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Animated agents in K-12 engineering outreach: Preferred agent characteristics across age levels

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ABSTRACT

Animated agents have been found to positively impact student learning and/or perceptions within computer-based learning environments. However, there is little research on the agent characteristics preferred by K-12 students. The main purpose of this study was to examine student preferences for individual pedagogical agents and their preferences for various agent characteristics. Student preferences for the following agent characteristics were assessed using survey methodology: agent gender, age, realism, clothing, personality, speech pace, and tutoring approach. A total of $N = 565$ students from elementary through high school watched a computer-based multimedia overview of engineering. Four engineering disciplines were introduced by four animated agents: a young female, young male, old female, and old male agent. Immediately after viewing the computer-based overview, students completed surveys assessing preferences for the four agents and for individual agent characteristics. Results indicated that all students preferred agents and specific external agent characteristics that are close to their own external characteristics and favored internal agent characteristics that they felt would promote understanding of the domain. These findings suggest that animated agents used in computer-based K-12 engineering outreach should be close to the student's external characteristics.

1. Introduction

An animated agent, i.e., a humanlike or otherwise animated onscreen character, can be used to tutor students in a particular domain and/or to affect perceptions about a topic (Baylor, 2011; Clark & Choi, 2005; Craig, Gholson, & Driscoll, 2002; Dehn & van Mulken, 2000; Gulz, Haake, Silvervarg, Sjoden, & Veletsianos, 2011; Murray & Tenenbaum, 2010; Woo, 2009; Yung, 2009). Animated agents are designed to serve one or more functions in learning environments: (1) motivation; (2) information; (3) information processing; (4) storing and retrieving; (5) transfer of information; and (6) monitoring and directing (Heidig & Clarebout, 2011; Klauer, 1985). Computer-based learning research is replete with an expansive array of animated pedagogical agents which provide instruction in a diverse set of domains (Clarebout, Elen, Johnson, & Shaw, 2002; Heidig & Clarebout, 2011). However, little previous research has investigated learner preferences for animated agents and their individual characteristics, or how those preferences change according to the learners' age. Furthermore, the recent review by Heidig and Clarebout (2011) indicates that animated pedagogical agents have most often been used to instruct learners in the science, mathematics, and instructional design fields. There is a paucity of research on the use of animated agents in engineering education (cf., Dirkin, Mishra, & Altermatt, 2005; Mayer, Dow, & Mayer, 2003; Moreno & Flowerday, 2006; Perez & Solomon, 2005; Wang et al., 2008). The current study investigates learner preferences for an animated engineering tutor for elementary, middle, and high school students.

1.1. Animated agents

Research demonstrates that people tend to treat computers as social entities (Nass & Moon, 2000; Reeves & Nass, 1996), and this anthropomorphism can be enhanced by displaying a physical image with human-like qualities (i.e., an animated agent; Baylor & Kim, 2009; Baylor & Ryu, 2003; King & Ohya, 1996; Lester et al., 1997; Mayer & DaPra, 2012; Moundridou & Virvou, 2002; Mumm & Mutlu, 2011). Lester et al. (1997) proposed the *persona effect*, that the presence of an animated agent in computer-based learning environments can improve learning and learners' perceptions of the experience. The authors suggested that animated agents can promote active learning processes (e.g., indicating relevant features of the problem) and initiate a social interaction which enhances student motivation.

Heidig and Clarebout (2011) found inconsistent evidence regarding general learning advantages of animated agents. Their

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examination of 15 experiments with adequate controls (i.e., experimental conditions providing identical instruction without an animated agent) revealed that only five studies showed learning benefits through the use of animated agents; the remaining ten investigations did not demonstrate a persona effect on learning outcomes. The authors suggested that research on animated agents should focus on identifying the conditions under which animated agents are effective, rather than attempting to demonstrate a universal benefit of agents. Their 'Pedagogical Agent-Conditions of Use Model' (PACU) provided four conditions influencing the efficacy of animated agents: (1) learning environment and domain; (2) learner characteristics; (3) the functions of the animated agent (i.e., instructional techniques); and (4) design characteristics of the agent. The current study investigates student preferences mostly for design characteristics (condition 4) and to some degree for instructional approaches (condition 3) within the engineering domain (condition 1). The following section examines the theoretical underpinnings and empirical research concerning these factors.

