagogical agent? The definition has commonly pointed to an understanding that it is a computer-generated representation; however, different definitions have accentuated different aspects of the agent to target specific purposes for two and a half decades. The exploration of pedagogical agents has routinely focused on the agent's human-like qualities to understand how to design and use agents in computer-based environments. One of the key findings for anthropomorphizing a pedagogical agent is the embodiment principle (Mayer & Dapra, 2012), which suggests that agents should be designed with natural human features such as lip movements that track speech, eye gaze, facial expressions, body sway, and the ability to gesture. Before the embodiment principle, previous research had explored isolated components of agent design, such as the presence principle (Mayer et al., 2003), voice principle (Atkinson et al., 2005), or debated whether the aesthetic relevance of design (Veletsianos, 2007) was an important factor for the agent's implementation in multimedia applications. However, it could be argued that agent design mirrored the advancement of technology, with more focus on human-like qualities as the technological advancements made it easier to build and manipulate agent features. Unlike humans, every aspect of a pedagogical agent has to be designed in software. Whether this is through drag-and-drop features within the software or manually manipulated through the software timeline, the degree to which an agent can be human-like depends on the software and its technical capabilities. For humans, the idea of embodiment is inherently present. Even though humans might need to be instructed on timing or have attention given to certain displays at particular times (i.e., eye gaze during presentations), humans are predisposed to perform all the embodied elements needed for interpersonal communication. Therefore, a recent trend in the literature of classifying human lecturers as pedagogical agents in videos and attributing pedagogical agent theories to humans is concerning because pedagogical agents and humans are distinctive elements within computer-based environments that require vastly different attention and consideration. Thus, the purpose of this article is to explore the history of how pedagogical agents have been conceptualized through various definitions, examine prominent theories and principles that guide pedagogical agent design, and explain why pedagogical agents are beneficial from both the design and learning points of view.

Literature Review

Pedagogical Agents

What is a pedagogical agent?

The concept of a pedagogical agent is multifaceted. To understand what a pedagogical agent is, readers and researchers must examine the early work of pioneers for a conceptual grounding that guides the field of research. Over the decades of research, pedagogical agents have undergone several different naming iterations that have branched into two different presentation designs, but the design concepts behind computer-generated images are ubiquitous to agents. Unlike recent research that included humans in the definition of pedagogical agents (Schneider et al., 2022), early pioneering research defined the agent in such a way that it was clear that the agent was not human but was replacing humans.

Naming

Before defining a pedagogical agent, it is important to understand the nuances within the naming of agents. Pedagogical agents are known by many different names in the literature; thus, it is important to separate the terminology that highlights some system differences in delivery. For example, agents known as conversational agents (Veletsianos & Russell, 2014), embodied conversational agents (ECAs, Cassell et al., 2000) or animated agents in intelligent tutoring systems, such as AutoTutor (Graesser et al., 2005), indicate that the agent interacts with one participant at a time to personalize instruction and provide feedback through computer programming algorithms. These algorithmic agents are functionally different because they interact with the user in a manner that is comparable to two people having a conversation on a focused topic. Another agent type of agent that presents information in a one-way direction similar to a lecture, although some can be animations that are similar to watching cartoons (Yung & Paas, 2015). These agents have been called animated pedagogical agents (Atkinson, 2002), pedagogical agents (Schroeder et al., 2013), virtual agents (Macedonia et al., 2014), and virtual humans (Craig & Schroeder, 2017). This agent type has undergone several different naming iterations, but the underlying foundation of the agent being a lecturer is the same regardless of the terminology. Thus, further reference to a pedagogical agent, or simply the term "agent," denotes the computer-based representation used in systems with a one-way delivery of information.

