Investigating the Impact of Pedagogical Agent Gender Matching and Learner Choice on

Learning Outcomes and Perceptions

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Abstract

The similarity attraction hypothesis posits that humans are drawn toward others who behave and appear similar to themselves. Two experiments examined this hypothesis with middle school students learning electrical circuit analysis in a computer -based environment with an Animated Pedagogical Agent (APA). Experiment 1 was designed to determine whether matching the gender of the APA to the student has a positive impact on learning outcomes or student perceptions. One hundred ninety-seven middle-school students learned with the computer-based environment using an APA that matched their gender or one which was opposite in gender. Female students reported higher program ratings when the APA matched their gender. Male students, on the other hand, reported higher program ratings than females when the APA did not match their gender. Experiment 2 systematically tested the impact of providing learners the choice among four APAs on learning outcomes and student perceptions. Three hundred thirty-four middle-school students received either a pre-assigned random APA or were free to choose from four APA options: young male agent, older male agent, young female agent, or older female agent. Learners had higher far transfer scores when provided a choice of animated agent, but student perceptions were not impacted by having the ability to make this choice. We suggest that offering students learner control positively impacts student motivation and learning by increasing student perceptions autonomy, responsibility for the success of the instructional materials, and global satisfaction with the design of materials.

Keywords: Gender studies, Human-computer interface, Interactive learning environments, Multimedia/hypermedia systems

Introduction

Multimedia learning environments are well-known to promote student learning (Mayer, 2005; Mayer, 2008). In such environments, verbal descriptions are presented either through narration or written text and are combined with visual depictions such as diagrams, tables, graphs, animations, or videos. A well-established line of research demonstrates that students learn better from words and graphics than from words alone (Mayer, 1989; Moreno & Mayer, 1999; Mayer, 2008). Such multimedia environments sometimes employ animated pedagogical agents to facilitate learning from multiple representations (e.g., text, diagrams, and equations) of information (Atkinson, 2002; Craig, Gholson, & Driscoll, 2002; Moreno, Mayer, Spires, & Lester, 2001; Moreno, Reisslein, & Ozogul, 2010; Ozogul, Reisslein, & Johnson, 2011).

Animated pedagogical agents (APAs) are humanlike or cartoon animated characters which are displayed within a computer-based learning environment to provide learners with pedagogical assistance (Bradshaw, 1997; Choi & Clark, 2006; Woo, 2009). APAs have the potential to increase learner engagement and the instructional methods they employ can increase learning (Baylor, 2009; Moreno, 2005; Choi & Clark, 2006). Moreno (2005) proposed that APAs have both internal and external properties which influence student learning. The internal properties of APAs concern the instructional methods used by the agent in facilitating learning. Instructional methods applied through APAs include directing learner attention through gestures (Moreno, 2004; Moreno, Reisslein, & Ozogul, 2010) and delivering feedback messages, verbal guidance, and modeling (Azevedo et al., 2009; Graesser et al., 2004; Moreno, Mayer, Spires, & Lester, 2001). External properties of APAs relate to the image and voice of the agent, and include such agent characteristics as gender, age, ethnicity, and tone of voice. In the current investigation, the multimedia environment is the setting in which the animated pedagogical agent

is used to facilitate instruction via narrated instruction and through signaling of relevant visual

information using hand gestures. These internal characteristics are invariant across the versions

of multimedia instruction. The reported experiments were conducted to examine the potential

effects of external properties of the animated agent (i.e., age and gender) on learning and learner

perceptions.

Although it may seem that external characteristics, such as agent gender or age, would

have trivial consequences for learning or affect, some research suggests that these properties can

play important roles (Ozogul, Reisslein, & Johnson, 2011; Van Vugt, Bailenson, Hoorn, &

Konijn, 2010). According to the similarity attraction hypothesis, humans are more attracted to

others who appear and behave similarly to themselves (Byrne & Nelson, 1965). It has been

suggested that this similarity attraction hypothesis may be applicable in computer-based learning

environments, since computer users attribute social presence to computers (Moreno &

Flowerday, 2006; Reeves & Nass, 1996). The following sections describe the use of APAs in

multimedia environments and present relevant empirical background on APAs in multimedia.

1.1. APAs in Multimedia

APAs are used in computer-based learning environments to provide learners with

pedagogical assistance using one or more instructional methods, such as directing attention to

relevant information, providing feedback messages, or delivering direct instruction (Heidig &

Clarebot, 2011; Dehn & van Mulken, 2000; Moreno, 2005). Such instructional methods are

intended to keep students focused on essential information and to provide context-specific

learning strategies (Clark & Choi, 2005). Apart from the didactic objectives of APAs, they are

also assumed to play motivational roles. By establishing a social interaction between learner and

agent, APAs may maintain learners' engagement in a learning task, ultimately promoting

learning outcomes (Baylor, 2011; Kim & Baylor, 2006; Moreno, Mayer, Spires, & Lester, 2001; Ryu & Baylor, 2005). According to the persona hypothesis, the visual presence of an APA in computer-based learning environments can increase learning outcomes and positively affect learners' perceptions of the learning experience (Cassell, Sullivan, Prevost, & Churchill, 2000; Lester et al., 1997; Mitrovic & Suraweera, 2000). The following section describes results from empirical work aimed at testing the persona hypothesis.

1.1.1. Persona hypothesis

Lester et al. (1997) presented learners with five different versions of a microworld centered on botany, each with a visually represented pedagogical agent "Herman the Bug". The different versions of the environment varied in the communicative behaviors used by the pedagogical agent. The authors found that all conditions led to higher scores at posttest, compared to pretest, and concluded that their findings supported a persona effect; that is, the visual presence of the animated agent led to increased student motivation and learning outcomes. This study has been criticized for not including a control group without the visual presence of the agent (Dehn & van Mulken, 2000; Heidig & Clarebot, 2011). In fact, few experimental studies have compared an APA condition to one using identical instruction without the visual presence of an agent. Heidig and Clarebot (2011) conducted a review of literature on APAs and found 15 experimental investigations which included an appropriate control condition. Nine of the 15 studies found no significant difference in learning between an APA condition and control. However, Atkinson (2002, experiment 2) found better learning outcomes from an APA condition, compared to text only or voice only conditions. Also, Moreno, Reisslein, and Ozogul (2010) found that an APA providing visual signaling within multiple representations led to better

posttest scores and program ratings than arrow signaling or a control condition without such signaling.

In summary, results are not conclusive and debate continues concerning the assumption that the visual presence of an agent increase motivation or facilitates learning. Heidig and Clarebot (2011) suggest that a more appropriate research goal would be to determine under what conditions an APA can be helpful. The following section reviews research exploring the effect of agent gender on learners' perceptions or learning outcomes.

1.1.2. Agent gender studies

Arroyo, Woolf, Royer, and Tai (2009) explored the effect of different gendered learning companions on students' attitudes about math, students' emotions during learning, and learning outcomes. The authors showed that female high school and undergraduate students had better learning outcomes and more positive attitudes about math after learning with the male learning companion, compared to the female learning companion. Learners' open-ended responses did not suggest that the female students liked the male agent better. The authors suggest that gender stereotypes about mathematics transfer to the computer environment and the female students thus regard the male companion's information as more credible. Similar findings were obtained with undergraduate students learning about blood pressure (Moreno, Klettke, Nibbaragandla, & Graesser, 2002); learning outcomes were higher with male agents than female agents, and stereotyping scales provided some evidence that participants applied gender stereotypes to the animated agents.

Baylor and Kim (2003) investigated the effect of student gender, student ethnicity, agent gender, and agent ethnicity on learning and learner perceptions of pre-service teachers learning about instructional design. Their results indicated that, overall, learners rated male agents as

more extroverted. Although learners reported greater satisfaction in their performance and more use of self-regulation after learning with a male agent, learning did not differ between male and female agent conditions. Kim, Baylor, and Shen (2007) had mixed results from two experiments with undergraduate students learning about instructional design. The first experiment used computer literacy students and demonstrated better recall from a male agent than a female agent; the second experiment did not replicate this finding with pre-service teachers.

Plant, Baylor, Doerr, and Rosenberg-Kima (2009) found that a female agent led to better math posttest scores, higher ratings of engineering utility, interest and self-efficacy than a control (no agent) condition, whereas the male agent only led to increased self-efficacy compared to the control condition. Furthermore, math scores were higher in the female agent condition compared to the male agent condition. The authors suggest that these middle school students have many experiences with female teachers, and thus view them as credible sources of information. Their interpretation may explain why this study stands out from other work demonstrating better outcomes with male agents.

To summarize, the results from several previous studies have shown that male agents often lead to better learning outcomes (Arroyo et al., 2009; Kim et al., 2007, exp. 1; Moreno, et al., 2002) and more positive evaluations of the learning experience (Arroyo et al., 2009; Baylor & Kim, 2003; Moreno et al., 2002) in math and technical domains than female agents; conversely, Plant et al. (2009) found better learning outcomes when using female agents for middle school students. A related research question is whether matching the gender of the agent to the learner can result in better learning or learner perceptions. The following section presents empirical research aimed at investigating the effect of agent similarity to learner, including gender matching.

1.1.3. Agent similarity hypothesis

Because humans often treat computers as social entities (Reeves & Nass, 1996), social accounts of interaction such as the similarity attraction hypothesis may be relevant to computer-based environments. The similarity attraction hypothesis in the context of learning with animated pedagogical agents would predict increased learning and more positive perceptions the greater the similarity between the learner and the agent. Previous research has explored agent similarity effects with regard to agent gender (Baylor & Kim, 2003; Behrend & Thompson, 2011; Lee, Liao, & Ryu, 2007; Moreno & Flowerday, 2006; Plant et al., 2009; Rosenberg-Kima, Plant, Doerr, & Baylor, 2010; Van der Meij, Van der Meij, & Harmsen, 2012), age (Rosenberg-Kima, Baylor, Plant, & Doerr, 2008) ethnicity (Baylor & Kim, 2003; Behrend & Thompson, 2011; Moreno & Flowerday, 2006; Pratt, Hauser, Ugray, & Patterson, 2007; Rosenberg-Kima et al., 2010), personality (Isbister & Nass, 2000; Moon & Nass, 1998; Nass & Lee, 2001), physical appearance (Rosenberg-Kima et al., 2008; van Vugt, Bailenson, Hoorn, & Konijn, 2010), and feedback style (Behrend & Thompson, 2011).

