Virtual Agents

HCI Capstone 2016
Final Report

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Introduction

The Articulab at Carnegie Mellon is working to improve the understanding of education and children, as well as how technology can be implemented to augment learning spaces. The SCIPR project - a multi-year endeavor headed by Justine Cassell - is working to bridge the gap between virtual agents, education, and the physical world. By investigating how virtual agents can extend beyond their digital confines to affect their environment in tangible ways, SCIPR seeks to understand how collaboration and curiosity in learning can be improved.

Our Task

As a team, we were tasked with exploring the mixed reality and education realm. We focused on strategies and technologies that could be utilized by the Articulab to extend virtual agents' influence to the physical world. Additionally, we experimented with how games and experiences could be implemented in conjunction with educational virtual agents.

We sought to provide valuable research and insight on three specific criteria: collaboration between virtual agents and children, curiosity and exploration, and player engagement.

Project Summary

To understand and define the problem space, we began by doing a preliminary literature review, video research analysis (videos provided by Articulab), and expert interviews. Our background research investigated topics such as learning through collaboration, technology in games, augmented reality, and embodiment. After compiling our findings in an affinity diagram, we realized the need for additional exploration by way of low-fidelity prototypes and testing. We brainstormed and sketched different ideas that would allow a virtual agent to affect the physical space, categorizing our ideas into three main categories: actuation, visualization, and sensing. Utilizing Wizard of Oz methodology, we tested low-fidelity versions of two different sketches on college students: digital physics and proxy (named BeepBoop).

We iterated on these conditions to test mid-fidelity in which we experimented further with embodiment in a game called Marble Run. For our mid-fi testing, we tested a new game called Marble Run in which players collaborated to construct a path that would move a marble from a starting point to end goal. The virtual agent was represented differently across three conditions: on a screen, as a robot on the game table, and on screen with a proxy on the table.

For our final exploration, we iterated both on Marble Run and on the forms of actuation we wanted to test. After conducting several pilots on college students, we narrowed down three experimental conditions: shadow drawing, shadow movement, and controller movement. We focused on experimenting with forms of actuation in these tests. Our virtual agent WoZ, dubbed Alex, sat behind a frame at the end of the table for each test. We were able to conduct a total of six tests with 10 kids. The results of these trials we've used to inform our understanding of actuation in practice, as well as how to engage children in educational learning scenarios.

Our Contribution

At our project's conclusion, we will be able to provide results from 3 rounds of testing, prototyping approaches for actuation, and data from tests with children. During the course of our brainstorming, we also designed a collaborative game, Marble Run. Marble Run has already gone through several rounds of iteration, and may act as inspiration for making future activities more engaging. In conjunction with our research and findings, we have also discussed how to implement various technologies in ways that would allow a virtual agent to interact in higher fidelity scenarios. Development of these technologies in relation to a complete virtual agent would allow the Articulab to eventually experiment in classroom settings.

Research

Research Goals

We performed a literature review, conducted expert interviews, and analyzed videos of children in play provided by the Articulab to inform our research phase.

Our goals:

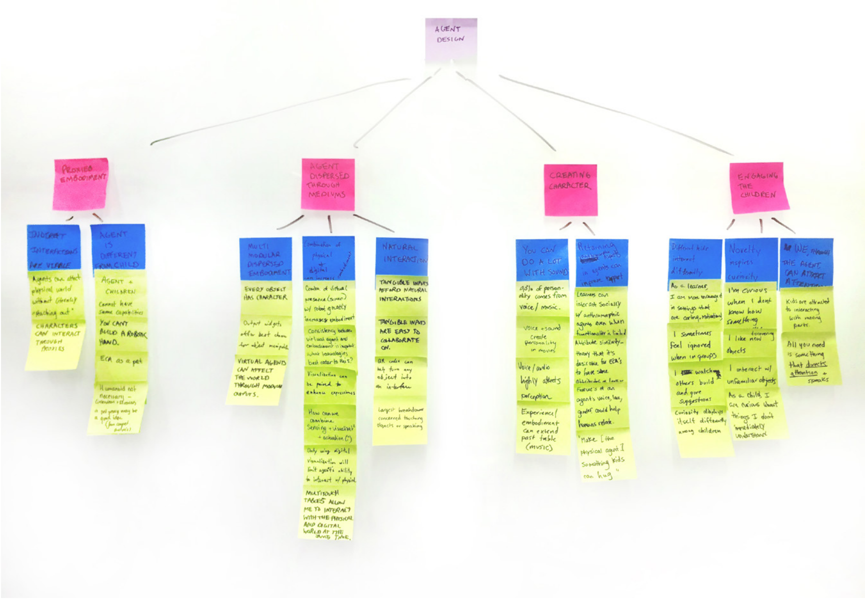
• Examine how virtual agents interact with humans
• Explored mixed-reality scenarios and different technologies that could be used to make them successful

Major Findings

Several points informed the direction of our project:

1. A robot with non-humanoid form can still elicit natural human interactions with a child.
2. Virtual agents can interact effectively in some cases through the use of a proxy.
3. Digital visualization and sensing can be as important to a successful experience as responsive actuation.
4. Project, robotics, and digital visualization have been used in various scenarios to create collaborative and engaging environments in play

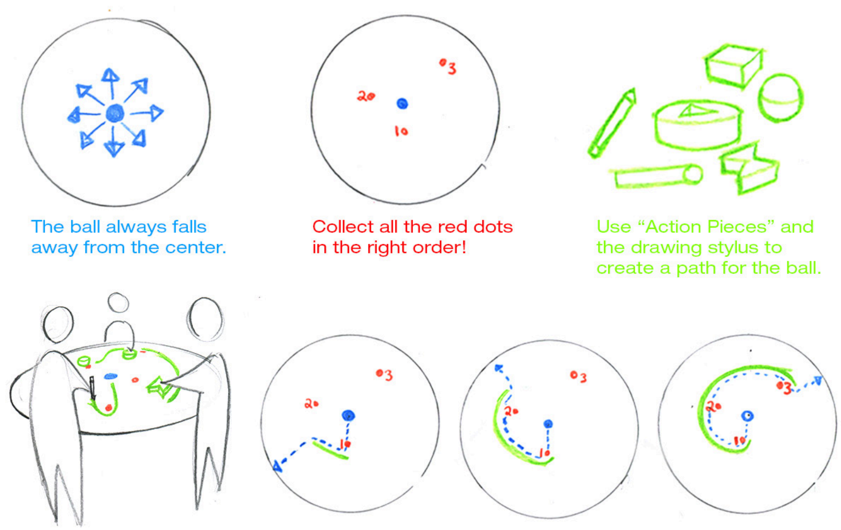
Affinity diagram used during the brainstorming process.