Definition

The definition of a pedagogical agent, regardless of function, has consistently incorporated the fundamental ideals of life-likeness (human-likeness) and learning. Some recent definitions have defined pedagogical agents as “a human-like character intended to facilitate the learner's learning” (p. 621, Li et al., 2022) and

“an image of a character presented on a screen intended to help student learning” (p. 250, Wang et al., 2018). Other definitions have combined these concepts with the environment; for example, “Animated pedagogical agents (APAs) are life-like characters specifically designed to facilitate learning in computer-based environments through various pedagogical strategies emphasizing social interactions (p. 2, Son, 2014),” and “Animated characters that are rendered using computer graphics (p. 124, Li et al., 2016). In addition to life-likeness (human-likeness), learning, and environment, other definitions have implied that pedagogical agents are substitutes for actual humans: “...agents reside in the learning environment by appearing as animated “humanlike” characters, which allows them to exploit nonverbal communication typically reserved for human–human interactions” (p.416, Atkinson, 2002), and “Pedagogical agents (PAs) are lifelike characters in technology-enhanced environments that help facilitate learning through social interactions by simulating a human role” (p. 460, Davis & Antonenko).

Early pioneers conceptualized pedagogical agents similarly, but the animated pedagogical agent was analogous to an intelligent tutoring system that interacted with the user. Lester et al. (1997) suggested that “Animated pedagogical agents that inhabit interactive learning environments can exhibit strikingly lifelike behaviors” and “offer great promise for delivering sophisticated, real-time problem-solving advice with strong visual appeal” (p. 359). Johnson et al. (2000) stated that pedagogical agents “need to give the user an impression of being lifelike and believable, producing behavior that appears to the user as natural and appropriate” (p. 2). Johnson and Lester (2016) acknowledge that pedagogical agents have evolved from their initial designs but have remained consistent with the original intention of being life-like through an animated persona and providing assistance during the learning process. The foundational element of any pedagogical agent is that it is life-like because the components of a suitable persona and how those components impact learning or perception is an ongoing process of discovery.

Therefore, what did the early researchers mean by an agent being “life-like?” Lester et al. (1999) suggested that life-likeness was tied to the believability of the agent. If the agent was believable, then users would believe they were interacting with a “sentient being with its own beliefs, desires, intentions, and personality” (p. 6). Thus, pedagogical agents are unconscious computer-generated representations that are manipulated in ways that support users’ expectations of human-to-human communication in computer-based environments that promote computer-to-human communication.

Can a Human Be a Pedagogical Agent?

In the literature, there is confusion about what can be considered a pedagogical agent. Schneider et al. (2022) conducted research with a human lecturer and labeled the human a pedagogical agent. Citing Heidig and Clarebout (2011) as a reference, the authors define pedagogical agents as “on-screen characters or displayed humans guiding learners through a learning environment” (p. 2). In the referenced article, Heidig and Clarebout (2011) stated that pedagogical agents were “lifelike characters presented on a computer screen that guide users through multimedia learning environments” (p. 28). Heidig and Clarebout (2011) never indicated that a pedagogical agent could be human, nor did the original authors insinuate that it was a possibility. However, the authors did discuss pedagogical agent representations and voice in relation to being human. As far as representations, the “global design level” of agents could be human or non-human, but the terminology is embedded in the idea that agents are computer generated. Heidig and Clarebout (2011) classified agents as human if they were designed with a human appearance. Conversely, non-human characters represent various forms, for example, anything from a bug (Moreno et al., 2001) or a blood cell (Yung & Paas, 2015). These agents do not have a human appearance, but their representations can exhibit human-like characteristics. Although there could be some debate on classifying fantasy agents, such as “Genie” (Choi & Clark, 2006), as human agents, in terms of agent design, both human and non-human designs refer to computer-generated images/representations that can be manipulated to perform in a desired manner.

Additionally, Heidig and Clarebout (2011) assessed voice as another human component of pedagogical agent design. Since computer-generated agents are not capable of self-generated vocals, voice has to be manually added. This can be done through human recordings or scripts typed into computer software that produces a machine-generated voice. Early researchers hypothesized that pedagogical agents with human voices aid participants' learning and perceptions (Mayer et al., 2003; Mayer, 2017), but recent advances in voice technology have shown that machine-generated voices are overcoming some of the sound limitations of previous technology (Craig & Schroeder, 2017). Therefore, Heidig and Clarebout's (2011) reference to human voice outputs was not a signal that the agent was a human but that the voice of the agent was recorded by a human or generated by speech software.