1.2. Agent characteristics

The visual and auditory representations of the agent (external properties) and the behaviors and instructional techniques used (internal properties; Moreno, 2005) have the potential to influence agent effectiveness. *External* properties (characteristics) include agent age, gender, race, clothing, realism, and speech qualities (such as speech pace); *internal* properties (characteristics) include agent personality and tutoring approach. Variations in external properties are assumed to affect learning and student perceptions because they impact agent credibility (Baylor & Ryu, 2003; van der Meij, van der Meij, & Harmsen, 2012) and the degree to which the learner feels connected to the agent. Internal properties related to instructional technique may influence learning similarly to the way that different instructional methods used by human tutors impact outcomes, although, to our knowledge, no investigation has examined this issue directly. Nonetheless, students may vary in the degree to which an animated agent with a fun vs. a serious personality or with a relaxed vs. strict tutoring approach affects learning.

Research supports the assumption that an animated agent's external characteristics can affect the influence of the message on viewers (Baylor & Ryu, 2003; Plant, Baylor, Doerr, & Rosenberg-Kima, 2009; Rosenberg-Kima, Baylor, Plant, & Doerr, 2008; Rosenberg-Kima, Plant, Doerr, & Baylor, 2010; Yilmaz & Kiliç-Çakmak, 2012) and that these external characteristics can impact learning outcomes (Arroyo, Woolf, Royer, & Tai, 2009; Baylor & Kim, 2004; Baylor & Kim, 2005; Kim, Baylor, & Shen, 2007; van der Meij, 2013). Lusk and Atkinson (2007) demonstrated that a fully embodied, dynamic representation of a pedagogical agent led to better near and far transfer performance than a voice-only condition. Rosenberg-Kima et al. (2008, Experiment 2) found that animated agents depicted as female, young, and "cool" (operationalized through dress) most positively impacted young womens' perceptions of engineering. Baylor and Kim (2004, Experiment 1) found that students had better transfer of learning after learning with a 'realistic' agent, compared to the identical instruction provided by a cartoon agent.

Arroyo et al. (2009) investigated the effect of male vs. female learning companions on learners' mathematics attitudes, emotions, and outcomes. Results demonstrated that the female learners from the study reported more positive attitudes and had better learning from the male agents. Similar results were attained in Baylor and Kim (2005) and Kim et al. (2007): student perceptions and learning were better with the male agents than the female agents. The authors of these papers contribute findings to stereotypes about males vs. females; students perceived the male agents as more knowledgeable and thus learned more and evaluated the experience more positively. This is consistent with research showing that parents, teachers, and peers often view males as more knowledgeable than females, particularly in masculine domains such as math and engineering (Kurtz-Costes, Rowley, Harris-Britt, & Woods, 2008).

Evidence from draw-an-engineer studies indicates that young students commonly envision engineers as male (Capobianco, Diefes-Dux, Mena, & Weller, 2011; Fralick, Kearn, Thompson, & Lyons, 2009; Karatas, Micklos, & Bodner, 2011; Knight & Cunningham, 2004). For instance, Capobianco et al. (2011) found in draw-an-engineer tests (Knight & Cunningham, 2004) that 58% of elementary school students drew the engineer as a male, whereas 18% drew a female, and 24% drew a group or a person without discernible gender. Similar studies by Fralick et al. (2009) and Karatas et al. (2011) found a pronounced dominance of the male gender, while Knight and Cunningham (2004) found that, of student drawings with gender attributes, 61% were of male engineers. Preconceived notions about the 'normal' characteristics possessed by engineers (e.g., dominant gender) may influence student preferences for agent characteristics in animated engineering tutors and the respective impacts of male and female agents on student learning and perceptions.

Taken together, the empirical work on external properties of animated agents shows that agent characteristics, such as age, gender, realism, and clothing, can influence the efficacy of an agent-based computer module. More specifically, previous studies assigned students to interact with agents with specific characteristics (e.g., gender) according to an experimental design and examined the effects of specific agent characteristics on student perceptions (e.g., Rosenberg-Kima et al., 2008, 2010) and learning outcomes (e.g., Arroyo et al., 2009; Kim et al., 2007). Complementary to these previous studies, the present study directly asked students about their preferences for agent characteristics. To the best of our knowledge, the present study is the first to examine preferences of students ranging from elementary school through high school for characteristics of animated agents functioning as tutors in the engineering domain. We acknowledge that student preferences for agent characteristics may not be in line with what best fosters learning or positive student perceptions; it is nonetheless important to identify attributes which are preferred by learners because using these characteristics may encourage persistence in the learning environment.

1.3. Similarity–attraction

Preliminary evidence suggests that learners will select agents that are more similar to them in various dimensions (Behrend & Thompson, 2011; Kim & Lim, 2012; Kim & Wei, 2011; Moreno & Flowerday, 2006). This tendency is attributed to the similarity–attraction hypothesis, which holds that people are more attracted to others who appear and behave similarly to themselves (Byrne & Nelson, 1965). Several studies have demonstrated that people will report higher attraction toward, attend to, and interact more with strangers who share similar physical characteristics, behaviors, and attitudes. Initial evidence suggested that this similarity–attraction is applicable in human–computer interaction (Isbister & Nass, 2000).