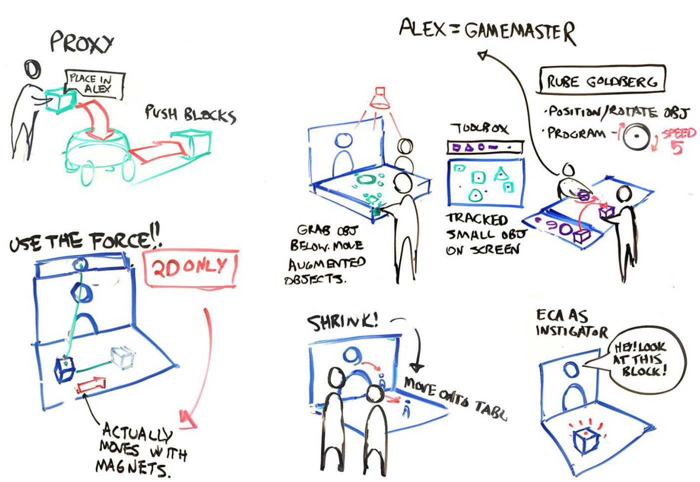


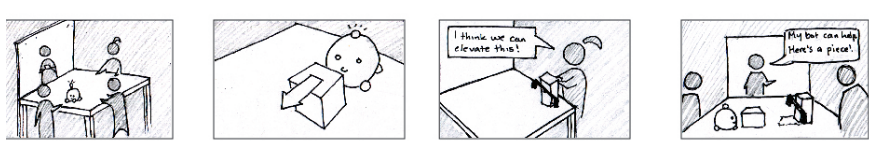
Ideation

We began brainstorming approaches that would allow a virtual agent to interact with children in play. We sketched our ideas and organized our content into three broad categories: actuation, visualization, and sensing.

Various phases of sketching and brainstorming that took place during the ideation phase. We eventually organized and then chose the ideas we found most promising to prototype.







ALEX has a pet Bot. Bot can push objects around. Tina suggests a new idea. ALEX helps through his proxy bot

Low-Fidelity Testing

Process Summary

For our low-fidelity testing, we prototyped and tested two conditions:

Using a Proxy (BeepBoop)
With this concept, the ECA interacts with the physical world through a proxy 'pet'. The pet is able to move about the table, pushing pieces in accord with the ECA's intent. In this sense, the proxy is able to help build as well as make suggestions as to courses of action in the physical space.

Digital Physics
This approach combines the physical and virtual world to create a mixed reality experience. Players are given a 'toolbox' of different objects. Players are instructed to help the ECA (visualized on a screen) achieve some goal by placing the objects on the table surface in front of them. As they place the objects, they can view how the ECA's world is affected in the virtual world by looking at the screen for feedback.

Major Findings

Overall, we found that BeepBoop brought interactions with an agent to the table and was overall really fun, likable, and capable of invoking curiosity. With that said, BeepBoop lacked a distinct function within the playspace. Because Alex had a lot of information within the digital physics game, Alex was able to interact meaningfully with the players but was more of a "teacher/parent" rather than a "companion".

Mid-Fidelity Testing

Process Summary

For our mid-fidelity testing, we prototyped and tested three conditions that varied forms of embodiment:

Virtual Agent on Screen
A laptop was placed at the end of the table surrounding the gamespace. Initially, one team member portraying the agent sat behind a wall, away from the game, and communicated with players through Google hangouts as displayed on the laptop.
A coordinating team member acted as the agent's influence on the game, and moved pieces on the gameboard.

Virtual Agent and Proxy
The setup for the virtual agent and proxy scenario was similar to the virtual agent on screen. However, for this scenario, instead of moving pieces by hand, the agent's actuator pushed an object meant to represent the proxy. We named the piece BeepBoop and gave it a face to suggest agency. The actuator communicated with the agent on screen by making 'beep boop' sounds.

Virtual Agent as Proxy
In this scenario, agent and proxy were played by the same team member. For setup, we placed a mobile phone on a wheeled platform that could be pushed around the gamespace, similar to BeepBoop. During each test, the team member portraying the agent would Facetime with the phone so that their face appeared in place of the proxy. The person playing the agent would also push the phone apparatus around the gamespace simultaneously to simulate actuation.

Major Findings

Perspective is Important
Perspective was shown to be critical in establishing the relationship between players and virtual agent. In almost all tasks, we observed the virtual agent as mostly dismissed by the players. When we interviewed players

about this after each trial, they responded that the agent seemed disconnected due to its lack of physical presence and mostly-vocal impact.

Players Move Fast
This was observed mainly from the perspective of teammates simulating actuation. In the conditions involving a proxy or the agent on the table, it was difficult to keep up with human players. Whereas humans could adeptly reach across a table and pick up one or multiple pieces at a time, a proxy takes considerably more time to navigate a table in order to nudge a block.

The Virtual Agent Needs To Be Involved
In interviews, some participants noted that the virtual agent really wasn't necessary in order to complete the scenario. One player described Marble Run as being potentially for individual gameplay, thus excluding the necessity of the virtual agent. Most players felt Marble Run was collaborative between the two human players, but the role of the virtual agent wasn't critical.

Testing the Virtual Agent + Proxy (BeepBoop) condition.