The purpose of a pedagogical agent is that it is not human; therefore, it can replace humans in computer-based environments. The definitions highlight that a pedagogical agent has to be life-like, or human-like, which is only a characteristic of something that is not human. Conversely, human lecturers are real; any

alterations to a human lecturer alter the perceiver's perception of what the human represents, not whether the human is a sentient being, which has been central to pedagogical agent design (Lester et al., 1999). In terms of life-likeness, human lecturers start with the presupposition that they have life, so any alterations are normally aesthetic in nature because it is not possible for the lecturer to appear more life-like but rather less life-like. In contrast, pedagogical agents are computer-generated representations devoid of life that require life-like qualities to be added to meet the expectations of something that possesses life. Thus, previous definitions of a pedagogical agent, and considerations within those definitions, would exclude human lecturers from the same classification. Not only have definitions highlighted the difference, but the theories guiding the design of pedagogical agents also indicate a clear distinction between agents and humans.

Pedagogical Agent Theories

Agent Persona

There are many theories or principles that provide guidelines for the design or presentation of pedagogical agents. Early pioneers of animated pedagogical agent research reasoned that if human users were to anthropomorphize agents, according to media equation theory that suggests that users humanize media (Reeves & Nass, 1996), then several capabilities would be necessary to enable that process. One fundamental consideration was to increase anthropomorphization by incorporating personality markers that would allow the user to perceive the system of having a personality (Nass et al., 1995). The authors suggested that manipulating simple aspects of the system could provide social cues to the user. Lester et al. (1997) suggested that animated pedagogical agents in interactive learning environments could exhibit a persona that could impact the user's perception of the experience and the agent; this was called the "persona effect."

Reflecting upon the initial assertion of the persona effect two decades later, Johnson and Lester (2016) recognize that their original assertions for creating personas are still important. Although the persona theory reflected the needs of animated pedagogical agents in interactive learning environments at the time, many of the suggestions have been found to be important when designing pedagogical agents in one-way lectures. The key components for persona, as it relates to pedagogical agents, is that agents provide eye gaze and gestures that serve as attentional guides, nonverbal feedback, conversational signs, and emotion elicitation (Johnson & Lester, 2016).

As research on pedagogical agents began to deviate from the original intention of interactive agents, Mayer (2005) proposed social agency theory, which suggested that the image and voice of the agent would display social cues that could activate social interaction schema found in human-to-human interactions. The agent's social cues could prime the user to cognitively engage with the information, and this engagement could lead to better learning outcomes. Mayer and Dapra (2012) advanced the concept of social agency theory by suggesting that the image of an agent should be designed according to the embodiment principle. The embodiment principle mirrors many of the same elements that Johnson and Lester (2016) suggested for agent personas in the early days of research, but the embodiment principle (Mayer, 2014) proposes that there are two types of embodiment, high and low, with high embodied agents presenting lip synchronization, eye gaze, facial expressions, body movements, and gestures, while low embodied agents are static or only display lip synchronization (Mayer & Dapra, 2012).

Agent Embodiment

Embodiment is extremely important for the anthropomorphization of an agent, as the agent should be able to present some of the social cues that are exhibited in human-to-human communication. The elemental social cues of lip synchronization and eye gaze are important because people's mouths move when they speak, and people use eye gaze to connect or direct attention during interactions (Hoffman & Haxby, 2000). Likewise, the agent has to present some level of facial expressions, body movements, and gestures that are commonly found in human interactions. A human-to-human interaction would be socially awkward if a person failed to display facial expressions, body movements, or gestures because these components, along with the strength of conveyance, actually express personality. With humans, these components are moderated by the person, but when designing a pedagogical agent, these components have to be constructed because the agent is virtually a blank slate.

The construction of embodiment is much more complex than the high and low dichotomy suggested by Mayer and Dapra (2012). In humans, voice, facial expressions, body movements, and gestures are multimodal systems (Rasenberg et al., 2020), so there is an inherent element of multiple systems working together to communicate in an appropriate manner. For pedagogical agent researchers, the parameters are not clear on how to combine these same systems that are inherently integrated in humans. If a researcher wanted to create an agent that showed annoyance, what strength of facial expressions should be presented, how is the eye gaze portrayed, and how are gestures delivered according to the vocal range? The baseline

for this design is not known, so how do the designs change if the researcher wants the agent to go from annoyance to rage? A human lecturer could be instructed to show more anger, and the integrated systems of voice, facial expressions, body movements, and gestures would react in proportional ways, although slight adjustments might be needed through further coaching. However, designing pedagogical agents to exhibit different personalities that go from annoyance to rage can cause issues because all systems used to display the appropriate messaging have to be individually aligned to fulfill Lester et al.'s (1999) concept of believability.

