Effects of Social Presence and Social Role on Help-Seeking and Learning

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ABSTRACT
The unique social presence of robots can be leveraged in learning situations to reduce student evaluation anxiety, while still providing instructional guidance on multiple levels of communication. Furthermore, social role of the instructor can also impact the prevalence of evaluation apprehension. In this study, we examine how human and robot social role affects help-seeking behaviors and learning outcomes in a one-on-one tutoring setting. Our results show that help-seeking is a moderator of the significant relationship between condition and learning, with the "human teacher" condition resulting in significantly less learning (and marginally less help-seeking) than the "human assistant" and both robot conditions.

Categories and Subject Descriptors
H.5.2 **[Information Interfaces and Presentation]**: User Interfaces-Interaction styles. K.3.1 [**Computer Uses in Education**]: Computer-assisted Instruction.

General Terms
Experimentation, Human Factors.

Keywords
Human-robot interaction, Pedagogical agents, Help-seeking, Evaluation apprehension, Educational technology, Social role.

1. INTRODUCTION
The argument has frequently been made that one way to achieve the effectiveness of human tutoring in educational contexts at a dramatically lower cost is by using intelligent tutoring systems, embodied agents, and robots [17]. However, the impact of the technology on learning is often hindered by the negative impact of dysfunctional help-seeking behavior, including limited or non-existent help-seeking [16] possibly due to evaluation apprehension anxiety (the fear of being judged). Addressing this problem with appropriate framing of the technology within the learning setting is an oft neglected endeavor. In this paper, we take an in-depth look at the affordances of educational technology to reduce this evaluation apprehension through manipulation of the technology's perceived social role. This study examines the potential for technology, specifically robots, to decrease evaluation apprehension and lead to better student help-seeking behavior and learning.

Help-seeking is a valuable skill that aids students in becoming self-regulated learners. However, past research shows that many students underuse or abuse available help facilities [16]. One of the reasons students may be avoiding the help facilities offered to them is due to a heightened fear of judgment or evaluation apprehension due to the social framing of the learning setting.

Ideally, the framing of the learning situation should reduce potentially harmful effects of social presence for learners with evaluation apprehension without eliminating valuable help resources. For example, if a student is kept alone in a room rather than with others present, there is no additional social presence and no one to deliver evaluation, but then a potentially valuable source of help is also removed. Learning materials still need to be delivered and explained through some means. A solution might be to leverage technology for both offering instruction and help while also reducing the level of evaluation apprehension through a reduction in perceived social presence as compared to human instructors. Robots may carry more social presence than virtual agents, but their larger communication bandwidth (i.e., the physical world) increases their pedagogical potential.

The level of evaluation apprehension of both robot and human tutors alike might be further reduced through manipulations in the social role of the instructor. We often think of human teachers as the ideal instructor, but they also carry considerably more potential for evaluation apprehension. Casting the help source in the social role of a learning assistant rather than a teacher should reduce this evaluation apprehension and thus result in a change in the learner's behavior. In this paper, we investigate how human and robot social role affects help-seeking behaviors and learning outcomes in a one-on-one tutoring setting, shown in Figure 1.

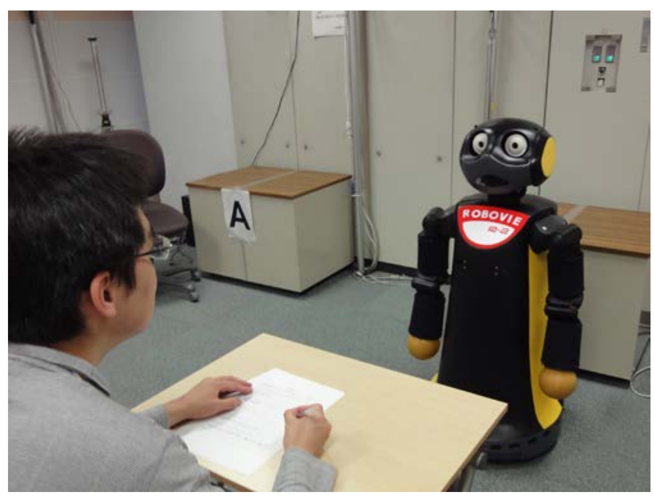

Figure 1. A photograph showing the laboratory setup for the robot condition. The human condition had a human tutor sitting in a chair in the same spot the robot is positioned.

2. PRIOR WORK

The work of Taylor and Robert [35] provides a conceptual frame for our work. Ten years ago they proposed that the role of computers in education could take the form of tutor, tool, or tutee. More recently, robots have begun to take up all of these roles as well. Where there is a need for personalized, one-on-one tutors, embodied agents and robots are filling those gaps. As we see this shift occurring, it is critical to ask which role(s) should these educational robots appropriate (tutor, tool, or tutee) and how might that role taking affect student behavior and learning?