Adaptations from Mid-Fi

Our mid-fidelity tests saw the virtual agent embodied in three different forms. Noting that embodiment is a more flexible dimension for future development, we pivoted to more exclusively focus on actuation as well as visualization techniques where appropriate. We found that while the concepts behind our testing conditions were sound, their implementation as WoZ was difficult to replicate and thus made the virtual agent useless in some situations. To rectify this, we incorporated aspects of prior testing conditions, yet attempted to make their application as a WoZ more seamless and effective for the experimenters.

We built a custom, rectangular table out of wood for these testing conditions. The surface of the playspace was made with a white, frosted acrylic that would allow us to illuminate from below. We extended one end of the tabletop with a wooden surface to allow for Alex to place a laptop in one of our testing conditions. We painted each side of the table a different color to designate each player's position: one side red, yellow, and two blue to account for Alex's changing position. A black curtain was velcroed around the sides of the table to obscure and lighting fixtures or experimenters working under the table during the course of each test.

Embodiment across all conditions was largely the same: the WoZ acting as the virtual agent, or Alex, sat at one end of the game table. In front of the WoZ was placed a wooden frame and screen to simulate being in the digital world. In prior tests we visualized the WoZ on a screen via Skype. We decided to forgo this method, as it didn't appear to convincingly separate the WoZ from the other players, it also had limited the WoZ's view of the board.

We also attempted to make actuation appear more natural and less intrusive in the game. In two conditions, we utilized magnets attached to Alex's pieces and a magnet mouse under the table to move pieces. In one condition, the WoZ moved the pieces, in another an additional experimenter under the table moved pieces. In our third condition, nothing was actuated by the WoZ, and illumination from below the table was used to show the movement of the WoZ's arms while drawing.

Over the course of our final study design, we iterated and experimented with several conditions:

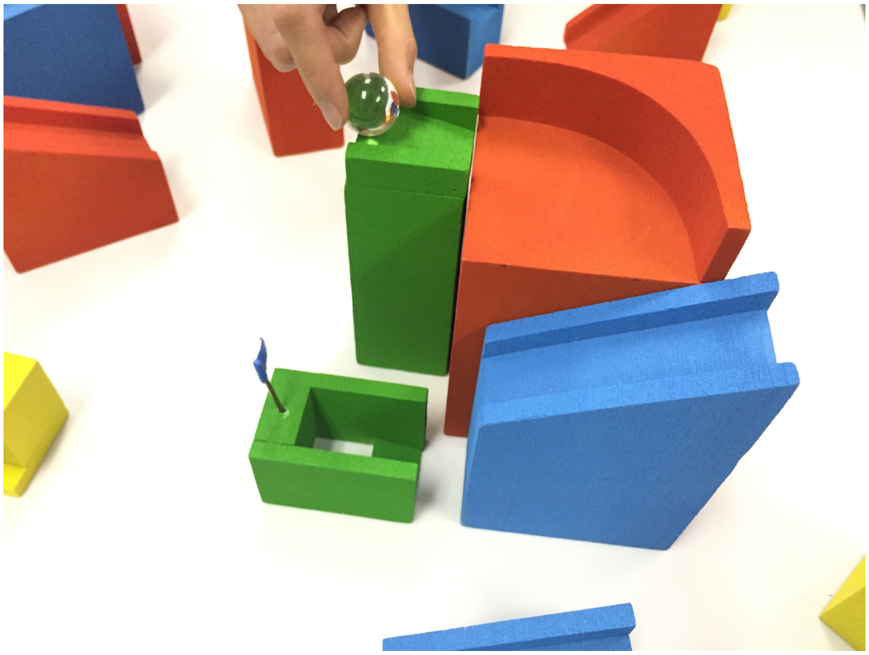
1. Drawing with a projector (eliminated due to difficulty or orienting projector)
2. Using a proxy/robot (eliminated because movement was too imprecise)
3. Illuminated Drawing
4. Illuminated Magnets
5. Magic Wand / Controller Movement

Marble Run Iterations

The game as we designed it was simple: using the pieces given, design a path that will guide a marble from a starting point to an end goal. Players were instructed to use the pieces to build a path to move the marble from its starting perch to one of three endpoints (each endpoint varied with the game level, and was indicated at level onset by a teammember).

The fundamental rules of Marble Run remained consistent from through mid and hi fidelity testing. However, in our last round of testing we found it was difficult for Alex to contribute to the game due to other players' speed and their tendencies to ignore Alex's advice. In light of this, we divided up all the available pieces into thirds and painted each group a different color (red, yellow, and blue). In our new version of the game, each player could only move their color pieces. This promoted collaboration and forced players to communicate with Alex in order to complete each puzzle. The only case in which this differed was in the shadow drawing condition where we required that players ask Alex where he wanted his pieces moved in advance.

Colored pieces in action, used to solve a sample puzzle in the Marble Run game.



Final Prototype

Testing Overview

The goal of this next phase of testing was to improve upon the actuation techniques utilized in our mid-fidelity, as well as create a more polished and applicable testing environment. We hoped to specifically test a virtual agent's reception as a player rather than a teacher, collaboration in gaming, and communication between children and virtual agents. The results derived from our research we hope will inform future work concerning realistic and feasible forms of actuation in practice.

The focus for this round of testing was actuation: How can we actuate a virtual agent's behavior in the gamespace to improve agent-child rapport? We tested across three experimental conditions:

Shadow Drawing
Shadow Movement
Controller Movement

Pilot

We performed a pilot study on four different college students, all at separate times. During this stage, we tested the following conditions:

• Control (virtual agent can only talk to offer suggestions)
• Using a proxy
• Controller Magnets
• Illuminated Drawing

Ultimately, we found that using a proxy was an ineffective and cognitively inconsistent condition. Participants were unsure of whether Alex was controlling the proxy, or whether the proxy acted independently.

To avoid further confusion, we decided to test an illuminated movement condition in which the WoZ would themselves use magnets to move their pieces under the table. We illuminated from below to show these movements to players.

