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Effect of a human-teacher vs. a robot-teacher on human learning a pilot study

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EFFECT OF A HUMAN-TEACHER VS. A ROBOT-TEACHER ON HUMAN LEARNING: A PILOT STUDY

by

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ABSTRACT

Studies about the dynamics of human-robot interactions have increased within the past decade as robots become more integrated into the daily lives of humans. However, much of the research into learning and robotics has been focused on methods that would allow robots to learn from humans and very little has been done on how and what, if possible, humans could learn from programmed robots.

A between-subjects experiment was conducted, in which two groups were compared: a group where the participants learned a simple pick-and-place block task via video of a human-teacher and a group where the participants learned the same pick-and-place block task via video from a robotic-teacher. After being the taught the task, the participants performed a 15-minute distracter task and then were timed in their reconstruction of the block configuration. An exit survey asking about their level of comfort learning from robot and computer entities was given upon completion.

Results showed that there was no significant difference in the rebuild scores of the two groups, but there was a marginally significant difference in the rebuild times of the two groups. Exit survey results, research implications, and future work are discussed.

DEDICATION

This thesis is dedicated to my father, Dr. Glenton A. Smith.

May he rest in peace.

ACKNOWLEDGEMENTS

I would like to acknowledge Dr. Valerie Sims for her mentorship and advising throughout the process of completing this thesis.

I also acknowledge Dr. Matthew Chin and Dr. Aman Behal for being on my thesis committee.

I would like to acknowledge my family, who has supported me in all of my endeavors to date and continue to do so on a daily basis.

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INTRODUCTION

Human learning has always been an area of focus within the research world. Over the past 50 years, it has been established that novel experiences are better remembered in the long-term when compared to familiar experiences (Tulving & Kroll, 1995). Numerous novel methods have been applied in regard to teaching humans. Avatars and virtual computer environments have become more mainstream within the past couple decades, with detailed software environments like Second Life being utilized in all levels of education. Falloon (2010) made the case that the enhanced learning engagement, focused communication, and better collaboration by student in group settings allowed avatars to be a useful tool in human learning. Interactive devices, like the Resusci-Annie used to train emergency medical technicians and medical students on how to perform in different emergency scenarios and other more high-fidelity mannequin simulators, have been shown to aid human learning of the concepts presented when compared to just reading about the concepts (Okuda & Quinones, 2008).

Robots are becoming an integral part of society, with their uses growing on a daily basis as technological breakthroughs and creative applications rise. Human-robot interaction is a growing area of research within the field of human factors psychology, which studies how humans interact with different forms of technology and entities on a daily basis. Human-robot interaction differs from human-computer interaction and human-machine interaction in that the field focuses on human interactions with systems – robots – that have complex control systems, can exhibit autonomy and cognition and which operate in constantly changing, real-world environments (Scholtz, 2002).

A specific definition for the term robot is hard to pinpoint, as it can be defined in many ways due to the different forms and functions of robots. In general, a robot is defined as an automatically guided machine, whether autonomously guided or remotely controlled, that can often sense and manipulate its environment and exhibit intelligent behavior (Moravec, 2011). One of the major components that makes something a robot is the concept of autonomy, defined as freedom from human intervention, oversight or control (Barber & Martin, 1999). Varying degrees of robot autonomy exist from stationary robots programmed with one function and used in the automation industry to robots with simple sensors to direct their movements like the Roomba vacuum robot to robots designed to explore dangerous landscapes and only report back to a human if certain target objects (e.g., bombs) or substances (e.g., water) are found. Robots can take many forms, from bare wire and metal-frame robotic arms to more anthropomorphic (human-like) shaped entities to box-shapes on wheels, designed to deliver food or vacuum a house. In regard to research regarding robots, much has been done into how robots can be incorporated into human lives to complete repetitive and/or difficult tasks, assist in various applied professions, like the medical field or automotive industries, and utilized in social settings, like nursing homes and schools.

Much research has been done into how robots can learn to recognize and sometimes imitate human behavior. By incorporating pattern recognition technologies, various algorithms and advanced camera and detection systems, scientists have worked extensively on ways in which robots can learn how to imitate human beings. Nicolescu and Mataric (2007) conducted various experiments wherein robots learned various tasks from humans via imitation of human action and programmed rules to complete a task. By programming the robot to alert a human observer through simplistic gestures and actions, much as a young child would do, when an error had occurred, allowed for more efficient completion of a given task. Much research has also been conducted into establishing the norms of robot behavior when they are intended for interactions with humans; the norms for a robot in an automobile factory are much different than the norms for a robot created to be an in-home companion. Dautenhahn (2007) worked to develop social rules for robot behavior that would establish rules that would make robots comfortable and acceptable to humans, a set of rules which she dubbed a “robotiquette.” With distinguishing different sets of norms for caretaker-robots and companion-robots, Dautenhahn helps to reveal the differences in how two types of robots interact with humans. However, neither of these categories can be directly applied to a robotic-teacher, which would be in a separate category than that of a companion or caretaker. By also emphasizing the point that interacting with a robot is not like interacting with another human and not the same as interacting with a computer, Dautenhahn points out one of the areas in need of further research within the domain of human-robot interaction.