Specific to the use of animated agents, results from Kim and Wei (2011) showed that when 9th grade students were given a choice of animated agent for learning about algebra, female students selected the female agent and males selected the male. Additionally, Caucasian students more often selected a Caucasian agent and Hispanic students selected a Hispanic agent. Our own research has shown that 89% of middle school children will select a same-gender animated agent when given a choice in an engineering learning environment (Ozogul, Johnson, Atkinson, & Reisslein, in press). However, Moreno and Flowerday (2006) found that college students were not significantly more likely to choose an agent that matched their gender. This finding suggests that the tendency toward same gendered agents may differ across age levels.

In summary, the existing studies on the similarity–attraction aspect of animated agents allowed students to select among a small set of agent characteristics and observed the resulting effects on student perceptions and learning. Complementary to the existing studies, the present study examines student preferences for a broad set of agent characteristics. Moreover, prior research has focused on high school or college-aged students, whereas the current study is unique in providing data on preferences of younger students (elementary and middle school) and on potential changes that occur across these ages up to and including high school.

1.4. Design and hypotheses

The present study was conducted with elementary, middle, and high school students to examine questions relating to computer-based engineering outreach interventions in K-12 students. The student preferences for an animated agent (out of four options: young male, young female, old male, and old female) as well as preferred external agent properties (i.e., gender, age, realism, clothing, and speech pace) and preferred internal agent properties (i.e., personality and tutoring style) were studied.

In order to assess student preferences for animated agents and agent characteristics, we first presented the learners a short computer-based introduction to engineering which incorporated the four options of agents, fully animated and with narration. In this short presentation, the agents functioned as "info-guides" similar to museum docents, providing an initial, simple overview of the engineering fields. This computer-based introduction served to exhibit the external characteristics of each animated agent in a neutral setting not directly related to learning, while not confounding the perceptions toward the on-screen characters per se with the perceptions of the animated agents in the specific role as a tutor. Immediately following the short introduction to engineering, students were asked to envision these animated agents, which they observed in a neutral "info-guide" setting, as engineering tutors. The students answered questions on the suitability of these agents as engineering tutors.

The similarity–attraction hypothesis predicts that students will select an animated agent that most closely resembles themselves. Specifically, it is expected that young girls will select a young female agent and young boys will select a young male agent (Hypothesis 1). However, given prior evidence indicating that young students envision engineers as men (Capobianco et al., 2011; Fralick et al., 2009; Karatas et al., 2011; Knight & Cunningham, 2004), a competing hypothesis is offered: students (both male and female) will select male agents as an engineering tutor (Hypothesis 2). Also, based on the similarity–attraction hypothesis, we predict that students will select options for individual agent characteristics that mirror their own characteristics (e.g., young, same gender; Hypothesis 3).

2. Method

2.1. Participants

Participants included 565 elementary, middle, and high school students from local, urban schools in the Southwestern US. Demographic information on the participants is reported in Table 1.

2.2. Computerized materials and apparatus

2.2.1. Engineering overview program

The computerized materials consisted of a computer program that included five phases: (1) a demographic questionnaire; (2) an introductory video that familiarized students with the field of engineering, noting the wide range of engineering disciplines and highlighting that the work of engineers relates to almost everything that humans eat, drink, wear, touch, see, hear and smell daily; (3) four videos that informed students about four engineering disciplines; (4) a summary video that concluded the overview of engineering; and (5) an agent rating questionnaire.

During phase (3), animated agents with pre-recorded human voices narrated a script and images were displayed concurrently to illustrate engineering processes and products. Phase (3) displayed four videos introducing students to four disciplines of engineering: electrical, chemical, biomedical, and environmental engineering. The videos briefly explained the problems that engineers within each discipline address and highlighted products that they develop, such as cell phones developed by electrical engineers. The presentation order of the engineering disciplines was fixed, and each was presented by one of four animated agents (order of agents was randomized): a young female agent, a young male agent, an old female agent, and an old male agent. The two young agents had characteristics which made them appear to be of young age (e.g., thin features and high pitched voice), and wore casual attire similar to the students (i.e., jeans, t-shirt, and sneakers). The two old agents had characteristics more typically seen in older people (e.g., grey hair, fuller figures, and lower pitched voice), and wore clothing similar to teachers (i.e., pant suit and dress shoes). Fig. 1 shows static images of the four agents used in the computer program. The animated agents pointed to images in the videos through deictic gestures, for example, pointing with arms and fingers.