Participants

We tested from a pool of children ages 7-13. Over the course of experimentation, we conducted 6 trials with a total of 10 unique children. The breakdown of participants per trial and per condition is as follows:

Shadow Drawing: 2 trials (*1 participant*, *2 participants*)

Shadow Movement: 2 trials (*2 participants*, *2 participants*)

Controller Movement: 2 trials (*2 participants*, *2 participants*)

Final Test Procedure

Pre-Experiment

The board was cleared except for game pieces. Pieces were organized according to color and the side of the table they belonged to. Alex began seated behind a frame. A black curtain was placed around the edges of the table except where the virtual agent sat for all conditions. This allowed us to hide technology under the table and, in the case of the controller movement, hide a person from the players.

For both the shadow drawing and the shadow movement conditions, a light was placed below the table. This effectively illuminated movement below the table on the top surface.

During the controller movement condition, a web cam was mounted on the top of the frame. The web cam then fed into a laptop placed in front of Alex. The experimenter moving the pieces under the table would take position, hidden from entering players.

During Experiment

Participant/s sat at opposing sides of the game table and given instructions on what the color of their side of the table meant. A general icebreaker was then performed with all participants and Alex.

The icebreaker consisted of a question set (e.g. name, favorite ice cream, favorite animal) and a quick game. The game varied by the condition being tested (e.g. Taking turns drawing an animal on the board or passing the marble around the board using a gamepiece).

The experimenter then explain the rules of Marble Run and the restrictions of Alex based on the condition being tested. Colored blocks pertaining to each player's side were then placed in front of them, and the starting and goal pieces were placed on the board. Players were instructed to begin playing.

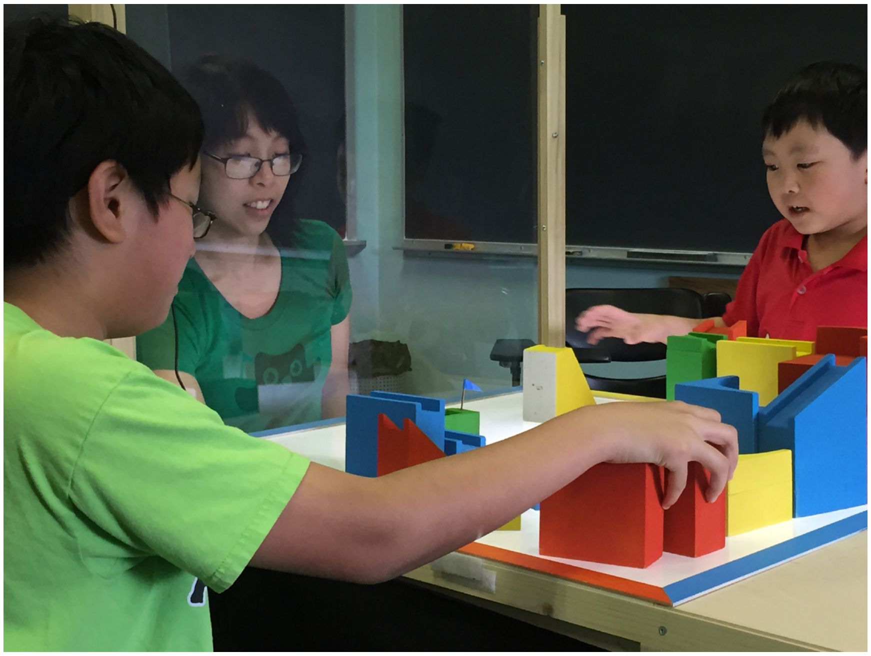
During actual gameplay, the Wizard of Oz playing Alex would have a reference sheet with different possible actions he/her could take according to the game condition. These actions were derived from a list of main strategies in raising and sustaining curiosity in learning contexts. This list of actions was preferred over a set script to keep the flow of the game more natural and dynamic.

(1) raise conceptual conflict/contradiction
(2) highlight conflict between student's approaches
(3) create paradox
(4) creating problem situation
(5) progressive fact disclosure
(6) encourage generation of hypothesis, exploration and reasoning

Post Experiment

Following the experiment, we administered a survey to each participant (see Appendix) and conducted a brief interview.

Testing the Shadow Movement condition with two participants.



Condition 1: Drawing

Overview and Setup

We focused on visual signaling and interpretation in this condition as opposed to physical motion. In this condition, we lit the game board from below and equipped the virtual agent with a marker. The virtual agent interacted with players by drawing below the table, which was illuminated and visible to players from above. Players worked in conjunction with the virtual to draw (on the top surface of the table) and solve each puzzle. Players maintained control over their color pieces, except for the virtual agent, who used drawing and motions below the table to signal where players should move its pieces.

To ensure that players utilized drawing instead of reverting to moving pieces, the experimenter instructed each player to first draw what they believed was a plausible path for the marble. Players were then free to continue the game as normal, with the virtual agent still represented through verbal communication and illuminated drawing.

Roles

Virtual Agent: Behind frame; can communicate verbally and by drawing.

Gamerunner/Interviewer

Condition 2: Shadow Movement

Overview and Setup

This condition coupled actuation and visualization. Prior to each test, the table was lit from below so as to illuminate the virtual agent's hand motions below the surface of the table. The virtual agent was equipped with a magnetic 'mouse' in this case. The virtual agent used the magnet mouse to move its pieces (the bottoms of which were outfitted with magnets) across the table. Players could observe the virtual agent's physical impact on the game, as well as the illumination of the hand reaching under the table.

Roles

Virtual Agent: Behind frame; can communicate verbally and by moving pieces by way of magnet under the table; can also use shadow of arm to point to objects.

Gamerunner/Interviewer

Condition 3: Controller Movement

Overview and Setup

Our third experimental condition appeared to players much the same as the shadow movement condition. In this condition, the WoZ playing Alex communicate via laptop and web cam with an experimenter hidden under the game table. The web cam, mounted above so as to give a view of the entire game board, was displayed on a program on Alex's computer. Alex could then use the program to draw arrows designating where blocks should be moved on the board. The person under the table, using a mobile phone to share Alex's screen, would see these indications and move the pieces by way of magnet mouse.