Comparatively little research has been done into how humans can learn from robots. Solis, Bergamasco, Chida, Isoda and Takanishi (2004) created an anthropomorphic flute playing robot to showcase a practical use for robots in a human living environment. Though initially focused on perfecting the robot from an engineering standpoint, Solis, et al used the robot to assist in reproducing human flute playing in efforts to teach young flute players, as well as evaluate the students’ performances and offer feedback, while a human teacher provided psychological motivation to the students. In an experiment comparing the students who had both the robot teacher and the human teacher to students who just had the human teacher, it was found that the students performed better in factors like sound harmonics and sound quality when the robot-teacher and human-teacher combination was used. This study is unique in that it focuses on the engineering behind the robot itself, but demonstrates the effect that a robot teacher can have on human-learning, a topic not covered in many other areas. Research into using robots as companions and even teachers to children with autism has emerged recently, as children with autism react positively to the predictable and reliable nature of robots. A mini-humanoid imitator robot, named Robota, was utilized by Billard, Robins, Nadel, and Dautenhahn (2007) as a companion to low-functioning children with autism, with the intent of teaching the children simple coordinated behaviors. The longitudinal study showed that the Robota robot was successful at eliciting imitative coordinative behavior from the children.

One reason why research into robots as teachers is very relevant is the concept of the human mirror neuron system. Originally discovered in monkeys, mirror neurons are a class of visuomotor neurons present in the premotor cortex of the brain that will activate when the animal is observing a relatable action conducted by another monkey (Rizzolatti, Fogassi&Gallese, 2001). In the monkeys, mirror neurons became active when a monkey had previously done an action itself and later observed another monkey making a similar action. However, these mirror neurons were not activated with when the action was mimicked without a specific target object or when the object was present by itself. In humans, by using brain imaging and electrophysiological techniques, evidence of areas of the brain that respond to identifiable observed behavior have been located. Specifically, electroencephalography (EEG) evidence was found for mirror neuron activity in human brains during the observation of human and humanoid robot actions, leading to the suggestion that realistic enough humanoid robots could trigger the human mirror neuron system (Oberman, McCleery, Ramachandran& Pineda, 2007). Oberman, et al, intend to possibly create a humanoid robot ‘Turing test’ that would help determine the level to which a robot was considered humanoid. By monitoring the EEG output from the brain of a person observing a humanoid robot, scientists would be able to identify the mirror neurons had been activated, indicating that the robot was sufficiently realistic.

Because interacting with a robot in a situation where the robot is in a teaching role would be a vastly novel experience, learning from a robot should allow for the improved learning of certain tasks by humans. While repeated exposure to a robot-teacher may cause some adaptation, the novelty of learning from a robot would still exist until the concept became more widespread. As research has shown, robot-teachers are beneficial for teaching interactive and social concepts to children with autism that are harder for them to grasp from other humans. Robot-teachers can also be utilized in coordination with human-teachers to teach concepts that are physical or mechanical in nature, like the technicalities of playing an instrument, constructing a specific design configuration, or writing a specific calligraphic character, due to the ability of a robot to perform an action precisely and identically every time. Another purpose for research into robot-teachers is to investigate whether the lack of human-to-human social interaction would help or hinder the learning of different concepts. Social interaction is present in every situation, where a teacher's disposition can vastly effect how well a concept is learned by a student (Hodkinson & Hodkinson, 2004). As robots have no intrinsic emotion or ability to cast judgment, robot-teachers would be able to convey concepts to students in an identical manner.

The current research is interested in finding how well humans learn from a robot-teacher compared to learning from a human-teacher. This research is necessary due to the lack of research conducted on humans learning from robots, especially when compared to the extensive research done on ways robots can learn from humans, in an effort to make robots more anthropomorphic. The current research will have participants learn a pick-and-place block building task from either a video of a human-teacher demonstrating the task or a video of a robot-teacher demonstrating the task. The hypothesis is that the rebuild score of a physical pick-and-place block building task will be improved for participants who learned the task from a robot-teacher when compared to participants who learned the same task from a human-teacher.

METHOD

Participants

Sixty (60) participants were recruited from the University of Central Florida student body via the SONA experiment recruitment system. Participants ranged from ages 18 – 26 (M = 18.7) and there were 45 females, 15 males. Participants were screened for color-blindness, due to the reliance on color differentiation necessary in the task. Partial course credit was given in exchange for participation.

Design

A between-subjects experiment was conducted, comparing two groups: a group where participants learned a simple pick-and-place block task from a video of a human-teacher and a group where participants learned the same pick-and-place block task from a video of a robotic-teacher. This task was chosen as it is physical in nature and, as such, tasks that a robot-teacher would be ideal for teaching due to the ability to consistently teach the task in an identical manner.

