Pedagogical Agent Design: The Impact of Agent Realism, Gender, Ethnicity, and Instructional Role

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Abstract. In the first of two experimental studies, 312 students were randomly assigned to one of 8 conditions, where agents differed by ethnicity (Black, White), gender (male, female), and image (realistic, cartoon), yet had identical messages and computer-generated voice. In the second study, 229 students were randomly assigned to one of 12 conditions where agents represented different instructional roles (expert, motivator, and mentor), also differing by ethnicity (Black, White), and gender (male, female). Overall, it was found that students had greater transfer of learning when the agents had more realistic images and when agents in the "expert" role were represented non-traditionally (as Black versus White). Results also generally confirmed prior research where agents perceived as less intelligent lead to significantly improved self-efficacy. The presence of motivational messages, as employed through the motivator and mentor agent roles, led to enhanced learner self-regulation and self-efficacy. Results are discussed with respect to social cognitive theory.

1 Introduction

Pedagogical agent design has recently been placing greater emphasis on the importance of the agent as an actor rather than as a tool (Persson, Laaksolahti, & Lonnqvist, 2002), thus focusing on the agent's implicit social relationship with the learner. The social cognitive perspective in teaching and learning emphasizes the importance that social interaction (e.g., Lave & Wenger, 2001; Vygotsky, Cole, John-Steiner, Scribner, & Souberman, 1978) plays in contributing to motivational outcomes such as learner self-efficacy (Bandura, 2000) and self-regulation (Zimmerman, 2000).
According to Bandura (1997), attribute similarities between a social model and a learner, such as gender, ethnicity, and competency, often have predictive significance for the learner's efficacy beliefs and achievements. Similarly, pedagogical agents of the same gender or ethnicity or similar competency as learners' might be viewed as more affable and could instill strong efficacy beliefs and behavioral intentions to

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learners. Learners may draw positive judgments about their capabilities when they observe agents who demonstrate successful performance.

Even so, while college students were not more likely to choose to work with an agent of the same gender (Baylor, Shen, & Huang, 2003), in a between-subjects study they were more satisfied with their performance and reported that the agent better facilitated self-regulation if it was male (Baylor & Kim, 2003). Similarly, Moreno and colleagues (2002) revealed that learners applied gender stereotypes to animated agents, and this stereotypic expectation affected their learning. With respect to the ethnicity of pedagogical agents, empirical results do not provide consistent results. In both a computer-mediated communication and an agent environment, participants who had similar-ethnicity partners than those with different-ethnicity partners presented more persuasive and better arguments; elicited more conformity to the partners' opinions; and perceived their partners as more attractive and trustworthy (Lee & Nass, 1998). In a more recent study, Baylor and Kim (2003b) examined the impact of pedagogical agents' ethnicity on learners' perception of the agents. Undergraduate participants who worked with pedagogical agents of the same ethnicity rated the agents as more credible, engaging, and affable than those who worked with agents of different ethnicity. However, Moreno and colleagues (2002) indicated that the ethnicity of pedagogical agents did not influence students' stereotypic expectations or learning.

Given their function for supporting learning, pedagogical agents must also represent different instructional roles, such as expert, instructor, mentor, or learning companion. These roles also may interact with the agent's gender and ethnicity given that human social relationships influence their perceptions and understanding in general (Dunn, 2000). In a similar fashion, the instructional roles of the pedagogical agents may influence the perceptions or expectations of and the social bonds with learners. Along this line, Baylor and Kim (2003c, in press) showed that distinct roles for pedagogical agents—as expert, motivator, and mentor—significantly influenced the learners' perceptions of the agent persona, self-efficacy, and learning.