The design of the animated agents was inspired by several similar avatars found in games that are popular among precollege students. More specifically, the agents were 3D computer agents created with Autodesk 3D Studio Max 5, a software for building, animating, and rendering 3D models and characters. The narration voice files were applied to the agents using the Ventriloquist program, which uses a collection of twelve phonemes to animate the agent's mouth and facial expressions in correlation to recorded speech. Additional facial expressions of eyebrow motions, eye movements, and head nods as well as animated body and hand movement were added. All of these animated movements were cued to the speech of the agents within 3D Studio Max. Completed agent animations were rendered by 3D Studio Max as video files which were imported into Adobe After Effects CS2.

In phase (5), the students completed a computerized questionnaire which posed several questions about the animated agents and about desired characteristics in an animated engineering tutor. The details of the questionnaire are presented in Section 2.2.2.

The computer-based engineering overview module used in the study was developed using Adobe Flash CS4 software, an authoring tool for creating web-based and standalone multimedia programs. Electronic log files were produced by the program, including participant demographic and survey responses. The equipment consisted of a set of laptop computer systems, each with a screen size 15.6 in. and a resolution of 1680×1050 pixels, and headphones.

2.2.2. Computerized agent rating questionnaire

The individual subsections of the agent rating questionnaire are presented in the following subsections. All questions from the questionnaire were stated using displayed text.

Table 1
Participant demographics, by age level.

	Total *N*	Gender		Age	Ethnicity					
		Male	Female	*M* (*SD*)	Hispanic	Caucasian	African American	Native American	Asian American	Other
Elementary school	223	108	115	9.95 (0.86)	80 (35.9%)	53 (23.8%)	26 (11.7%)	15 (6.7%)	6 (2.7%)	43 (19.3%)
Middle school	200	99	101	11.9 (0.90)	49 (24.5%)	98 (49.0%)	13 (6.5%)	4 (2.0%)	9 (4.5%)	27 (13.5%)
High school	142	79	63	15.5 (1.49)	59 (41.5%)	35 (24.6%)	15 (10.6%)	10 (7.0%)	5 (3.5%)	18 (12.7%)

Fig. 1. Four animated agents used in study. Left to right: young female, young male, old female and old male.

2.2.2.1. Preference among four presented agents. The questionnaire displayed all four animated agents used in the program side-by-side. Students were required to select which agent they would choose to learn from (i.e., "Who do you want as your engineering tutor?").

2.2.2.2. Preferences for characteristics of each of the four agents. Students were also asked about their preferred characteristics for each of the four presented agents. Specifically, students were shown each animated agent (in random order) on separate successive screens and asked to answer the question "What do you like the MOST about this tutor?" The question was answered by ticking checkboxes for at least one and up to three positive agent characteristics out of a total of 14 options (displayed in random order), which were garnered from open-ended survey responses from a preliminary study (Ozogul, Johnson, & Reisslein, 2012).

2.2.2.3. Preferences for general agent characteristics. The computerized questionnaire was also used to ask participants to characterize their favorite engineering tutor by selecting one forced-choice option from each of the following seven categories: gender (female or male); age (young or old); realism (realistic looking or looking like a cartoon figure); clothing (business-like clothing or casual clothing); personality (serious personality or fun personality); speech pace (talks fast or talks slow); and tutoring approach (strict tutoring or relaxed tutoring). Immediately beneath each forced-choice selection for each category was an open-ended question asking students for a justification for their preference (i.e., "Why?"). In order to progress to the next screen of the questionnaire, students were required to make a forced-choice selection for each category. Since young students with developing typing skills participated in the study, they were not required to provide a typed justification for each selection to complete the questionnaire.

2.3. Procedure

Participants were assessed during their regular class meetings, in groups of 10–31 students. At the beginning of the session, each participant was provided with a laptop, headphones, and his or her subject identification number. The researcher instructed students to begin the computer-based module by entering their subject identification number and demographics. They were then instructed to put on their headphones and work independently on all sections of the multimedia program. The average time for students to view the computerized overview program, was 12.2 min ($SD = 3.8$ min). After the students responded to the questionnaire, the researcher collected all the laptops for data entry and analysis.

2.4. Qualitative coding of justifications

Qualitative data obtained from the students' open-ended justifications for preferred characteristics were analyzed independently by two researchers. During the analysis, researchers identified characteristics of the agents noted by the students. Any characteristic that was noted only once and did not fit into any already existing category was classified in the "other" category. When a particular characteristic was noted two or more times, a new category was established. Across all seven categories, three justifications for decisions were present: general preference, Promotes understanding, and Same as me/Relatable.