Participants were randomly assigned to the two conditions. The type of teacher, robotic or human, was the independent variable and the reconstruction accuracy score (rebuild score) and the amount of time the reconstruction of the block configuration took (rebuild time), as well as the responses to the exit survey questions, was the dependent variables. The rebuild score for this task was out of a total of 10 possible points, based on ascoring sheet created for the block configuration; the scoring sheet can be found in Appendix A. The rebuild time was kept from when the participant touched the first block during reconstruction to when the verbally said "Done," as instructed by the researcher.

Apparatus

The pick-and-place building task block configuration was comprised of basic sponge building blocks of different colors. The robot-teacher in the video shown to the participants was a robotic arm constructed of a K'Nex modeling set and controlled by a Lego Mindstorms NXT programmable robotic brick. The robotic arm was based off the NXT Programs Robot Arm design (Parker, 2007), but was modified for requirements specific to this study. The robotic arm was 12 inches in length and had a simple 2-sided clamp appendage at the end of the arm.

The videos of the teachers were shot from the perspective of the participant, looking at the blocks on the table in front of them, with only the human-teacher's arm from elbow to fingers visible. The robot-teacher video was 55 seconds in length; the human-teacher video was 35 seconds in length. Both videos displayed the final configuration for 2 seconds at the end of the video. There was no sound in either of the videos.

A basic stopwatch was used to time how long the participants took to reconstruct the block configuration. The exit survey was comprised of eleven (11) 7-point scale questions about the comfort level of learning from robotic and computer entities, as well as two (2) yes/no questions asking about the participants' exposure to online classes, robotic entities, computer programming, and two (2) questions asking their age and gender. The videos teaching the block configuration to the participants and the exit survey were administered via computer.

Procedure

Instructions were given to the participants before the task was demonstrated that the video was silent and not very long, so attention was necessary. Participants were allowed to repeat the video as many times as they wanted for up to five (5) minutes; the researcher kept time. The blocks configuration was comprised of six (6) sponge building blocks of various colors and was built stacked on top of each other in the configuration shown below, as well as screenshots from the human-teacher and robot-teacher videos.

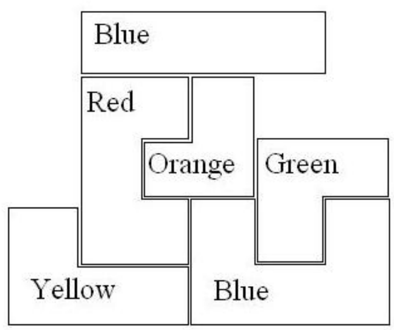


Figure 1. Block configuration.

Figure 2. Screenshot from human-teacher video

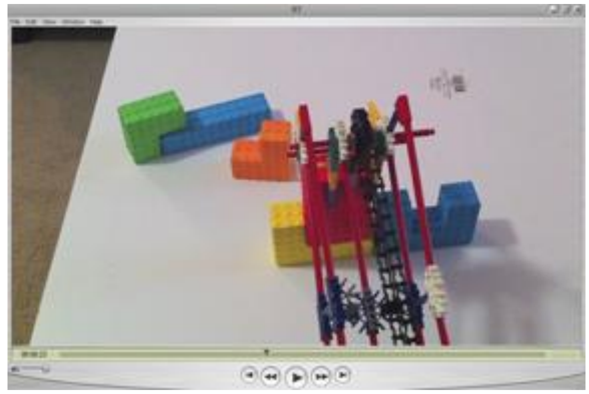


Figure 3. Screenshot from robot-teacher video

After watching the video of either the human-teacher or robot-teacher constructing the block configuration for up to 5 minutes, participants were given a 15-minute distractor task in the form of a 100-piece jigsaw puzzle. After 15 minutes, timed by the researcher, the building blocks were presented to the participant and they were instructed to reconstruct the configuration they had learned; they did not have to construct it in the exact order it was shown to them, but they should do it as quickly and accurately as possible and they were told to say “Done” out loud when they were finished. Time was kept by the researcher, with time starting when the participant touched the first block and ending when they said “Done.” An exit survey was then given via computer, asking their levels of comfort learning from a robot and computer entities, as well as their exposure to online classes, robots, computer programming, and basic demographic information. The accuracy of the participants’ block configuration reconstruction was scored using the scoring sheet found in Appendix A.

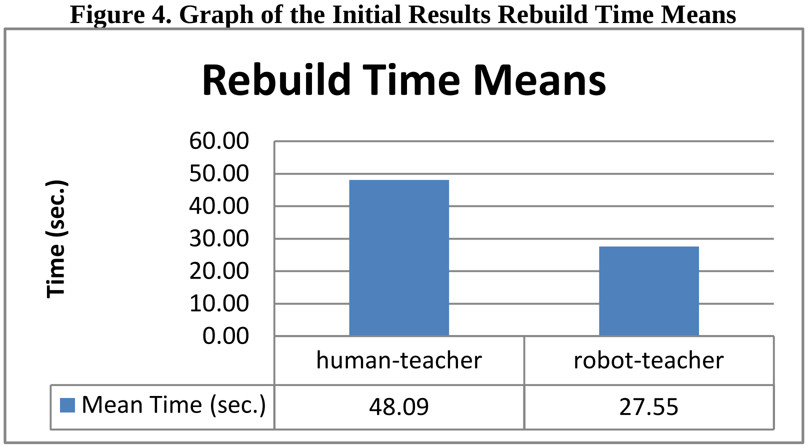
RESULTS

A between-subjects experiment was conducted with two groups of 30 participants each: one group that had learned the block building task from watching the video of a human-teacher and one group that had learned the block building task from watching the video of the robot-teacher. A T-test for independent means was conducted to analyze the rebuild time and score data, as well as the responses to the exit survey questions.

