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# Ballbit Adventure: A Physical Game for Collaborative Racing

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**Abstract**

Playtime accounts for one of the most critical learning periods for children [9], as they learn how to interact and socialize with their playmates. In this paper, we present a new kind of cooperation-based physical game called Ballbit Adventure. Our game provides a collaborative environment for children to communicate, cooperate, and empathize through solving challenges in an interactive maze. Each player must drive a robotic ball and work together to complete different tasks that would ultimately lead them to the finish line. Through the format of a physical racing game, Ballbit Adventure hopes to show the value of face-to-face play experience to counterbalance the disconnected online interactions that children have with video games.

**Author Keywords**

Cooperation based game; Social Gaming; Tangible Interaction; Hybrid game; Strategic Gameplay.

**CCS Concepts**

•**Human-centered computing** → **Interaction design**; *Human computer interaction (HCI)*; •**Social and professional topics** → **K-12 education**; **Children**; •**Computing methodologies** → **Artificial intelligence**; •**Hardware** → **Integrated circuits**;

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Figure 1: "Overcooked!" gameplay.



Figure 2: Hot Wheels Tower Shark Loop Racetrack Toy Play Set Ultimate Garage Kids Child.



Figure 3: Two Ballbits (Sphero) shown in white. The modules in red and blue are the casings.

## Introduction

### *The current climate of playtime*

With the arrival of the digital age, modern video games have taken over a significant role in children's playtime [8], which is a crucial period for them not only to have fun but also to develop essential social skills. Video games are a fun and engaging way to cultivate children's social skills, as suggested by prior researches [12]; however, these studies do not emphasize the shortcomings of digital interfaces for interactive play. For instance, children must learn to communicate, cooperate, and interact with others in virtual worlds that are defined by circumstances detached from the reality. The result is a social experience that is less sincere and realistic compared to a real life social interaction [5]. Are there any alternatives that allow children to develop social skills interactively and holistically? This question prompted us to develop Ballbit Adventure, a physical game centered around cooperation and communication. Our game is designed to provide a natural, comfortable, and engaging environment so that the players can bond.

## Related Works

Ballbit Adventure was inspired by cooperation-based video games and racing toys. We intended to take the best of both categories and combine them to create an ideal environment for collaboration. (see Figure 4).

### *Cooperation-based Video Games*

Cooperation-based video games in recent years have become more popular with the debut of video game platforms like Nintendo Switch. Games like "Overcooked!" [4], "Snipperclips: Cut It Out, Together!" [11], "Lovers in Dangerous Space Times" [1] have been successful because they have featured their game design around the cooperative local multiplayer system that Nintendo Switch provides. The game "Overcooked!" (see Figure 1) exemplifies a suc-

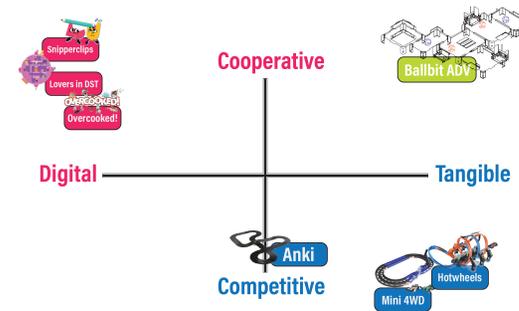
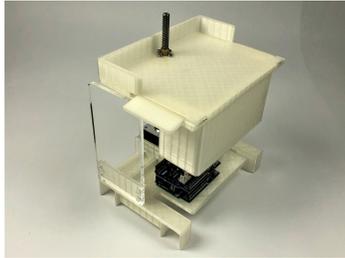


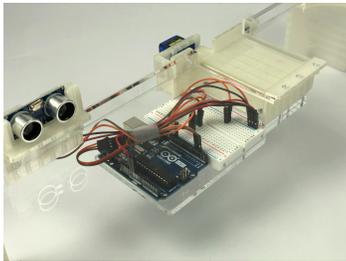
Figure 4: Ballbit Adventure combines a cooperative game play with a physical one.