2.1 Educational Robots

There is a well-established literature on the benefits of virtual agents and intelligent tutoring systems to student learning [17]. These virtual tutors take the physical appearance of everything from text-only agents in a chat room [5]to animated and three-dimensional characters [13]. Many of the benefits of animated pedagogical agents, including increases in student engagement, motivation, and increased nonverbal communication, can be anticipated for pedagogical robots as well, perhaps even more so. However, robots, by existing in the physical world, bring a multitude of additional factors and abilities to learning activities.

One of the factors that pedagogical robots share with pedagogical computer agents is what purpose the robot serves. Robots used as educational tools are effective, such as the Lego Mindstorms robotic construction kits which are popular with the engineering education community [15]. By constructing a robot from the Lego Mindstorms kit, a student can learn programming concepts and embedded system design. Work on the robot-as-tutee also exists, although it has only just begun, with the user-centered design research of a teachable geometry robot described by [32].

Evaluation studies show that robot tutors have measurable advantages over some other approaches. For example, students working with personal robotic tutors that teach English outperform students using audio books and web-based instruction [9]. In this study, children in the robot learning group also exhibited significantly higher levels of concentration and self-reported interest than those in other conditions. Another study [14] examined the robot-tutor from a more social, peer-tutoring perspective and found that young students who interacted more with an English tutor robot during the second week of deployment achieved greater English skills. Beyond the general positive effect of interaction with social robots on learning in this study, the authors also found that having something in common with the robot helped to increase the chances of interaction. Both of these papers point to increased student engagement with the robot as the reason for the success over traditional learning methods.

While robots already exist as educational tutors, tools, and tutees, little work exists within education settings to examine how differences in these roles might affect the learning process.

2.2 Social Presence

One of the paths through which both human and robot social role might have an impact on interaction is through varying amounts of evaluation apprehension, or a person's concern about being evaluated [8]. For this study and future work, we are operationalizing social presence as the extent to which a social other is located in a room with a social being. For instance, one is less likely to be afraid of being judged by a computer agent, than a robot, than a single human, than multiple humans. Collocation and physical embodiment may be another dimension of this social presence continuum that some prior literature explores.

Powers et al [22] examined the impact of computer agents, video-projected robots, and collocated robots on perception of social presence, and how varying the perceived presence of the agent impacted users' behavior and attitudes. The authors found that participants disclosed the least information with the collocated robot, then the remote robot, and then the agent. The authors proposed that a collocated robot causes more evaluation apprehension (fear of judgment) resulting in less information being shared. If we view the collocated robot as causing the most evaluation apprehension and the software agent as causing the least, participants' disclosure behaviors fall nicely along this social presence continuum.

Powers et al.'s continuum did not include a human condition, we can hypothesize that it would occupy a more evaluation apprehension prevalent position than the collocated robot. Other studies point to the same hypothesis. For example, one study examined the extent to which adults hesitated in turning a robot off despite its pleas otherwise [2]. The results suggest that humans afford robots rights somewhere between an inanimate object and another human~~.~~ So, while robots are viewed as closer to humans than a houseplant, the social presence, and therefore the level of evaluation apprehension caused by the robot, may not be as extreme as another human.

Beyond self-disclosure, Heerink et al (2009) shows that elderly users also experience more enjoyment with an agent with more social behaviors and social presence [10]. Being in the presence of social others also impacts performance of many other activities including memorization [33], and other more complex tasks such as seeking help, which is the focus of this paper. Considering some learners view a need to seek help as a sign of their own incompetence [29], it renders them vulnerable to evaluation and judgment, much like self-disclosure of sensitive topics.

In the social and organizational psychology literature, help-seeking is often described as a dilemma in which the help-seeker must weigh not only the potential benefits but also the potentially considerable costs [19]. The perception of these costs depends on an interaction between the learner's individual sensitivity to evaluation apprehension and the actual potential for negative evaluation in that context. For example, previous research shows that a participant is less likely to request assistance when the potential helper is perceived to be of higher status [27], likely due to an increased perception of potential of negative evaluation. It is plausible that a student is less concerned with evaluation from a robot than evaluation from a human, and this reduction in evaluation apprehension can have some important benefits to certain learning processes.