Of the sixty participants, 2 of them completed the entire jigsaw puzzle distractor task within the 15 minutes allotted; 59 of them attempted to complete the puzzle. Forty-four (44) participants earned a perfect score of 10 on the rebuild task.

A marginal significance was shown between the teacher type and the rebuild time, $t(58) = 1.841$, $p = .07$, with the rebuild times for participants with the human-teacher (M=48.09, SD=55.83) being much greater than the rebuild times for participants with the robot-teacher (M=27.55, SD=24.85).

Figure 4. Graph of the Initial Results Rebuild Time Means



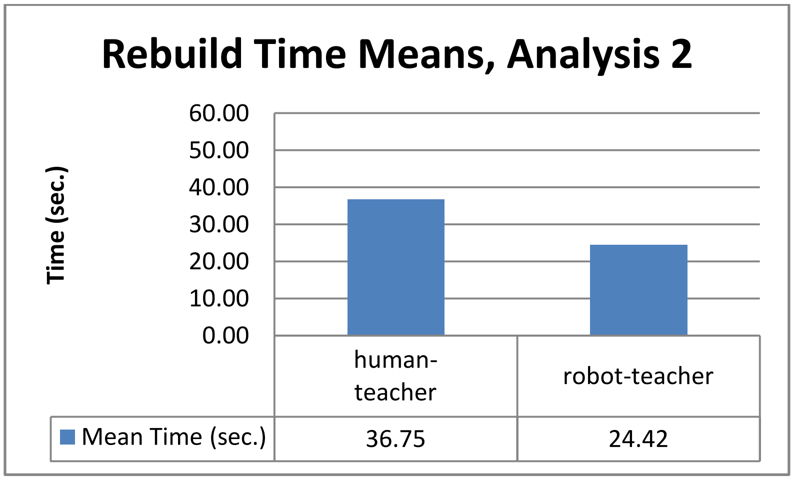
$t(58) = 1.841$, $p = .07$

Figure 5. Table of the Initial Results

Group Statistics						
	Teacher		N	Mean	Std. Deviation	Std. Error Mean
Rebuild Time		Human	30	48.0900	55.83044	10.19320
		Robot	30	27.5533	24.84575	4.53619
Rebuild Score		Human	30	8.6333	2.20475	.40253
		Robot	30	9.2000	1.82700	.33356

Due to the great variability in the rebuild times in the human-teacher condition (*M*= 48.09, *SD*= 55.83) compared to the robot-teacher condition (*M*= 27.55, *SD* = 24.85), the data was re-run with participants with a rebuild time exceeding three (3) minutes (180 seconds) removed, as well as the one participant who did not attempt to complete the distractor jigsaw puzzle.

Figure 6. Graph of the Reanalysis Rebuild Time Means



$t(55) = 1.631$, $p = .11$

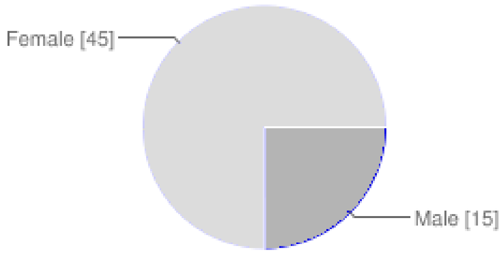
Figure 7. Table of the Reanalysis Results

Group Statistics						
	Teacher		N	Mean	Std. Deviation	Std. Error Mean
Rebuild Time		Human	28	36.7536	36.21665	6.84430
		Robot	29	24.4207	18.28771	3.39594
Rebuild Score		Human	28	8.8571	2.06764	.39075
		Robot	29	9.4138	1.42722	.26503

A complete summary of the data from the exit survey questions can be found in the table below. With two exceptions, questions were answered using a 7-point Likert scale, in which 1 was strongly disagree, 4 was neutral, and 7 was strongly agree. Two questions, concerning having taken online classes and having encountered robots at some point, were yes or no questions. The majority of participants "strongly agreed" that they were comfortable using computers for education purposes (63%), entertainment purposes (60%), and socializing purposes (53%). Only 48% of the participants had taken an online class, though 80% of the participants agreed in some capacity that they were comfortable learning via computers. Ninety (90%) of the participants agreed that they preferred learning in a classroom face-to-face, with the other 10% being neutral. In regards to robots, 60% of the participants responded as not having encountered a robot in some aspect of their life, with generally neutral responses in regards to comfort with robots used for education, entertainment, and socializing. The majority of participants (68%) disagreed in some capacity that they would feel comfortable learning from a robotic teacher.