Moreno and Flowerday (2006) randomly assigned learners to a choice condition, in which learners selected an agent from 10 options, differing in gender and ethnicity, or a non-choice condition, in which learners were assigned to an agent. Results first indicated that overall learners did not select an agent that matched their gender or ethnicity more often, but students of color were more likely to select an agent with the same ethnicity than their Caucasian counterparts. Next, the results did not indicate positive effects of gender similarity or ethnicity similarity on retention, transfer, or program ratings. Furthermore, the students who were able to choose had lower transfer scores, lower retention scores, and lower program ratings when the agent matched their ethnicity.

Behrend and Thompson (2011) did not find positive effects of gender similarity and surprisingly found a negative effect of ethnic similarity on utility ratings of the agent. However, these two effects were shown to be additive for engagement; the highest engagement ratings were obtained in the group where both gender and ethnicity was matched to the learner. Learning outcomes were not significantly influenced by gender or ethnicity similarity. Baylor and Kim (2003) found that Caucasian students rated Caucasian agents as more engaging and affable, whereas African American students rated these characteristics higher for African American agents. The researchers did not find better learning, self-reported self-regulation or self-reported satisfaction for agents who matched the learners in gender or ethnicity.

Rosenberg-Kima et al. (2008; Experiment 2) explored participant perceptions of engineering (self-efficacy, interest, stereotypes, and utility) after learning with one of eight agents differing on three factors (age, gender, and 'coolness'). The authors expected that participant perceptions would be most impacted after viewing an agent they considered similar or aspired to (i.e., young and 'cool'). Results supported this hypothesis; the two conditions (male and female) with young and 'cool' agents led to higher self-efficacy and interest than the remaining six conditions. Lee, Liao, and Ryu (2007) explored gender similarity using a computerized voice only. The authors showed that male participants rated a male agent's voice more likeable than a female agent, whereas no difference in voice likeability was found for female participants. A similar pattern was found in participants' ratings of voice credibility, content quality, and self-confidence in the topic discussed (e.g., skin care and makeup or dinosaurs). Learning outcomes were not measured by Rosenberg-Kima et al. (2008) or Lee et al. (2007).

The results from these studies do not provide evidence for a positive impact of gender matching on learning outcomes. However, there is some support for the similarity attraction hypothesis on perceptions of the computer programs. Little prior investigation has been conducted on the agent similarity attraction hypothesis using younger, middle-school aged students (cf. Lee, Liao, & Ryu, 2007). Experiment 1 in this study was conducted to investigate the effect of matching gender to middle school students on learning outcomes and learner perceptions. The next section presents empirical research aimed at investigating the effect of providing choice of APA to learners.

1.1.4. Agent choice

Providing learners with choice may elevate feelings of autonomy, leading to greater motivation and self-efficacy in the task (Bandura, 2001; Ryan & Deci, 2000). However, there is little empirical evidence on the effect of agent (or APA) choice on learning or learning perceptions. Moreno and Flowerday (2006) did not find a beneficial effect of agent choice on learning, and in fact, when provided a choice of APA, learners who chose ethnically similar agents had lower learning outcomes than those who chose ethnically dissimilar agents. The authors conclude that the students who chose ethnically similar agents focused attention on the agent, rather than the instructional materials, diverting cognitive resources to the APA (Moreno & Flowerday 2006). Kim and Wei (2011) also did not find any positive impact of agent choice on learning. Their results indicated that male students had more positive attitudes toward mathematics and higher feelings of self-efficacy after learning with an agent of their choice, whereas female students had more positive attitudes and higher self-efficacy after being assigned an agent randomly. Behrend and Thompson (2012) found increased self-efficacy with learner choice of the agent appearance. These prior investigations did not provide evidence for a positive impact of learner choice of

APA on immediate learning outcomes from a computer-based learning environment. Further, prior results are mixed concerning the effect of choice on learner perceptions of the learning environment and domain. Experiment 2 was conducted to investigate the effect of providing choice of APA on learning outcomes and learner perceptions with middle-school students. The next section describes a preliminary study conducted to investigate students' self-reported preferences for APAs and characteristics of APAs.

2. Preliminary Study

2.1. Method

A preliminary study was conducted to determine which image of an animated agent appeals to middle school students and what external and internal properties of agents the students prefer. Participants were 77 middle school students (54.5% female) at a public middle school in the Southwestern U.S with the mean age of 12.83 years ($SD = 0.84$). The students completed a survey with pictures of three agents: an old male, dressed in clothing that resembled a teacher's, and a young female and young male, both approximately the same age as the participants and dressed in casual attire similar to the middle schoolers' (see Figure 1). The survey posed several questions about agent preferences. First, students selected which agent they would prefer to learn about engineering from (agent choice, "Which of the below would you want to teach you about electric circuits in the computer?"). Second, the survey asked the students to list three reasons for their agent selection (agent choice rationale). Third, the survey included six forced-choice items requiring students to indicate their preferences for an animated engineering tutor on six dimensions: gender preference (girl or boy), age preference (young or old), personality preference (fun or serious), speech rate preference (talks fast or talks slow), clothing preference (dresses serious or dresses cool), and realism preference (cartoon human or real human). Each of

the forced choice items also included an open-ended question asking students to explain their choices in detail. Finally, the survey asked students to indicate their own gender. Students were given as much time as needed to complete the survey.

Quantitative and qualitative data analysis techniques were used to analyze students' responses to the survey items. Frequencies were obtained for agent choice and each agent characteristic dimension preference and analyzed quantitatively for significant differences. Students' open-ended responses for agent choice rationale were coded by two independent researchers. The researchers identified agent characteristics noted by the students within their open-ended responses. Any characteristic that was noted only once which did not fit into any already existing category was coded as "other". For any characteristic noted by two or more participants, a category was established. From this coding procedure, seven superordinate categories emerged: Age, Gender, Appearance, Personality, Speech, Teaching, and Other. The Age superordinate category was comprised of two subordinate categories: Young and Old. Gender included three subordinate categories: Male, Female, and Opposite. Appearance included four subordinate categories: Dress, Pretty, Profession, and Realistic. Personality included 10 subordinate categories: Comfortable, Cool, Fun, Good, Interesting, Interested, Nice, Relatable, Smart, and Trustworthy. Speech included three subordinate categories: Boring, Clear, and Slow. Teaching included seven subordinate categories: Comprehensive, Effective, Examples, Friend, Gesturing, Patient, and Understands. Table 1 displays the seven superordinate categories and their corresponding subordinates, with example statements from the students.

2.2. Results

2.2.1. Agent choice

Students were more likely to choose either the young female or young male agent as an engineering tutor, $\chi^2(2, N = 77) = 10.62$, $p = .005$. Twenty-eight (36%) of the students chose a young male agent to be their engineering tutor. Thirty-six (47%) of the students preferred a young-female agent. Thirteen (17%) of the students preferred an old-male agent for engineering tutor.

2.2.2. Agent choice rationale

Table 2 displays the number of participants who noted one of the 30 agent choice rationale categories for each of the three agents. Students who chose the young male agent frequently noted Teaching-Effective (13 students), Personality-Cool (11), Age-Young (9), and Appearance-Dress (9) as reasons for their choice. Students who chose the young female agent frequently noted Gender-Female (16 students), Teaching-Effective (14), Appearance-Real (13), and Personality-Smart (11) as reasons for their choice. Because fewer students chose the old male agent to learn with, the frequencies of rationales were lower: Teaching-Effective (13 students), Personality-Smart (8), and Appearance-Professional (4).

2.2.3. Characteristics preferences

2.2.3.1. Gender preference

There was not an overall significant difference in the gender preferred by participants, $\chi^2(1, N = 77) = 0.12$, $p = .73$. Forty participants (52%) preferred a female engineering agent, and 37 participants (48%) preferred a male engineering agent. However, male and female students demonstrated a significant preference toward an agent that matched their own gender, $\chi^2(1) = 21.75$, $p < .001$. Seventy-six percent of female students reported that they preferred a female agent and 77% of males preferred a male agent. Example student rationales for preferring

matching gender are "I am a girl too", "boys are better than girls", "I am a boy too", and "they [boys] would be cooler."

2.2.3.2. Age preference

Overall, students preferred a young agent over an old agent for their learning interactions, $\chi^2(1, N = 77) = 17.78$, $p < .001$. Seventy-four percent of all students reported preference for a young agent. Eighty-six percent of the females chose a young agent, whereas 60.0% of the male students chose a young agent. The preference for a young agent among female students was significant, $\chi^2(1, N = 42) = 21.43$, $p < .001$, while there was not a significant preference among male learners. Example student rationales for preferring a young agent are "[young] up to date", "I can relate to them", "they don't need to stop and think", "he understands us because he is young,", "it would be like a friend teaching me," and "old people don't get my attention."

2.2.3.3. Personality preference

Overall, learners preferred a 'fun' personality, compared to a more 'serious' personality, $\chi^2(1, N = 77) = 12.48$, $p < .001$. Seventy percent of all learners reported preference for an agent with a fun personality. Eighty-one percent of females preferred a 'fun' agent, whereas 57% of male students preferred a 'fun' agent. The difference in number of males preferring a fun agent over a serious agent was not significant, $\chi^2(1, N = 35) = 0.71$, $p = .40$. However, female learners did demonstrate a significant inclination toward a 'fun' pedagogical agent, $\chi^2(1, N = 42) = 16.10$, $p < .001$. Example student rationales for choosing a fun personality agent are "serious is boring", "fun is good", "I learn more", "make you laugh", "make subject fun", "to make the learning process fun", and "it will make learning easier."

2.2.3.4. Speech rate preference

Overall, learners preferred an agent with slow speech rate for their engineering domain learning interactions rather than a fast speech rate, $\chi^2(1, N = 77) = 31.18, p < .001$. Eighty-two percent of the learners reported preference for an agent with slow speech rate. Example rationales for preferring a slower speech rate are "so I could understand it", "that is good that he talks slow", "slow is better", "so I can hear everything they are saying", "explains more clearly", "so he explains it step-by-step", and "it lets me memorize."

2.2.3.5. Clothing preference

There was a marginally significant preference, across all participants, for animated agents with dress described as 'cool', compared to agents with 'serious' dress, $\chi^2(1) = 3.75, p = .053$. Sixty-one percent of all learners reported a preference for an agent with 'cool' wardrobe, whereas 39% of the students preferred an agent with a "serious" wardrobe. Example rationales for preferring an agent with cool clothing are "I dress cool", "she looks great", "makes me want to pay attention", "class would go easy", "more fashion the better", "they look pretty", and "so you could learn fast."