Torrey et al [30] explored the topic of how humans respond differently to different linguistic moves from robot and human experts in the context of baking. While imperative statements from the baking expert were perceived as equally controlling from both humans and robots, the use of discourse markers allowed robots to be viewed as significantly more considerate than humans using discourse markers. This collection of studies shows that human social response to offers of help differs depending on whether the help-giver is a human or a robot. These results, while focusing on help-giving, make it plausible to see similar differences between social responses to human and robot helpers in help-seeking situations.

2.3 Social Role

While the human-robot social presence continuum discussed above provides a foundation for our work, a different and potentially interacting factor to consider in connection with help-seeking and learning is social role. Shirouzu & Miyake [26] explore the use of robots as discussion facilitators and found that students viewed the robot as espousing different conversational roles depending on the experimental condition. In their study, the roles of "co-solver" and "knower" arose naturally as part of the group discussion process, but it is also possible to manipulate roles to better understand what might lead to increases in learning.

Furthermore, when professional service robots are presented as coworkers, human participants take more responsibility for success on a task when the robot is more machine-like, especially when the machine-like robot is presented as a subordinate [11]. This superior-peer-subordinate distinction is important for help-seeking in human-only workplaces as well. For example, Lee [18] observed that doctors and nurses were more likely to seek help from peers rather than superiors or subordinates, when adopting a new computer system within a hospital. Similar roles for a learning setting can be extrapolated from those in a work setting. A "superior" robot could be perceived as a teacher, a "coworker" as a peer, and a "subordinate" as a tool or helper. However, the social expectations and responsibilities assigned to a teacher and learning assistant are different than a workplace boss and subordinate. It is possible that since the role of a learning assistant is slightly less defined than that of a teacher, the help-seeking behaviors will reflect that.

2.4 Help-Seeking

There are additional factors that influence how and when learners seek help, both in the classroom and while using educational technologies. Nelson-Le Gall's model of help-seeking states that a student must (1) first become aware of need for help, (2) decide to seek help from an external source, (3) identify potential helpers, (4) implement strategies for engaging the helper, and (5) reflect upon the help-seeking attempt [21]. Aleven et al. adapt this model of classroom help-seeking to help-seeking within interactive learning environments with minimal adjustments but stop short of exploring help-seeking within robot-enhanced learning environments [1].

Individual differences may affect different student's learning behaviors in different situations. The second step of Nelson-Le Gall's help-seeking theory, "Decide to seek help from an external source," fails to define what processes go into making that decision. There are certainly social and self-perception concerns. Individual learners have varying perceptions of how help-seeking impacts their self-presentation. In some cases, a learner might think that help-seeking means they are incompetent [29] or that seeking help may challenge their autonomy. They may perceive that their potential helper is of too high status from which to request help [7]. Furthermore, while some students may be concerned with self-presentation issues, others may be hesitant for other reasons, or not at all.

3. STUDY DESIGN AND METHODOLOGY

While many factors increase the evaluation apprehension of a situation, we focus on social presence (human versus robot) and social role (teacher versus learning assistant). In order to examine how the social presence of robots and humans impacts help-seeking, we designed two separate conditions, one with a robot tutor and one with a human tutor. To explore the impact of social role on help-seeking, we crossed the social presence factor with two more conditions manipulating the social role by presenting the tutor as either a teacher or a learning assistant.

This 2X2 experiment allows us to better understand how social presence and role of the one-on-one tutor impact conceptual learning and help-seeking behaviors on a human circulatory learning task. From the literature, we constructed a conceptual model of factors impacting a learner's decision to seek help, as shown in Figure 2. From this, we hypothesized:

> *Hypothesis 1:* Participants will be more likely to request help from a robot tutor than a human tutor, due to a decreased prevalence of evaluation apprehension.
>
> *Hypothesis 2:* Participants will be more likely to request help from a learning assistant than a teacher due to a tutor's elevated social status.
>
> *Hypothesis 3:* Participants who are extra sensitive to evaluation apprehension will be significantly more impacted by manipulations of evaluation apprehension.

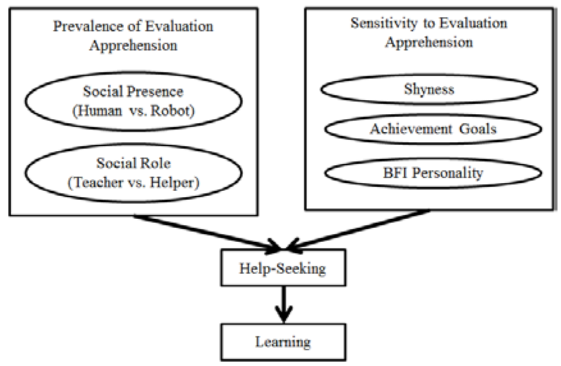

Figure 2. Our conceptual model linking evaluation apprehension to help-seeking and learning.

