DIGITAL FUN:

MAXIMIZING THE ENJOYMENT OF YOUTH PLAYSPACES

by

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Abstract

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This project explored the “fun” of youth digital play through a custom built interactive playtool. This research is based in the developmental value of play for children, the changes to youth play that have taken place as interactions have become increasingly digital, and the design benefits of unobtrusive interfaces. Using academic research sources from both paediatric occupational therapists and Human Computer Interaction (HCI) specialists, a variety of parameters were developed to maximize the developmental value and fun of digital play. These parameters created a guideline of design considerations for the target users of children six to nine years old. An open-ended Natural User Interface (NUI) was designed and built that encourages explorative interactions as a method of understanding its use. User testing was then used to establish if the open-ended play was evaluated as more “fun” than more traditional collaborative or competitive gaming.

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Table of Contents

List of Tables

List of Illustrations

1 Introduction

Play is a fun activity that is an important part of all stages of life. Play performs a particularly important role in childhood, as it allows for exploration and creative expression. Academics through many decades have attempted and failed to definitively define child's play, as it is established by the individual child in the moment (Einarsdottir 2014; Fleer 2015; Nicholson et. al. 2014; Rogoff, 2003; Vygotsky 1978). This lack of a fixed definition makes it difficult for interactive designers to best consider what is most engaging when producing systems and environments for digital play.

Purely imaginative play does not need any tools, as the child at play can conjure whatever they like based on their own thoughts and experiences. Many adults attempt to design systems to support imaginative play for children through new experiences by creating digital environments that support open and unrestricted play. These play experiences have the potential to be magical as they need not abide to the physical laws of reality. Instead, the virtual space can be an escape that allows simple interactions to be an opportunity for imaginative pretence. This play environment is a digital playspace.

Within the context of this paper, playspaces differ greatly from playtools. The researcher has determined defining qualities of each, which hold true for the duration of this paper. It has beed decided that playspaces are digital environments in which open, unstructured play may take place. Users engage with the playspace. This differs from a digital game, as games have set rules and a designated end to the interaction. Games may be developed in a playspace by the user in the moment, but the rules to the game are established by the player(s) at the time, not by anyone else.

Playtools, on the other hand, are physical constructions that are used for play, like toys. A digital playtool can host a playspace (for open play), but at a separate time may also host a similar digital interaction that is a game (with rules). Users engage <u>with</u> a playspace, but they <u>use</u> a playtool.

When creating a digital playspace, typical requirements of fun must be considered, as well as the benefits and concerns unique to youth playing in digital interactions. This presents the question: how can designers consider the benefits of play to produce the most enjoyable form of digital play? Following an academic survey of the value of play, this paper summarizes the research and development of a digital interactive project based on a framework of qualities that results in an enjoyable interaction. The contributions of this paper are that it evaluates “fun” for children in a non-restricted gestural interface, where the targeted participants are between the ages of six to nine years old.

2 The Significance of Youth Play

2.1 Defining The Activity of Play

Play is recognized by the United Nations High Commission for Human Rights as a right for every child (United Nations). It is acknowledged to be an important part of social and cognitive development, and should be a major part of childhood. Youth play, while easy to recognize when it is happening, is difficult to define, particularly from an academic perspective. Paediatric occupational therapists agree that there is ambiguity to the action of play; The motions, purpose and definition all vary (Stagnitti 2003, 3). However, if some uncertainty as to the limits of what is to be identified as play can be accepted (Sutton-Smith 2001), many repeated traits are noted from studies of children as to what they view as play.

Through a survey of a variety of publications (Einarsdottir 2014; Fleer 2015; Nicholson et. al. 2014; Rogoff, 2003; Vygotsky 1978), recurring trends have been noted regarding what children consider to be play. The investigation is summarized in a definition that includes "associations with having fun, activities and experiences that are voluntary, freely chosen, and not supervised or shaped by adults' agendas... Further, children associate play with friendship... positive emotions... and toys" (Nicholson et. al. 2014, p. 141). Across all studies the most often repeated trait that adds value to play is autonomy. The children studied in existing literature wanted minimal adult involvement and instruction, as the primary differentiating factor between work and play in their perspective is work is an adult-directed or given activity (Edwards 2011; Nicholson et. al. 2014). Self-directed play, without the influence of an adult or strict rules allows freedom for creative pretence, which is key to social and cognitive development (Vygotsky, 1978). Thus to best design a playtool for children, to maximize the positive emotions associated with play, it must primarily allow the user(s) the flexibility to explore a self-determined agenda as they play.

2.2 The Developmental Benefits of Play

Despite the difficulty defining it, the importance of youth play is agreed upon by academics (Bretherton 1989; Edwards 2011; Einarsdottir 2014; Rogoff 2003; Stagnitti 2004; Vygotsky 1978). It allows for development of a variety of important social and cognitive skills. In viewing play as part of child development it has been linked to exploration, as it is a stimulus-seeking behaviour that allows “cognitive development, problem solving and creative thought” (Stagnitti 2004, 4). This exploration is beneficial as experimentation, emotional relationships, and relating content are developed (Edwards 2011, 196; Vygotsky 1978).

The aforementioned development of creative thought is stimulated through imaginative play. Imagination is a “psychological function... [a] way of interacting with the social and cultural world” (Edwards 2011, 198). Although it can exist in an abstracted fantasy space, its value comes from allowing children to connect to and interpret reality. By playing imaginative games in the real world with real objects, youth can discover unexpected outcomes (Edwards 2011, 199).

The expansion of emotional relationships is directly linked to multi-user play as it allows for group involvement with other children, where the players can practice social roles (Stagnitti 2004, 5). In studying how children in the age range of three to five years old play in social situations, it is noted that they often form “clusters,” and although they may play in isolation at times, they often quickly return to interacting with those around them (Arnott 2016, 276). When designing for children in and near to this age group, social interactions must be carefully considered. The option to withdraw from group interactions, even momentarily, allows users of various social comfort levels the ability to retreat from a situation that may be overwhelming, while still interacting with the playtool.