2.2.3.6. Realism preference

Overall no significant differences were found for the choices for a cartoon or real human image, $\chi^2 (1, N = 77) = 0.12, p = .73$. Fifty-two percent of the students preferred a cartoonlike image for the engineering animated agent. Example rationales for preferring a cartoon-like image are "cartoon humans grab my attention", "it would be fun and educational", "funny" and "engineer teachers look like a cartoon", "I would focus more on the problems", and "it's cool and funny". Forty-eight percent of the students preferred a real-humanlike image for the engineering tutor, and example rationales for this preference are "serious", "helps us understand

more", "so I can ask questions back at her", "they explain better", "to explain easier and no distraction", "it would look better", and "it would be more realistic."

2.2.4. Summary of findings

Results from this preliminary study indicated that when provided static images of animated agents, middle school students choose young agents which match their gender. The most common reason for selecting either the young male agent or the old male agent was the perception that they would be effective teachers, whereas the most common reason for selecting the young female was because she was female. However, this should not be taken as evidence that the participants did not see the young female agent as an effective teacher, since the same number of students indicated that she would be an effective teacher ($n = 14$). Closer inspection of those who noted female gender as the reason for choosing the young female agent revealed that 87% of those students were female. In addition to the students' tendency toward young agents of their own gender, they also all preferred an agent with cool clothing and a slow rate of speech. Additionally, female students preferred young agents with fun personality, whereas male students did not have these inclinations.

3. Experiment 1

The results from the preliminary study indicated that middle school students would prefer to learn from a young agent that matches their gender. However, the inclination toward agents of the same gender does not necessarily imply that students will learn better from or have more positive perceptions of learning from a same-gendered agent. Experiment 1 was designed to determine whether gender matching has a positive impact on learning outcomes or student perceptions. The experiment set out to answer three primary research questions: 1) Does matching the gender of the APA to the learner impact learning outcomes?; 2) Does matching the gender of the APA to the learner impact learners' subjective perceptions of the computer

program?; 3) Does gender matching of an APA have a differential impact on male and female learners?

3.1. Method

3.1.1. Participants and Design

The participants were a total of 197 6th, 7th, and 8th grade students in a public middle school in the Southwestern U.S., 109 females and 88 males. The mean age of the participants was 12.1 years ($SD = 1.01$ years). Eighty-two (41.6 %) of the students reported that they were Hispanic American, 36 (18.3 %) students reported they were Caucasian, 29 students (14.7%) reported they were African American, 23 students (11.7 %) reported being of other ethnicities, 20 (10.2 %) reported they were Asian American, and seven (3.6 %) reported their ethnicity as Native American. The students had no school instruction on electrical circuits prior to participating in this study.

To determine the effect of matching APA gender to participant gender, we manipulated whether students received an APA which matched their gender or one which was opposite in gender (Match, Opposite). Dependent variables included performance on the posttest and student ratings of perceived difficulty and attitudes toward the instructional module. All participants were randomly assigned to one of the two experimental conditions. There were 96 students in the Match (M) condition and 101 students in the Opposite (O) condition. Within the Match condition, there were 54 females and 42 males. Within the Opposite condition, there were 55 females and 46 males.

3.1.2. Materials and Apparatus

3.1.2.1. Computerized materials

For each participant, the computerized materials consisted of an interactive program that included: (1) a demographic questionnaire asking participants to report their gender, age, ethnicity, and interest in engineering, electric circuits, mathematics, and learning from a computer; (2) an introduction to the objectives of the instructional program; (3) an instructional session providing a brief conceptual overview of a single-resistor electrical circuit; (4) a simulation session; and (5) a program rating questionnaire. The topic domain of electrical engineering was chosen since engineering instruction is becoming increasingly important for K-12 students (Brophy, Klein, Portsmore, & Rogers, 2008; Carr, Bennet, & Strobel, 2012; Reisslein, et al., 2013) as well as the general population (Ozogul, Johnson, Moreno, & Reisslein, 2012; Pearson & Young, 2002). Also, teachers often have reservations about teaching engineering; thus computer-based education is an important avenue for K-12 engineering instruction.

Both conditions contained an identical introduction to the objectives presented by the appropriate APA (step 2). Also, both conditions had identical narrated explanations and calculations using Ohm's Law equation as well as identical depictive representations, including the circuit diagram and the Cartesian graph of voltage as a function of current in the instructional session (step 3) and the simulation session (step 4). As illustrated in Figure 2, the presentation screen in the simulation session contained a circuit diagram depicting the considered circuit and a Cartesian graph that depicted a plot of the voltage as a function of the current in the considered circuit. The circuit diagram contained the equations specifying the given resistance and current values. In addition, the sequence of equation calculation steps for evaluating the voltage using Ohm's Law was presented to the left of the voltage source symbol of the circuit diagram. In summary, the simulation session employed multiple representations, namely narration and

mathematical equations, i.e., descriptive representations, as well as a schematic circuit diagram and a plot relating system quantities, i.e., depictive representations.

The simulation session first presented an electrical circuit with given default resistance and current values and explained how to obtain the voltage value by using Ohm's Law equation or the Cartesian graph of voltage as a function of current. Then, students were given three opportunities to select different current or voltage values and observe the outcome of their selection. For each of the selected current or voltage values, the simulation session explained how to use the corresponding Ohm's Law equation and Cartesian graph and how to obtain the missing voltage or current value using both Ohm's Law equation and the Cartesian graph. More specifically, for a given circuit example, the simulation session first introduced the given circuit and then calculated the missing circuit quantity using Ohm's Law equation. Subsequently, the simulation session explained how to obtain the missing circuit quantity using the Cartesian graph, and finally related the result found in the Cartesian graph back to the result found with Ohm's Law equation and the given circuit. During the simulation session, the APA appeared on the screen to dynamically point to the visual element of the multiple representations in the display screen that corresponds to the present passage in the narrated explanation. The APA pointed to the visual element through deictic gestures, e.g., pointing with arms and fingers, as illustrated in Figure 2. More specifically, the agent provides visual attention guidance by signaling relevant information on graphs and electric circuit diagrams in synchrony with the narrated message. The primary pedagogical functions of the animated agent are to 1) deliver verbal instruction on the fundamentals of electric circuits and Ohm's Law and 2) assist learners in identifying relevant visual information which corresponds to the verbal message (i.e., narration).

The instructional program was presented using one of two animated pedagogical agents: a young male agent or a young female agent. Both animated agents were approximately of the same age as the student participants, and had casual attire similar to the students, see Figure 1. The design of the APAs was inspired by several similar avatars found in games that are popular among precollege students. More specifically, the APAs 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 APAs 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 within 3D Studio Max to the speech of the agents. Completed APA animations were rendered by 3D Studio Max as video files which were imported into Adobe After Effects CS2 to be layered onto the static image of the multiple representation screen. The experimental conditions differed only in which animated agent was used: In the Match (M) condition, the APA matched the gender of the participant, in the Opposite (O) condition, the APA's gender was opposite to the participant.

The last section in the computer program was an 18-item Likert instrument, which included 10 items asking participants to rate their learning perceptions concerning the program (e.g., "I would recommend this program to other students") and 8 items related to cognitive load. All items were on a 5-point scale ranging from 0--strongly disagree to 4--strongly agree. The learning perceptions questionnaire was a revised version of a 16-item survey that the authors had developed in collaboration with experts in computer-based engineering education (Moreno, Reisslein, & Ozogul, 2009; Reisslein, Moreno, & Ozogul, 2010). The construct validity of the

revised survey was assessed with the judgment of subject matter experts in electrical engineering instruction.

To examine the reliability of the program rating instrument in the present study, we conducted a factor analysis using principal axis estimation, with all 18 items from the program rating instrument. Results demonstrated that three factors accounted for 61.7% of the variance for student ratings. Extraction of three factors was based on a threshold of one eigenvalue. The three identified factors related to 1) evaluations of the program or content matter (eight items, such as "I would recommend this program to other students" and "I would like to learn more about electrical circuits", with factor loadings ranging from .47 to .77), 2) evaluations of the graphics used in the program (four items, such as "The graphics made the lesson easier to understand" and "The graphics in the program helped me to learn", with factor loadings ranging from .55 to .75), and 3) difficulty ratings (six items, such as "The lesson was difficult" and "The topics that were covered in the lesson were difficult", with factor loadings ranging from .41 to .90). As measured by Cronbach's alpha (Allen, Reed-Rhoads, Terry, Murphy, & Stone, 2008), the internal reliability of the program rating scale was .91, internal reliability of the graphics rating scale was .86, and internal reliability of the difficulty ratings was .89. A program ratings score, a graphics ratings score, and a perceived difficulty score were computed by averaging the ratings from the respective questions which loaded on these factors.

The program rating questionnaire also included four open-ended questions to capture what students liked best and least about the computer-based instructional module and about the animated agent used in the program. Two researchers independently examined participants' responses from these four open-ended questions. The characteristics noted by the students were identified and from this initial inspection, 14 coding categories for program characteristics

emerged (including an 'Other' category) and 17 coding categories for agent characteristics (including 'Other'). All of the open-ended responses were coded following this coding scheme[1]. A subset of this data (30%) was coded by both researchers to determine interrater reliability; there was agreement on 74.1% of responses, an acceptable percentage agreement for open-ended qualitative coding (Stemler, 2004).

The computer-based learning module used in the study was developed using Adobe Flash CS4 software, an authoring tool for creating web-based and standalone multimedia programs. The module provided log files, including participant responses to the demographic and program rating questionnaires and interaction data (e.g., time on task). The equipment consisted of a set of laptop computer systems, each with a screen size of 1680 x 1050 pixels, and headphones.