Researchers have attempted to explore differing roles or levels of personality (Baylor and Kim, 2005; Kim, 2007) with pedagogical agents, but no baselines or best practices have been established. Baylor and Kim (2005) discovered that users could distinguish between different roles and personalities, but the design principles from the study provide little understanding of how to replicate or design agents to provide a similar experience. Thus, embodiment is recognized as being beneficial for providing social cues that assist with agent persona and anthropomorphization, but there is a lack of understanding about the different parameters of representation. Thus, the physical presentation of embodiment in humans and pedagogical agents resides on opposite ends of the design spectrum.

Embodiment and Gestures

Although the embodiment principle consists of several components, the design of lip synchronicity, body movement, and eye gaze has not been explored with any concerted effort. Even though these are important nonverbal social cues, the complexity of these elements is narrow in their potential scope. For example, lip synchronization can be tested as present, absent, or at predetermined milliseconds before or after vocal delivery. Facial expressions have been explored (Baylor & Kim, 2009; Bringula et al., 2018), but not much is understood about designing facial expressions from a technical standpoint. In other words, each researcher or designer creates facial expressions according to intuition to determine whether the facial expression matches the intended facial expression. In human-to-human communication, facial expressions and voice work together (Schirmer & Adolphs, 2017). However, these elements must be designed for the pedagogical agent to appear life-like.

Conversely, gestures are the most examined component of the embodiment principle, even though there is much more to learn. Humans perform gestures naturally and without much thought in natural communication (Iverson & Golden-Meadow, 1998), but for pedagogical agents, gestures are complicated

movements that require advanced software. From 2002 to 2016, most pedagogical agents were designed with deictic (pointing) gestures. Deictic gestures are easy to create for a pedagogical agent because the arm extends outward from a hold position with the hand forming a point toward an object; the extension and point are held for a predetermined time before being retracted, most often to the original hold position. Another gesture form that is easy to create, but has little research isolating the gesture to understand how users interpret the movements, is the beat gesture. Beat gestures are simple hand movements that are coordinated with the prosody of speech to emphasize important words or phrases (Thuene & Brandhorst, 2009) or boost attention (Rohrer et al., 2020). Other gestures, such as iconic (concrete information) and metaphoric (abstract information), are more complicated movements because these gestures convey semantic information.

Gesture Design

For humans, unless the person is injured or impeded in some way, the delivery of iconic or metaphoric gestures is simple because the body effortlessly aligns all body parts to represent the object or idea being expressed. There is no natural alignment with pedagogical agents performing any kind of gesture. For example, a simple iconic gesture such as a ball or the sun would be presented with the hands creating half circles and coming together to create a full circle. One of the first decisions is where the gesture will be delivered in space. Will it be at the stomach level, chest level, shoulder level, face level, above the head, or outside the shoulder on one side of the body? From the agent's hold position to the completion of the delivery position, the pedagogical agent's joints (shoulder, elbow, and wrist) and body sway must align naturally throughout the delivery. Then, the hands and fingers have to rotate and create half circles. Creating the half circles requires the wrists to be angled properly to make the hands visible to the viewer; then, the designer has to manipulate the phalanges in the fingers. The proximal, intermediate, and distal phalanges (thumb only has proximal and distal) must be angled properly to create half circles that resemble a full circle when brought together. Although advanced software provides the capability to use the timeline to start at a beginning position and jump to a final position to create the finishing arrangement, allowing the software to create the transitional movements, the smoothness, timing, and malfunctioning of joints can be an issue. In other words, the process of embodying a pedagogical agent with gestures is far more complicated than having a human instructor show embodiment in a video.