Lastly, Norman (1994; 1997) expressed concerns about human-like interfaces. If an interface is anthropomorphized too realistically, people tend to form unrealistic expectations. That is, a too realistic human-like appearance and interaction can be deceptive and misleading by implying promises of functionality that can be never reached. On the other hand, socially intelligent agents are of "no virtual difference" from humans (Vassileva, 1998) and can provoke "illusion of life" (Hays-Roth & Doyle, 1998), thus impressing the learners interacting with a "living" virtual being (Rizzo, 2000). So, we may inquire how realistic agent images should be to establish social relations to learners. Norman argues that people will be more accepting of an intelligent interface when their expectation matches with its real functionality. What extent of agent realism will match learners' expectations with agent functionality is an open question, however.

Consequently, the relationships among pedagogical agent gender, ethnicity, instructional role, and realism seem to play a role to enhance learner motivation (e.g., self-efficacy), self-regulation, and learning. The purpose of this research was to examine these relationships through two controlled experiments. Experiment I examined the impact of agent gender, ethnicity, and realism; Experiment II examined the impact of agent gender, ethnicity, and instructional role.

2 Experiment I: Agent Realism, Gender, Ethnicity

2.1 Agent Design

Eight agent images were designed by a graphic artist based on the same basic face, but differing by gender, ethnicity, and realism. The animated agents were then developed using a 3D character design tool, Poser 5, and Microsoft Agent Character Builder. Next, the agents were incorporated into the web-based research application, MIMIC (Multiple Intelligent Mentors Instructing Collaboratively) (Baylor, 2002). To control confounding effects, we used consistent parameters and matrices to delineate facial expression, mouth movement, and overall silhouettes across the agents. Also, except for image, the agents had identical scripts, voice, animation, and emotion. For voice, we used computer-generated male and female voices. For animation, blinking and mouth movements were included. Emotion was expressed using the scripts together with facial expression, such as smiling. Figure 1 presents the images of the eight agents used in the study.

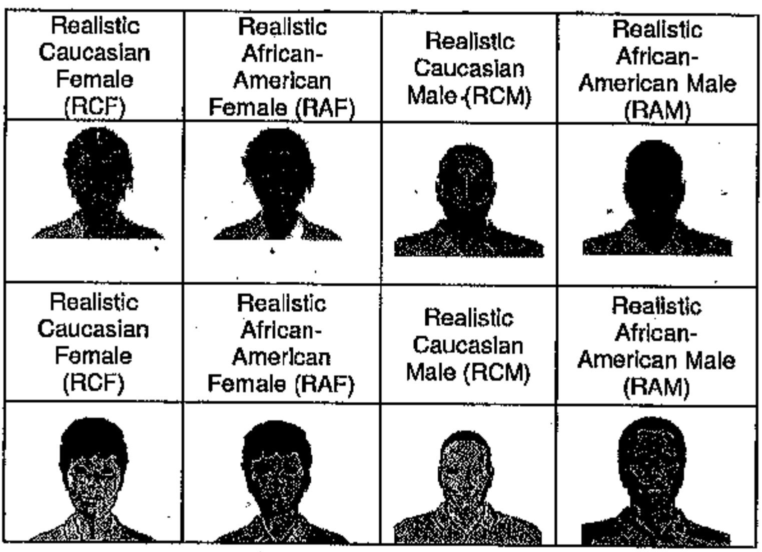


Fig. 1. Images of eight agents in Experiment I

Validation. In a controlled between-subjects study with 83 undergraduates, we validated that each agent effectively represented the intended gender, ethnicity, and degree of realism.

2.2 Method

Dependent Variables. Dependent variables included self-regulation, self-efficacy, and learning and were identical for both Experiment I and II.

Self-regulation. Learners' self-regulation was assessed through three Likert-scale items: 1) I stopped to think over what I was learning and doing; 2) I kept track of my progress; and 3) I evaluated the quality of my lesson plan. The students rated their self-regulation on a five-point scale ranging from 1 (*Strongly disagree*) to 5 (*Strongly agree*). Item reliability was evaluated as $\alpha = 0.85$.