cessful cooperation game. It is a co-op cooking game for 1-4 players, in which players must work together in a variety of kitchen settings to prepare, cook and deliver dishes to a hoard of hungry customers within a limited period of time. The game's simple mechanics and focus on creating a cooperative environment have established it as a popular game for small gathering occasions. However, despite these features of Overcooked!, co-op video games limit the opportunities for collaboration because several of the real world physical and social contexts have been replaced with fictional ones that are shared only virtually by players via a screen. A significant part of the socializing experience is lost due to the lack of a shared physical context that makes up a holistic social experience.

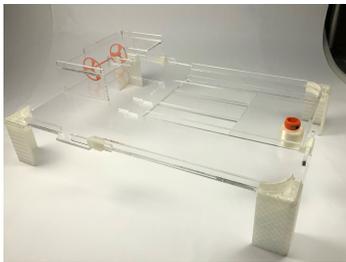
Games like "Overcooked!" took a significant step in creating a genuine cooperative experience, but they do not provide an ideal atmosphere for players to cooperate and communicate. Ballbit Adventure hopes to incorporate all the great aspects of cooperation-based video games and further the experience through the format of a physical racing game,



**Figure 5:** Ballbitvator with the flaps out.



**Figure 6:** Flipper mechanism: triggered through an ultrasonic sensor.



**Figure 7:** Parallel Maneuver Module and Access Key in orange.

in which players are able to see, hear, feel, move around, point, touch, and experience the physicality of their inputs.

### *Track-Based Racing Games*

A popular genre of toys in the post-computer era was the racing toys. A significant part of what made them fun was the fact that children could play with them together through direct manipulation. Tangible toys like Hotwheels [13], Mini 4WD [6], and Anki Overdrive [3] were big hits because of the exciting play experience they offered. Hotwheels sold racing track-sets that came in different modular pieces, allowing the players to arrange them in any way they desired. Additionally, these tracks have many ingenious mechanisms to interact with the cars. For example, some devices propel the cars into the main racing tracks while others eject cars into the mouth of a shark (see Figure 2), suggesting that the player loses the race. These mechanisms and racing tracks add another layer of narrative and playability to the overall experience, and give the players a sense of uniqueness and freedom. Ballbit Adventure aims to incorporate the custom-tailored experience of racing games, but with an emphasis on building a collaborative gameplay.

### **What is Ballbit Adventure?**

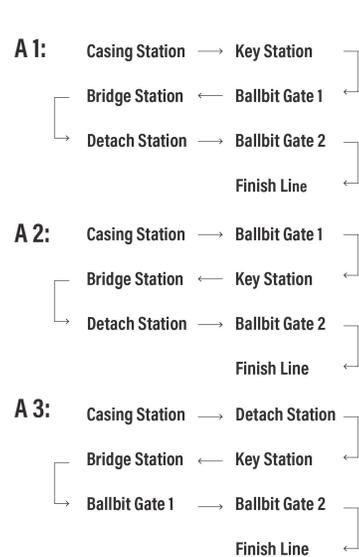
Ballbit Adventure is an interactive game that requires a minimum of two players. Each player controls a robotic ball known as the "Ballbit." For prototyping purposes, we used an existing toy called Sphero (see Figure 3) [10]. The Ballbits will interact with a series of stages that have a collection of different modules and contraptions. One of the main modules the Ballbits can interact with is called a casing (see Figure 3). The Ballbits can wear a casing to magnetically attach to other modules that will help them progress through different obstacles throughout the stages. For example, one of the stages has an automatic door that can only be opened for a short duration with an access key. The

access key can be magnetically attached to the magnetic strips on a casing. After both Ballbits have a casing, they must each retrieve an access key and open the door for each other accordingly. The scenario above is just one example of possible interactions the players can have with the different varieties of stages and modules. Since every stage is an individual module on its own, the players may reconfigure the layout of the adventure and create their own experience and objectives.