A statement was coded as a general preference when no specific justification for a preference was provided (e.g., "Because it's better for me."). Statements were coded as 'Promotes understanding' when the participant noted that her/his selection was made because she/he felt that their choice would lead to better understanding of the material (e.g., "I would want a slow talker because you could understand them."). Statements were coded as 'Same as me/Relatable' when the participant noted the choice was made because the agent characteristic mirrored the student's own or made the agent easier to connect with (e.g., "I'm a girl and I relate to girls better.").

3. Results

3.1. Preference among four presented agents

Table 2 presents percentages of students who selected each of the four agents, along with the results of inferential tests for each age level. A χ^2 test of independence was conducted within each age level on student preferences for the four agents (young female, young male, old female, and old male) to determine overall preferences among the four options. The results showed that, for each age level, the distribution of the student's preferences for the four animated agents differed significantly from what would be expected by chance. A higher proportion of students indicated they would like to learn from a young agent rather than an old agent.

In addition, for each age level, a 2 (student gender: male or female) × 4 (agent: young female, young male, old female, and old male) χ^2 test of independence was conducted to examine the relation between student gender and agent preference. Consistent with the similarity–attraction hypothesis (our Hypothesis 1) that students would select an agent that matched their gender, the results revealed that the distribution of the students' preferences for the four animated agents differed significantly from what would be expected by chance. Male students demonstrated a significant preference toward the young male agent, whereas female students showed a significant preference toward the young female agent.

3.2. Preferences for characteristics of each of the four agents

Table 3 presents the frequencies and percentages of students noting each of the fourteen characteristics for the individual agents, by age level. For the young female agent, commonly selected positive characteristics included that the agent was 'smart' (246 out of 564 students), 'helpful' (195/564), had a 'clear voice' (182/564), and was 'young' (176/564). For the young male agent, students commonly indicated the following characteristics as most liked: 'smart' (229/564 students), 'helpful' (193/564), 'young' (187/564), and 'clear voice' (186/564). For the old female agent, commonly selected positive characteristics were 'smart' (241/564 students), 'helpful' (213/564), 'clear voice' (179/564), and 'professional' (164/564). Finally, commonly noted positive characteristics for the old male were 'smart' (233/564 students), 'helpful' (218/564), 'clear voice' (199/564), and 'professional' (154/564). In summary, the most commonly selected positive characteristics were similar across animated agents; all four shared the positive characteristics of 'smart', 'helpful', and 'clear voice'. Students also selected 'young' as best liked for the two young agents, and 'professional' for the two old agents.

3.3. Preferences for general agent characteristics

Table 4 reports the student preferences (in percentages) for seven general agent characteristics, namely gender, age, realism, clothing, personality, speech pace, and tutoring approach. For each age level, a series of seven χ^2 tests of independence were conducted on student preferences for agent characteristics. The significance level for these tests was set to Bonferroni corrected p-value of .007 (.05/7). In addition to the overall student preferences, it was expected that male and female students would differ in their preferences for specific agent characteristics. At each age level, 2 (student gender: male or female) × 2 (agent characteristic preference) χ^2 tests of independence were conducted for each of the seven agent characteristics. The results of these analyses are reported in Sections 3.3.1–3.3.3.

3.3.1. Elementary school students

The results from the analyses for elementary students showed significant preferences for young, realistic looking, and casually-dressed agents with a fun personality, slow rate of speech, and a relaxed tutoring approach. The overall preference for male or female agents, as indicated in Table 4, was not significant. Additional analysis, that is not displayed in Table 4, indicated a significant relation between student gender and general preference for agent gender, χ^2 (1, N = 223) = 163.69, p < .001. Ninety-one percent of males preferred a male agent; 95% of females preferred a female agent. There were no significant relations between student gender and any of the remaining preference categories.

3.3.2. Middle school students

The χ^2 tests for the middle school students largely mirrored the results obtained for the elementary students. No significant

Table 2
Preferences for four presented animated agents, by age level and student gender.