Unlike the shadow movement condition, the visualization for this actuation took place in the screen area, not on the table. Thus, the person playing Alex held a controller and would appear to point and command pieces that were moving across the board, simulating a 'magic wand' effect. This was done in conjunction with the experimenter under the table moving pieces.

Roles

Virtual Agent: behind frame with laptop; communicates with helper under table to move pieces.

Actuator: lies under the table; shares virtual agent's screen on phone; uses magnet mouse to move pieces

Gamerunner/Interviewer

Observations

Condition 1: Drawing

Drawing can be a physical impediment to Alex as a player

Players noticed Alex's lack of physical ability during the drawing condition. This was because Alex could not move blocks him/herself and had to ask other players to do so. One subject said "Alex wasn't part of the game because he couldn't move anything". Having Alex draw underneath the table also limited his capabilities, as blocks on the table could make it difficult to visually locate drawings.

Drawing is not instinctual to some players, but also enabled more quiet players

Using drawing to explain and share ideas was not the most natural form of communication for players. Some players felt forced to draw in certain scenarios and only would do so if Alex suggested. On the other hand, the more quiet and analytic players took to drawing without instruction.

Visualized paths are used as a reference line and help tool

Players would often refer to previously drawn paths or block routes when the current working solution had problems. The previous path was used as a reference line to point out flaws or to rework ideas. Players would also engage in more analytical conversations about momentum, speed, and the block path when pointing out the drawings.

Alex can communicate intention but not attention with shadow drawing

Players could easily understand what Alex's intentions were when describe routes and block suggestions through drawing. That being said, drawing alone did not attract attention well, Alex often would have to speak in order to bring the other players' attention toward the drawing.

Condition 2: Shadow Movement

Alex can keep up with other human players while having small physical limitation

Alex was able to physically engage and keep up with human players. Giving Alex the speed and block-moving capability of other players made him, “feel just like another human player”. One player even mentioned that they felt they were “a robot like Alex”, as they had similar physical capabilities. That being said Alex still had slightly less physical ability as he/she could not reach the far third of the table. Also Alex could not pick up blocks vertically, leaving the human players to help at times.

Players rely on pointing to communicate

In order to communicate which blocks and paths were being talked about, players would mostly use pointing as the gesture of reference. It was through the color of the block a player would communicate to another player instead of saying that player’s name directly.

Players are focused on the board and hands

When playing the game players would mostly be focused on the task and movement on the game table. They mainly gazed at the board, blocks, hands, and Alex’s shadow instead of player’s faces when communicating with each other.

Condition 3: Controller Movement

Players laugh over Alex’s struggle to move blocks

Players found comic relief and would joke over Alex’s struggle to move objects. This would happen when Alex had to slowly move blocks into tight spots, often being jerky and pushing other objects out of the way.

Players and Alex communicate ideas by moving blocks

When trying to explain ideas about certain game pieces and routes players would do so by physically moving and grabbing blocks. If a turn piece was the subject, then a player would grab their turn piece and rotate it in the different ways they were suggesting. Alex did the same by "grabbing" other blocks using his/her controller.

Players tell and command Alex to move blocks

Because of the longer time to move blocks, players would more often command Alex to move blocks when his/her was needed. This was to prompt Alex earlier so he had the time to move a block.

Survey & Interview Results

Survey

The survey investigated perceived agency, curiosity, collaboration and engagement. Players were asked to agree/disagree with statements on a Likert scale. To tailor the survey toward children smiley faces were shown on both ends of the scale.

Players were asked to judge the following:

• Alex can make decisions
• Alex has a personality
• Alex knows how I feel
• I played this game with other people
• I wanted to know more about what was happening in the game
• I was very focused on the game
• I played this game alone

Results

Feelings of collaboration were high across all conditions
Curiosity was higher in the drawing condition
Perceived agency was slightly lower in the table magnets condition

Interview

The interview was a seven to eight minute open discussion with the game participants. The topics and questions discussed centered around qualitative feedback about the Marble Run game task, collaboration within the game, Alex's mode of interaction and engaging with Alex during the game.

Example Questions:

How did you enjoy the game? What part of it?
How was playing the game with Alex?
Would you rather play this game alone or with other people?
Was there anything hard about the game?

What was it like interacting with Alex the way he/she was moving the blocks? (Depending on the condition we specifically ask about the way Alex was moving blocks. Example for shadow drawing - "What was it like interacting with Alex when he was drawing on the table?")

How word would you use to describe Alex in the game? How would you describe Alex's role in the game?

Results

"The fact that it was hard made it fun"

Participants enjoyed the challenging nature of the Marble Run game. Kids enjoyed making mistakes and were not afraid of making them in front of Alex.

"I liked this game because I like to be creative and happy"

Kids liked the creativity of trying out different solutions and thinking of new ideas as they were placing the game blocks together.

"Alex could give suggestions but... when a robot gives ideas they're probably all right"

Kids did not want Alex to give too many suggestions - they thought he may know the whole solution because he's a "robot" or "is virtual"

"Alex wasn't as a part of the game because he couldn't move anything"

In the drawing condition, users felt like Alex was not as much a part of the game because he could not move objects.

Takeaways

Players felt like Alex was just like another human player

In the results of our observations, surveys, and results players reported that they felt Alex was just another player like them. This is important in the totality of our project, as previous iterations led players to think Alex was more of a teacher. One reason for such conclusion could have been because Alex was played by a human behind a glass, but we are not sure of the difference between this state and the previous one tested where Alex was on a computer screen. Being viewed as another human player, Alex was able to have a more active role in the game, and could hopefully achieve the goals in line with ArticuLab's vision for Alex.

Players liked that Alex had a personality, and thus were able to connect to him/her

Players reported that they enjoyed Alex having a personality. This enabled participants to connect with Alex and create a relationship where they could be more open to collaborate and discuss.

Building early rapport among players and with Alex is important

We found that it was important to build rapport among players and Alex, and to do so early. This formed social bond helped create a better atmosphere and increase both collaboration and engagement in the Marble Run task itself. To do so Alex can mime the same awkward beginnings participants feel at the start of a task, start introductions with other players, or play an icebreaker game. Having an icebreaker game showing Alex's mode of interaction is helpful, as it allows players to adjust and learn the way Alex can communicate with them.