However, designers are afforded the luxury of being able to preplan all gestures, which is equally as effective

as spontaneous gestures (Hostetter, 2011). Although the production of gestures might be more fluid when using a human, researchers and designers are able to sequence and choose gesture types according to a predefined strategy. One strategy is to have the agent perform conversational gestures that are gesture-like movements that have no intended meaning (Schroeder & Adesope, 2015; Davis & Vincent, 2019). The main purpose of conversational gestures is for the agent to appear embodied, but the gestures provide no semantic or nonrepresentational benefits to the user. Inherently, the brain recognizes the nonverbal communication of gestures by activating the same neurons that are activated with spoken language (Rizzolatti et al., 1996); however, the brain fails to activate with random movements that have no purpose (Johnson-Frey et al., 2003). Thus, conversational gestures can be used with pedagogical agents to maintain the resemblance of high embodiment, but the gestures do not contribute to the processing of information.

Discussion

Why the Need for Pedagogical Agents

Because pedagogical agent design and functionality require attention to many elemental details that are not necessary when filming with humans, there are questions about the need for pedagogical agents in computer-based environments. There are certain affordances, limitations, and potentials for both pedagogical agents and humans. Early researchers recognized the potential of pedagogical agents as an interactive element that could enhance the user's experience within a computer-based environment. Lester et al. (1997) suggested that agents could be designed to use customized feedback to help improve motivation and potentially increase learning. Again, the original intention of a pedagogical agent was to be an intelligent tutoring system with the agent being guided by computer code, which is not possible with humans in videos at the moment. However, there are several benefits to using pedagogical agents instead of humans in computer-based environments.

Agent Attributes

One potential advantage of using pedagogical agents is the ability to change their attributes. Since agents are computer-generated in software, physical characteristics such as age, height, weight, race, attractiveness, or a number of other attributes, either isolated or combined, can be altered to target the needs of the designer or users. This has been examined by early researchers, but not enough data have been collected to fully

understand how any of these physical characteristics impact the perception of or learning from particular representations. For example, researchers have examined gender (Baylor & Kim, 2005; Kim et al., 2007; Rosenberg-Kima et al., 2008; Shiban et al., 2015; Schroeder & Adesope, 2015), ethnicity (Baylor & Kim, 2005), age (Rosenberg-Kima et al., 2008), and random attributes such as coolness (Rosenberg-Kima et al., 2008; Shiban et al., 2015). Although limited research has not produced foundational results for an understanding of best practices, the simplicity of designing components of a presentation and then systematically altering design features through manual sliders in the program allows for more comparable results. For instance, to understand how the age of a presenter impacts measured outcomes, researchers would have to hire multiple human lecturers. Inherent problems such as gesturing, body sway, voice prosody, clothing, perceived attractiveness, and intangible qualities such as charisma could become extraneous variables. The pedagogical agent, on the other hand, is a computer-generated image that allows functionality to remain constant, while isolated features, such as age, are controlled via algorithms on an interface within the program. An agent can resemble a 20-year-old individual and, two seconds later, possesses all the physical features of a 50-year-old individual by manipulating age sliders on the interface. Once the pedagogical agent is designed to meet certain specifications, alterations or isolation of particular components are much easier and, in some cases, provide better comparisons. However, it must be noted that many features of pedagogical agent design rely on the agent's voice. Voice provides many nonverbal social cues, such as age, weight, race, and role (Krauss et al., 2002). Thus, voice can be a necessary focus with pedagogical agents, whereas this component is inherent to the human lecturer.

Environment Construction

Another consideration for the practicality of using pedagogical agents involves the environment. Designers can use computer software to create environments that would otherwise be too expensive for set design or inaccessible to human lecturers. Commercialized software companies often have marketplaces where customers can purchase complete scenes or the necessary components to create a scene. For example, a designer can purchase resource packs to recreate the streets of Hong Kong, Miami, or New York. Additionally, depending on the designer's needs, random locations such as a museum, doctor's office, café, underwater coral forest, conference rooms, school rooms, and many other areas can be easily designed. Then, there are settings that are inaccessible to humans and that would require expensive production budgets to recreate. For instance, Yung and Paas (2015) created an animation with pedagogical agents (red blood cells, white blood cells, and a full-bodied male) that guided middle school students through the

cardiovascular system. There are potentially many educational experiences, such as lava chambers in a volcano or deep-sea creatures at the bottom of the Mariana Trench, that allow designers to create environments that are otherwise inaccessible. Software programs that allow for customized creation enable one designer, with the necessary voice tracks, to create environments that match reality or the user's expectations, or to produce a fantastical environment that captures the user's imagination. However, videos produced with human lecturers could require a team of professionals, time, and great expense to produce. The use of a green screen could assist in perception but may lack the sense of depth that is created by the animation software that is used for most pedagogical agent designs.