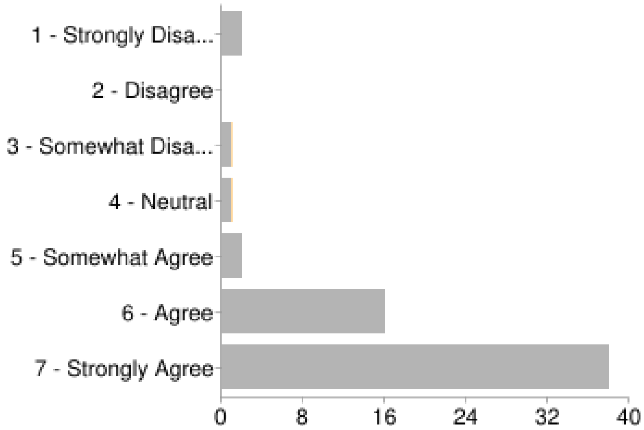
Table 1. Summary of Exit Survey Data

Gender



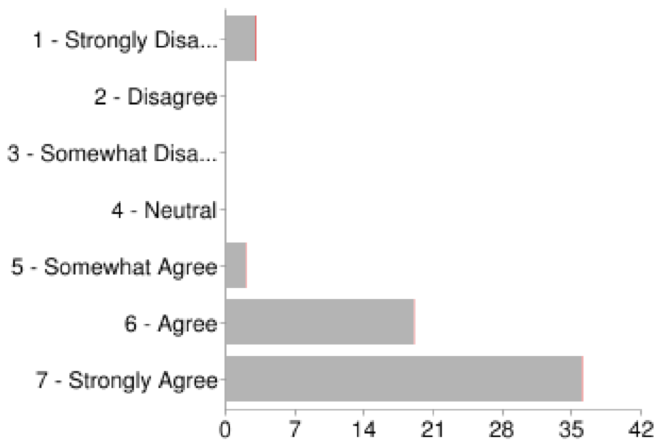
Male	**15**	25%
Female	**45**	75%

I am comfortable using my computer for education purposes.



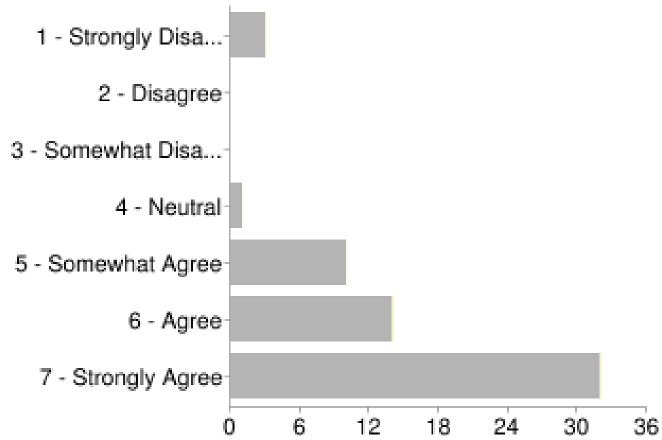
1 - Strongly Disagree	**2**	3%
2 - Disagree	**0**	0%
3 - Somewhat Disagree	**1**	2%
4 - Neutral	**1**	2%
5 - Somewhat Agree	**2**	3%
6 - Agree	**16**	27%
7 - Strongly Agree	**38**	63%

I am comfortable using my computer for entertainment purposes.



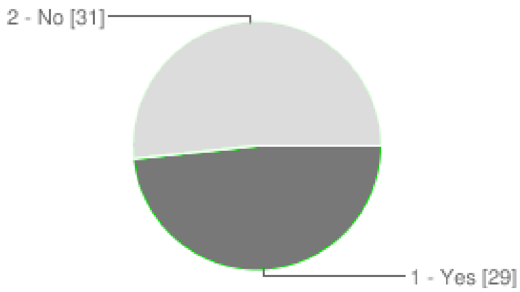
1 - Strongly Disagree	**3**	5%
2 - Disagree	**0**	0%
3 - Somewhat Disagree	**0**	0%
4 - Neutral	**0**	0%
5 - Somewhat Agree	**2**	3%
6 - Agree	**19**	32%
7 - Strongly Agree	**36**	60%

I am comfortable using my computer for socializing purposes.



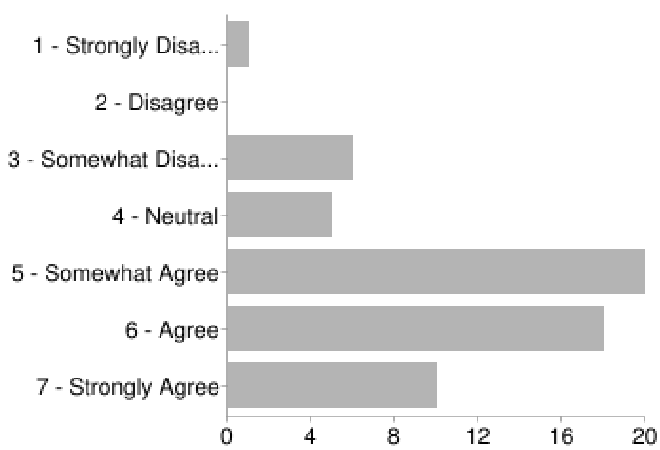
1 - Strongly Disagree	**3**	5%
2 - Disagree	**0**	0%
3 - Somewhat Disagree	**0**	0%
4 - Neutral	**1**	2%
5 - Somewhat Agree	**10**	17%
6 - Agree	**14**	23%
7 - Strongly Agree	**32**	53%

I have taken online classes.