Self-efficacy. Learners' self-efficacy beliefs about the learning tasks were measured with a one-item question developed according to the guidelines of Bandura and Schunk (1981) for specificity. The guidelines emphasize that self-efficacy is the degree to which one feels capable of performing a particular task at certain designated levels (Bandura, 1986). The participants answered the question, "How sure are you that you can write a lesson plan?" on a scale ranging from 1 (*Not at all sure*) to 5 (*Extremely sure*) after the intervention.

Learning. Learning was assessed by an open-ended question where the participants had to transfer their knowledge to a new situation. The participants were asked to write a brief instructional plan with the following prompt:

> Applying what you've learned, develop an instructional plan for the following scenario: Imagine that you are a sixth grade teacher of a mathematics class. Your principal informs you that a member of the president's advisory committee will be visiting next week and wants to see an example of your instruction about multiplication of fractions.

The overall quality of a the answers were evaluated by two instructional designers, who scored the students' answers with a detailed scoring rubric on a scale ranging from 1 (*very poor*) to 5 (*excellent*). Inter-rater reliability was evaluated as Cohen's *Kappa* = 0.95.

Sample. Participants included 312 pre-service teachers enrolled in an introductory educational technology class in two large southeast universities in the United States. Approximately 30% of the participants were male and 70% were female; 53% of the participants were Caucasian, 33% were African-American, and 14% were others. The average age of the participants was 20.54 years (SD=2.63).

Procedure. The experiment was conducted during a regular session of an introductory educational technology course. The participants were randomly assigned to one of the eight agent conditions. They logged on the web site loading MIMIC (Multiple Intelligent Mentors Instructing Collaboratively), which was designed to help the students develop instructional planning. The participants were given as much time as they needed to finish each phase of the tasks. The entire session took about an hour with individual variations.

Design and Analysis. The study employed a 2 × 2 × 2 design, including agent gender (Male vs. Female), agent ethnicity (Caucasian vs. African-American), and agent realism (realistic vs. cartoon-like) as the factors. For self-regulation, a MANOVA (multivariate analysis of variance) was conducted. For self-efficacy and learning, analysis of variance (ANOVA) was conducted. The significance level was set as $\alpha = 0.5$.

2.3 Results

Self-regulation. MANOVA revealed a significant main effect for agent gender, Wilks' Lambda = .97, F (3, 287) = 3.45, p = .01, where the presence of a male agent led to significantly more reported self-regulatory behavior than the presence of a female agent. Follow-up post-hoc univariate analyses (ANOVA) revealed significant main effects for each of the three sub-measures (all p<.05).

Self-efficacy. ANOVA indicated a significant main effect for agent gender where the presence of the male agent led to increased self-efficacy, F(1, 289)=4.20, p<.05. Analysis of additional Likert items revealed that students perceived the male agents as significantly more interesting, intelligent, useful, and leading to greater satisfaction than the female agents.

Learning. For all students (male and female) ANOVA revealed a marginally significant main effect for agent realism on learning, F (1, 289) = 4.2, p =.09. Overall, students who worked with the realistic agents (M = 3.13, SD = 1.05) performed marginally better than students who worked with the cartoon-like agents (M = 2.94, SD = 1.1). Interestingly, a post-hoc ANOVA indicated a significant main effect for agent realism where males working with realistic agents (M=3.50) learned more than males working with cartoon agents (M=2.51, F(1,84) =6.50, p=.01. For female students, the main effect for agent realism was not significant.

3 Experiment II: Agent Role, Ethnicity, and Gender

3.1 Agent Design

For the second study, a different set of twelve agents, differing by gender, ethnicity, and role, were designed using a 3D character design tool, Poser 5 and Mimic Pro 2. These agents were richer than those in Experiment I, where the focus was on the agent image. Consequently, to establish distinct instructional roles, it was important to consider a set of media features that influence agent "persona," including image, animation, affect, and voice. Image is a key factor in affecting learners' perception of the computer-based agent as credible (Baylor & Ryu, 2003b) and motivating (Baylor