We made sure Ballbit Adventure is not only simple to play but also exciting and appealing to a wide range of audiences. We achieved this through extensive user testing and research with children and adolescents ranging from 8 to 16 years old, ensuring that their experiences with the game were challenging but not frustrating, exciting but not overwhelming. In the end, we were able to create well-coordinated co-op experiences even among children of different age groups. Ballbit Adventure went through many stages of prototyping ranging from mock-ups made with foam core to working prototypes made with wood, all to test and modify the play experience according to the feedback we received.

### **Emergent Gameplay and Collaboration**

Emergent gameplay is a phenomenon when open and straightforward game mechanics produce complex and interesting experiences [2]. This gameplay is a core aspect of Ballbit Adventure because it creates opportunities for creative solutions, in-depth communications and interesting interactions among the players. Our project has an open system that welcomes different possible interactions in every part of the game. For instance, during the setup, players can arrange the layout of the stages and set objectives and achievements they wish to accomplish. In addition, the in-game experience was designed to be simple, yet



full of different possibilities. The modules in the game can be used creatively for different purposes. For instance, the casing mechanism can be used to attach the access keys from both the upright and upside-down orientation. With several other design considerations similar to this one we leave room for players to reach an objective without having to follow a specific path. This openness aims to generate discussions and creative approaches to overcoming the obstacles in the game. Last but not the least, the most distinguishable feature of Ballbit Adventure is its focus on collaborative teamwork rather than independent skills. The objectives and obstacles are designed to be overcome with quality teamwork, instead of individual performance. The tailored experience, flexibility, and focus on a collaborative experience of Ballbit Adventure provide an opportunity for the players to engage in real-time free-form interaction, which is an effective way to promote frequent and quality communication, as suggested by prior research [7].

**Figure 8:** Three possible arrangement of the levels.

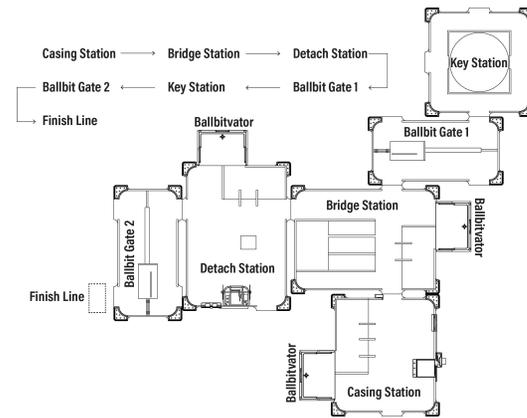


**Figure 9:** Setting up Ballbit Adventure.

## Design and Gameplay

### Pre-setup

The objective of Ballbit Adventure is to control a robotic ball and pass through all the levels of the game. Because Ballbit Adventure is co-op centered, a minimum of two players is required. The first component of the game that the players can interact with are the levels, which consists of different mechanisms and modules that serve different purposes in the game. The players can arrange the levels as they like and create their objectives (see Figure 8 and 9). The figure on the top (see Figure 10) shows one possible arrangement. After the players set up the levels, they connect their phones to the Ballbits to control their movements. The Ballbits are highly versatile units that can wear different modules to perform many tasks. With the Ballbits connected and the levels arranged, the pre-setup of Ballbit Adventure



**Figure 10:** Each individual level of Ballbit Adventure can be arranged in different orientations. Image above is one possible layout.

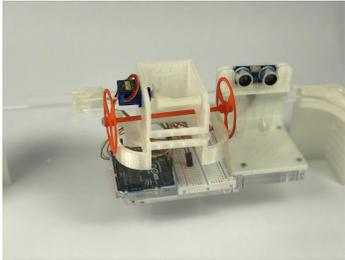
is complete. We will present a brief overview of the functions of each level.