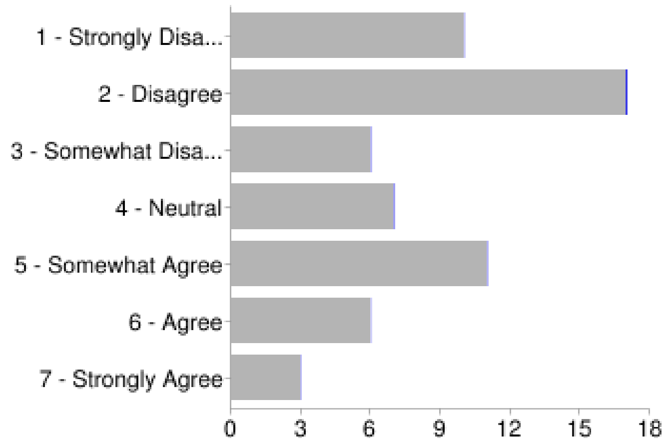
1 - Yes	**29**	48%
2 - No	**31**	52%

I am comfortable learning via computers.



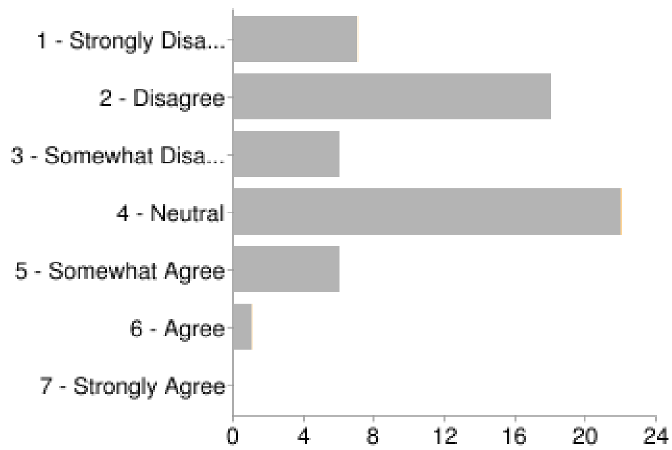
1 - Strongly Disagree	**1**	2%
2 - Disagree	**0**	0%
3 - Somewhat Disagree	**6**	10%
4 - Neutral	**5**	8%
5 - Somewhat Agree	**20**	33%
6 - Agree	**18**	30%
7 - Strongly Agree	**10**	17%

I have computer programming experience.



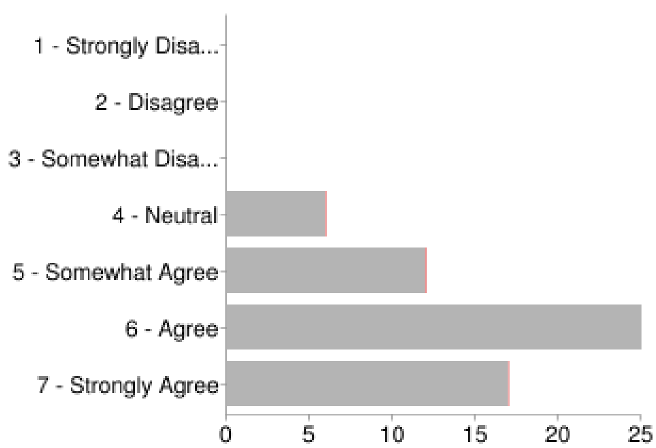
1 - Strongly Disagree	**10**	17%
2 - Disagree	**17**	28%
3 - Somewhat Disagree	**6**	10%
4 - Neutral	**7**	12%
5 - Somewhat Agree	**11**	18%
6 - Agree	**6**	10%
7 - Strongly Agree	**3**	5%

I prefer to learn via a computer.



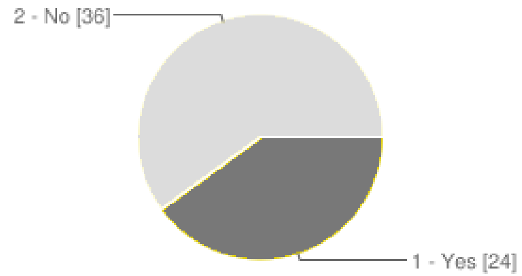
1 - Strongly Disagree	**7**	12%
2 - Disagree	**18**	30%
3 - Somewhat Disagree	**6**	10%
4 - Neutral	**22**	37%
5 - Somewhat Agree	**6**	10%
6 - Agree	**1**	2%
7 - Strongly Agree	**0**	0%

I prefer to learn in a classroom face-to-face.