& Kim, 2003a; Baylor, Shen, & Huang, 2003; Kim, Baylor, & Reed, 2003). Animation includes body movements such as hand gestures, facial expression, and head nods, which can convey information and draw students' attention (Cassell, 1998; Johnson, Rickel, & Lester, 2000; McNeill, 1992; Roth, 2001). Affect, or emotion, is also an integral part of human intellectual and cognitive functioning (Kort, Reilly, & Picard, 2001; Picard, 1997) and thus was deemed as critical for facilitating the social relationship with learners and affecting their emotional development (Saarni, 2001). Finally, voice is a powerful indicator of social presence (Nass & Steuer, 1993), and so the human voices were recorded to match the voices with the gender, ethnicity, and roles of each agent and with their behaviors, attitudes, and language. Figure 2 shows the images of the twelve agents.

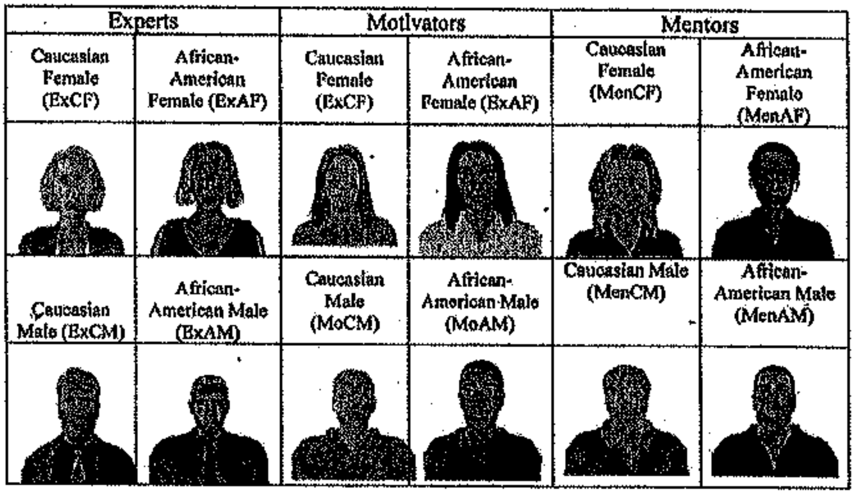


Fig. 2. Images of twelve agents in Experiment II

The agent-student dialogue was pre-defined to control for agent functionality across students. Given that people tend to apply the same social rules and expectations from human-human interaction to computer-human interaction (Reeves & Nass, 1996), we referred to research on human instructors for implications for the agent role design.

Agent as Expert. The design of the Expert was based on research that shows that the development of expertise in humans requires years of deliberate practice in a domain (Ericsson, Krampe, & Tesch-Romer, 1993) and that experts exhibit mastery or extensive knowledge and perform better than the average within a domain (Ericsson, 1996; Gonzales, Burdenski, Stough, & Palmer, 2001). Also, experts will be confident and stable in performance and not swayed emotionally by instant internal or external stimulation. Based on this, we operationalized the expert agent through the image of a professor in forties. His animation was limited to deictic gestures, and he spoke in a formal and professional manner, with authoritative speech. Being emotionally detached from the learners, his function was to provide accurate information in a succinct way (see sample script in Table 2).

Agent as Motivator. The design of the Motivator was based on social modeling research dealing with learners' efficacy beliefs, a critical component of learner motivation. According to Bandura (1997), attribute similarity between the learner and social model significantly affects the learners' self-efficacy beliefs. In other words, learning and motivation are enhanced when learners observed a social model of the same age (Schunk, 1989). Further, verbal encouragement in support of the learner performing a task facilitates learners' self-efficacy beliefs. Thus, we operationalized a motivator agent with a peer-like image of a casually-dressed student in his twenties, considering that our target population was college students. Given that expressive gestures of pedagogical agents may have a strong motivating effects (Johnson et al., 2000), the agent gestures were expressive and highly-animated. He spoke enthusiastically and energetically, while sometimes using colloquial expressions, e.g., 'What's your gut feeling?' He was not presented as particularly knowledgeable but as an eager participant who suggested his own ideas, verbally encouraged the learner to sustain at the tasks, and, by asking questions, stimulated the learners to reflect on their thinking (see sample script in Table 2). He expressed emotion that commonly occurs in learning, such as frustration, confusion, and enjoyment (Kort et al., 2001).

