# Social Play and Bimanual Activities through Interactive Experiences for Children with Cerebral Palsy

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Abstract: The World Health Organization (WHO) defines activity as "the execution of a task or action by an individual" and identifies activity limitation as "difficulties an individual may have in executing activities". Children with unilateral spastic Cerebral Palsy (CP)–a permanent disorder that affects one side of the body, and frequently involves the hand more than the leg– have activity limitations, hindering social and motor skills. In such cases, children often have limited bimanual upper extremity use (i.e. activities that involve both hands simultaneously). Increasing bimanual activity levels for children with CP can prevent subsequent functional limitations resulting from muscle weakness. Previous studies exhibit the potential for Active Video Games (AVG) to serve as an alternative to physical therapy for people with CP. This paper explores a digital interactive system as a means for promoting social play and the mastery of bimanual activities in children between six and eight years old with CP. Achievements of both of these goals will improve their performance in daily activities and have roles that are more active in social settings. Prototypes shown feature the design of multiplayer interactive experiences in combination with Tangible User Interfaces (TUI) – a type of interface that combines physical objects and digital interfaces– adding the therapeutic benefit gained from manipulating physical objects.

***Key words: Interaction Design, Gamification, Tangible User Interfaces, Cerebral Palsy, Social Play, Social Skills, Bimanual Activities, Fine Motor Skills, Early Childhood***

## 1. Introduction

Bimanual activities are those tasks where an individual uses both hands in coordination. Opening a jar or a food container, chopping vegetables, pulling a cap from a pen are some examples of everyday activities that require a degree of bimanual manipulation. Often, one hand stabilizes an object and the other hand is in charge of manipulating it; in other words, the bimanual interaction is asymmetric. Other types of bimanual activities, where both hands work simultaneously, are called symmetric interaction [7], like typing or lifting a box. All these activities require not only manipulation with both hands but also regulation on how much force one applies to perform the task [22]. The amount of force and accuracy needed to pull a cap from a pen is different from the effort and force needed to open a big package.

Children with unilateral spastic CP–the most common physical impairment in children [23]– have limited bimanual upper extremity use due to a variety of factors. Among those factors is developmental disregard, which is the habit of underusing an affected extremity regardless of its functional abilities [10]. This habit contributes to a downward spiral in which children do not have adequate levels of bimanual activity because they do not feel confident in their mobility; therefore, the children's bimanual coordination level cannot improve due to the lack of bimanual activity.

Mobility is linked to social development. Six to eight-year-olds typically participate in group activities, including playing in teams; such participation in organized activities is often extremely important to their social development [15]. Children with CP may perceive themselves as different from other children and isolate themselves from social situations so they will not feel hurt or excluded [15]. Just as not using an extremity due to disability leads to a downward spiral of bimanual activity levels, similar problems occur socially for children not participating in social activities because of perceived difference. However, a different point of view provides us with another explanation, the issue is more than activity limitations– it is a matter of not having alternative approaches for becoming physically active. The design of systems that facilitate children to play cooperatively can invite them to become more active while also developing social skills. Through design, it is possible to create fun, challenging, and competitive tools that offer social status and encouragement to increase capability and a sense of mastery in children with CP. These tools will serve as motivators while providing enjoyment as children practice bimanual activities. Enjoyment and engagement incorporate activity into children's lifestyles in a fun and playful way, rather than in the discriminating or intimidating environment of clinical physical therapy.

## 2. Related Work

As enthusiastic adopters of new technological tools and environments, children spend a great amount of time in screen-related activities such as internet, television, and videogames [10]. The pervasive nature of such screen-related activities make computer-based games an accessible and engaging tool for physical therapy. Lately researchers have studied the use of Active Video Games (AVG) as an alternative way for people with CP to practice physical therapy [10] through commercial game consoles like Nintendo Wii and Xbox Kinect [16]. Computer-based games possess unique affordances that make them attractive to children. However, the majority of current video games are not inclusive enough, having accessibility barriers where players cannot customize the controls of a game or the navigation menu is hard to use [18]. These barriers prevent people with physical disabilities like CP from engaging in independent play.