Age level	Student gender	N	Animated agent				Inferential statistics			
			Young female	Young male	Old female	Old male	Difference in preference across agents		Relation between student gender and preference for agent	
			Percent	Percent	Percent	Percent	χ^2 (3, N = 223)	p	χ^2 (3, N = 223)	p
Elementary school	Male	108	7.4	71.3	3.7	17.6			144.41	<.001
	Female	115	76.5	7.0	14.8	1.7				
	Total	223	43.0	38.1	9.4	9.4	87.73	<.001		
Middle school	Male	99	11.1	58.6	4.0	26.3			113.72	<.001
	Female	101	73.3	8.9	16.8	1.0				
	Total	200	42.5	33.5	10.5	13.5	57.68	<.001		
High school	Male	79	21.5	41.8	11.4	25.3			28.74	<.001
	Female	62	56.5	24.2	17.7	1.6				
	Total	141[a]	36.9	34.0	14.2	14.9	24.93	<.001		

[a] There was an error in logging interaction data for one high school student. All results from the computerized surveys are for a sample of 141 students.

Table 3
Frequencies and percentages of students selecting most liked characteristics for each of the four presented animated agents. Each student could select up to 3 out of the 14 positive characteristics.

Agent	Agent characteristic													
	Smart	Helpful	Clear voice	Young/older	Interesting	Professional	Realistic	Woman/man	Nice	Slow speech	Cool	Dress	Trustworthy	Fun
Young female	246 43.62%	195 34.57%	182 32.27%	176 31.21%	119 21.10%	64 11.35%	66 11.70%	116 20.57%	62 10.99%	61 10.82%	87 15.43%	35 6.21%	37 6.56%	41 7.27%
Young male	229 40.60%	193 34.22%	186 32.98%	187 33.16%	127 22.52%	64 11.35%	93 16.49%	47 8.33%	69 12.23%	65 11.52%	93 16.49%	48 8.51%	33 5.85%	45 7.98%
Old female	241 42.73%	213 37.77%	179 31.74%	48 8.51%	109 19.33%	164 29.08%	79 14.01%	112 19.86%	81 14.36%	71 12.59%	32 5.67%	52 9.22%	55 9.75%	31 5.50%
Old male	233 41.31%	218 38.65%	199 35.28%	78 13.83%	121 21.45%	154 27.30%	76 13.48%	37 6.56%	88 15.60%	89 15.78%	33 5.85%	54 9.57%	56 9.93%	21 3.72%

Table 4
Preferences for general agent characteristics.

Age level				
Agent characteristic	Dominant preference	Percent	Inferential statistics	
Elementary school			χ^2 (1, N = 223)	p
Gender	Female	53	1.01	.32
Age	Young	85	110.5	<.001
Realism	Realistic	61	11.7	<.001
Clothing	Casual	70	37.1	<.001
Personality	Fun	78	67.8	<.001
Speech pace	Slow	77	63.5	<.001
Tutoring approach	Relaxed	88	131.1	<.001
Middle school			χ^2 (1, N = 200)	p
Gender	Female	54	1.28	.26
Age	Young	67	21.8	<.001
Realism	Realistic	66	20.5	<.001
Clothing	Casual	67	23.1	<.001
Personality	Fun	86	103.7	<.001
Speech pace	Slow	71	33.6	<.001
Tutoring approach	Relaxed	92	137.8	<.001
High school			χ^2 (1, N = 141)	p
Gender	Female	52	0.35	.56
Age	Young	73	29.97	<.001
Realism	Realistic	71	24.69	<.001
Clothing	Casual	57	3.13	.077
Personality	Fun	83	61.3	<.001
Speech pace	Slow	60	5.97	.015
Tutoring approach	Relaxed	85	72.35	<.001

Table 5
Frequencies of justifications by N = 565 students for preferences of general agent characteristics.

Preference category	Preference selection	Justification		
		General preference	Promotes understanding	Same as me/Relatable
Gender	Female	11	46	98
	Male	11	29	67
Age	Young	8	31	142
	Old	0	2	3
Realism	Real looking	26	37	125
	Looking like a cartoon	28	10	1
Clothing	Business-like	6	7	0
	Casual	34	9	29
Personality	Serious	16	16	2
	Fun	174	114	14
Speech pace	Fast	30	36	7
	Slow	6	318	5
Tutoring approach	Strict	2	20	0
	Relaxed	174	74	6

preference was indicated for male or female agents, but students preferred young, realistic looking agents, with casual dress, fun personality, slow speech, and a relaxed tutoring approach, as reported in Table 4. Additional analysis indicated a significant relation between student gender and gender preference, χ^2 (1, $N = 200$) = 84.84, $p < .001$. Seventy-nine percent of males preferred a male agent; 86% of females preferred a female agent.

3.3.3. High school students

The results of the χ^2 tests of independence on high school students' preferences for agent characteristics again showed significant preference for young, realistic looking agents, with a fun personality and relaxed tutoring style. However, unlike the elementary and middle school students, the high school students did not show a significant preference for casual dress or slow rate of speech, although the direction of preference was the same as for the younger students, see Table 4. Additional tests again indicated a relation between student gender and gender preference, χ^2 (1, $N = 141$) = 35.19, $p < .001$. Seventy percent of males preferred a male agent; 81% of females preferred a female agent.