Development of relationships through play is also linked to the freedom of choice of social roles in child driven environments. The option to choose what role they would like to play differs from the rest of a child’s life, where they have little control over outcomes and activities that are determined by adults. In North American society, a growing number of young children live such scheduled lives that they lose the opportunity for explorative imaginative play, a loss to which a variety of negative effects have been linked, from behavioural issues to a loss of creativity (Nicholson et. al. 2014, 137). Free play has been replaced with structured guided activities, typically lead by adults (Fleer 2015, 1801). In analyzing the adult's traditional role in youth play, is has been acknowledged that adults and/or teachers are often found outside of the boundaries of imaginary spaces (Fleer 2015, 1802). Adults may exist in imaginative spaces, and are beneficial in the construction of the imagined space, but not in the action of play. This further reinforces the previous belief that when designing playtools, minimizing direct adult involvement is ideal.

Play has been proven to be important to various developmental aspects of childhood. However, concerns have been raised in moving from traditional physical play towards digital interactions as play, as it is still a relatively new field.

2.3 Concerns Surrounding Youth Digital Play

Adult involvement is often cited as necessary to supervising youth digital play, as there are concerns about the effects of use of such tools (Rogoff 2003, 274). Although direct involvement from an adult hinders the play experience, in regard to digital play the role of adult supervision should be focused on ensuring that the nature of the activity is appropriate for the age group of the child/children at play.

Like everything in life, extended use of digital playtools presents a variety of physical and social concerns (Selwyn 2009, 368). The majority of this concern centres around behavioural and intellectual issues based on a dependance on technology, as defined by Presnky's theory of the "Digital Native" (2001). However, this theory has been contended by academics in the years since publication, (Selwyn 2009; James et. al. 2010) who argue that digital fluency is not based entirely on age, and behavioural development is not hindered solely by technological involvement (Selwyn 2009). Digital tools, when designed with the developmental needs of their intended audiences in mind, can prove to be as beneficial, if not more so, than non-digital means (Bird & Edwards 2015). Digital "play is not necessarily of inferior quality in so much as it represents an adjustment to the developmental demands of [the user's] context" (Edwards 2013, 205). A well designed tool can create dynamic and beneficial play that supports the needs of the user.

Another concern regarding digital play involves a movement in post-industrial, technologically developed cultures towards children, even toddlers, playing with cognitive tools (Edwards 2013, 201), such as computers or video games in place of other people (Rogoff 2003, 274). Some are designed to be constructive and collaborative, while many exist for isolated play. Although parental involvement is still from a slightly removed position, in this type of play there are no other people actively interacting with the youth. The reduction of the human element can hinder social development, in a manner that may be more subtle than expected. Toddlers rely on nonverbal cues from adults, both for permission and for correction of errors (Rogoff 2003, 274). If the primary interactions of a child in their formative years are digital, their social development may be impeded. This reinforces the previous belief that including social interaction should be considered when designing digital playtools.

Another major issue presented regarding digital play is the distance created between objects and their meanings. Without the direct connection, it was initially assumed that replacing traditionally physical experiences with their digital equivalent would hinder cognitive development (Bird & Edwards 2015, 1150; Edwards 2013, 203). However, after further research and exploration, it was decided that, "Digital technologies may be seen to support children's achievement of symbolic representations and their engagement in complex acts of pretence" (Bird & Edwards 2015, 1158). What this presents is an opportunity to design within the digital space, where the tool allows for these "complex acts of pretence" while also being grounded enough to encourage connections to the materiality of the virtual objects. Children, while interacting with digital representations of real objects, can interact with them in an entirely unrealistic way, allowing their imagination to run free.

2.4 Advantageous Applications of Youth Digital Play

Various types of digital play can be seen to provide the same benefits as more traditional play. Cognitive development can still take place through digital interactions, as computerized play can also provide opportunities for complex problem solving. Content relation between digital symbolism and representation to physical objects in digital spaces has been proven to be as relevant as physical interactions (Edwards 2013, 204). Children playing with digital tools can fully relate the rendered imagery to corresponding physical entities. Edwards validates this in considering a child's understanding of an animated avatar moving through a virtual space. As a child "playing with an avatar is likely to have a fairly sophisticated grasp of how to separate meaning from object because she needs to know that, 'symbolically' she herself is represented on the screen by the digital image" (Edwards 2013, 204).

An additional benefit of interacting with digital interfaces is that the virtual environment is entirely constructed and thus does not need to faithfully represent reality. It can instead present a fantasy world where the physical laws of reality cease to exist. As such magical and fanciful events, situations, and actions can take place in virtual play that could not otherwise exist in the physical world. These unreal circumstances have previously had the potential to exist in purely imaginative play, and now can be represented visually by the user in digital spaces, allowing for the sharing of more complex play fuelled by imagination with other children. Digital play can be an escape that allows simple interactions to be an opportunity for imaginative pretence.

The research conducted has provided an overview of what characteristics can be integrated into a digital playtool to make it as enjoyable as possible to the target audience of young children. The most often repeated desire involves minimizing adult involvement in the playspace. Not only does this make it appear to be more fun for children, but it additionally allows for social development (Edwards 2011; Vygotsky 1978). Ideally, children can interact with each other through the tool, allowing for autonomy with which they practice various social roles. A well-designed device could function based off of intuition and explorative interaction, further minimizing the need for adult involvement. If the playtool were to instead be a playspace that provides an environment that allows for explorative play, it would support imaginative expansion.

To successfully build a digital device that maximizes the benefits of play while also allowing for the most enjoyable experience, the attributes of fun and play presented by the academic research conducted must be considered.