Agent as Mentor. An ideal human mentor does not simply give out information; rather, a mentor provides guidance for the learner to bridge the gap between the current and desired skill levels (Driscoll, 2000). Thus, a mentor should not be an authoritarian figure, but instead should be a guide or coach with advanced experience and knowledge who can work collaboratively with the learners to achieve goals. Thus, the agent as mentor should demonstrate competence to the learner while simultaneously developing a social relationship to motivate the learner (Baylor, 2000). Consequently, the design of the Mentor included an image that was less formal than the Expert, yet older than the peer-like Motivator. The Mentor's gestures were designed to be identical to the Motivator, incorporating both deictic and emotional expressions. His voice was friendly and approachable, yet more professional and confident than the Motivator. We operationalized the Mentor's functionality to incorporate the characteristics of both the Expert and Motivator, (i.e., to provide information and motivation); thus, his script was a concatenation of the content of the Expert and Motivator scripts.

Validation. We initially validated that each agent was effectively representing the intended gender, ethnicity, and roles with 174 undergraduates in a between-subjects design. The results indicated successful instantiations of the twelve agents.

3.2 Method

Dependent variables were identical to those employed in Experiment I and included self-regulation, self-efficacy, and learning.

Sample. Participants included 229 undergraduates enrolled in a computer literacy course in a large university in the Southeastern United States. Approximately 39% of the participants were male and 61% were female; 70% of the participants were Caucasian, 10% were African-American, and 20% were others. Approximately 39% of the participants were male and 61% were female. The average age of the participants was 19.39 (SD=1.64).

Procedure. The experiment was conducted during a regular session of a computer literacy class. The participants were randomly assigned to one of the twelve agent conditions. They logged on the web site loading a modified version of MIMIC (Multiple Intelligent Mentors Instructing Collaboratively), which was designed to help the students develop instructional planning for e-Learning. The participants were given as much time as they needed to finish each phase of the tasks. The entire session took about an hour with individual variations.

Design and Analysis. The study employed a $2 \times 2 \times 3$ design, including agent gender (Male vs. Female), agent ethnicity (White vs. Black), and agent role (expert vs. motivator vs. mentor) as the factors. For self-regulation, a MANOVA (multivariate analysis of variance) was conducted. For self-efficacy and learning, analysis of variance (ANOVA) was conducted. The significance level was set as $\alpha = 0.5$.

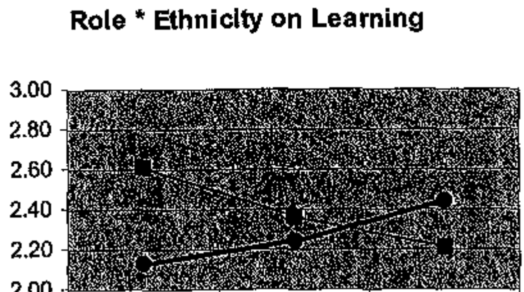
3.3 Results

Self-regulation. MANOVA revealed a significant main effect for agent role on self-regulation, Wilks' Lambda = .94, $F(6, 430) = 2.22$, $p < .05$. Overall, students who worked with the mentor or motivator agents rated their self-regulation significantly higher than students who worked with the expert agent. MANOVA also revealed a main effect for agent ethnicity on self-regulation where Black agents led to increased self-regulation as compared to White agents, Wilks' Lambda =.96, $F(3, 205) = 2.90$, $p < .05$.