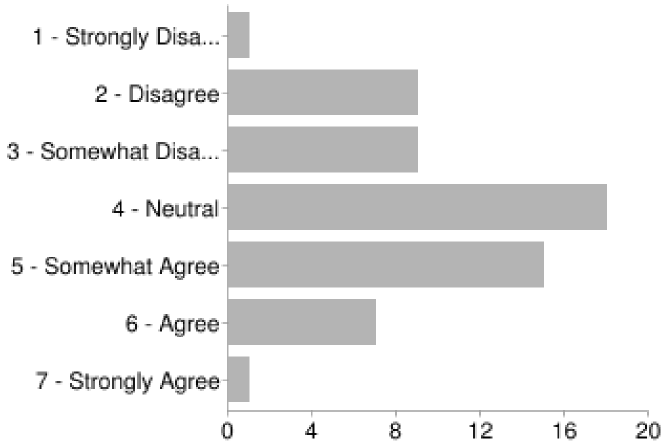
1 - Strongly Disagree	**0**	0%
2 - Disagree	**0**	0%
3 - Somewhat Disagree	**0**	0%
4 - Neutral	**6**	10%
5 - Somewhat Agree	**12**	20%
6 - Agree	**25**	42%
7 - Strongly Agree	**17**	28%

I have encountered robots in some aspect of my life.



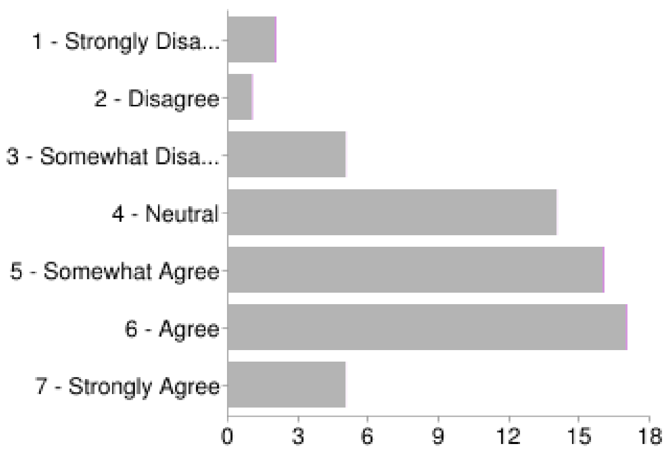
1 - Yes	**24**	40%
2 - No	**36**	60%

I am comfortable with robots used for education purposes.



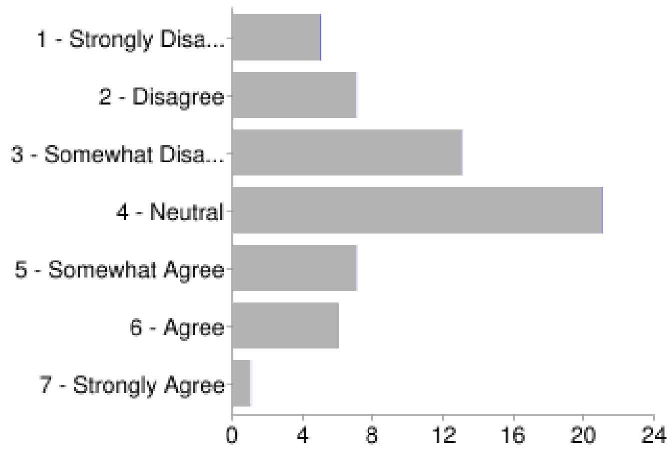
1 - Strongly Disagree	**1**	2%
2 - Disagree	**9**	15%
3 - Somewhat Disagree	**9**	15%
4 - Neutral	**18**	30%
5 - Somewhat Agree	**15**	25%
6 - Agree	**7**	12%
7 - Strongly Agree	**1**	2%

I am comfortable with robots used for entertainment purposes.



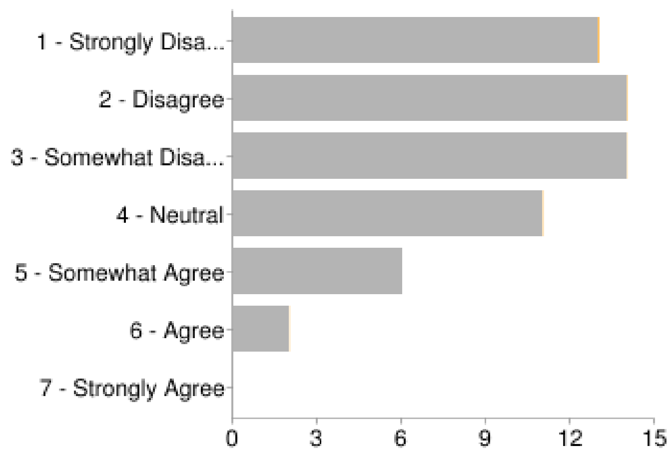
1 - Strongly Disagree	**2**	3%
2 - Disagree	**1**	2%
3 - Somewhat Disagree	**5**	8%
4 - Neutral	**14**	23%
5 - Somewhat Agree	**16**	27%
6 - Agree	**17**	28%
7 - Strongly Agree	**5**	8%

I am comfortable with robots used for socializing purposes.