3 Designing Effective Digital Playtools

3.1 Implementing Intuitive and Natural Interactions

When creating a digital playspace, typical requirements of fun must be recognized, as well as benefits and concerns unique to youth playing through digital interactions. After considering what actions constitute as play, and the values that are important in both traditional and digital play, certain traits appear to be common when examining digital playtools. A lack of instructions or outside involvement has been identified to be key (Fleer 2015, 1802), but with no instructions how can the user know how to interact with a new tool?

The concept of “intuitive” interactions often appears in reference to tools that need little to no guidance to prompt interaction. However, the idea of an action being intuitive is largely disagreed upon in academic circles, as the manner in which someone will interact with what is before them is based entirely on their previous experiences (Israel et. al. 2009; Krishna 2015; Macarnas et. al. 2015). As such, there is no one universal design definition of “intuitive.” Instead, the word is used in digital design to address ease of use, in which a user needs little to no direct assistance from another human to use a new product. This is done through signifiers and affordances.

In the field of Human Computer Interaction (HCI), the meaning of the word “affordance” is based on the use by Don Norman in 1988. He believed that, “An affordance is a relationship between the properties of an object and the capabilities of the agent that determine just how the object could possibly be used” (Norman 2013, 11). Affordances are thus visible or invisible ways that any object may be used. Ease of use of any object is directly linked to the user being able to understand their relationship to, or the affordances of, the object. To maximize the potential ease of use, designers must effectively communicate to users where to interact with these objects. Norman also coined the term “signifiers” as the term for “valuable clues as to the nature of the world and of social activities” (Norman 2013, 17). These signifiers may be digital or physical, and can be as blatant as signs or so subtle they are not noticeable. Whatever they may be, they indicate how to interact with whatever is in front of the user. Thus the concept of an “intuitive” interaction is actually a combination of inconspicuous signifiers that prompt a user to call on previous experiences to interact with an interface.

Digital theorists and designers often proclaim that the most successful interfaces are not noticeable at all (Krishna, 2015). Instead, they allow users to achieve their intended goal without having to consider how it is being done. To achieve this, the designer of the digital tool must consider the impact of signifiers to indicate the available affordances. The ideal playspace does not encourage the user to focus on the technology at hand, but instead uses signifiers to indicate use while having the tech disappear into the interaction. Otherwise a focus on the technology used pulls the user's attention away from the interaction, making it appear less seamless (Carvalho et. al. 2017; Krishna 2015; Watson 2017).

Various interfaces present different affordances, and as such the possibilities for interaction change. Screen based interactions have moved their focus from "traditional WIMP based interface[s] (Windows, Icons, Menus, Pointing device)" to user-oriented controls (Carvalho et. al. 2017). Inputs have evolved from typing to include various periphery devices, and are now increasingly dependant on touch-based interactions. With the development of gestural and body-based computational controls came new terminology: Natural User Interface (NUI). "Natural," in this use, is as vague a word choice as intuitive, and "natural interactions" are just as much based on a user's prior experience as intuitive interactions (Falcaoa et. al. 2015). However, through early evolutions, NUIs have held to a lofty goal: "these new technologies offer an intuitive interface modality, one that does not require users to develop specialist techniques for communicating to computers. What users need to do, instead, is what comes naturally" (O'Hara et. al 2013, 5). NUI's are promised to allow the path to become an expert user (i.e. learning curve) is reduced, and the user feels that their needs are fulfilled (Falcaoa et. al. 2015).

Although "intuitive" interaction may not exist, with careful consideration and an anticipated understanding of common past technological interactions amongst potential users, signifiers can be designed to indicate the affordances of a tool to the user.

3.2 Technical Considerations in Support of Ease of Use

A primary determining factor of the nature of interaction between a user and object is the type of input system implemented. When determining how best to maximize the enjoyability of a youth digital playspace, two significant modes of interaction were considered for this research: Tactile and gestural. Each presents various benefits and different affordances. Specifically for digital spaces, designers must consider the limitations created by the physical and technical features and affordances. More traditional forms of imaginative play allowed children to create anything they could consider from nothing through pretence, thus determining all the rules of interaction themselves (Bretherton 1989). However, the previously stated restrictions of the digital playspace created boundaries within which imaginative pretence must exist.

Play is confined to the type(s) of input supported by the system, and the results of interactions are limited to predetermined outcomes designed into the playtool. Studies show that tactile feedback from tangible interactions has been proven to be highly engaging for users, particularly children, as it allows for affordances and signifiers to be built on real-world interactions (Hornecker 2012). This means that children can easily draw on a variety of previous interactions and experiences when approaching a new playtool. Despite these benefits, the disadvantage presented is that the scope of interactions is limited to the physical reality of the input. However, a digital playspace with no set goal provides a framework for interactions that may prompt imaginative pretence within the limitations of the digital input and outcomes. Thus the value of gestural input is presented.

Research has been conducted to identify the developmental differences of children across a variety of ages when considering interaction with gestural inputs. It has been observed that skills develop extensively between the ages of four to twelve, and basic skills such as “pointing and dragging” are typically fully developed by the age of eight (Carvalho et. al. 2017; Joiner et. al. 1998). As such, the intended group of users for this playtool was selected to be within the low-to-mid age of the previously studied range. An ideal selection of participants would involve an even mix of children across the ages of six to nine, in which half are expected to be below the developmental milestone of eight. This relatively limited age group would present a diverse variety of dextral skill and technical capabilities, while still presenting a level of cognitive maturity that may not be present in younger children.

Due to the limited timeline of this research project and the unpredictability of the target age group, a pre-existing gestural input system was selected to minimize physical wear and allow for quick repairs. When considering various sensors that are designed to capture human motion, two stood out based on the literature provided by both the design and HCI communities: Microsoft's Xbox Kinect, which excels at complex full-body tracking, and the LeapMotion, a simple desktop hand-tracker. Both presented Open-Source libraries to allow for modified use. Children identify LeapMotion as an easier form of input, as it pulls less of the user's attention, allowing them to focus on the task at hand instead of the nature of the interaction (Carvalho et. al. 2017).