Kids always assume Alex, the "robot", is right

Participants felt that Alex was another just like them, but the fact that Alex was a virtual player still had certain biases. Kids always assumed Alex was right, as they believed computer programs would always suggest correct answers. Due to this players would choose to follow Alex's suggestions closely, or ignore them entirely as they wanted to find out their own solution.

Participants saw Alex as a helpful, supportive player

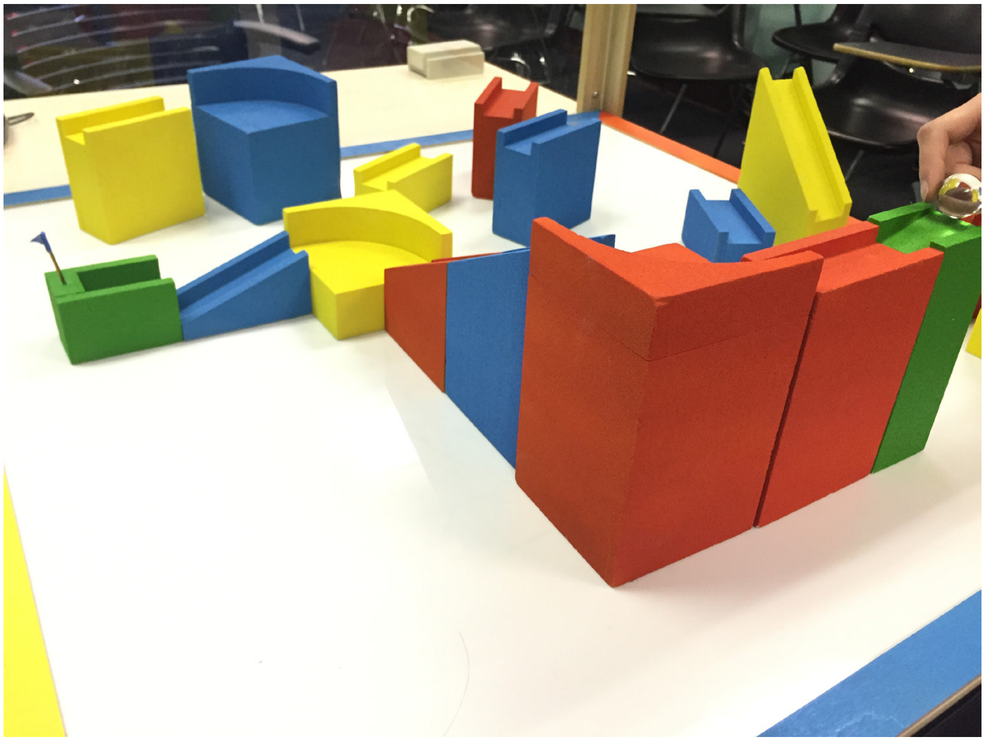
Children reported that they saw Alex as a player who helped them explore and be creative. They described Alex as "help only when needed", "a sound board", or "a help button". This may have been because of Alex's physical capabilities, thus causing him/her to be a less active player and us only jumping in when a challenge occurred. It would be interesting to see if changing Alex's personality would affect his role as a player.

Next Steps

A clear obstacle throughout our high-fidelity testing as well as our previous experiments was representing a virtual agent using WoZ. While our observations and feedback indicate that we made strides in this regard, being able to test and gather data conclusively seems to be most hindered by this aspect of experimentation. We recommend future tests integrate, at least visually, a virtual agent that is representative of the SCIPR vision. Interacting with a real virtual agent versus a human acting as one, we predict, will yield significant results as to children's engagement and willingness to collaborate.