We recruited 59 students from a local university in Japan for the study: 39 males and 20 females (M = 22 years old, SD = 2.15). Participants were semi-randomly assigned to one of four conditions in a 2X2 factorial experiment: human or robot tutor, and helper or teacher role. In this paper we will refer to the teaching role, either "helper/assistant" or "teacher" as the tutor. 21 participants were assigned to the "robot helper" condition, 20 to the "robot teacher" condition, 9 to the "human helper", and 9 to the "human teacher" condition.

A human operator tele-operated the 110 cm tall ATR Robovie R2 robot through a Wizard-of-Oz interface who also performed the role of the human tutor. Using Wizard-of-Oz techniques ensures that the tutor's social timing and phrasing was kept as similar as possible across all conditions. The Wizard-of-Oz interface was mostly prescripted with standard statements used in helper/teacher conditions, but when a participant's statement could not be answered with the pre-written responses, a text-to-speech interface could be employed to construct a custom statement. Prescripted utterances included welcome remarks, a summary of the learning content, as well as task-related instructions and time announcements. There was also an additional set of responses to anticipated questions, tailored to the helper versus teacher conditions designed specifically for the "worksheet phase" as described in Section 3.2. A voice synthesizer generated the robot's speech.

The tutor (or his chair, for the human tutor) was positioned the same distance from the participant's desk as shown in Figure 1 and Figure 3, while the operator was located in a neighboring room. We placed a small video camera on the wall behind the tutor, and an additional microphone on the front of the participant's desk, where it could not be seen. The participant placed paper materials used during the session into a box located next to the participant's desk.

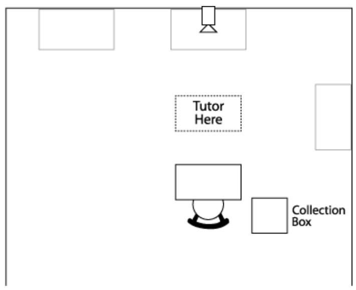

Figure 3. A diagram showing the room set-up of our one-on-one tutoring lab study. The "tutor here" box indicates where either the robot or the human's chair was placed.

The robot remained still throughout the interaction, except for head (three degrees of freedom) and arm movements (4*2 degrees of freedom). We designed the robot's gestures based upon an informal observation of one-on-one tutoring videos, with brief pilot testing to ensure believability. The robot's gaze generally focused on the participant during conversation, and as the participant completed non-interactive tasks (e.g., reading, test-taking) the robot would look away from the participant's desk, and occasionally direct its gaze back towards the participant. After extensive pilot testing and observation of the robot condition, the human tutor attempted to mimic the robot gaze and gesture via limited arm movements and a similar gaze strategy, but it is unlikely that human gesture and gaze was identical to the robot.

While it is possible to simply introduce the robot as a teacher or a helper without differences in behavior, as done in [11], in a real world setting a teacher robot would behave very differently from a helper robot. In this experiment, we expressed this "very different" behavior in the types of help the robot tutor offers. In the "helper" conditions, the tutor introduces himself as a helper for this learning task and mentioned that he preferred giving answers to questions. In the "teacher" tutoring condition, the tutor introduced himself as the teacher and that he preferred providing hints. The tutor's behavior generally followed the experimental condition preference: when participants asked the "helper" a question, they received an answer. The "teacher" answered questions with hints. For more specific questions from the participant, such as confirmation of a fact (i.e., "deoxygenated blood is handled by the right side of the heart?") the tutor would provide the correct answer.

3.1 Learning Materials

The human circulatory system is the domain of interest for this experiment as there is a considerable body of research exploring the topic for learning (see [12] and [4]) which allows us to leverage some of the existing understanding of student conceptions of the human circulatory system. Additionally, as all humans have a circulatory system, and relevant topics such as heart attacks and heart disease appear frequently in the news media [25], the topic of the human cardiovascular system may be seen to be of some intrinsic value for individuals to understand. Furthermore, the human circulatory system is a domain that one can readily learn more than rote facts, but also processes and how multiple systems interrelate, providing an approachable way to explore not just memorization of facts, but procedural knowledge as well.

In this experiment, we adapted learning materials used by Chi et al. in [4] for one-on-one human tutoring of the human circulatory system. The same reading materials from [31] were used, but with some minor adjustments; we removed in-depth explanation of diffusion, as well as references to the names of the valves in the heart, phases of the heartbeat, and subsystems of the cardiovascular system (i.e., coronary circulation, renal circulation, etc.). This simplified some of the vocabulary in the reading, as well as provided the opportunity to test the participants on knowledge they could not gain from the reading.