3.1.2.2. Paper and pencil materials

The paper and pencil materials consisted of a pretest and a posttest on electric circuit analysis. The pretest was a 12-item multiple-choice test on students' domain-specific prior knowledge (with internal reliability of $\alpha = .56$), and the posttest included 13 novel single-resistor electrical circuit problems to be solved both with the symbolic approach using Ohm's Law equation and with the graphical approach using the Cartesian graph (internal reliability: $\alpha = .89$). A posttest problem was presented as a circuit diagram of a single-resistor circuit with given voltage of $V = 20$ V and resistance $R = 5$ Ω and asked to find the current in the circuit a) using Ohm's Law equation, and b) using the provided Cartesian graph of voltage as a function of current. Eleven near transfer items required learners to use a provided Cartesian graph or Ohm's Law equation to determine or calculate voltage, (or current) for given resistance and current (or voltage) values following the same solution procedure as taught in the computer module. Two

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[1] The same coding scheme was used in Experiment 2, except an additional category was added because several participants noted liking the ability to choose their animated agent in the choice condition.

far transfer items required the students to identify different correspondences between the Cartesian graphs and given single resistor problems than directly taught in the computer module, such as mapping a given single-resistor problem to a Cartesian graph, or reasoning about the behaviors of current when the resistance value changes in a circuit with a given source voltage. Correct solution of the far-transfer problems required a deep understanding of the relationships between current, voltage, and resistance in a single-resistor circuit. Both pretest and posttest were designed and printed using the same color and layout scheme as the computer program. Two independent scorers who were blind to the conditions of the participants scored the pretest and posttest (interrater reliability 98.5%).

3.1.3. Procedure

Each participant was provided with a laptop, headphones, and two closed envelopes, which contained the paper-based pretest and posttest. The subject identification number and the letter representing the condition of the student were written on the envelope. The envelopes were randomly distributed to the students. First, the researcher instructed students to start working on the pretest envelope. Once they were done with the pretest and returned the pretest back to the envelope, the researcher had the students start the computer-based module by entering the combination of identification number and condition letter on the envelopes. They were then instructed to put on their headphones and work independently on all sections of the module. Once the computer-based learning session was over, participants were instructed to open the posttest envelope, and complete the posttest. After completing the posttest, the students returned the posttest to the envelope, and closed it. The researcher then collected all the laptops and the pretest and posttest envelopes for scoring and data analysis.

3.2. Results

An initial 2 (Condition: Match and Opposite) X 2 (Participant gender: Male and Female) ANOVA was conducted on pretest scores. The main effect for condition was not significant, $F(1, 193) = 1.15$, $p = .29$. There was also no significant difference in pretest scores between male and female students, $F(1,193) = 2.09$, $p = .15$, nor a significant interaction between condition and participant gender ($F < 1$). The participants spent on average 6.6 minutes ($SD = 1.6$ minutes) on demographic questionnaire, introduction, and instructional session (steps 1-3) and on average 10.2 minutes ($SD = 0.8$ minutes) on the simulation session (step 4). A t-test on the total time spent on the computer-based module (steps 1-4) indicated no significant differences between conditions, $t(195) = 0.83$, $p = .41$.

Table 3 displays the means and standard deviations for total posttest scores, near and far transfer scores, program ratings, graphics ratings, and difficulty ratings by experimental condition and participant gender. Analyses of variance (ANOVAs) were conducted on students' posttest scores, program ratings, graphics ratings, and difficulty ratings using experimental condition and participant gender as between-subject factors. A series of 2 (Condition: Match and Opposite) X 2 (Participant gender: Male and Female) univariate analyses of variance were conducted to determine whether there was a main effect of experimental condition, a main effect of participant gender, or an interaction between experimental condition and participant gender on each of the dependent variables. The respective ANOVAs on total posttest scores, near transfer scores, and far transfer scores indicated no significant main effect for experimental condition, no significant main effect for participant gender, nor a significant interaction between condition and participant gender (All p's $> .10$).

The ANOVA on program ratings indicated no significant main effect for experimental condition ($F < 1$). A significant main effect of participant gender was indicated, $F(1,193) = 5.89$,

MSE = 0.71, *p* < .05, η_p^2 = .03. Male participants rated the program significantly higher than females. Also, results indicated a significant interaction between experimental condition and participant gender, *F*(1,93) = 6.58, *p* < .05, η_p^2 =.03. Follow-up analyses indicated that female participants rated the Match condition significantly higher than the Opposite condition, *t* (107) = 2.15, *p* < .05. Although the mean program rating of male participants was actually higher for the Opposite condition compared to the Match condition, this difference was not statistically significant, *t*(86) = 1.52, *p* = .13. Within the Opposite condition, males had higher program ratings than females, *t*(99) = 3.61, *p* < .001; no significant difference was found between males and females in the Match condition, *t*(94) = 0.10, *p* = .92. No significant main effects or interactions were revealed for participants' graphics ratings or difficulty ratings.

Tables 4 and 5 display the number of participants who noted various categories as best and least liked about the program and about the agent, respectively. The most common characteristics of the computer program noted as liked best were Graphics (*n* = 58 participants), Topic (*n* = 43), Agent (*n* = 39), and Difficulty level (*n* = 28). The most common characteristics of the program noted as liked least were Boring (*n* = 45), Difficulty level (*n* = 38), Agent (*n* = 13), Graphics (*n* = 13), and Questions (*n* = 13). The most common characteristics noted as liked best about the agent were Pointing (*n* = 41), Helpful (*n* = 37), Examples/Explanations (*n* = 31), and Agent speech (*n* = 18). The most common characteristics noted as least liked about the agent were Agent speech (*n* = 31), Pace (*n* = 29), Image (*n* = 22), and Movements (*n* = 18).

To examine whether matching the agent gender to the student impacted the characteristics favored and disliked by the students, 2 (match or opposite) x 2 (noted or not noted) chi-square analyses were conducted on each category. The results of these chi-square analyses are reported in Tables 4 and 5. Results suggested that the match condition did not

significantly impact students' most liked characteristics of the program as a whole. However, more students in the opposite condition noted the difficulty level as the least liked characteristic of the program, compared to the match condition. Concerning agent characteristics, results indicated that significantly more match condition participants noted the agent personality as their favorite characteristic, compared to the opposite condition. More students in the opposite condition noted the examples or explanations as their least favorite aspect of the agent, compared to the match condition, whereas more of the match participants noted realism as their least favorite aspect.

3.3. Summary of findings

As previously noted, Experiment 1 was designed to address three research questions. While this experiment did not produce evidence that matching the gender of the APA to the learner impacted learning outcomes, it did reveal that female students reported higher program ratings when the APA matched their gender. On the other hand, when the APA did not match their gender, male students reported higher program ratings than females. Qualitative analysis of participants' feelings toward the program and agents revealed that: 1) when the APA did not match student gender, participants more frequently noted difficulty level as least favorite aspect of the program and examples/explanations as least favorite aspect of the agent; and 2) when the APA matched student gender, participants more often noted agent personality as favorite aspect of the agent and agent realism as least favorite aspect of the agent.

4. Experiment 2

In Experiment 1, students were not given a choice over whether the APA matched their gender or not, which is an example of system or program control approach to instructional design (Clark & Mayer, 2011). In contrast, a learner control approach to instruction provides learners with a varying range and degree of control over the instruction. This can include selecting the

sequencing, pacing, content, and appearance of the instructional environment. For certain learners, allowing some degree of control over the learning process elevates their feelings of autonomy, leads to greater motivation and self-efficacy in the task, and better learning outcomes (Bandura, 2001; Clark & Mayer, 2011; Ryan & Deci, 2000). To address this issue, Experiment 2 was designed to systematically test the impact of providing learners the choice among four APAs. Specifically, Experiment 2 was conducted to investigate three primary research questions: 1) Does providing learners a choice of animated agent influence learning outcomes or learner perceptions?; 2) Does the age of the animated agent have an impact on learning outcomes or learner perceptions?; and 3) Do the influences of choice, agent age, and gender matching interact to influence learning outcomes or learner perceptions?

4.1. Method

4.1.1. Participants and design

The participants were a total of 334 6th, 7th, and 8th grade students in a public middle school in the Southwestern U.S., 161 females and 173 males. The mean age of the participants was 12.3 years ($SD = 0.86$ years). One hundred ninety-three (57.8 %) of the students reported that they were Hispanic American, 66 (19.8 %) students reported they were Caucasian, 38 students (11.4 %) reported they were African American, 20 students (6.0 %) reported being of other ethnicities, nine (2.7 %) reported they were Asian American, and eight (2.4 %) reported their ethnicity as Native American. The students had no school instruction on electrical circuits prior to participating in this study.

To determine the effect of allowing learners the choice of APA, we manipulated whether students received a pre-assigned random APA or whether they were free to choose from four APA options based on the agents' static image. The dependent variables included performance

on the posttest, student ratings of perceived difficulty and attitudes toward the instructional module. All participants were randomly assigned to one of the two experimental conditions. There were 170 students in the Choice (C) condition and 164 students in the No Choice (NC) condition. Within the Choice condition, there were 90 females and 80 males. Within the No Choice condition, there were 71 females and 93 males.

4.1.2. Materials and apparatus

4.1.2.1. Computerized materials

The computerized materials in Experiment 2 were identical to those used in Experiment 1, except for the addition of the pretest to the computer program. Thus, the program for Experiment 2 consisted of: (1) demographic questionnaire; (2) pretest; (3) introduction to the objectives; (4) brief conceptual overview of simple circuit; (5) simulation session; and (6) program rating questionnaire. As in the first experiment, the program rating questionnaire included four open-ended questions to capture what students liked best and least about the computer program and the agents. A subset of this data (30%) was independently coded by both researchers to establish interrater reliability; the coders agreed on 77.5% of responses. The computerized pretest used in the computer program was identical to the paper and pencil pretest used in Experiment 1.

The instructional program was presented using one of four animated pedagogical agents: a young male agent, older male agent, young female agent, or an older female agent, see Figure 1. The two young agents were of approximately the same age as the participants, and wore casual attire. The two older agents wore clothing that resembled that of a teacher's. The voices of the older agents were identical to those used by the young agents. The experimental conditions differed only in whether a choice was provided in animated agent: In the Choice (C) condition,

immediately before the introduction (step 3), a screen displayed the still images of the four

agents and participants were able to choose the APA from these options. In the No Choice (NC)

condition, there was no choice screen presented; the APA was randomly selected from the four

alternatives for them.

4.1.2.2. Paper and pencil materials

The paper and pencil materials consisted of the posttest on electric circuit analysis. The

posttest included 9 novel single-resistor electrical circuit problems to be solved both with the

symbolic approach using Ohm's Law equation and with the graphical approach using the

Cartesian graph (internal reliability: $\alpha = .74$). These nine items included six near transfer items

and three far transfer items (see explanation of near and far transfer items in section 3.1.2.2.).

The posttest was printed using the same color and layout scheme as the computer program. Two

independent scorers blind to the conditions of the participants scored the pretest and posttest

(interrater reliability 98.5%).

4.1.3. Procedure

The procedure for Experiment 2 was identical to Experiment 1 except the pretest was

completed within the computer-based module.