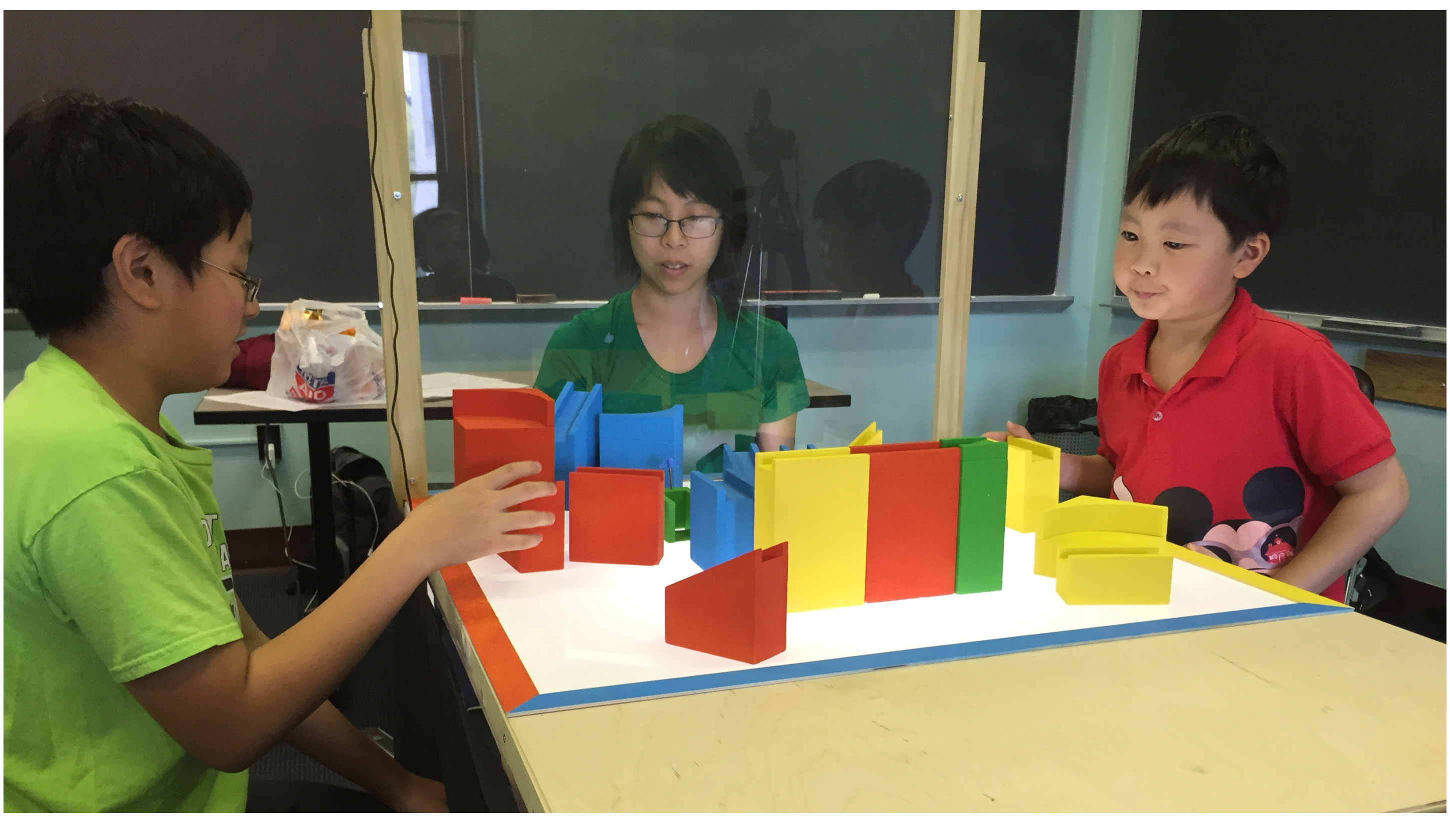
Appendix

Marble Run V. 2

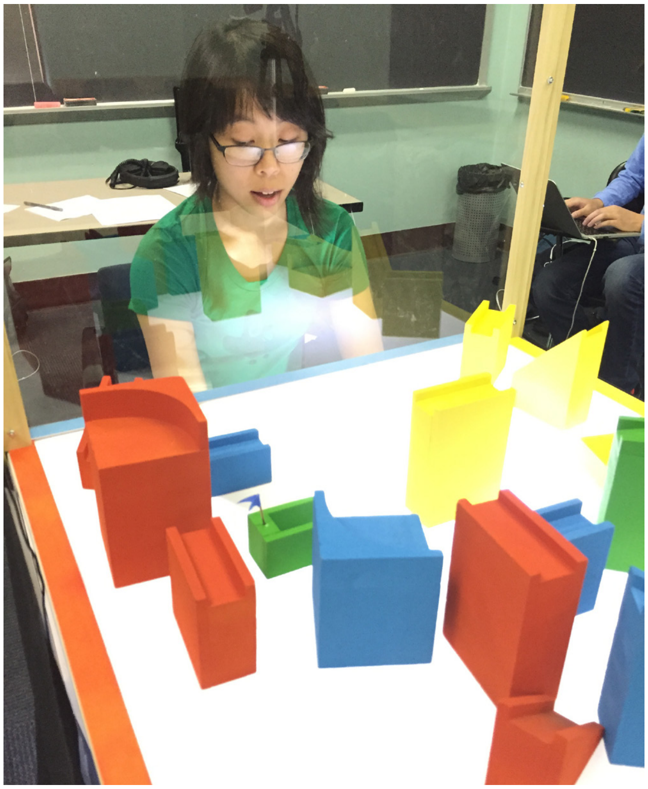


In the updated version of Marble Run, players were assigned blocks based on color.

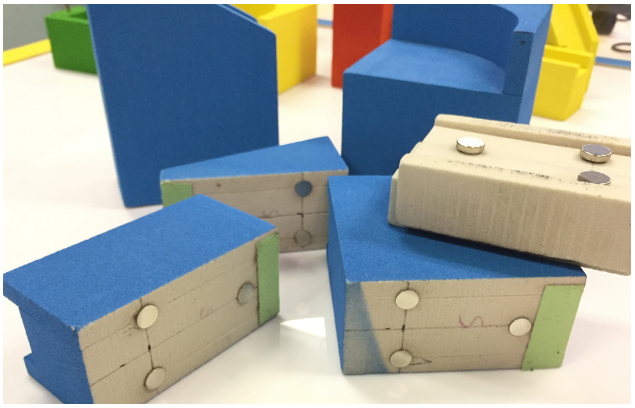
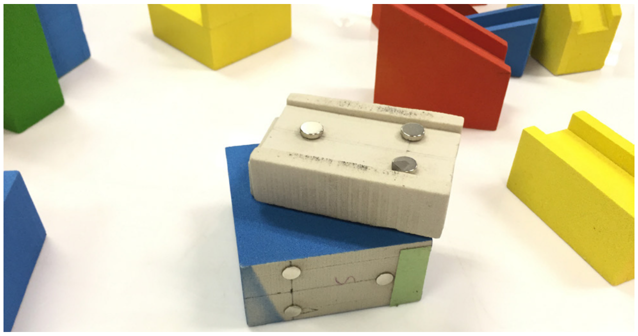
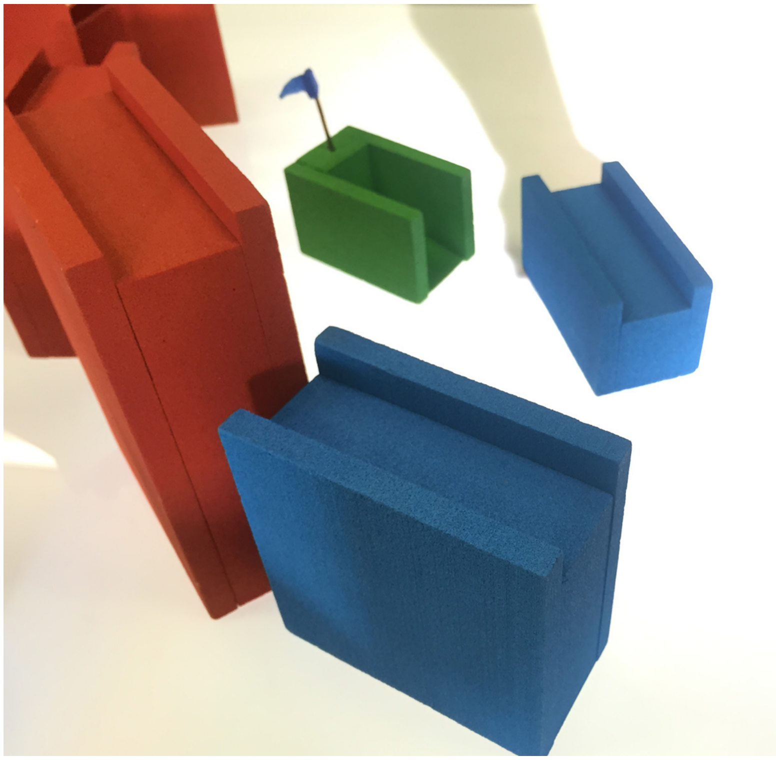
The virtual agent in these scenarios would sit behind a wooden frame and screen.