The preference from the target audience, in addition to the physical movement of intended interactions (just hands, and the location directly above the screen) and a desired ease of installation in various physical spaces, the LeapMotion was selected. The LeapMotion has been noted to have issues such as delays and difficulties capturing minuscule gestures (Falaco et. al. 2015; Smeragliuolo et. al. 2016; Weichert et. al. 2013), but the design of this specific tool factors the restrictions in, and compensates for them.

4 Anticipated Framework of a "Fun Interaction"

4.1 Guidelines to Create an Engaging Playspace

By combining the definition of play with what is indicated to be most enjoyable by academic research, as well as interactive digital design considerations, a framework was developed within which a playspace can be constructed. The ideal playspace includes:

Table 2: Guidelines to Create an Engaging Playspace

Specification	Benefit
Minimal Adult Involvement	Allows a safe space for children to explore boundaries and determine their own roles.
No Set Instructions, Rules, or Goals	Children have autonomy to decide their own actions with no set timeframe.
Multi-User OR Individual Play	Creates a trial ground for various social roles and permits withdrawal from interaction with others if a child is not comfortable
Support Explorative Investigation	Encourages children to think critically so that they may understand the tool in front of them

The framework indicates that instead of creating a device that tells children what to do, to maximize fun, the interface should react to whatever the user wants to do. This allows the option to control social participation on a unique level; both sustained collaboration and individual interactions can take place, perhaps even at the same time. When combining the factors that makeup the framework into a single tool, it presents an opportunity for the user to engage in unstructured play in a supportive environment.

4.2 Comparing the Anticipated Fun to Currently Popular Digital Play

As of 2016, the second most popular digital play system of all time is Minecraft, second only to Tetris (Callaghan). As Tetris is a game with set rules, it can be assumed that Minecraft is the most popular digital playspace. It is a digital world that users a can build and explore, both in isolation or collaboratively. This play environment does meet the more significant criteria that are part of the anticipated framework of a "fun interaction." Playing in the virtual space does not require direct adult supervision and instructions for every interaction, and users can function independently or connect with other players. In addition to this, there is an ease of access as to the platform as it can be played on any computer. It is acknowledged that the need for a paid membership, internet access, and computer access prevents it from being financially available to all children. However, those who do have access play with Minecraft in a manner that the overwhelming popularity of the play environment supports much of the proposed framework.

However, the nature of the interaction does in theory allow for expansion of how "fun" it could be. Although this sandbox-type of gaming is academically recognized as explorative play, (Tornqvist, 2014), it does lack physicality. This creates limitations as to how engaged in the environment the user can be. Although creative expression is supported, it is restricted to traditional Graphical User Interface (GUI) controls. As such, the interface will always be a visible inhibition of the interaction. Users adapt to the interactions, and become comfortable with them as they immerse themselves in the digital environment, but it is still a learned activity. Interacting through the GUI is not the most "natural" or "intuitive" possible way to build the virtual environment, and movements to involve tangible interactions are severely restricted in what can be done. An example of this is littleBits, a form of physical snap circuitry that has integrated interfacing with Minecraft (littleBits, 2015). The types of interactions developed are limited to the allowances of the types of littleBits that the user has.

5 Implementation

5.1 Physical Design Considerations of the Apparatus

The first step to designing a playspace is considering the playtool that supports it. For this research, an entirely customized structure was a built to meet the goals outlined in the framework. The digital limitations of the LeapMotion impacted the physical structure of the playtool. Due to the nature of the LeapMotion, considerations do not have to be made for a dominant left or right-hand user, as the system registers both hands equally. With the selected gestures recognized for this system the difference between the users' left and right hands did not affect the outcome.

Firstly, the range of vision impacted the scale of the projected space. In reading values from the LeapMotion, movements parallel to the alignment of the user's shoulders were recorded as the x-axis, and movements extending arms closer and further away from the torso were recorded as the z-axis (Illustration 1). The y-axis recorded the height of a hand above the LeapMotion sensor.

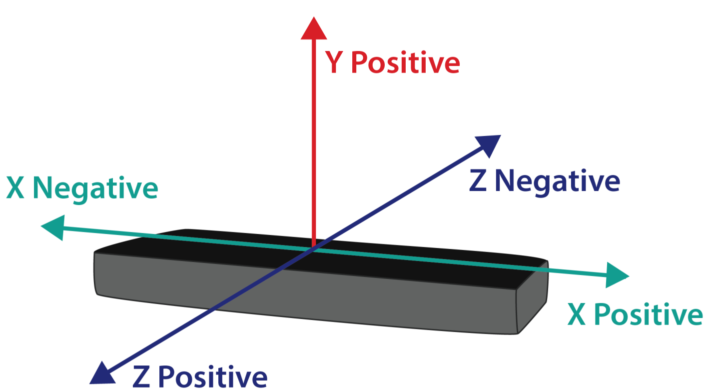


Illustration 1: Axis recognition of a LeapMotion Sensor

The projection surface could only be as wide as the x-axis of each LeapMotion (71 cm). As each user was standing on opposite sides of the structure, the length of the projection surface could be twice the length of the maximum z-axis value from the front of the sensor. This allowed each user approximately half the projected area as their own space to play (Illustration 2). All z-axis values that were z-negative were outside the physical structure (i.e. between the sensor and the player's torso), and as such were not processed.