4.2. Results

An initial set of analyses was conducted to determine the pattern of choices made by

participants within the Choice condition. Table 6 shows the frequency of male and female

participants who chose each type of animated agent. Participants overwhelmingly chose to learn

with a young animated agent that matched their gender. A χ^2 test of independence indicated that

the proportion of students who selected a young agent (85%) was significantly higher than for

the old agent, $\chi^2 (1, N = 170) = 81.9, p < .001$. Results also demonstrated that the proportion of

students who selected a matched-gender agent (89%) was significantly higher than for opposite-gender, χ^2 (1, $N = 170$) = 102.5, $p < .001$.

An initial 2 (Condition: Choice and No Choice) X 2 (Participant gender: Male and Female) ANOVA was conducted on pretest score. There were no significant differences between conditions ($F < 1$). There was also not a significant difference in pretest scores between young agent and old agent, $F(1,326) = 3.48$, $p = .45$, or between gender-matched agents and non-gender-matched agents, $F(1,326) = 1.82$, $p = .58$. The analysis further indicated that none of the interaction terms were significant (all F's < 1). The participants spent on average 10.8 minutes ($SD = 2.6$ minutes) on demographic questionnaire, pretest, introduction, and instructional session (steps 1-4) and on average 10.1 minutes ($SD = 1.0$ minutes) on the simulation session (step 4). A t-test on the total time spent on the computer-based module (steps 1-4) indicated no significant differences between conditions, $t(332) = 0.15$, $p = .88$.

Table 7 displays the means and standard deviations for total posttest scores, near and far transfer scores, program ratings, graphics ratings, and difficulty ratings by experimental condition, agent age, and agent-participant gender match (match/opposite). Analyses of variance (ANOVAs) were conducted on students' posttest scores, program ratings, graphics ratings, and difficulty ratings using experimental condition, agent age, and agent-participant gender match as between-subject factors. A series of 2 (Condition: Choice and Non-choice) X 2 (Agent age: Young and Old) X 2 (Gender match: Match and Opposite) univariate analyses of variance were conducted for each of the dependent variables. The ANOVA on overall posttest scores indicated no significant main effects for the three factors and no significant interactions among the factors (all p's > .10). The ANOVA on near transfer scores also indicated no significant main effects or interactions (all p's > .1).

The ANOVA on far transfer scores indicated a significant main effect for Choice, $F(1,326) = 4.33$, $p < .05$, $\eta_p^2 = .013$. Students in the Choice condition scored significantly higher on far transfer items than those in the No Choice condition. There was also a marginal main effect of Agent age, $F(1,326) = 3.84$, $p = .051$, $\eta_p^2 = .012$. Students who learned with an old agent scored significantly higher on far transfer items than did those who learned with a young agent. There was a significant main effect for Gender match, $F(1,326) = 4.38$, $p < .05$, $\eta_p^2 = .013$. Students who learned with an agent of an opposite gender scores significantly higher on far transfer items than did those who learned with a same-gendered agent. Although there was not a significant interaction between experimental condition and Agent age ($p = .26$) or Gender match ($p = .15$), we suspected that these factors influenced students in the Choice condition more than their counterparts in the Non-choice condition. Therefore, we conducted follow-up tests comparing far transfer scores between Young and Old agents and between Opposite-gendered and Matched-gendered agents within the two conditions. There was not a significant difference between young and old agents in far transfer performance within the Non-choice condition, $F(1,162) = 1.05$, $p = .31$. However, within the Choice condition, students who chose an old agent scored significantly higher than those who chose a young agent, $F(1,168) = 4.99$, $p < .03$, $\eta_p^2 = .029$. Also, there was not a significant difference between Opposite gendered and Matched gendered agents on far transfer performance within the Non-choice condition ($F < 1$). Within the Choice condition, students who chose an opposite gendered agent scored significantly higher than those who chose a matched gendered agent, $F(1,168) = 5.43$, $p < .05$, $\eta_p^2 = .031$. To further elucidate potential differences between the students who chose old agents and those who chose opposite gendered agents for the learning session, we compared their individual difference measures (i.e., age and prior knowledge). Students who chose to learn with an old agent were

significantly older ($M = 12.6$, $SD = 0.81$) than those who chose a young agent ($M = 12.2$, $SD = .82$), $t(168) = 2.03$, $p < .05$. These students also had significantly higher pretest scores ($M = 4.08$, $SD = 1.97$) than those who chose a young agent ($M = 3.08$, $SD = 1.95$), $t(168) = 2.41$, $p < .05$. Furthermore, the students who chose an opposite gendered agent were significantly older ($M = 12.7$, $SD = 0.56$) than those who chose a matched gendered agent ($M = 12.2$, $SD = 0.84$), $t(168) = 2.61$, $p < .01$. There was not a significant difference in pretest scores between students who chose opposite or matched gendered agents, $t(168) = 0.04$, $p = .97$.

The ANOVA on program ratings, graphics ratings, and difficulty ratings indicated no significant main effects or interactions for the three factors (All p's $> .10$).

Table 8 and 9 display the number of participants who noted various categories as best and least liked about the program and about the agent, respectively. The most common characteristics of the computer program noted as liked best were Graphics ($n = 76$ participants), Agent ($n = 62$), Topic ($n = 44$), and Formulas ($n = 37$). The most common characteristics of the program noted as liked least were Pace ($n = 47$), Difficulty level ($n = 33$), Graphics ($n = 24$), and Formulas ($n = 19$). The most common characteristics noted as liked best about the agent were Helpful ($n = 79$), Examples/Explanations ($n = 71$), and Agent speech ($n = 37$). The most common characteristics noted as least liked about the agent were Agent speech ($n = 73$), Pace ($n = 26$), Movements ($n = 22$), and Unhelpful ($n = 20$).

To examine whether providing choice of animated agent impacted characteristics favored or disliked by the students, 2 (choice or no choice) x 2 (noted or not noted) chi-square analyses were conducted on each category. The results of these chi-square analyses are reported in Tables 8 and 9. Results suggested that providing choice did not significantly impact students' least liked characteristics of the program generally. More students in the choice condition reported that the

pace of the instruction was their favorite characteristic, compared to the no choice condition. Concerning agent characteristics, results showed that significantly more choice condition participants noted agent personality as their favorite characteristic, whereas the no choice participants noted agent movements as their favorite characteristic. More of the choice participants indicated that the examples or explanations provided by the agent were their least liked characteristic of the agent, compared to the no choice condition.

4.3. Summary of findings

Findings from the second experiment showed, similar to the preliminary study, that when given a choice of animated agents, young students will select a young agent that matches their gender. Analyses did not indicate significant effects of providing choice of agent on near transfer, but far transfer scores were higher for the choice students than the non-choice students. Furthermore, when provided a choice, students who selected an older agent scored higher on far transfer items than those who selected a young agent. Also, students who selected an opposite-gendered agent scored higher on far transfer than those who selected a same-gendered agent. An analysis of individual differences indicated that students who selected older agents and opposite-gendered agents were older than their counterparts who chose young, same-gendered agents. Program ratings, graphic ratings, and difficulty ratings did not differ among the experimental conditions. Qualitative analysis of participants' feelings toward the program and agents revealed that: 1) students in the choice condition more often noted instructional pace as the favorite aspect of the program, agent personality as favorite aspect of the agent, and examples/explanations as least favorite aspect of the agent; and 2) students in the no choice condition more often noted agent movements as favorite aspect of the agent.

5. Discussion

The results from the preliminary study and Experiment 2 show that middle school learners, when given a choice in animated pedagogical agent, will select a young agent that matches their gender. These findings support the similarity attraction hypothesis in learners' preferences for animated agents in computer-based learning environments (Byrne & Nelson, 1965). There is increasing evidence that younger students have a greater likelihood of selecting agents of the same gender. Eighty-nine percent of the middle school participants from experiment 2 selected agents in this manner. The proportion of high school students from Kim and Wei's experiment (2011) who chose a gender-matched agent was lower (79% of all participants). In Moreno and Flowerday (2006), which used college-aged students, the difference in the proportion of participants who selected a gender-matched agent and those who selected an opposite-gendered agent was not significant. This variation in preferences for students of different developmental levels may signify that the optimal agent to be used in computer-based learning environments depends on the age of the student. More research is needed to determine how student age interacts with the external and internal properties of an animated agent.

Although our results show students will select agents with similar characteristics to them, analysis of posttest scores do not support the hypothesis that matched-gender agents lead to better immediate learning outcomes. In Experiment 1, posttest scores were not significantly different between matched- and opposite-gendered experimental conditions. Furthermore, non-choice learners in Experiment 2 did not learn more from the matched-gendered agents. These results reflect similar findings from earlier experiments; studies thus far have not found significant learning benefits of gender matching (Berhend & Thompson, 2011; Baylor & Kim, 2003; Moreno & Flowerday, 2006). Although immediate learning benefits of matching the gender of the agent to the learner have not been demonstrated, to this point, the effect of gender

matching has not been tested in settings in which learners can use learning environment(s) repeatedly. Since young students show a strong preference to matched-gender agents, they may be more likely to re-engage with a learning environment that fulfills this preference.

Results from the first experiment indicate that, in general, male students had significantly higher positive perceptions of the program than female students. However, an important finding from Experiment 1 is that female students' perception of instruction can be positively impacted when provided a same-gendered agent; females had higher program ratings when the APA matched their gender than when a male agent was presented. Female students may perceive the program using a same-gendered agent more favorably than when using opposite-gendered agents because of gender stereotypes concerning women in engineering (Byrne, 1993; Capobianco, Diefes-Dux, Mena, & Weller, 2011; Johnson, Ozogul, Moreno, & Reisslein, 2013; Knight & Cunningham, 2004). The use of a peer-model to explain engineering problem-solving to female students may increase the female learners' feelings of self-efficacy toward engineering. This finding is important because, although gender matching has not been shown to have a significant impact on learning outcomes, if this manipulation impacts female learners' subjective perceptions of the learning environment, they may be more likely to persist within the environment or, more generally, persist in studying engineering or mathematics in the future.

Experiment 2 showed a beneficial effect of agent choice on learning outcomes. Learners in the choice condition had significantly higher far transfer scores than the learners in the no choice condition, but no significant differences were found for near transfer. Examination of the descriptive statistics for total near transfer scores suggests a ceiling effect; for this set of participants, performance was very high on near transfer and there was little variability in the scores.