When children are around six years old, they make new friends mostly through playful behaviors while interacting with two or more persons, these behaviors are also called social play [1]. Social play functions in two layers depending on the type of social relationship derived from it. The first layer is in the territory where the participants play with the system. Katie Salen and Eric Zimmerman [19] define this area as *the magic circle*, and it includes all the interactions related to the act of playing a game, having a role, and following the rules. The second layer contains those social experiences that belong outside the magic circle yet affect it somehow, like previous friendship or the predisposition of being a leader. Hence, a play environment that can foster a "can do" attitude for exploration, growth, curiosity, and creativity is crucial for social development.

In recent years, there has been a rising practice focused on taking advantage of the engaging nature of games and applying it to non-game related activities. Also known as gamification, this framework consists in the design and use of game-based mechanics and game thinking [12]. Gamification has proven to be successful at encouraging interactive play through Tangible User Interfaces (TUI) – a type of interface that combines physical objects and digital interfaces – in children with multiple disabilities [8]. Commercial game consoles, such as the Wii, have been modified by researchers to help children with CP to improve their motor function outside physical therapy sessions [20], thus developing their mobility in a more enjoyable manner.

Even though AVGs have proven effective as an alternative to physical therapy in the case of bimanual activities and their transference to the performance of daily tasks, they lack the essential therapeutic benefit gained from manipulating physical objects. A combination between tangible objects and digital interfaces can expand the desirable properties of the two types of interactions. The advantage of using physical objects is that children have the opportunity to manipulate real objects and apply different types of force depending on the task they want to accomplish. Designing objects that interact with digital interfaces provides a way to augment their standard capabilities through a virtual environment. Interactive environments combining TUIs and digital, or Graphic User Interfaces (GUIs), have been developed for 3D model generation using blocks to operate the elements of a GUI [17]. Even though cases including TUI, GUI, and bimanual activities are not that common, case studies such as "VLEGO" [13] and "Cubical User Interface (CUI)" [14] show how the use of blocks and two-hand manipulation is used for 3D modeling. The two case studies take advantage of the physicality of the blocks and the elasticity of digital environments, where structures and modeling materials are "unlimited". Taking the case studies mentioned above as a reference, the design of a system that combines a GUI and TUI could incorporate exercises that promote bimanual activity of upper extremities while promoting fun through gamified activities.

## 3. Methods

### 3.1 Observational Study

The purpose of the observations (n=13) was to witness the ways in which children from six to eight years old interact with each other, parents, staff members, and with physical objects in a setting where they are encouraged to learn through play. Since all the activities in the selected location (Marbles Kids Museum in Raleigh, US) focus on physical artifacts, there was a specific interest in observing the affordances of such materials that could be extended or enhanced through interaction with digital technologies. Marbles Kids Museum has seven exhibitions for different age ranges; the study focused on three of them based on the age range of the investigation–six to eight years of age. The first one, ideaWORKS, was a place for children to construct products and structures while learning how physics affect their creation. The second one was artLOFT, a setting meant to encourage free expression through art. Finally, the Power2Play exhibit served as an initiative to incorporate play and physical activity to promote healthy environments. The participants included children between six and eight years old, parents, and staff members for the museum. Observation for each activity lasted for 90 min, concentrating on a single child or group of children for intervals of 20 minutes.

Using a customized data collection sheet based on the AEIOU [2] organizational framework–Activities, Environments, Interactions, Objects and Users (Stakeholders)–the study not only takes into consideration the interactions but also the context in which they unfolded. The interactions were coded intro two main categories, divided by types of communications (verbal vs. non-verbal) and types of interactions (exchange, competition, conflict, collaboration, and accommodation).