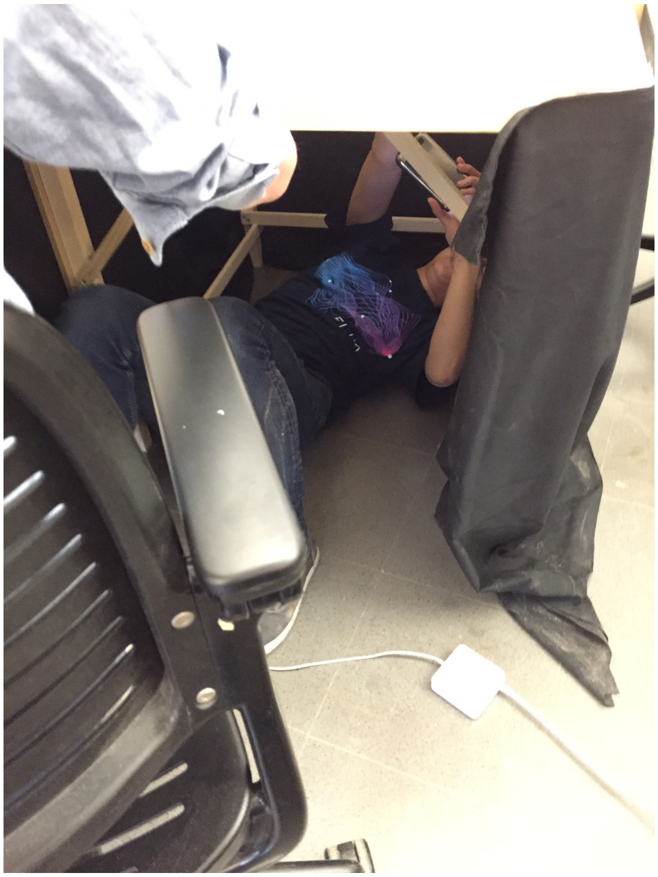
Condition 1: Shadow Drawing




Condition 2: Shadow Movement

Condition 3: Controller Movement



Testing Script

Thank you for participating in this research study. Before we begin, I'm going to give you a little background about what we're doing today.

Today, you will be playing an early version of a computer game my team and I are creating called Marble Run. The goal of the game is to use the colored blocks to create a path that will lead a marble from the starting ramp to the goal with the flag. To change the path of the marble, you can use different ramps and blocks. However, you can only move your color of blocks.

A major part of the game is that you will be working with a virtual player - kind of like a digital friend - like SIRI. In the final version of the game, the virtual player will be displayed on a screen. However, because we haven't gotten that far in development yet, one of our team members will be acting as the virtual player, who you can call Alex.

Alex knows the rules of the game and can talk to you...

DRAWING:

...but cannot pick-up or move his pieces. Instead, Alex will draw on the table to express what he wants to do.

At the start of each round, you must work together to first draw the path before placing any pieces. You each have your own marker and are free to markup the surface of the table.

HAND:

...Alex can also control his own blocks.

MAGIC WAND:

...Alex can also control his own blocks with a controller.

We're still working out a lot of the kinks with this technology, so don't be flustered or surprised if Alex makes some mistakes along the way.

We encourage to talk, draw, and test your solution as many times as you need to. There is no time limit and no award for completing the path faster, so please work together and explore different options.

You'll be playing through a few different levels together. Afterwards, we'll have a quick survey and then ask you a few questions about what you thought. Most importantly, try your best and have fun!

Do you have any questions before we start the first round?

Link to Video Compilation

A compilation of testing footage and interview feedback can be viewed on Google Drive

https://drive.google.com/folderview?id=0Bx5PifVr3kn5WHpSd0FIZFZXUXc&usp=sharing

Link to Raw Observation Data

Google Sheets doc with raw observations from final testing trials:

https://docs.google.com/spreadsheets/d/1B84ghxuKnqXIJgjzHioDmct3Q47mRFuZbbyANJAVWLE/edit?usp=sharing

Virtual Agent Activity Matrix

Strategy	**Control**	**Drawing**	**Hand**	**Magic Wand**
Raise conceptual conflict/contradicti on	Suggest an alternative path	Draw a different path from what appears to be the route of the current solution	Show and suggest a block different from what a player suggests	When a player suggests a block, move a block to suggest something different
Highlight conflict between student's approaches	Ask players what they think of other's approach	Circle/highlight a placed block Draw the possible paths if two solutions are suggested	Ask players what they think of other's approach	Ask players what they think of other's approach
Create paradox	Make an incorrect suggestion	Draw an incorrect path	Place an incorrect block	Move an incorrect block into place
Creating problem situation	Suggest a block that would make the path more difficult	Draw a suggestion to move a block for a harder solution	Place a block to change the route	Place a block to change the route
Progressive Fact Disclosure	If stuck, give a suggestion about where the next block should be Ask players to test the current working solution.		Ask players to test the current solution	
Encourage generation of hypothesis, exploration and reasoning	Ask players what they think the path of the ball will be.	Ask players to draw what they think the path of the ball will be	Show a block and ask players how they think the path of the ball will change.	Show a block and ask players how they think the path of the ball will change.