We conclude that providing choice of animated agent in educational technology can positively impact student motivation and learning in three ways. First, allowing students to select an animated agent for instruction represents learner control, such that choice condition participants experience greater feelings of autonomy, leading to higher motivation and self-efficacy during the task and ultimately better learning outcomes (Bandura, 2001; Behrend & Thompson, 2012; Clark & Mayer, 2011; Ryan & Deci, 2000). Second, participants in the choice condition may feel some amount of responsibility for the success of a learning environment which they perceive as partially 'developed' by themselves, even to a small degree (i.e., selecting the agent used in instruction). This perceived responsibility for the success of the learning materials can further promote motivation and learning outcomes. Third, learner control in instruction may simply make learners more satisfied with the task, also improving motivation and learning. An interesting future direction for research on agent choice is to offer students an array of choices related to multiple internal and external properties of APA (e.g., gender, age, personality, speech rate, and clothing). Findings from the preliminary study indicated that middle school students had strong preferences in these categories.

Analyses from Experiment 2 first seemed to show that older agents and opposite-gendered agents led to better learning than younger agents or matched-gendered agents. However, further inspection of the data showed that older agents and opposite-gendered agents resulted in higher far transfer scores only for the choice condition participants. However, we noted that choice condition participants who selected older or opposite gendered agents were significantly older than their counterparts. This suggests that these students may be more mature and thus more interested in the opposite gender and in learning from 'instructors' that appear

older and more knowledgeable about the content. This same maturity level may also be associated with better student focus on instruction and better learning outcomes.

5.1.Conclusions

In sum, this investigation provides additional support for the similarity attraction hypothesis in terms of learners' perceptions of the instructional experience while suggesting a caveat. Consistent with this hypothesis, female students in Experiment 1 perceived the instructional experience more positively when the APA matched their gender. However, the hypothesis was not supported by the findings that male students actually had descriptively higher ratings when the APA did not match their gender, than when the APA matched. This suggests that the hypothesis may need to take into consideration a students' gender.

The results from Experiment 2 support the assumption that providing a greater degree of learner control in learning technologies can improve student motivation and learning by increasing perceived autonomy. We further suggest that providing learner choice may elicit a feeling of responsibility for the success of the learning materials and an enhanced feeling of satisfaction toward the learning task; both of these factors have potential to increase student motivation and learning. Practically, findings from Experiment 2 provide further evidence that computer-based learning environments should include features which increase learner control (Clark & Mayer, 2011). More specifically, these results suggest that when such environments involve animated pedagogical agents, students should be offered choice of animated agent to be used in instruction.

References

Allen, K., Reed-Rhoads, T., Terry, R.A., Murphy, T.J., & Stone, A.D. (2008). Coefficient alpha: An engineer's interpretation of test reliability. *Journal of Engineering Education*, *97*(1), 87-94.

Arroyo, I., Woolf, B.P., Royer, J.M., Tai, M. (2009) *Affective Gendered Learning Companion.* International Conference on Artificial Intelligence and Education, Brighton, England, IOS Press.

Atkinson, R. K. (2002). Optimizing learning from examples using animated pedagogical agents. *Journal of Educational Psychology, 94*(2), 416-427.

Azevedo, R., Witherspoon, A., Graesser, A., McNamara, D., Chauncey, A., Siler, E., Cai, Z., Rus, V., & Lintean, M. (2009). *MetaTutor: Analyzing self-regulated learning in a tutoring system for biology*, In V. Dimitrova, R. Mizoguchi, B. Du Boulay, & A. C. Graesser (Eds.) Artificial Intelligence in Education: Building Learning Systems that Care: From Knowledge Representation to Affective Modeling (pp. 635 637). Amsterdam: IOS Press.

Bandura, A. (2001). Social cognitive theory: An agentic perspective. *Annual Review of Psychology, 52*, 1–26.

Baylor, A. L. (2009). Promoting motivation with virtual agents and avatars: role of visual presence and appearance. *Philosophical Transactions of the Royal Society B*, *364*, 3559-3565.

Baylor, A. L. (2011). The design of motivational agents and avatars. *Educational Technology Research and Development, 59*(2), 291-300.

Baylor, A. L., & Kim, Y. (2003). The Role of Gender and Ethnicity in Pedagogical Agent

    Perception. In G. Richards (Ed.), *Proceedings of World Conference on E-Learning in*

    Corporate, Government, Healthcare, and Higher Education 2003 (pp. 1503-1506),

    Chesapeake, VA: AACE.

Behrend, T. S., & Thompson, L. F. (2011). Similarity effects in online training: Effects with

    computerized trainer agents. *Computers in Human Behavior, 27*, 1201-1206.

Behrend, T. S., & Thompson, L. F. (2012). Using animated agents in learner-controlled training:

    The effects of design control. *International Journal of Training and Development, 16*,

    263-283.

Bradshaw, J. M. (Ed.). (1997). *Software agents*. Cambridge, MA: MIT Press.

Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in

    P-12 classrooms. *Journal of Engineering Education, 97*(3), 369-387.

Byrne, D., & Nelson, D. (1965). Attraction as a linear function of proportion of positive

    reinforcements. *Journal of Personality and Social Psychology Bulletin, 4*, 240–243.

Byrne, Eileen M. 1993. *Women and Science: The Snark Syndrome.* London*:* Falmer Press.

Capobianco, B. M, Diefes-Dux, H. A., Mena, I., & Weller, J. (2011). What is an engineer?

    Implications of elementary school student conceptions for engineering education. *Journal*

    of Engineering Education, 100(2), 304-328.

Carr, R.L., Bennet, L.D., & Strobel, J. (2012). Engineering in the K-12 STEM standards of the

    50 U.S. States: An analysis of presence and extent. *Journal of Engineering Education,*

    101(3), 1-26.

Cassell, J., Sullivan, J., Prevost, S., & Churchill, E. (Eds.). (2000). *Embodied conversational*

    agents. Cambridge, MA: MIT Press.

Choi, S., & Clark, R. E. (2006). Cognitive and affective benefits of an animated pedagogical

> agent for learning English as a second language. *Journal of Educational Computing*

> *Research, 34*(4), 441-466.

Clark, R. E., & Choi, S. (2005). Five design principles for experiments on the effects of animated

> pedagogical agents. *Journal of Educational Computing Research, 32*(3), 209-225.

Clark, R.C., & Mayer, R.E. (2011). *ELearning and the science of instruction; Proven guidelines*

> *for consumers and designers of multimedia learning* (3rd Edition). San Francisco:

> Pfeiffer.

Craig, S.D., Gholson, B., & Driscoll, D.M. (2002). Animated pedagogical agents in multimedia

> educational environments: Effects of agent properties, picture features, and redundancy.

> *Journal of Educational Psychology*, *94*(2), 428-434.

Dehn, D. M., & van Mulken, S. (2000). The impact of animated interface agents: A review of

> empirical research. *International Journal of Human-Computer Studies, 52,* 1-22.

Graesser, A. C., Lu, S., Jackson, G. T., Mitchell, H. H., Ventura, M., Olney, A., & Louwerse, M.

> M. (2004). AutoTutor: A tutor with dialogue in natural language. *Behavioral Research*

> *Methods, Instruments, and Computers, 36,* 180-193.

Heidig, S. & Clarebot, G. (2011). Do pedagogical agents make a difference to student motivation

> and learning? *Educational Research Review, 6*, 27-54.

Isbister, K., & Nass, C. (2000). Consistency of personality in interactive characters: Verbal cues,

> non-verbal cues, and user characteristics. *International Journal of Human-Computer*

> *Studies, 53*(2), 251-267.

Johnson, A.M., Ozogul, G., Moreno, R., & Reisslein, M. (2013). Pedagogical Agent Signaling of Multiple Visual Engineering Representations: The Case of the Young Female Agent. *Journal of Engineering Education, 102*(2).

Kim, Y. & Baylor, A. L. (2006). A social-cognitive framework for pedagogical agents as learning companions, *Educational Technology Research &Development, 54*(6), 569–596.

Kim,Y., Baylor, A.L., & Shen, E. (2007). Pedagogical agents as learning companions: the impact of agent emotion and gender. *Journal of Computer Assisted Learning, 23*, 220–234.

Kim, Y., & Wei, Q. (2011). The impact of learner attributes and learner choice in an agent-based environment. *Computers & Education, 56*, 505-514.

Knight M. & Cunningham C. (2004). Draw an engineer test (DAET): development of a tool to investigate students' ideas about engineers and engineering. *ASEE Annual Conference Proceedings*, 4079–4089.

Lee, K. M., Liao, K., & Ryu, S. (2007). Children's responses to computer-synthesized speech in educational media: Gender consistency and gender similarity effects. *Human Communication Research, 33*, 310-329.

Lester, J. C., Converse, S. A., Kahler, S. E., Barlow, S. T., Stone, B. A., & Bhogal, R. S. (1997). The persona effect: Affective impact of animated pedagogical agents. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 359-366). New York, NY: ACM.Mayer, R. E. (1989). Systematic thinking fostered by illustrations in scientific text. *Journal of Educational Psychology, 81*(2), 240-246.

Mayer, R. E. (2005). Cognitive theory of multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 31-48). New York: Cambridge University Press.

Mayer, R. E. (2008). Applying the science of learning: Evidence-based principles for the design of multimedia instruction. *American Psychologist, 63*(8), 760-769.

Mitrovic, A., & Suraweera, P. (2000). Evaluating an animated pedagogical agent. *Lecture Notes in Computer Science, 1839*, 73-82.

Moon, Y., & Nass, C. (1998). Are computers scapegoats? Attributions of responsibility in human-computer interaction. *International Journal of Human-Computer Interaction, 49*(1), 79-94.

Moreno, K. N., Klettke, B., Nibbaragandla, K., & Graesser, A. C. (2002). Perceived characteristics and pedagogical efficacy of animated conversational agents. *Lecture Notes in Computer Science: Intelligent Tutoring Systems, 2363*, 963-971.

Moreno, R. (2004). Decreasing cognitive load for novice students: Effects of explanatory versus corrective feedback in discovery-based multimedia. *Instructional Science, 32*, 99–113.

Moreno, R. (2005). Multimedia learning with animated pedagogical agents. In R. Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning* (pp. 507-524). New York: Cambridge University Press.

Moreno, R., & Flowerday, T. (2006). Students' choice of animated pedagogical agents in science learning: a test of the similarity attraction hypothesis on gender and ethnicity. *Contemporary Educational Psychology, 31*, 186–207.