### 3.2 Semi-structured Interviews

The aim of the interviews was to gather qualitative data regarding the lives of children with CP before and after they turn six years old in social and educational contexts. One of the purposes was to identify how schools integrate play in physical rehabilitation and social environments through tools, technologies, and activities available for the children. Semi-structured interviews (n=3) to teachers and a program manager from two non-profit organizations focused on children with CP were conducted individually. The organizations that participated in the study are "Asociación pro personas con PArálisis Cerebral" APAC (Association Pro People with Cerebral Palsy) in Hermosillo, Mexico, and Charlie Gaddy Children's Center, a member of Easter Seals United Cerebral Palsy (UCP), in Raleigh, US. Each interview had an approximate duration of 40 to 60 minutes; a list of questions guided the interviewer through the process giving flexibility to focus on specific areas and allowing fluid communication. The participants gave permission to audio record the interviews, and the interviewer transcribed them for future data analysis.

## 4. Data Analysis

The aim of the data analysis was to figure out the activities and functions that a new system should incorporate in order to satisfy the different stakeholders needs and desires, however, it was important to not only interpret what the participants wanted, but also understand why they wanted it. Combining context-based design techniques from the book Rapid Contextual Design[9] with an activity theory framework created a platform for examining activities in a socio cultural context that could reveal existing patterns of interaction. This approach helped in the generation of a series of principles that could guide the introduction of new activities in the current space where the participants currently interact with each other. Consequently, it aided in the identification of leverage points that could be expanded by the design of artifacts using the capabilities of digital technologies, as well as a place and time where these activities could fit in the lives of the participants. The principles, patterns, and leverage points guided the process for designing prototypes of artifacts that mediate activities of participants' new practices.

### 4.1 Affinity Diagramming

To begin the analysis of the observations and interviews, the data went through rounds of interpretation capturing key moments into notes. The process consisted of recounting the interview and observations guided by transcriptions and notes without summarizing or leaving anything behind. The approach used for capturing and classifying the different moments was to think in terms of observations, gaps, questions, issues, insights, and design ideas during descriptions of specific events, use of artifacts, important characteristics, and cultural differences.

The captured key moments from the observations and interview experiences were assembled into an affinity diagram. Looking beyond key words and focusing on how the moment revealed relevant issues for the new practice, clusters of notes emerged in an organic way based on the type of reasoning the notes were addressing. Activating the participants' voice through first-person statements provided a reference point to label and summarize the created clusters. The following statements encapsulate the collected data:

1. Real tools and autonomous activities make me feel more independent.
2. I like to play with physical tools.
3. Tangible objects stimulate my senses and exercise my motor skills through instant feedback.
4. I feel engaged when both my senses and cognition are stimulated.
5. Friends and toys help me exercise my motor skills.
6. I like using various types of communication to socialize.
7. I perform better when the result of the activity is broadcasted and I can keep track of my progress.

8. Assessment, communication, and my parents are key aspects of my development.
9. Typical activities make me feel part of the group.
10. I like to participate in typical activities; my teachers think creatively to adapt them and generate an inclusive environment.
11. Digital tools facilitate my participation in typical activities.

From the above statements, five overarching topics have arisen:

- Tangible Objects: Statements 1-3.
- Stimuli and Senses: Statements 3 and 4.
- Socialization and Communication: Statements 5-7.
- Goals, Progress, and Documentation: Statements 7 and 8.
- Typical Activities and Inclusive Environment: Statements 9-11

### 4.2 Personas

Drawing on insights from the affinity diagram it was possible to define the children's core behaviors and needs through the creation of personas, a method first described by Alan Cooper[4].

Table 1. Personas for Designing to Develop Social and Fine Motor Skills in Children with CP