Self-efficacy. There was a significant main effect for agent gender on self-efficacy, $F(1, 217) = 6.90$, $p < .05$. Students who worked with the female agents (M = 2.36, SD = 1.16) showed higher self-efficacy beliefs than students who worked with the male agents (M = 2.01, SD = 1.12). Analysis of additional Likert items revealed that students perceived the female agents as significantly less knowledgeable and intelligent than the male agents. There was also a significant main effect for agent role on self-efficacy, $F(2, 217) = 4.37$, $p = .01$. Students who worked with the motivator (M = 2.37, SD = 1.2) and mentor agents (M = 2.32, SD = 1.2) showed higher self-efficacy beliefs than students who worked with the expert agent (M = 1.86, SD = 0.94).

Learning. There was a significant interaction of agent role and agent ethnicity on learning, $F(2, 214) = 3.36$, $p < .05$. Post hoc t-tests of the cell means indicated that there was a significant difference between the Black (M = 2.61, SD =.75) and White

Experts (M = 2.13 , SD =.84, p<.01), indicating that the Black agents were significantly more effective in the role of Expert than the White agents. This interaction is illustrated in Figure 3. Additional analysis of Likert items regarding the level to which students paid attention during the program revealed that students with the *Black Experts better "focused on the relevant information"* ((*M = 3.03, SD =1.08 vs.* M = 2.42, SD =1.11) and "concentrated" (M = 2.70, SD = .95 vs. M = 2.23, SD = 1.10).



	Expert	Motivator	Mentor
White	2.13	2.24	2.44
Black	2.61	2.36	2.21

Fig. 3. Interaction of Role * Ethnicity on Learning

4 Discussion

Results from Experiment I highlight the potential value of more realistic agent images (particularly for male students) to positively affect transfer of learning. This supports the value in designing pedagogical agents to best represent the live humans that they attempt to simulate (e.g., Hays-Roth & Doyle, 1998; Rizzo, 2000). Even so, a variety *of permutations of agents with different* levels of realism needs to be examined to more fully substantiate this finding.

In Experiment II, the Black agents in the role of expert led to significantly improved learning as compared to the White agents as experts, even though both had identical messages. Students working with the Black experts also reported enhanced concentration and focus, which could be explained by the fact that they perceived the agents as more novel (and thereby more worthy of paying attention to) than the White experts. *Similarly, Black agents overall (in all roles) led to enhanced learner self-*regulation in the same experiment, perhaps because they also warranted greater attention and focus. In support of this explanation (i.e., that students pay more attention to agents that represent non-traditional roles), we recently found that a female agent acting as a non-traditional engineer (e.g., outgoing, highly attractive) significantly enhanced student interest in engineering as compared to a more stereotypical "nerdy" version (e.g., introverted, homely) (Baylor, 2004).

The importance of the agent message was demonstrated in Experiment II, where the presence of motivational messages (as delivered through the motivator and mentor agent instructional roles) led to greater learner self-regulation and self-efficacy. This finding is supported by Bandura (1997), who suggests that such verbal persuasion leads to positive motivational outcomes.

Our prior research has indicated that agents that are perceived as *less* intelligent lead to greater self-efficacy (Baylor, 2004; Baylor & Kim, in press). This was replicated in Experiment II since the female agents (who were perceived as significantly less intelligent than the males) led to enhanced self-efficacy. Similarly, the finding that the motivator and mentor agents led to greater self-efficacy could be attributed to the fact that they were validated to be perceived as significantly less expert-like (i.e., knowledgeable, intelligent) than the expert agents. While results from Experiment I initially seem contradictory because the agents rated as most intelligent (males) also led to improved self-efficacy, this can be attributed to an overall positive student bias toward the male agents in this particular study (e.g., they were rated as more useful, interesting, and leading to overall more satisfaction and self-regulation).

Overall, while the agent message is undoubtedly important, results support the conclusion that a seemingly superficial interface feature like pedagogical agent image plays a very important role in impacting learning and motivational outcomes. The image is key because it directly impacts how the learner perceives it as a human-like instructor; consequently, pedagogical agent designers must take great care in choosing how to represent the agent's gender, ethnicity, and realism.

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