Moreno, R., & Mayer, R. E. (1999). Cognitive principles of multimedia learning: The role of modality and contiguity. *Journal of Educational Psychology, 91*(2), 358-368.

Moreno, R., Mayer, R.E., Spires, A.H., & Lester, J.C. (2001). The case of social agency in computer-based teaching: Do students learn more deeply when they interact with animated pedagogical agents? *Cognition and Instruction, 19*, 177-213.

Moreno R., Reisslein, M., & Ozogul, G. (2009). Optimizing worked-example instruction in electrical engineering: The role of fading and feedback during problem-solving practice, *Journal of Engineering Education, 98*(1):83-92.

Moreno R., Reisslein, M., & Ozogul, G. (2010). Using virtual peers to guide visual attention during learning: A test of the persona hypothesis, *Journal of Media Psychology: Theories, Methods, and Applications, 22*(2):52-60.

Nass, C., & Lee, K. M. (2001). Does computer-synthesized speech manifest personality? Experimental tests of recognition, similarity-attraction, and consistency-attraction. *Journal of Experimental Psychology: Applied, 7*(3), 171-181.

Ozogul, G., Johnson, A.M., Moreno, R., & Reisslein, M. (2012). Technological literacy learning with cumulative and stepwise integration of equations into electrical circuit diagrams, *IEEE Transactions on Education, 55*, 480-487.

Ozogul, G., Reisslein, M., & Johnson, A. M. (2011). Effects of visual signaling on pre-college students' engineering learning performance and attitudes: Peer versus adult pedagogical agents versus arrow signaling. In *Proceedings of the 118th Annual Conference and Exposition of the American Society for Engineering Education.*

Plant, E. A., Baylor, A. L., Doerr, C. E., Rosenberg-Kima, R. B. (2009). Changing middle-school students' attitudes and performance regarding engineering with computer-based social models. *Computers & Education, 53*, 209-215.

Pearson, G. & Young, A.T. (2002). *Technically speaking: Why all Americans need to know more about technology*. Washington, DC: Nat. Acad. Press.

Pratt, J. A., Hauser, K., Ugray, Z., & Patterson, O. (2007). Looking at human-computer interface design: Effects of ethnicity in computer agents. *Interacting with Computers, 19*(4), 512-523.

Reisslein, J., Johnson, A.M., Bishop, K.L., Harvey, J., & Reisslein, M. (2013). Circuits Kit K-12 Outreach: Impact of Circuit Element Representation and Student Gender, *IEEE Transactions on Education, 56*.

Reisslein, M., Moreno R., & Ozogul, G. (2010). Pre-college electrical engineering instruction: The impact of abstract vs. contextualized representation and practice on learning, *Journal of Engineering Education, 99*(3):225-235.

Reeves, B., & Nass, C. (1996). *The media equation: How people treat computers, television, and new media like real people and places*. Cambridge, MA: Cambridge University Press.

Rosenberg-Kima, R. B., Baylor, A. L., Plant, E. A., & Doerr, C. E. (2008). Interface agents as social models for female students: The effects of agent visual presence and appearance on female students' attitudes and beliefs. *Computers in Human Behavior, 24*(6), 2741-2756.

Rosenberg-Kima, R. B., Plant, A., Doerr, C. E., & Baylor, A. L. (2010). The influence of computer-based model's race and gender on female students' attitudes and beliefs towards engineering. *Journal of Engineering Education, 99*(1), 35-44.

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic

motivation, social development, and well-being. *American Psychologist, 55(1), 68–78.*

Ryu, J., & Baylor, A. L. (2005). The psychometric structure of pedagogical agent persona.

Technology, Instruction, Cognition and Learning, 2, 291-314.

Stemler, S. E. (2004). A comparison of consensus, consistency, and measurement approaches to

estimating interrater reliability. *Practical Assessment, Research & Evaluation*, 9(4).

Van der Meij, H. and Van der Meij, J. and Harmsen, R. (2012) *Animated Pedagogical Agents:*

Do they advance student motivation and learning in an inquiry learning environment?

Technical Report TR-CTIT-12-02, Centre for Telematics and Information Technology

University of Twente, Enschede.

van Vugt, H. C., Bailenson, J. N., Hoorn, J. F., Konijn, E. A. (2010). Effects of facial similarity

on user responses to embodied agents. *ACM Transactions on Computer-Human*

Interaction, 17(2), 1-27.

Woo, H.L. (2009). Designing multimedia learning environments using animated pedagogical

agents: Factors and issues. *Journal of Computer Assisted Learning, 25*, 203-218.

Figure 1. Agents. Left to right – Old male, Young female, Young male, Old Female
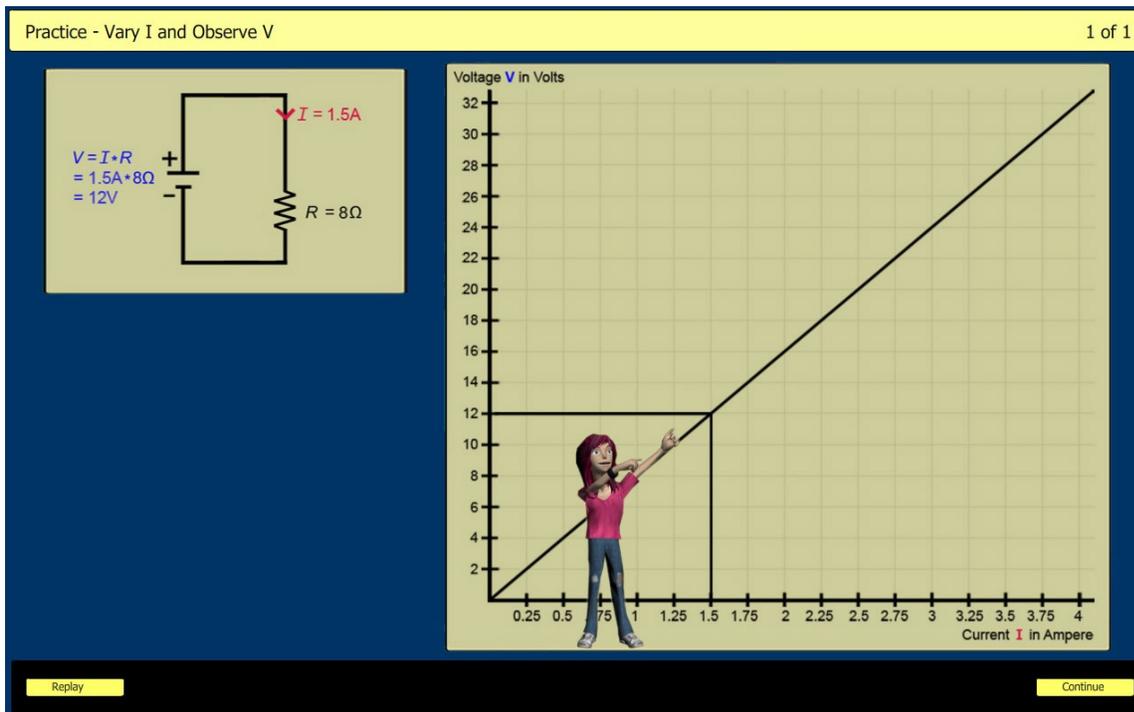
Figure 2. Sample screen shot of multi-representation display screen with Ohm's Law equation calculations, a circuit diagram, and a Cartesian graph of voltage as a function of current used in the simulation session.

Table 1

Preliminary Study: Agent Preference Superordinate and Subordinate Categories, with Example Statements

Superordinate Category	Subordinate Category	Example Statements
Age	Young	He looks younger (Young)
	Old	He is older he may know more (Old)
		She seems more of my age (Young)
Gender	Male	She is a girl (Female)
	Female	He is the opposite sex (Opposite)
	Opposite	Women know a lot of thing (Female)
Appearance	Dress	She has cool shoes (Dress)
	Pretty	He dresses like us (Dress)
	Professional	He knows how to dress (Dress)
	Realistic	
Personality	Comfortable	He looks like someone to trust (Trustworthy)
	Cool	She looks like she is interested (Interested)
	Fun	Because he looks like someone I would get along (Relatable)
	Good	
	Interesting	
	Interested	
	Nice	
	Relatable	
	Smart	
	Trustworthy	
Speech	Boring	It looks he doesn't talk fast (Slow)
	Clear	Talk clear (Clear)
	Slow	
Teaching	Comprehensive	He is smarter as a teacher (Effective)
	Effective	He looks like a person who explains things to you (Effective)
	Examples	He might teach me a lot (Effective)
	Friend	
	Gesturing	
	Patient	
	Understands	
Other		Feels more better
		Because I don't know her, and I would like to know what she likes
		The others do not influence me

Table 2

Preliminary Study: Frequency of Participants Noting Agent Characteristics, by Agent Chosen

Superordinate Category	Subordinate Category	Chosen Agent		
		Young Male ($n = 28$)	Young Female ($n = 36$)	Old Male ($n = 13$)
Age	Young	0	0	2
	Old	9	4	0
Gender	Male	3	0	0
	Female	0	16	0
	Opposite	1	0	0
Appearance	Dress	9	5	0
	Pretty	0	2	0
	Professional	0	1	4
	Realistic	6	13	0
Personality	Comfortable	0	1	0
	Cool	11	3	2
	Fun	3	1	2
	Good	1	0	1
	Interesting	0	2	0
	Interested	2	1	0
	Nice	4	2	1
	Relatable	3	0	0
	Smart	7	11	8
	Trustworthy	2	2	0
Speech	Boring	1	1	0
	Clear	0	5	1
	Slow	1	0	1
Teaching	Comprehensive	2	0	1
	Effective	13	14	13
	Examples	0	1	3
	Friend	0	2	0
	Gesturing	1	1	0
	Patient	0	1	0
	Understands	0	1	0
Other		5	6	3

Table 3

Experiment 1: Descriptive Statistics for Posttest Scores and Ratings, by Experimental Condition and Participant Gender