| | PERSONA TYPES | | | |
|---|---|---|---|---|
| | I Do | I Am | I need or want | I like |
| Profile | "Creating things makes me feel independent"<br><br>"I participate in activities that let me display my work"<br><br>"I use digital tools that facilitate my participation in typical activities" | "I tend to focus more if I know what my goal is"<br><br>"I often use non verbal communication to play with my peers"<br><br>"I socialize better in a relaxed environment" | "Sometimes I need alternative ways to encourage myself to keep doing an activity"<br>"Viewing and tracking my progress helps me to accomplish my goals"<br><br>"My parents' involvement affects my performance" | "I like to feel and touch objects that give me immediate feedback"<br><br>"I notice cause/effect patterns through activities related to real life situations"<br><br>"I like to be part of the whole" |
| Goals | Broadcast his/her work to get recognition<br><br>Have sense of mastery in typical activities | Solve problems and challenges<br><br>Improve communication skills<br><br>Self-determination and formation of identity | Maintain interest in activities<br><br>Accomplish goals and/or milestones. Observe and keep track of progress.<br>Maintain close relationship with parents | Participate in inclusive environments<br><br>Stimulate her/his senses through instant feedback and objects<br>Meeting an making friends |
| Tasks | Create his/her work while practicing fine motor skills<br>Share his/her work with peers, parents, and teachers | Participate in collaborative quests<br><br>Make decisions (personas and as a group) | Self report progress<br><br>Share progress with parents<br><br>Collect rewards | Stimulate his/her senses<br><br>Incorporate tangible objects<br><br>Be part of typical activities |

## 5. Prototypes

These three prototypes show possible applications when designing for the development of social and fine motor skills for children with unilateral spastic CP through multiplayer experiences. The design of discrete moments demonstrate how interactive systems would live in the existing environment, and exhibit ways in which different stakeholders would approach this new activity. Figure 1 shows a proposed layout, where the TUIs interact with multiple tablets that would communicate with each other based on proximity. The designed activities are for a school environment, where children play socially in their spare time. Having multiple devices instead of a single tabletop provides two major affordances. On one hand, a group of children can arrange the devices in a variety of ways, providing flexibility and a wide array of gameplay options. On the other hand, a child can use a single tablet for individual play, in different settings other than school.

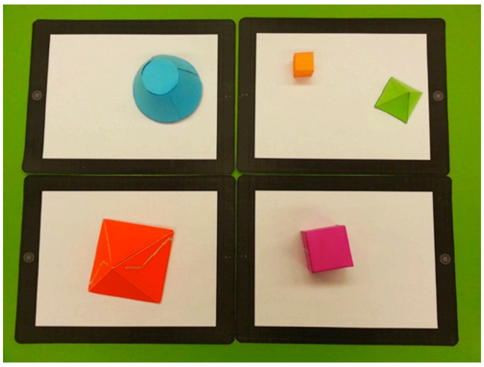

Figure.1 Paper prototype of the basic layout for TUIs and multiple tablets

### 5.1.1 Design of Avatars to Contribute the Sense of Mastery in Bimanual Activities

According to James Paul Gee "Video games recruit identities and encourage identity work and reflection on identities in clear and powerful ways" [5]. The principles of learning in video games can be used in the practice of fine motor skills through a gamified experience. As a child develops a virtual identity (see Figure 2), he or she projects his/her real identity on the virtual character. Once a child gets involved with the character, he/she will look for the success of the virtual identity. The child achieves success through activities that involve the practice of fine motor skills. The aspirations a child has for the virtual identity becomes the motivator to keep practicing these activities.

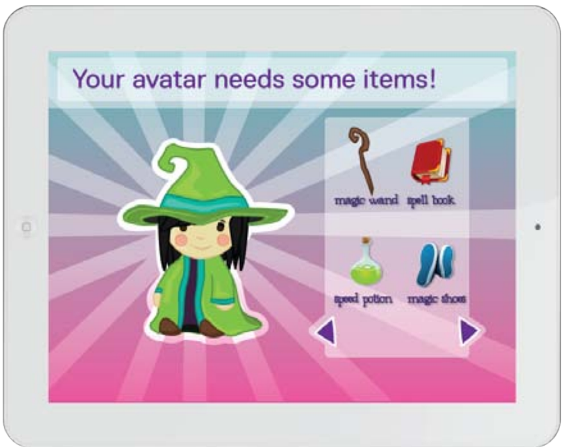


Figure.2 In order to get items and achievements for the virtual identity the child has to solve challenges that would require the practice of fine motor skills

In addition, as seen in Figure 3, the system could use the moment where a child creates the avatar to assess his/her initial mobility level to tailor the difficulty of the activities accordingly. The system would ask the child to alternate hands, detecting which hand is dominant and encouraging him/her to use the non-dominant hand in gameplay. As the child advances in the game, he/she sees a visualization of the avatar's growth and development. Parents, teachers, and physical therapists have access to the child's progress visualization. He/she can also choose to share it with friends.