Potential conceptual knowledge participants had the opportunity to learn included:

- Text-Explicit knowledge: concepts and facts that were explicitly stated in the reading materials.
- Text-Implicit knowledge: concepts that could be acquired by combining multiple sentences in the reading, but were not explicitly stated therein.
- Model-Implicit knowledge: knowledge that relies on the participant having an accurate mental model of the human circulatory system.
- Help-Available knowledge: concepts that the participant cannot find in the reading, but appear on the worksheet and tests that the tutor will provide if the participant asks for help. That is, unless a participant begins the experiment already knowing this knowledge, the participant must otherwise ask her tutor in order to learn these particular concepts.

Text-Explicit, Text-Implicit, and Model-Implicit knowledge are all terms that are borrowed from and described more in depth by [4]. We designed Help-Available knowledge to ensure that even if the participant learned everything possible from the reading, that help from the tutor would still be necessary. These four types of conceptual knowledge vary greatly in difficulty and complexity.

All materials, after being finalized in English, were translated to Japanese and then proofread by another Japanese-native speaker.

3.2 Procedure

Participants first took a dispositional pre-questionnaire and then were led to the experimental lab room by an assistant where they then completed an introductory interaction with their tutor (3 minutes), a pretest (15 minutes), a reading activity (10 minutes), listened to a summary from their tutor (1 minute), and then completed a worksheet (20 minutes), and a posttest (15 minutes) before being led out of the room to complete a post-questionnaire. The *introductory interaction* expressed the tutor's social competence by conversing casually about the participant's experience with learning biology in the past. During the *reading activity*, participants read instructional materials about the circulatory from system by themselves, as discussed in the previous section. The *summary* displayed the tutor's content knowledge. It consisted of a brief summary overviewing the general concepts discussed in the reading. The *worksheet activity* followed the reading phase, and helped the students reflect on concepts they learned from the reading with additional assistant from the human or robot tutor, as needed. Questions on the worksheet were adapted from questions used by one-on-one human tutors in [4]. The worksheet questions were open-ended, and also probed for the four level of knowledge types (e.g., text explicit/implicit, model implicit, and help-available).

The *pretest* and *posttest* were identical and consisted of 23 questions, with 21 being multiple-choice. 6 of these test questions were Text-Explicit, 5 were Text-Implicit, 6 were Model-Implicit, and 4 were Help-Available. The first two questions on the tests probed the participant's mental model of the circulatory system, by having the participant draw the process and explain her drawing. The worksheet consisted of 16 open-ended questions, 4 were Text-Explicit, 2 were Text-Implicit, 7 were Model-Implicit, and 3 were Help-Available.

If participants completed a phase of the experiment early, the tutor encouraged them to check their answers before moving on to the next phase. While this is not strict control of time-on-task, it is a more realistic procedure for one-on-one tutoring interactions.

Participants were informed before the reading and worksheet phase that they could ask their tutor for help.

3.3 Additional Measures

Evaluation apprehension is discussed as an environmental variable to be manipulated, whereas there is no formal measure of one's sensitivity to evaluation apprehension. As proxies for sensitivity to evaluation apprehension, we used scales for Shyness [3], the short Big Five Index [23] personality and Achievement Goal Orientation [6].

The Big Five personality traits consist of: openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism. Of these, extraversion and neuroticism may be the personality traits most relevant to a sensitivity of evaluation apprehension.

Achievement goal orientation consists of three main dispositions: learning orientation (one does an activity for the joy of increasing knowledge), performance-approach orientation (one does an activity to show others how competent they are), and performance-avoidance orientation (one avoids activities to prevent displays of low competence) [6]. So, a person who views help-seeking as a display of incompetence might avoid asking questions, if they are performance-avoidant. In this way, performance-avoidance orientation might be interpreted as highly evaluation apprehensive. Likewise, shyness may be related to evaluation apprehensiveness as well.

Much like the other materials used in this study, questionnaire materials were first formed in English, translated to Japanese, and checked by a second native Japanese speaker for correctness. Since these questionnaire items were not norm-validated for a Japanese sample, this may introduce some issues, although it may allow for better comparison with samples from other locations.

4. RESULTS

Our results suggest partial support for our hypotheses: participants sought marginally less help from human-teachers, with the three remaining conditions statistically indistinguishable. Help-Available question-asking was a marginal moderator on the relationship between condition and Help-Available learning. So while condition only had a marginal effect on the number of questions asked, it was a significant factor, along with help-seeking, in determining student learning.