Targeted Populations

In addition to these benefits, there is evidence that the image of a pedagogical agent is beneficial for students diagnosed with autism syndrome disorder (ASD). It must be noted that interventions for ASD students often involve intelligent tutoring systems, but there is empirical evidence that ASD students prefer to interact more with computers than with humans (Williams et al., 2002; Tartaro & Cassell, 2006, 2008; Putnam & Chong, 2008); therefore, pedagogical agents in intelligent tutoring systems can be less stimulating than can actual humans. Some students on the ASD spectrum can be overwhelmed by visual details and non-verbal information with social interactions that can lead to sensory overload; however, agent features and non-verbal cues can be muted or systematically controlled to meet the needs of the student (Milne et al., 2011). The design flexibility with using a virtual environment with pedagogical agents allows designers to ultimately control and meet the needs of ASD students. For example, systems have been designed for adults with ASD to train for job interviews with different agent representations, vocational fields, settings, and differing conversational modes to prepare for various experiences (Harthbolt et al., 2019). The flexibility of altering the components of an entire system and the ability to diminish or mute agent characteristics (i.e., facial features) that could overwhelm individuals diagnosed with ASD provide opportunities that are often time consuming, impractical, or problematic for humans.

In essence, pedagogical agents can be molded to any desired vision. If a designer wanted to substitute a humanoid agent for an alien agent throughout the entire storyline, this could be done in a matter of seconds. Additionally, any changes to the character, such as clothing, height, weight, age, and any factors inherent to display, can be changed within the timeline with little difficulty. Likewise, environments can be created that

are either dangerous or impossible in the real world. A designer could create sets for human actors or lecturers to tour the cardiovascular system, similar to Yung and Paas (2015), or one proficient designer could create the whole presentation in a computer-based environment if all the voice clips, scripts, and storyboards needed for the storyline are provided. Finally, certain populations might be more receptive to pedagogical agents than humans are. There are benefits to using humans as instructors, but pedagogical agents also have advantages that cannot be easily dismissed; therefore, it is best for researchers to help discern the context in which one form of presentation might be more advantageous than the other. There is a place for both in educational technology, but that does not mean that the theoretical underpinnings for pedagogical agents can be adopted for human lecturers, and vice versa. Human lecturers in videos and pedagogical agents are separate entities that may overlap in certain areas but require vastly different design considerations. Therefore, a proper definition for a pedagogical agent might be: computer-generated images that employ pedagogical strategies to facilitate human-computer interaction to increase social engagement and encourage learning in computer-based environments.

Conclusion

Pedagogical agents and humans are different. Early pioneers of animated pedagogical agent research sought to replace humans in videos with computer representations that could be considered sentient. However, the affordances and capabilities of the two are different. Much of what is explored with pedagogical agents is based on human-to-human interaction or communication; thus, humans serve as a standard for what researchers have been trying to assess in computer-based environments. From a human-computer interaction perspective, pedagogical agent researchers are still exploring the theoretical underpinnings of what humans expect from an agent, as well as the level of response by humans to certain design features that are inherent to being human. For example, do human users expect pedagogical agents to perform gestures at the same frequency as their human counterparts, or can less gesturing that is strategically placed be just as acceptable? Additionally, with the pedagogical agent being a computer-designed representation, do people ignore the more robotic delivery of gestures that would be considered unnatural in a human communicator? Therefore, the field of pedagogical agent research often compares what is known about human-to-human expectations to understand whether the same rules apply to computer-generated representations that deliver information. Comparisons between humans and pedagogical agents can be carried out to understand whether the agents are perceived similarly to humans, but the inverse is not true.

Comparing humans to the theories and principles that guide pedagogical agent design and delivery creates a false dichotomy that hinders what is known, or could be known, about agent design and interaction. A human cannot be a pedagogical agent, but researchers are assessing how human a pedagogical agent can be or needs to fulfill the intended purpose.

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Received: April 7, 2024 / Peer review completed: May 23, 2024 / Accepted: June 29, 2024