Due to the mapping of the dome-shaped range of vision (Illustration 3), there are some restrictions within this structure. Each boundary line of data collection is curved, as is demonstrated in Illustration 2. As such, the projection space was made to be slightly shorter than

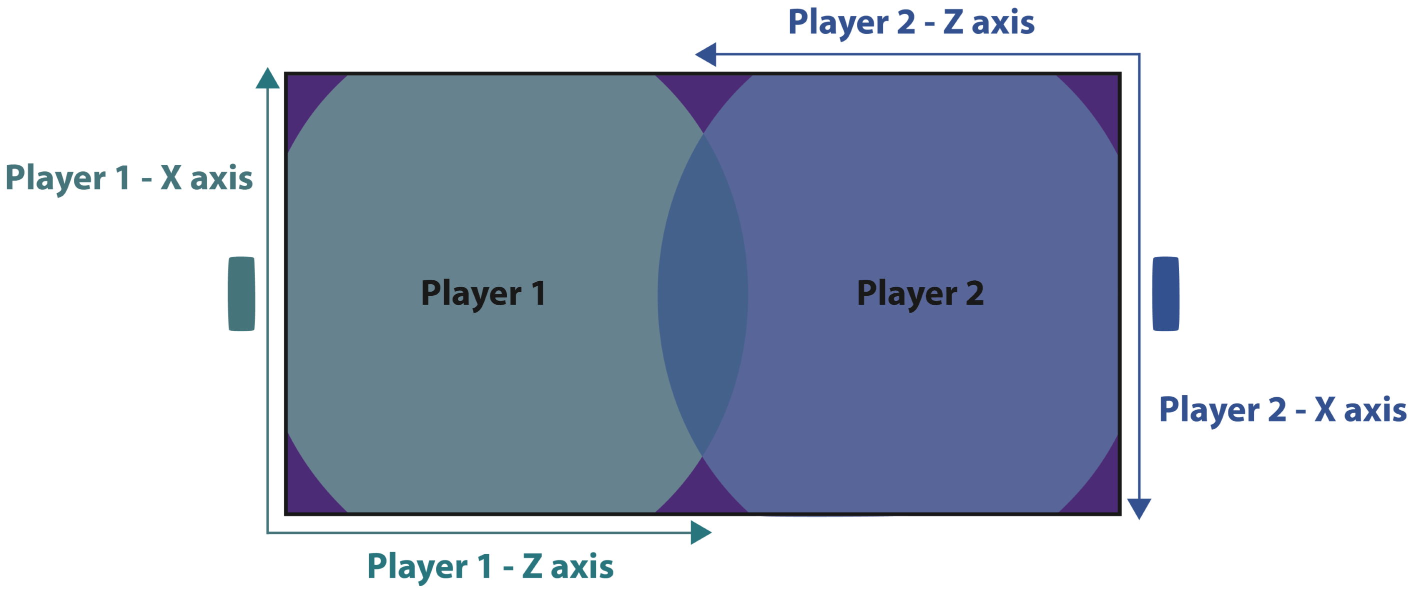


Illustration 2: Overhead representation of each player's "playable space" and noted "dead zones"

twice the maximum z-axis value available (91 cm), to minimize "dead space" (see the purple area in Illustration 2) where no user interactions can take place. This resulted in an overlap between the highest points of the z-axis of each LeapMotion, as illustrated in Illustration 2.

The curved boundaries also affected the gesture recognition in the corners above the projection space, but the system could be designed to adjust to compensate for the specific dead spaces. Through considering the technical specifications provided of the LeapMotion in addition to measurement through trial and error, the ideal size of the intended projected space was determined.

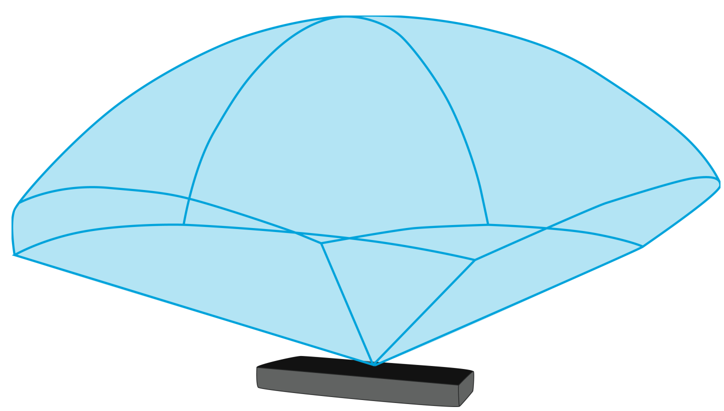


Illustration 3: Range of vision of a LeapMotion sensor

With the scale of the projection determined, the nature of the motions to be identified and inputs was next to be decided. The four basic gestures recognized by the LeapMotion are: Swipes, Circles, Key Taps and Screen Taps. Swipes and circular motions naturally mimicked organic interactions with water, and the up/down motion of key taps aligned well with virtually tapping the surface of a body of water. However, screen taps were an action that took place parallel to the location of the screen. Were the screen to be a real body of water, a screen tap would have no impact. As such, screen taps are not a recognized form of input in the designed playspace.

The choice of physical materials was based on two factors: The nature of the motion and on the intention to make the project easily installable. To minimize installation time, the screen was decided to be a rear projection from below (as opposed to a ceiling mount). This provided the added benefit of eliminating shadows cast by the participants' hands, hiding their physicality so that they were not distracted from the experience of the interaction they are engaged in. The selected height of the tool was based on the average height of a seven year old. A stool was placed near each user's location to accommodate users that were not tall enough to see the screen. The projection surface was intentionally selected to be a thin plastic, to maximize the visual effect of each users movements. Gestures above the plastic screen were echoed not only in the projected imagery, but created motion in the air that physically moved the plastic, forming a bridge between the digital motion and the real world. This merged the two, making the virtual motion seem more real and reducing the amount of attention drawn by the potentially jolting juxtaposition of smooth digital movement on a rigid surface. After considering the suggestions of the framework and the digital limitations of the intended sensors, the physical structure of the playtool was designed and constructed.

5.2 Technical Design Considerations of the Apparatus

The interactive experience of the playtool was built using Java in Processing, an open object-oriented development platform. It made use of the contributed library "LeapMotion for Processing" developed by LeapMotion for the Processing environment. As only one LeapMotion can be recognized by a computer at a time, and the tool was intended to be multi-user, the project used two separate computers, each running their own Processing sketch that was recognizing a LeapMotion as input. Computer A collected one user's gestural data, mapped it down to a scale that was easily represented on the projected surface, and sent the data of use to Computer B via OSC (over the Internet). The use of networked transmission allows for a future potential expansion into remote or large-scale interaction.