3.3.4. Justifications for characteristics preferences

Table 5 presents justifications for participants' selection of the seven general agent characteristics. Participants most frequently made their selections for agent gender, age, and realism because the selections matched the participant or made the agent more relatable (i.e., same gender, young, and realistic looking). Learners most often indicated a general preference for their choice of clothing or personality. However, another common reason for selecting an agent with a fun personality was that the selection would promote understanding. Students overwhelmingly noted promoting understanding as the justification for selecting a slow rate of speech.

4. Discussion

The study was conducted to investigate two primary issues concerning the use of animated agents in computer-based tools for engineering outreach to K-12 students. First, what animated agents do K-12 students choose to learn from? Second, what general characteristics do they look for in animated agents designed to tutor them about engineering?

4.1. Preference among the four presented agents

Consistent with our first hypothesis, the results showed that students preferred gender congruent agents. Within each age level, students selected animated agents that were young and matched their own gender, which lends support to the hypothesis that individuals extend social interaction practices to human–computer interaction (Reeves & Nass, 1996). Specifically, young girls chose the young female agent and young boys chose the young male agent. This pattern was particularly strong for elementary and middle school students, see Table 2. Interestingly, high school students appeared to be drawn less to gender congruent animated agents. As students age and become more interested in the opposite sex, many may become interested in learning from animated agents of the opposite gender as well (Arroyo et al., 2009; Zanbaka, Goolkasian, & Hodges, 2006). This may account for the lack of a relation between participant gender and choice of agent gender in Moreno and Flowerday (2006), which examined college students.

Our second hypothesis, that elementary students would more often select the male engineering tutors, was not supported by the data. Although male elementary students more often chose the young male agent, female students were more likely to select the young female agent. These young students' attraction toward gender congruent agents outweighed preconceived notions about the disproportionate number of male vs. female engineers. These findings suggest that although young students suspect that most engineers are male (Capobianco et al., 2011; Fralick et al., 2009; Karatas et al., 2011; Knight & Cunningham, 2004), they still would rather learn from an agent that looks like them, and therefore, may be more like them. This is consistent with research on children's peer preferences. Elementary school children prefer same-sex peers to other-sex peers, a pattern that holds for known and unknown peers (Lobel, Bar-David, Gruber, Lau, & Bar-Tal, 2000; Powlishta, Serbin, Doyle, & White, 1994; Serbin, Powlishta, & Gulko, 1993; Sippola, Bukowski, & Noll, 1997).

4.2. Preferred characteristics of each of the four presented agents

Student responses regarding their favorite characteristics of each of the four presented agents showed that perceived positive characteristics were similar for young agents (see Table 3). Specifically, students indicated that they felt the positive attributes of the two young agents were intelligence, helpfulness, clear speech, and youth. Many of the positive characteristics selected for the young agents were shared by the older agents (i.e., smart, helpful, and clear voice). In addition, the old agents were viewed to be professional. These responses indicate that students prefer agent characteristics that mirror the attributes of effective real-life tutors, such as being smart, helpful and speaking in a clear voice. The preference for youth furthers the argument that K-12 students prefer agent characteristics which they share; the learners preferred young agents *because* they were young.

4.3. Preferences for general agent characteristics

Preferences for general agent characteristics supported our third hypothesis, that the students would select external agent characteristics that matched their own (see Table 4). These findings are similar to those found in other studies (Kim & Wei, 2011; Moreno & Flowerday, 2006), and extend beyond to reveal parallel patterns for agent age and clothing. Furthermore, analysis of the open-ended justifications for the external characteristics of age, gender, and realism substantiate the assumption that the students chose young, same-gendered, realistic looking agents because these attributes matched their own. Students may perceive agents with shared characteristics as 'better' tutors or social models because they feel they will more easily relate to the character and thus understand the message more easily. Research on sex segregation supports this hypothesis. Children and adolescents typically interact more with same-sex than other-sex peers because they are drawn to others who share similar characteristics, such as temperament, activity level, or interests (Fabes, 1994; Serbin, Moller, Gulko, Powlishta, & Colburne, 1994). Interactions with same-sex peers are preferred because boys and girls can more easily relate to individuals that share common characteristics.