Figure.3 While a child is creating an avatar the system will give him/her prompts to gather data about his/her mobility calculating time spent and accuracy of movements.

### 5.1.2 Cooperative Play for Development of Social Skills

In this case, the children engage with a collaborative drawing activity that encourages the practice of social skills. During the activity, each child begins by drawing in the game. After a while, the system sends an alert to the children and the drawings exchange devices, leaving each child with a peer's drawing. Continuing on the acquired drawing, the children exercise social skills such as, social awareness, by showing understanding and empathy for others; responsible decision making, by making constructive choices both as an individual and as a group; and relationship skills, by working in teams (See Figure 4).


Figure.4 Children play together using tablets connected via Bluetooth. At a certain point, the system alert the participants' that they will exchange drawings, and the children continue their peer's drawing.

### 5.1.3 TUI and GUI for Practicing Bimanual Activities

The combination of Tangible User Interfaces (TUI) and Touch-based User Interfaces –like the iPad or Android tablets– can work together to create enjoyable and fun experiences for children with CP. This prototype displays potential interactions that involve bimanual activities with specific range of motor skills such as gripping, reaching, releasing, coordination, and stabilization. The selected motor skills are a deconstruction from a list of daily activities found on CHEQ [21], a questionnaire designed to assess children and adolescents' –6 to 18 years old– hand-use experiences (See Figure 5 and 6).

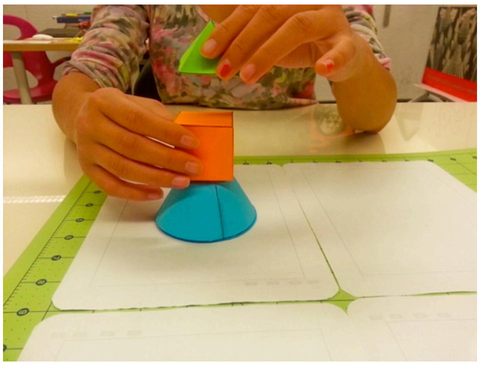

Figure.5 Coordinating and stabilizing objects with two hands


Figure.6 Grip and reach during a collaborative quest

Since the objects are Tangible User Interfaces, they become a connection between the physical and the digital world. The children collaborate using the characteristics of their avatars and interact with the objects building structures, sequences, or using them as tools to solve challenges.

## 6. Conclusions and Future Work

Bimanual manipulation plays an important role in day-to-day activities that influence the quality of life for people with and without disabilities. Case studies related to the practice of a bimanual training approach known as

HABIT (Hand-Arm Bimanual Intensive Therapy) have shown improvements not only in the practiced activities, but exhibited better transferability when compared to constraint-induced movement therapy, where a person uses a cast or glove on the dominant hand [6, 3]. Transferability refers to the act of taking a learnt skill and applying it to non-practiced activities that require a similar set of skills. Providing new options of fun and engaging activities for children with CP to practice social and fine motor skills can lead to the development of continuous and enduring habits that could increase their well-being. Additionally, such activities have potential to benefit the general population. A wide variety of products and services that were initially designed for people with disabilities now have positive impact for everyone that uses them. In the world of information technology this is known as Electronic Curb-cut Effect [11]. Based on ECE, the design of an interactive environment to promote acquisition and development of bimanual motor skills for children with CP can ultimately benefit all children, providing a way to practice and improve bimanual coordination.

Ultimately, this investigation displays the potential for designers to apply design in diverse social and cultural practices. Thinking critically, designers can identify opportunities that connect people by designing for inclusive experiences. Taking advantage of digital technologies and mediums that offer fun and engaging activities can extrapolate possibilities from therapeutic exercises and contribute to positive social change and wellness.

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