The majority of the computational processing was executed by Computer B, which was also collecting and mapping a user's gestural data, in addition to receiving data sent from Computer A. As a user's gesture was registered by either LeapMotion, the useful attributes of each instance of every gesture (see Table 2) were recorded. See Appendix B, Illustration I for the Network Topography.

Table 2: Types of gestures recognized and the values attributed to them

Type of Value	Type of Gesture		
	Swipe	Circle	ScreenTap
Identification Number of Gesture	x	x	x
Location: X	x	x	x
Location: Y	x	x	x
Location: Z	x	x	x
Duration	x	x	
Speed	x		
Radius		x	
Progress (position of finger along circumference)		x	

Based on the attributes of that particular gesture, a circle was drawn at the x/z location of the user's hand on the projected screen. As each user stood at a position along the height of the screen, the x-position of their gesture was recognized along the y-axis of the overall Processing sketch. The z-position of the movement, which was the distance the user's hand s extended from their body, was mapped to x-axis of the half of the projection surface that the user was closest to.

The stroke thickness and size of each circle was based on the strength of the gesture. The strength was determined differently for each type of gesture. Swipes used duration and speed to establish how fast and how long a gesture was. A faster, long gesture was the strongest type of swipe, while a slower short gesture was the weakest. Swipes, generally, were the strongest type of gesture as they involved the most physical movement from the user. The strength of a circular gesture was based on the radius of the circular movements of the user's hand, and the duration of the gesture. To mimic real water, sustained circular gestures in the same location resulted in a visual representation of concentric circles. As such, movements of longer durations created stronger movements, and to encourage more hand and arm movement from users, a wider radius of motion also created stronger circles in the projection.

Circular gestures typically were the second most powerful gesture. Each tap gesture was recognized and represented as a single circle directly below the location of the tap. The size and strength were determined based on the speed and duration of the gesture. Every circle created drifted towards the centre, fading both visually and in strength as it gradually became bigger. As circles collided they interacted, with whichever circle presented a higher strength value in the moment making the weaker circle disappear.

The technical design was developed to exist within the physical restraints mentioned in Section 5.1 of this paper. When combined, the physical and technical construction create a playtool.

5.3 Summary of the Playtool

The parameters of the framework of a fun interaction were used to develop a playspace that maximized the benefits of gestural tools such as the LeapMotion to allow for open digital play without the restrictions of a fixed interface. Children interacted with this tool by waving their hands above it. A LeapMotion sensor detected various types of hand gestures (taps, swipes, and circular motions) and caused a reaction in the projected virtual space that the user was standing in front of. Two users could interact with it at once, standing on opposite sides of a 71cm by 91cm flat projected area. Below the projected area was a mounted projector, that projects onto the underside of the translucent surface.

The visuals of the interface were an artistic interpretation of water; the projected imagery behaved somewhat like a small body of water. The hand movements created ripples and waves in the water. The graphics were rendered to loosely echo water but not present a direct representation, as the ambiguity of the of the visuals was intended to allow for the user to create apply their own narrative. The use of water as the basis was selected as it was not totally foreign to the intended audience, so that a base familiarity existed, inviting users to continue interacting with it. Users were not given specific instructions as to how to interact with this tool, as part of the research involved individual exploration.

Signifiers to prompt the intended use were carefully designed. The standby mode of the playspace included silhouettes of hands moving slightly from side to side, projected in line with where the user positioned and moved their hands to interact. When users aligned their hands and were recognized by the LeapMotion sensor, the silhouettes quickly disappeared, leaving the user with a gentle hint as to what motion to mimic. To ensure that users were informed of their completion of the correct interaction, a reward system was implemented.

Every gesture within the scope of what the LeapMotion could recognize triggered the visuals of the playtool, but each one also resulted in a sound that was unique to that type of gesture. Each sound was a signifier that an action had been recognized. Users were rewarded for exploring different interactions by a variety of sounds. To compensate for the “dead spaces” of the corners that offer limited gestural recognition, as a user interactions grew closer to the corners, they became less powerful, to discourage users from keeping their hands in those areas

This instance of the playtool interface supported open play. The environment would be considered to be a playspace. Based on all research conducted, the expected outcome was that open play, with little adult interference, would be viewed as fun. However personal experience with digital play and children within the age range of focus lead the researcher to believe that competitive gaming would ultimately be the most engaging, due to the thrill of winning.

6 Evaluation/Results

6.1 Evaluation

Participants were given five minutes to explore the interface of the playtool through open play. With no instructions from the researcher, they were just asked to "play" with the playspace. This was followed by a short break where each participant was given the first part of the feedback form. Data collection was conducted through a simple form that was repeated at the end of each session, with infographics reflecting the mood that the interaction evoked. The use of infographics was as a result of considering the reading level of younger participants. In place of reading complex terminology and forcing them to put their emotions into words, participants were asked to select an emotion icon (or "emoji").

The next two stages of testing used the same overall structure of the playtool as the previous stage, but were designed with set game mechanics. As such, they involved rules and instructions, and were not considered to be part of the playspace, instead were a use of the playtool. When the part of the feedback form regarding open play was completed, the first gamified segment of the playtool was introduced. The first game involved collaborative play. This game was introduced by an adult before the users started playing. After interacting with the tool while in "playspace mode," participants were expected to have some understanding of how to make the waves, and how to control their strength. As such, no instructions as to how to interact with the tool were included. The two participants received instructions not on gestural controls, but in regard to the game itself. They were asked to communicate with each other and work together to achieve a particular goal. In this case, a visual countdown of a time limit was on screen. Before the timer was reduced to zero the participants had to together achieve a set "score." The scoring system was based on the type of motion, in addition to the speed and the frequency with which gestures occurred. Participants either won together or failed together.