Experimental Condition	Participant Gender	Total Posttest (max = 13)		Near Transfer (max = 11)		Far Transfer (max = 2)		Program Rating		Graphics Rating		Difficulty Rating	
		EMM	*SE*	*EMM*	*SE*	*EMM*	*SE*	*EMM*	*SE*	*EMM*	*SE*	*EMM*	*SE*
Match (*n* = 96)	Female (*n* = 54)	10.58	0.46	9.32	0.42	1.26	0.09	2.68[a]	0.12	3.07	0.12	1.69	0.14
	Male (*n* = 42)	10.43	0.52	8.98	0.48	1.45	0.11	2.66	0.13	2.83	0.14	1.60	0.15
	Total	10.51	0.35	9.15	0.32	1.36	0.07	2.67	0.09	2.95	0.09	1.65	0.10
Opposite (*n* = 101)	Female (*n* = 55)	9.94	0.46	8.52	0.42	1.42	0.09	2.34	0.11	2.79	0.12	1.80	0.13
	Male (*n* = 46)	10.22	0.50	8.72	0.46	1.50	0.10	2.95[b]	0.13	2.98	0.13	1.70	0.15
	Total	10.08	0.34	8.62	0.31	1.46	0.07	2.64	0.08	2.89	0.09	1.75	0.10
Totals	Female (*n* = 109)	10.26	0.32	8.92	0.30	1.34	0.07	2.51	0.08	2.93	0.09	1.75	0.10
	Male (*n* = 88)	10.32	0.36	8.85	0.33	1.48	0.07	2.81[b]	0.09	2.91	0.10	1.65	0.11

[a] Significantly (*p* < .05) higher than rating for Opposite condition
[b] Significantly (*p* < .05) higher than females

Table 4

Experiment 1: Frequencies of Participants Who Noted Program Characteristics Best and Least Liked, by Condition

	Liked Best			Liked Least		
	Opposite (*n* = 101)	Match (*n* = 96)	$\chi^2(1), p$	Opposite (*n* = 101)	Match (*n* = 96)	$\chi^2(1), p$
Agent	18	21	0.51, .48	8	5	0.59, .44
Agent speech	2	1	0.29, .59	5	7	0.47, .49
Computer-based	2	1	0.29, .59	1	-	0.96, .33
Difficulty Level	14	14	0.02, .89	**<u>25</u>**	**<u>13</u>**	**<u>3.97, .< 05</u>**
Examples/Explanations	9	8	0.02, .89	2	-	1.92, 0.17
Formulas	-	1	1.06, .30	2	3	0.26, .61
Fun/Boring	3	4	0.21, .65	18	27	2.96, .09
Graphics	29	29	0.05, .82	5	8	0.91, .34
Interactivity	5	6	0.16, .69	1	1	0.00, .98
Modality	2	1	0.29, .59	1	1	0.00, .98
Questions	-	-	N/A	8	5	0.59, .44
Pace	1	-	0.96, .33	5	2	1.19, .28
Topic	24	19	0.46, .50	6	3	0.90, .34
Other	2	2	0.00, .96	9	2	4.35, .04

Table 5

Experiment 1: Frequencies of Participants Who Noted Agent Characteristics Best and Least Liked, by Condition

	Liked Best			Liked Least		
	Opposite (n = 101)	Match (n = 96)	$\chi^2(1), p$	Opposite (n = 101)	Match (n = 96)	$\chi^2(1), p$
Agent is female	1	1	0.00, .98	-	-	N/A
Agent is male	-	-	N/A	2	-	1.92, .17
Helpful/unhelpful	19	18	0	10	4	2.45, .12
Distracting	-	-	N/A	1	3	1.13, .29
Examples/Explanations	15	16	0.12, .73	<u>7</u>	<u>1</u>	**<u>4.38, .04</u>**
Fun/Boring	2	5	1.50, .22	4	5	0.18, .66
Image	5	10	2.09, .15	13	9	0.61, .44
Movements	1	1	0.00, .98	13	5	3.48, .06
Pace	2	6	2.30, .13	14	15	0.12, .73
Personality	<u>-</u>	<u>4</u>	**<u>4.30, .04</u>**	-	-	N/A
Pointing	21	20	0	-	1	1.06, .30
Realism	2	3	0.26, .61	<u>-</u>	<u>6</u>	**<u>6.51, .01</u>**
Relatable	1	4	2.01, .16	-	-	N/A
Repetitive	1	2	0.39, .53	5	6	0.16, .69
Smart	2	-	1.92, .17	-	-	N/A
Agent speech	9	9	0.01, .91	18	13	0.68, .41
Other	9	7	0.17, .68	4	5	0.18, .67

Table 6

Experiment 2: Frequencies of APA Selections of Choice-Condition Participants, by Participant Gender

	Young Male	Old Male	Young Female	Old Female
Male (n = 80)	58	11	10	1
Female (n = 90)	6	2	70	12

Table 7

Experiment 2: Descriptive Statistics for Posttest Scores and Ratings, by Experimental Condition, Agent Age, and Gender Match

Experimental Condition	Agent age	Agent-participant gender match	Total Posttest (max = 9)		Near Transfer (max = 6)		Far Transfer (max = 3)		Program Rating		Graphics Rating		Difficulty Rating	
			EMM	*SE*	*EMM*	*SE*	*EMM*	*SE*	*EMM*	*SE*	*EMM*	*SE*	*EMM*	*SE*
No choice (*n* = 164)	Young (*n* = 81)	Opposite (*n* = 40)	6.01	0.34	4.61	0.25	1.40	0.15	2.56	0.12	2.75	0.14	1.67	0.16
		Match (*n* = 41)	5.74	0.33	4.62	0.25	1.12	0.15	2.73	0.12	3.03	0.14	1.95	0.15
		Total	**5.88**	**0.24**	**4.62**	**0.18**	**1.26**	**0.11**	**2.65**	**0.09**	**2.89**	**0.10**	**1.81**	**0.11**
	Old (*n* = 83)	Opposite (*n* = 39)	6.53	0.34	5.14	0.25	1.39	0.15	2.55	0.12	2.78	0.14	1.57	0.16
		Match (*n* = 44)	6.42	0.32	4.99	0.24	1.43	0.14	2.51	0.12	2.61	0.13	1.75	0.15
		Total	**6.47**	**0.24**	**5.07**	**0.17**	**1.43**	**0.13**	**2.53**	**0.09**	**2.70**	**0.10**	**1.66**	**0.11**
	Total		**6.18**	**0.17**	**4.84**	**0.12**	**1.34**	**0.07**	**2.59**	**0.06**	**2.79**	**0.07**	**1.73**	**0.08**
Choice (*n* = 170)	Young (*n* = 144)	Opposite (*n* = 16)	7.13	0.53	5.44	0.40	1.69 [c]	0.24	2.67	0.19	2.75	0.22	1.96	0.25
		Match (*n* = 128)	5.90	0.19	4.73	0.14	1.17	0.08	2.63	0.07	2.79	0.08	1.96	0.09
		Total	**6.51**	**0.28**	**5.08**	**0.21**	**1.43**	**0.13**	**2.65**	**0.10**	**2.77**	**0.11**	**1.96**	**0.13**
	Old (*n* = 26)	Opposite (*n* = 3)	6.67	1.23	4.33	0.92	2.33 [c]	0.55	2.50	0.45	2.25	0.50	1.67	0.57
		Match (*n* = 23)	6.59	0.45	4.98	0.33	1.61	0.20	2.70	0.16	2.86	0.18	1.68	0.21
		Total	**6.63**	**0.66**	**4.66**	**0.49**	**1.97** [b]	**0.29**	**2.60**	**0.24**	**2.55**	**0.27**	**1.67**	**0.30**
	Total		**6.57**	**0.36**	**4.87**	**0.27**	**1.70** [a]	**0.16**	**2.63**	**0.13**	**2.66**	**0.14**	**1.82**	**0.16**

[a] Significantly (*p* < .05) higher than rating for No choice condition
[b] Significantly (*p* < .05) higher than rating for Young agents (within Choice condition)
[c] Significantly (*p* < .05) higher than rating for Matched-gendered agents (within Choice condition)

Table 8

Experiment 2: Frequencies of Participants Who Noted Program Characteristics Best and Least Liked, by Condition

	Liked Best			Liked Least		
	No Choice ($n = 164$)	Choice ($n = 170$)	$\chi^2(1), p$	No Choice ($n = 164$)	Choice ($n = 170$)	$\chi^2(1), p$
Choice	-	5	N/A	-	1	0.97, .33
Agent	28	34	0.47, .49	9	5	1.35, .25
Agent speech	2	3	0.17, .68	12	5	3.31, .07
Computer-based	3	4	0.11, .74	-	-	N/A
Difficulty Level	7	9	0.19, .66	17	16	0.09, .77
Examples/Explanations	16	9	2.40, .12	6	7	0.05, .83
Formulas	17	20	0.17, .68	7	12	1.21, .27
Fun/Boring	6	4	0.49, .48	6	8	0.23, .63
Graphics	42	34	1.49, .22	13	11	0.27, .61
Interactivity	4	2	0.75, .39	-	2	1.94, .16
Modality	4	3	0.11, .74	5	1	2.87, .09
Questions	2	3	0.17, .68	8	4	1.54, .22
Pace	**<u>1</u>**	**<u>8</u>**	**<u>5.34, .02</u>**	23	24	0.00, .97
Topic	20	24	0.27, .60	2	3	0.17, .68
Other	-	5	4.90, .03	8	9	0.03, .86

Table 9

Experiment 2: Frequencies of Participants Who Noted Agent Characteristics Best and Least Liked, by Condition

	Liked Best			Liked Least		
	No Choice (*n* = 164)	Choice (*n* = 170)	$\chi^2(1), p$	No Choice (*n* = 164)	Choice (*n* = 170)	$\chi^2(1), p$
Agent is female	1	2	0.30, .58	2	-	2.09, .15
Agent is male	-	-	N/A	-	-	N/A
Helpful/unhelpful	33	46	2.22, .14	9	11	0.14, .71
Distracting	-	-	N/A	1	-	1.04, .31
Examples/Explanations	34	37	0.05, .82	<u>2</u>	<u>9</u>	**4.35, .04**
Fun/Boring	2	6	1.91, .17	7	3	1.80, .18
Image	8	12	0.71, .40	11	7	1.10, .29
Movements	<u>7</u>	<u>-</u>	**7.41, .006**	10	12	0.13, .72
Pace	3	7	1.51, .22	14	12	0.25, .61
Personality	<u>1</u>	<u>8</u>	**5.34, .02**	1	1	0.00, .97
Pointing	14	10	0.88, .35	2	3	0.17, .68
Realism	4	1	1.94, .16	1	3	0.94, .33
Relatable	1	6	3.47, .06	-	-	N/A
Repetitive	1	3	0.94, .33	2	5	1.21, .27
Smart	-	3	2.92, .09	-	-	N/A
Agent speech	22	15	1.79, .18	34	39	0.24, .62
Other	19	11	2.67, .10	21	15	1.38, .24