1 - Strongly Disagree	5	8%
2 - Disagree	7	12%
3 - Somewhat Disagree	13	22%
4 - Neutral	21	35%
5 - Somewhat Agree	7	12%
6 - Agree	6	10%
7 - Strongly Agree	1	2%

I would feel comfortable learning from a robotic teacher.



1 - Strongly Disagree	13	22%
2 - Disagree	14	23%
3 - Somewhat Disagree	14	23%
4 - Neutral	11	18%
5 - Somewhat Agree	6	10%
6 - Agree	2	3%
7 - Strongly Agree	0	0%

Discussion

This research is interested in how humans learn from a human-teacher compared to a robot-teacher. The hypothesis was that the rebuild score would be improved for participants who had learned the task from the robot-teacher compared to those participants who had learned the same task from the human-teacher. Though there was no significant difference between the scores of the two groups based on the type of teacher, both the initial analysis mean rebuild score for the robot-teacher group (*M*=9.20, *SD*=1.82) and the reanalysis mean rebuild score for the robot-teacher group (*M*=9.41, *SD*=1.42) were higher than those of the human-teacher group, in both the initial analysis (*M*=8.63, *SD*=2.20) and the reanalysis (*M*=8.86, *SD*=2.07). This data is in line with the hypothesis that the rebuild scores of those in the robot-teacher group would be improved.

Based on the exit survey results, it is apparent that the participants would not feel comfortable learning from a robotic teacher, despite the fact that half of them learned the block building task from a robotic teacher. This begs the question if the lack of research into the area of humans learning from robots may be partially due to humans being uncomfortable learning from robots. While the majority of participants agreed they were comfortable using their computers for educational purposes and learning via computers, the majority strongly disagreed to being able to comfortably learn from a robotic teacher. Reasons for this difference may include the lack of exposure to robots (60% of participants stated they had not encountered a robot in any aspect of their life), a wariness about robots brought about by popular culture references like *The Terminator* and *Matrix* movies, and fear about not being able to learn and grasp concepts when your robot-teacher can literally "break" due to mechanical or software failures.

These results indicate that more research needs to be done into the ways in which robot-teachers can be utilized in society. Though there was no specific significant difference between the rebuild scores or rebuild times of the two groups, the fact that the robot-teacher could even be similar to that of a human-teacher is still a useful finding that needs to be explored further in regards to different types of tasks and lessons that can be taught by a robot. Studying how students respond to robot-teachers in response to different types of lessons would also prove insightful into analyzing current standard teaching methods and ways in which they can be improved.

Limitations

There were a few limitations present in this study. The fact that participants were taught the block-building task via video instead of by in-person teachers may have added another variable to the experience. There also appeared to be a ceiling effect with the rebuild task, as, based on anecdotal data from the researcher, a few participants were able to play around with the blocks until they figured out the configuration, not necessarily reflecting actual learning of the configuration. Increasing the difficulty of the configuration and adding different types of tasks to be learned could rectify this limitation.

Future Work

This research was a pilot study into an area of research that has not been extensively covered to date. In the future, teaching the participants in-person with “live” teachers, as in having them learn directly in-person from a programmed robot and a human teacher, would be ideal, as opposed to the videos of the different teachers utilized in this pilot study. Establishing a more difficult task for the participants to learn would also be essential, as the 6-block configuration appeared too simple a task for determining if the type of teacher made a difference on the rebuild score; researcher observations during the rebuild task revealed that some participants were able to play around with the blocks until they got something that they “guessed” was correct, with it often times being correct. Controlling the number of times participants could watch the videos, or have the lesson demonstrated by the live teacher, would allow for more concrete data; also having a control group that just saw the final configuration, but not the process, and have them construct the configuration would provide beneficial information.

Having other types of tasks, like a word memory task or a multi-modal lesson (for example a history lesson, remembering numbers, words and concepts), along with a creative, physical task like the block building would be relevant to research, as the different types of information may be taught more successfully by one type of teacher when compared to the other. Also using standardized short and long term memory tests, like the Corsi Block-Tapping Task, could allow for direct comparison of how the participants are learning from the different teachers compared to standardized scores from the general population. Testing long-term learning by bringing the participants back a week or more later to retest their learning would definitively allow the researchers to learn if there are any long-term difference in how human learn from robot-teachers compared to human-teachers. Being in such a relatively novel area of research, this pilot study lends itself to much expansion in future studies.

APPENDIX A: BLOCK CONFIGURATION SCORE SHEET

Part. #:______ Teacher:_______ Completion Time:__________

Scoring Guide

Object	**Points**	**Participant's Points**
Yellow Block on bottom	1 point	
Yellow Block on left	1 point	
Yellow Block correct orientation	1 point	
Blue block on bottom	1 point	
Blue block on right	1 point	
Green block in Blue block	1 point	
Green block correct orientation	1 point	
Orange Block in Red block	1 point	
Red/Orange set on top of Blue/Green Set	1 point	
Blue block on top	1 point	
Score:	10 points total	

Drawing of participant's reconstruction here.

Time Stamp of Completion: ___________________________________

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