The final stage of testing was a competitive game. The two participants played against each other, to see who created the strongest waves. The scoring system was the same as the collaborative mode, with the exception that each participant had an individual score. The first to create enough gestures to elevate their score to a predetermined value was deemed the "winner."

The participants were again instructed by an adult before they started play. The instruction for this type of gaming was to use this format to compete against each other to create more dominant waves. This competitive gameplay happened for five minutes, after which the participants were given the third and final part of the feedback form.

6.2 Subjects

Initial testing was conducted with two users, a pair of brothers aged 9 (User A) and 7 (User B). They entered the experience with preexisting technical knowledge, both with computers and gaming. However, neither of them had used a gestural input before. An additional bias that has been identified is the competitive nature of siblings. The outcomes of this research will consider the effects of the particular test subjects on the results.

6.3 Results

Results from this stage of testing are based on the feedback documented on the participant's forms, as well as direct quotes that both users specifically asked the researcher to make note of and include in this paper.

From the forms, it is noted that when considering the first option (open play) both users agreed that they "liked moving [their] hands to control the game" and that the open play "made [them] feel good" (both selecting 5 out of 6 for a positive emotional response) and was "very fun" (an average 5.75 out of 6 for a value of fun). Users A and B opted to select that they wanted to play both alone and with other children on the system.

When initially interacting with the system, they discussed with each other how they thought it functioned. As each user explored how to interact with the tool, they shared their discoveries with the other. Once they understood how to make it work, without being prompted, they both started narrating how they were playing. This was beneficial to the research, as they were explaining their own imaginative pretence. User B focused on a story in which he was "attacking" User A, who was exploring the movement of the shapes. When the five minutes of this stage of testing ended, the users were hesitant to stop despite being reassured that they would continue to play soon. Regarding the desire for instructions, User B did not desire instructions beyond the designed guide (the hand silhouettes), while User A indicated that he would like more “hints” about where to place his hands to specifically control interactions. His suggestion was a visual frame of reference indicating each user’s arm space prior to the interaction.

The second type of interaction, collaborative, was the least popular. Although both participants indicated that they liked playing with other children, it ranked lower on the emotional response scale (presenting an average of 4 out of 6) and the fun value (5 out of 6). The response was still positive, but the participants indicated that the free play, with no rules, was more “fun.”

The final iteration, the competitive play, proved to be the most popular. Both participants added to the feedback scales, as they did not think the maximum was enough to convey their elation, and how enjoyable the experience was. User A asked that it be noted that, “it made [him] happy, even though [he] lost.”

Both User A and User B ranked the competitive play as their favourite, followed by open play, then collaborative. They were then given the option to play with any of the three versions, and after playing competitively for 10 minutes, they chose to switch to the unstructured version, where they played uninterrupted for over 30 minutes.

Table 3: Initial Testing Results

	Emotional Response	**Fun Value**	**Overall Ranking**
Unstructured Play	5/6	5.5/6	2nd
Collaborative Play	4/6	5/6	3rd
Competitive Play	6/6	6/6	1st

6.4 Interpretation

The quantitative feedback from the users indicates that the overall interaction with the tool designed is positive; it is indeed a fun experience. Although the collaborative play was ranked as enjoyable, it was the least engaging and was not selected by the participants for re-play when they were given control. The results comparing the competitive play and open play proved to be the most compelling. Measured results indicate that the competitive version of the playspace was ranked as the "most fun." However, the measurable results do not show the tendency the participants demonstrated to elect to have the longest interaction with the unstructured play after having experienced them all. The participants grew bored of the competitive play faster than they did the unstructured play; although it did not present the thrilling rush of winning, it did hold their attention for longer.

The theory that unstructured digital play will allow room for creative pretence has been confirmed not through the measured results, but through the nature of the users' participation and their commentary as they interacted with the play format.

6.5 Further Work

This is a work to be further explored, with feedback from a larger pool of participants across the full age range. The low sample size is an acknowledged limitation. Testing with the pair of participants resulted in surprising outcomes that will drastically alter the nature of future feedback forms. The initial testing presented unexpected interesting comparisons between the nature of the types of play that indicates the potential for more compelling research. Testing with a larger group of participants may suggest that the unstructured play may hold the user's attention for longer periods of time or inversely that competitive play will always be explicitly stated to be preferred by users. The execution of future testing will be structured to explore not just the enjoyability of a type of interaction, but additionally the length and nature of the interaction. Based on the unmeasured feedback, future feedback forms will be tailored to allow for more feedback, not just limited to the enjoyability of a type of interaction.

In the event of this, additional more complex interactions can be developed within the digital space of the playtool to explore the thrill of winning as opposed to the various developmental benefits of explorative play. Due to the limited sample size, and the nature of sibling interactions, the lower scores of collaborative play may not be representative of all potential users. Further testing with a larger audience with varying relationships to each other will be needed to identify if this is a constant recurrence.

Design changes to be considered from the feedback resulting from the initial user testing include more signifiers. They must be included to help users frame the limitations of their interactions in the physical world. A visual cue indicating the scope of each user's area of interaction may be beneficial for the first few seconds of interaction. In the future, additional academic research is to be conducted exploring the effects of collaborative and competitive play, as the physical, emotional, and social outcomes were not within the framework of the initial research.

7 Conclusion

Through a combined effort of academic, qualitative, and explorative research, a series of preliminary guidelines were developed to aid designers considering creating an interactive playspace for children ages six to nine years old. Based on the academic research conducted, the four core values of an enjoyable playspace include:

1) Minimal adult involvement
2) No set instructions, rules, or goals
3) The option to engage in multiuser or individual play without having to change the setup of the playspace
4) Supportive of explorative investigation

After building a playspace according to the framework developed, play within it was tested in comparison to collaborative and competitive gaming on the same playtool. With an initially small sample size, the outcomes of qualitative feedback identified competitive play as the most "fun" that produced the highest positive emotional response. All three types of interaction with the playtool were ranked high on the feedback scale for both fun and emotional response, indicating that the overall playtool developed presents an enjoyable interaction.