### Ballbitvator

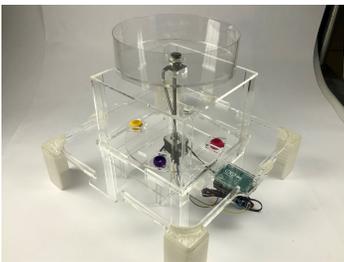
Because the majority of main levels have two floors, a Ballbitvator (see Figure 5) is needed for the Ballbits to travel between the floors. Ballbitvator consists of a platform that carries the Ballbits up and down, powered by a stepper motor and an Arduino. Ballbitvator also has two side flaps that can fold out when the platform reaches a certain height. This feature enables Ballbitvator to be placed in different orientations, allowing different arrangements of levels. A Ballbitvator accompanies every level with two floors.

### Casing Station

The Casing Station is the first level of Ballbit Adventure. It consists of two floors, a Ballbitvator, and a mechanism



**Figure 11:** Parallel Maneuver Module resting inside the Module Detachment Mechanism.



**Figure 12:** Key Station with four different colored keys.



**Figure 13:** Playtest for wooden prototype with fellow classmates from Industrial Design Department of Rhode Island School of Design.

called The Flipper (see Figure 6). The primary purpose of this level is to equip the Ballbits with casings. A Casing is a specially designed plastic housing that can be looped around a Ballbit to enable it to attach to other modules. The casing has a metal strip around the top half of its body. The Ballbits can use the metal strip on the casing to attach other modules in later levels. In the Casing Station, players must find a way to loop a casing around their Ballbits; one possible way to do this is to have the Ballbits travel to the second floor through a Ballbitvator and drop into the casing. Another way to put on a casing involves the Flipper mechanism. The Flipper is a distance-triggered mechanism that flips an object when activated. First, players have to push a casing onto the Flipper. Then a Ballbit should trigger the sensor to flip the casing onto the other Ballbit. The Flipper is also beneficial for flipping the casing into the right orientation for attachments. The methods mentioned above are just a few examples of the possible ways to put on a casing. The players may develop more accessible and faster ways to do so.

#### *Bridge Station*

The Bridge Station consists of two floors, a module called Parallel Maneuver Gear, a module called Access Key, and a narrow bridge (see Figure 7). The goal of this level is to retrieve the Access Key that players will need in later levels. The Access Key is located on an island disconnected to the main level, and the only path to the Access Key is through a narrow bridge. Because it is impossible to drive a Ballbit across the narrow bridge alone, the Ballbits must attach their casings magnetically to the Parallel Maneuver Gear in order to cross the bridge in a joint effort. As one Ballbit crosses the bridge, the other Ballbit must guide its movement with the Parallel Maneuver Gear. Once the Ballbit crosses the bridge, it can magnetically attach the Access Key to its casing and make its way back.

#### *Detach Station*

The Detach Station consists of two floors, an Access Key, and a mechanism called the Module Detachment Mechanism. The primary purpose of this level is to detach the Parallel Maneuver Gear from the Ballbits (see Figure 11). To do this, the Ballbits can slide into the Module Release Mechanism, which is activated by an ultrasonic sensor as the Ballbits park near. When the gear is detached, the Ballbits need to move away together to avoid getting caught by the Parallel Maneuver Gear again.

#### *Ballbit Gate*

The Ballbit Gate is a one-floor station that requires the use of the Access Key. The gate can only be temporarily opened when a Ballbit scans its access key near the RFID switch. Since the door only opens for a short duration, the Ballbits need to work accordingly with each other: one Ballbit must activate the door while the other waits to pass through. The Ballbit that passes through can then activate the door for the second Ballbit on the other side of the bridge. There is usually more than one Ballbit Gate for the player to pass through, some require different Access Keys that can be obtained at different levels.