4.1 Learning

We designed our learning materials to assess learning at several complexity levels including: Text-Explicit, Text-Implicit, Model-Implicit, and Help-Available. As these different conceptual levels vary greatly in difficulty and learning process, we anticipated differences in learning outcomes as well. We measure learning by controlling for pretest scores when predicting posttest scores. An analysis of covariance (ANCOVA) controlling for pretest supports this hypothesis that conceptual type has a significant effect on learning, $F(3, 231) = 5.62$, $p = .001$, $\sigma = 0.12$. Figure 4 shows the differences in percentage improvement from pre- to posttest by conceptual levels, and a post-hoc Student's t-test reveals that participants improved significantly more on Help-Available and Text Explicit, than Text Implicit and Model Implicit. As Text Explicit knowledge requires less cognitive processing than Text Implicit and Model Implicit, these results seem appropriate.

We focus the rest of our analysis on Help-Available knowledge, as this type of knowledge required participants to ask for help to improve. In this way, we can examine how help-seeking and condition interact with learning.

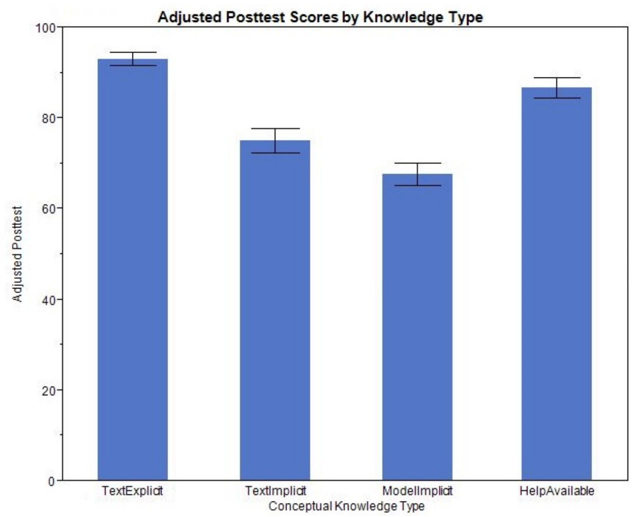

Figure 4. Adjusted posttest scores by conceptual level, with standard error bars.

4.2 Help-Available Knowledge

First, we tested whether tutor condition affected learning of Help-Available knowledge. We performed a nested analysis of covariance (ANCOVA) with condition as the independent variable and Help-Available pretest score and number of Help-Available questions nested within Condition as covariates. Our analysis shows Condition as a significant predictor of learning, $F(3, 50) = 6.74$, $p = .0007$ ($R^2 = 0.17$). Post-hoc comparisons using the Student's t-test reveal that participants in the "human teacher" condition learned statistically significantly less than the other three conditions. Figure 5 shows how adjusted posttest scores differed between the conditions.

4.3 Help-Seeking

In the second step of our nested ANCOVA analysis, we examined the relationship that Help-Available question-asking had on learning, by condition. Help-Available question-asking was a marginal moderator of the relationship between condition and learning, $F(4, 50) = 2.35$, $p = 0.07$, R^2 of 0.30 ($\Delta R^2 = .13$), $\sigma =$

0.52. Looking closer at the relationship between Help-Available question-asking and condition, an ANOVA analysis revealed a marginal effect of condition on Help-Available question-asking, $F(3, 55) = 2.45$, $p = 0.07$, as shown in Figure 6. Although a post-hoc Student's t-test reveals that participants in the human teacher condition asked significantly fewer questions about the Help-Available knowledge concepts than the other conditions with the "human helper" condition being not statistically distinguishable from the other conditions. So, being in the Human Teacher condition reduced the number of questions a student asked about Help-Available knowledge (more so than other conditions), which in turn resulted in those participants learning significantly less than the participants in other conditions.

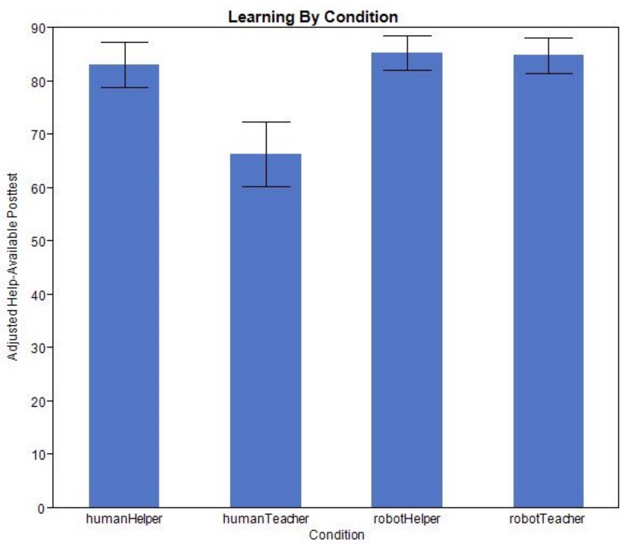

Figure 5. The differences in the learning on Help-Available knowledge items by Condition, with standard error bars.