In addition to student preferences for external agent characteristics, the results of the present study demonstrated that K-12 students prefer animated agents with fun personalities and a relaxed tutoring approach. Elementary and middle school students also showed preference for slow rate of speech. Although the trend was in the same direction for high school students, the preference for slow speech did not reach significance. The open-ended justifications (see Table 5) indicated that the students chose fun personality, slow speech pace, and relaxed tutoring because they felt these characteristics would promote understanding within the domain. These justifications suggest that students' decisions for internal agent characteristics are shaped more through consideration of which attributes may positively impact learning, rather than by simply selecting agent features which match their own.

4.4. Summary

Taken together, the student preference findings suggested that animated tutors should be designed to overlap the target student in as many physical dimensions as possible (age, gender, and realism). This can be attributed to the similarity–attraction hypothesis, in which humans are attracted to those who look and act similarly to themselves (Byrne & Nelson, 1965). However, an unresolved empirical question is whether this attraction toward similar engineering agents would translate to better learning outcomes or to persistence in engineering learning environments which utilize animated agents.

4.5. Limitations

Although our study employed a large sample of elementary, middle, and high school students, future work could test the outreach intervention in other regions of the United States to support generalization of our conclusions to different regions and population types. Such an investigation would serve to bolster the recommendation for broadening the use of such outreach interventions. Moreover, our study was limited in that the four considered agents represented the Caucasian race. Future studies could examine the effectiveness and preferred characteristics of agents of different races and ethnicities, such as the Hispanic ethnicity, which is widely represented in the Southwestern US.

Our results provide strong evidence for the preference for an animated engineering tutor that has characteristics which match the learner, but does not allow conclusions that such a tutor would necessarily lead to better learning outcomes in a computer-based learning environment. However, one may assume that if features of the agent are made more attractive to the learner, he or she will be more likely to re-engage with the learning environment. Future research could investigate whether matching the characteristics of the agent to the learner would positively impact learning outcomes and/or the likelihood the learner would return to or spend more time engaging with the learning environment.

It is possible that some of the student responses concerning their preferences toward individual agent characteristics were influenced by the initial presentation of the four agents. In particular, because the agents used in our engineering overview were all realistic (i.e., humanlike), with relatively slow rates of speech, students may have been primed to respond that they preferred realistic looking agents with slow rates of speech. Future research may vary the realism and speech rate in demonstrations preceding survey measures on agent preferences.

Our study examined the preferred agent characteristics for a one-time intervention. Subsequent studies could examine these preferences for repeated or longitudinal interventions; such research could provide supporting evidence that students will be more persistent in a learning environment if agents match learner characteristics.

5. Conclusions

The results of the present study showed that elementary, middle, and high school students preferred animated engineering agents whose characteristics matched their own over those that did not. Students reported preferring young, realistic looking agents to old, unrealistic ones, and students overwhelmingly favored same-gender agents over those that were of the opposite gender. Students also reported preferring agents that were intelligent, helpful, and spoke in a clear voice. The findings on the rationales for the student preferences suggest that it is important to construct animated agents that share features with their intended audience and harbor characteristics that promote student understanding. Such agents may positively impact student learning and ultimately their performance in and desire to persist in computer-based educational modules.

This study contributes to the empirical knowledge base on K-12 student preferences for external properties (e.g., gender and age) and internal properties (e.g., tutoring style and personality) of animated agents teaching engineering. The student preferences reported in this study complement previous studies that examined the influence of agent properties (characteristics) on student perceptions and learning (such as Arroyo et al., 2009; Rosenberg-Kima et al., 2010) by directly examining student preferences for agent characteristics. Moreover, this study complements previous studies that examined student choices of agent characteristics and their implications for student perceptions and learning (such as Behrend & Thompson, 2011; Kim & Wei, 2011; Moreno & Flowerday, 2006). These previous studies considered student preferences for a relatively narrow set of agent characteristics (mainly gender and ethnicity). In contrast, the present study has examined student preferences for a broad set of agent characteristics as well as the students' rationales for their preferences.

The domain of engineering has been considered in relatively few prior studies on animated agents, such as studies by Plant et al. (2009) and Rosenberg-Kima et al. (2008, 2010), which have been limited to middle school students and college students. The present study contributes to the knowledge base for computer-based instruction and outreach to the K-12 student population by covering the age range from elementary school through high school. While the importance of engineering instruction and outreach to K-12 students (Adams et al., 2011; Carr, Bennet, & Strobel, 2012; Reisslein, Moreno, & Ozogul, 2010; Reisslein, Seeling, & Reisslein, 2006) as well as the general population (Ozogul, Johnson, Moreno, & Reisslein, 2012; Pearson & Young, 2002) is growing in importance, relatively few teachers have engineering background and expertise; thus, computer-based instruction may be a promising avenue for this domain.

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