#### *Access Key Station*

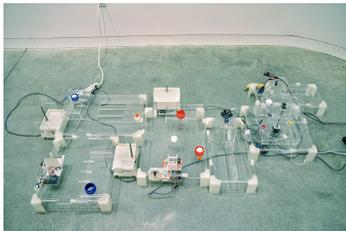
The Access Key Station is a unique one-floor level with a pre-programmed Ballbit involved (see Figure 12). The goal of this level is to acquire the correct Access Key from a rotating wheel controlled by a pre-programmed Ballbit. The pre-programmed Ballbit is located in a transparent bin on the very top of the level. It spins around randomly inside the bin, and its spinning motion controls the direction of the rotating wheel, where all the Access Keys are. There are a total of four Access Keys, with only two of them working. The players must each collect a working Access Key as these keys can open specific Ballbit Gates.



**Figure 14:** Foam core prototype with Arduinos and mechanisms.



**Figure 15:** Testing with children at Lexington Montessori School.



**Figure 16:** Final acrylic prototype.

## Iterations and Findings

### *Wood Prototype and User Testing*

The initial development stage of Ballbit Adventure includes rapid prototyping of different casings and mechanisms and their corresponding interactions. This process includes mock-ups made with foam core and 3D printed parts. After we established the underlying logic and flow of the game, we quickly constructed a working plywood prototype (see Figure 13). To test the playability of the first wooden prototype, we invited our classmates at Rhode Island School of Design to do the first round of user test. The feedback we received was consistent: the game was too challenging and was not designed well enough for a smooth play experience. For instance, the ramps for the Ballbits to go between floors were too hard to climb onto, because the momentum and torque of the Ballbits were not strong enough. We took this feedback and addressed it in the next iteration.

### *Arduino-assisted Prototype and User Testing*

The main issue with the previous wooden prototype of Ballbit Adventure was its challenging gameplay. The difficulty boils down to three aspects: firstly, there were not enough flexible alternatives that could create different ways of achieving goals in the game. Secondly, there were not enough interactions that could counteract some of the dead-ends of the game. Lastly, the structure of each level does not support cooperative interaction very well. To overcome these difficulties, we incorporated many Arduino-powered mechanisms to smoothen out the gameplay. We built a foam core version of the game (see Figure 14) and brought it to a local elementary school, where we tested our prototype with children aging from 8 to 14 years old (see Figure 15). We were delighted to see that the added sensors and actuators contributed to a better cooperative experience. Children were teaching each other the functions of different mechanisms and assisting each other through

words and actions in every part of the game. Besides, we noticed that players would walk around and follow wherever the Ballbits were going during play. Sometimes they had to bend over to locate the perspective of their Ballbits, while other times they would tell each other to move around in order to see the operation at a different angle. This phenomenon made the players more engaged in the adventure, and thus they became more active in communication and cooperation. Inspired by this observation, we decided to use an acrylic sheet to maximize the clarity and transparency of the levels.

### *Final acrylic prototype*

We built the final prototype with laser-cut acrylic sheets, 3D printed Parts, Arduino, servos, and sensors (see Figure 16). Like our previous prototypes, we invited our classmates, children in targeted age groups, parents, teaching faculties at Rhode Island School of Design and visiting critics to test and give feedback on the experience of the game.

## Conclusion

With the introduction of technology into the fabric of daily experiences, the quality of social interactions is often compromised for convenience [5]. Ballbit Adventure takes advantage of technologies but does not compromise or dampen the cooperative social experience. In the format of a collaborative physical racing game, our project aims to create an environment that cultivates children's ability to communicate, cooperate, and empathize with each other. However, there are many aspects of Ballbit Adventure that need to be improved. The next iteration of Ballbit Adventure will include an expansion of new components that will add more unique interactions and customizability. Ultimately, we wish to cultivate a community where everyone can share the layout of their racing adventures by fostering collaborations beyond the gameplay.

### Acknowledgements

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