While the difference in Help-Available questions asked by condition was only marginally statistically different, the overall counts of these questions asked during the 20 minute time period were rather similar: students in the Human Teacher condition asked a median of 0 questions ($M = 0.56$), students in the Human Helper condition asked a median of 2 questions ($M = 1.56$), the Robot Helper condition had a median of 2 questions ($M = 1.67$), and the robot teacher condition also had a median of 2 questions ($M = 1.65$).

Looking at the quantity of questions that could only be asked during the 20 minute worksheet phase, for each level of conceptual knowledge, there was not a significant difference between conditions. The median number of Text-Explicit questions asked across all conditions was 0 ($M = 0.59$), Text-Implicit questions had a median of 0 ($M = 0.70$), Model-Implicit was 2 ($M = 2.18$), and Help-Available knowledge had a median of 1 ($M = 1.48$). While it appears that there is an increasing number of questions for increasing difficulty of knowledge, Help-Available knowledge questions does not appear to follow this general pattern.

4.4 Evaluation Apprehension

Examining evaluation apprehension as a situational factor in our study was done through manipulating the social presence and social role of the tutors, however, participants with varying individual factors might be impacted differently by these situational factors. We measured achievement goal orientation, shyness, and the big five index personality scales as proxies for individual sensitivity to evaluation apprehension.

We did not find any relationship between achievement goals and help-seeking. This suggests that perhaps achievement goals are not appropriate proxies for "sensitivity to evaluation apprehension." However, there was a significant negative effect of shyness on number of questions asked when performing a linear regression, $F(1, 57) = 19.87$, $p < .0001$ ($R^2 = 0.26$), although this effect was only marginal when looking specifically at Help-Available knowledge questions, $F(1, 57) = 2.86$, $p = .096$. So, while shyness might affect one's overall likelihood to ask questions in this setting, it is only a marginal trend when it comes to Help-Available Questions. This suggests that shyness may have a greater effect on topics where students had exposure to material, and a lesser effect on help-seeking on topics to which they were not previously exposed. Our hypotheses predicted enhancing interactions between Shyness and Condition on Help-Available help-seeking, but there was not a significant relationship.

Supporting our shyness related results, an ANOVA analysis shows that BFI-Extravert was significantly positively related to the number of Help-Available Questions, $F(1, 57) = 8.2$, $p < .006$ ($R^2= 0.13$) and BFI-Neuroticism was significantly negatively related to Help-Available Questions, $F(1,57) = 16.24$, $p < .001$ ($R^2 = 0.22$).

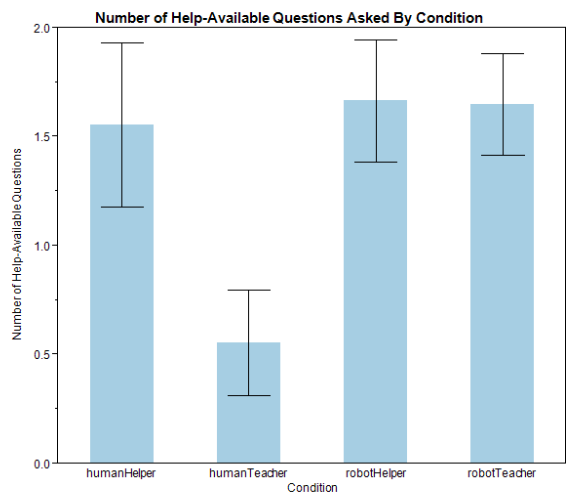

Figure 6. Marginally significant differences in the mean number of Help-Available questions asked by condition.

5. Discussion

Our results show that students learned significantly less from the human teacher, partially due to the fact that they asked the human teacher marginally fewer questions. While students asked marginally fewer Help-Available questions from human teachers than the human helper, we did not see the same distinction made for robot teachers and helpers. So, our Hypothesis 1 (participants will seek more help from robots) appears to only have support when considering human teachers in contrast to robots, and Hypothesis 2 (participants will seek more help from a learning assistant) is only supported if we consider the human teacher separately from the robot teacher condition.

There are a few possible explanations for this, the first being that the robot's perceived social status is so low that the robot teacher did not cause enough evaluation apprehension to affect question asking and learning. Or perhaps perceived social status of robots is still such a novel concept that participants cannot consistently place the robot on the social presence continuum.