Despite the qualitative feedback, unmeasured values indicated different types of enjoyment between the competitive and open play. When offered the opportunity to choose which type of interaction to participate with, the initial selection was competitive, but the participants soon grew bored and elected to play in the open playspace for a much longer period of time without any guidance or outside interference. Further research will explore and measure this comparison in a larger sample size.

This research has not only resulted in the framework, but has laid groundwork for further research, as it has helped identify a more specific area of research. The most successful outcome is the overall enjoyment measured by the participants interacting with the playtool in all formats. The research and development resulted in both an enjoyable playtool and playspace. Appendices

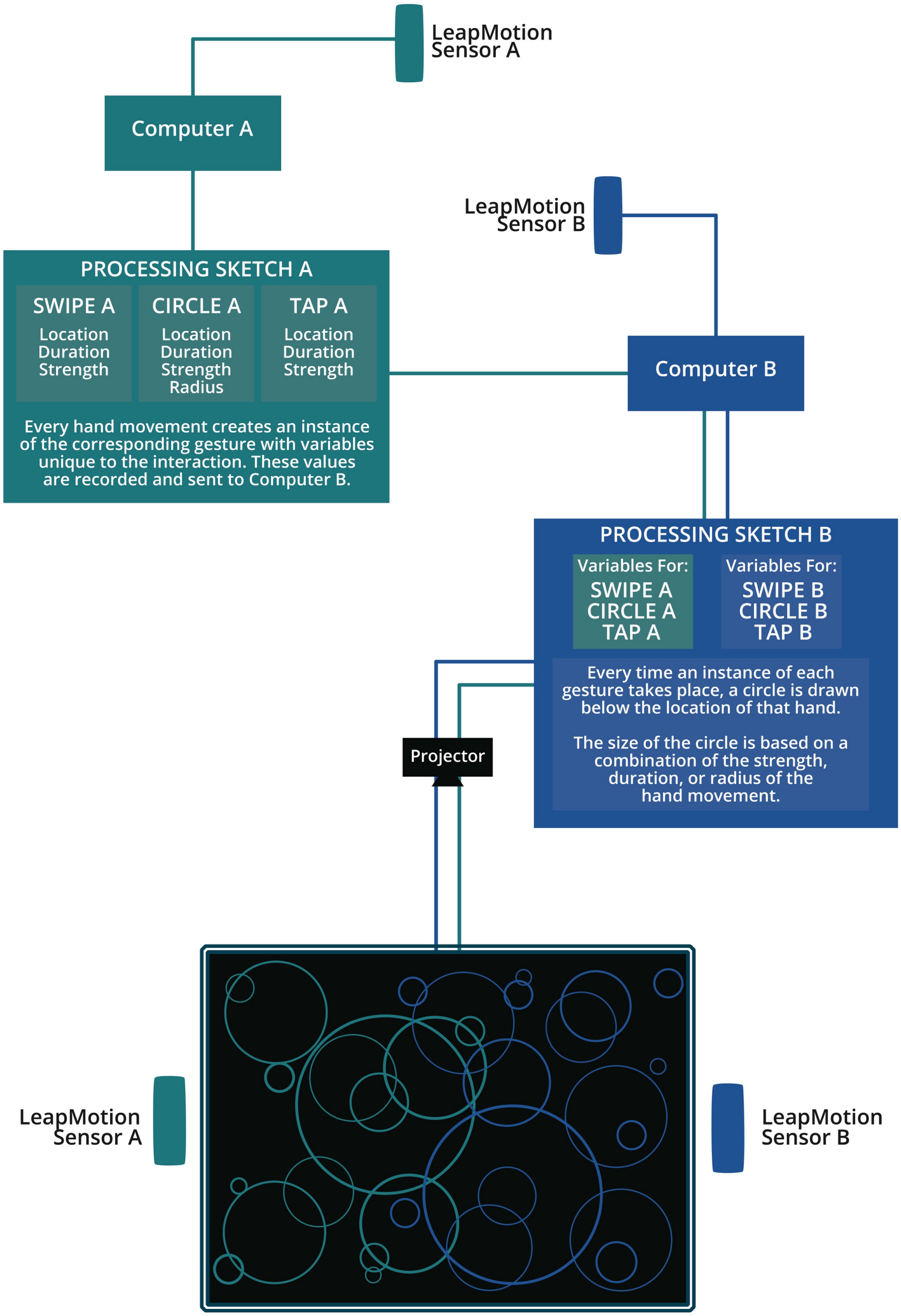
Appendix A: Glossary of Research Terms

Term	Meaning
Game	A structured form of play. It involves set goals, and an ability to win. The user must play according to predetermined rules in attempting to achieve the goals.
Gestural Input	Computational data collected based on the body movement of users.
Imaginative Pretence	The act of pretending based on creativity or inventiveness; “make-believe.”
Interface	A program or system that allows a user to interact with a digital tool. Types of interfaces include, but are not limited to: command line, graphical, gestural, tactile.
Intuative	A common term used when describing interactions that need no guidance; has been proven to be an incorrect assumption. Typically used in place of “ease of use.”
LeapMotion	A tabletop gestural sensor initially developed to allow users to control computer screens with hand motions in place of a keyboard or mouse.
OSC	Open Sound Control, a method of transmitting data packages between devices and software over a network.
Play	An enjoyable activity that is self-determined fun for the participant.
Playtool	A physical constructions that is used for play, such as a toy.
Playspace	A digital environment in which open, unstructured play may take place.
Processing	A software sketchbook used for coding in the visual arts.
Sandbox-Type Play	Digital play with no set storyline, where the participant sets their own rules and activities.

Term	Meaning
XBox Kinect	Motion sensing input device developed by Microsoft for body tracking and voice recognition.

Appendix B: Additional Illustrations

i) Topography of Interactive Network



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