Help-seeking was an informative factor as a moderator, but our hypotheses lead us to predict the conditions to result in a stronger effect on help-seeking behavior. One explanation is that social role and presence impacted the kinds of questions asked, rather than the quantity of questions asked, and viewing the questions as an overall sum is obfuscating the more subtle effects these conditions have on help-seeking.

Our learning and help-seeking results are seen only on Help-Available knowledge which could only be learned from asking questions and not from the reading or other materials. That is, we explicitly designed Help-Available content so that in order to see learning gains on those concepts, participants had to ask the tutor questions. This explains why increases in help-seeking result in increases in learning on Help-Available concepts.

Furthermore, while our results touch on proxies for measuring evaluation apprehension, it is clear that a formal measure of "evaluation apprehension anxiety" is important to our hypotheses (Hypothesis 3, sensitive participants will react more strongly to manipulations of evaluation apprehension), but since evaluation apprehension is largely seated in the organizational psychology literature, it is often treated as an environmental factor, and not an individual factor. That is, one can increase (or decrease) the evaluation apprehension prevalence of a situation perhaps by hiring a human tutor instead of a robot tutor, but formal questionnaire measures to directly measure sensitivity to that prevalence do not appear to exist. Instead, we included achievement goal orientation, shyness, and personality scales as potential proxies for evaluation apprehension anxiety. However, these factors did not interact with condition to impact help-seeking. It is possible that people who are shy about asking questions from humans may also be shy about asking questions from robots. More research needs to be done to determine how to best measure sensitivity to evaluation apprehension, and how it might impact help-seeking.

5.1 Limitations

Several factors likely heavily influenced our manipulation of human versus robot including the appearance of both the robot and the human. Since the human tutor operated the robot as well, the personality and gender of the human may also impact this work and different results might possibly occur if a different human operator and tutor are used. Introducing the teacher and helper with two different titles while also giving two different kinds of help, may also affect participant behavior in a way that makes it difficult to distinguish the tutor's introductory role from its behavior. Due to time constraints, the number of participants in the human conditions is not evenly balanced with the robot conditions. Ideally, these conditions would all be equal, and much larger. Furthermore, only using one human or one robot somewhat limits the generalizability of these results to only similar robots and humans.

Also, as this study took place in a suburban area of Japan, results may be limited to similar demographics considering the tremendous impact culture may have on perceived social role. The strong response to only the human teacher condition may not appear the same if this study is redone in other countries.

5.2 Future Work

Future work involves analyzing the types of questions participants asked during the 20 minute worksheet reflection phase. It is possible that the social role and presence of our pedagogical agents impacted whether participants asked simple clarification questions, or more complex questions combining several knowledge components. The types of questions asked may affect learning as well. Only after analyzing participant help-seeking deeper can we determine whether social presence and role had an impact on beneficial help-seeking.

Furthermore, there are many other factors that impact people's decision to seek help, and analyzing a larger, more inclusive model may reveal a more complex and complete story about how using a robot changes participant learning behavior.

The Robovie R2 used in this study was Wizard-of-Ozed, and there are many steps necessary to accomplish before our robot tutor might be autonomous. Advances in language recognition must improve to allow Robovie to parse student questions. Once learner statements can be properly parsed, the robot still needs to be able to answer those questions. For anticipated questions this may not be so difficult, as in this study we most often used pre-written responses for both the human and the robot tutors. However, this can be more complicated for novel questions from learners. Significant training on the participant questions and biology content could help improve the coverage of pre-written questions. Furthermore, once a fully autonomous pedagogical robot exists, it may be difficult to do direct comparisons between this autonomous robot and a human tutor as the social timing may not be the same. Such a study should include a human tutor, a human-controlled robot tutor, and an autonomous robot to properly examine the differences in both embodiment and social cue dimensions. It is possible that less ideal social responses may result in interpreting the robot as less likely to be judgmental, thereby resulting in reduced evaluation apprehension and more question-asking.

6. CONCLUSION

In some learning situations, the use of robot pedagogical agents may be more beneficial to learning than with human pedagogical agents. Our work shows that while learners may not view distinctions in robot social role the same way they view distinctions in human social role, robotic tutors can perform at the same level as our human learning assistants.

While a one-on-one robot or human tutor is not always practical, these same issues with help-seeking, evaluation apprehension, social role, and social presence may all impact the effectiveness of a tutor supervising an entire classroom of students. That is, some of the same concerns we identified in our one-on-one tutoring situation may be applicable to learning situations with larger groups of students.

Even beyond groups of students, help-seeking and learning occur outside of the classroom as well, and dedicated thought should be invested into how social roles are constructed in our workplaces and public spaces so that people may seek help and acquire new knowledge in the best way possible.

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