Animated Props for Responsive Playspaces

by Susanne Seitinger

Master in City Planning
Massachusetts Institute of Technology, 2004

Bachelor of Arts in Architecture
Princeton University, 2001

Submitted to the Program in Media Arts and Sciences,
School of Architecture and Planning in partial fulfillment of the
requirements of the degree of Master of Science

at the

Massachusetts Institute of Technology, June 2006.

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Abstract

Playgrounds are special places within the urban landscape specially designed for children. Here, they encounter the outdoors and the physical properties of large spaces through play, which allows children to develop their physical skills, explore the natural and built environment as well as interact with their peers. Even more importantly, children direct their own play activities in playgrounds in an open-ended way. As digital technologies become increasingly present in children’s lives an important question arises regarding their role in playgrounds.

This thesis contributes to playground design in a meaningful way by exploring how digital technologies can enhance children’s open-ended and physically active play in outdoor settings. Can animated playground props support and possibly enhance open-ended and physically active play in playgrounds? This thesis expands the repertoire of objects conceived specifically for children’s outdoor play environments through a review of existing technologies and designs followed by a design exploration with a new category of animated playground prop.

I develop an ecological approach to children’s digital playground props which takes into account the links among children ↔ props ↔ play settings. In playing with objects, children gather information about the physical characteristics and embedded meanings of their three-dimensional surroundings. In other words, children’s interactions with play props are one lens for experiencing the world. This theoretical framework leads me to a new category of animated prop called “space explorer”.

The thesis describes a design process for one prop, an autonomous, pneumatic playground ball which is part of the “space explorers” category. The method combines design development with input from children in two workshops about their playground and specific objects. The design and research exploration concludes with reflections and recommendations for future attempts to design more autonomous and responsive objects which can enrich children’s outdoor play experiences.

William J. Mitchell, Professor of Architecture and Media Arts and Sciences
Thesis Supervisor
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Reader Biographies

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Mitchel Resnick explores how new technologies both necessitate and facilitate deep changes in the ways people think and learn. Resnick’s Lifelong Kindergarten group, at the MIT Media Lab, has developed a variety of educational tools, including the “programmable bricks” that were the basis for LEGO’s award-winning Mindstorms robotics construction kit. Resnick also led the development of StarLogo, a software toolkit for modeling decentralized systems. He also co-founded the Computer Clubhouse project, a network of after-school learning centers for youth from underserved communities, and co-developed The Virtual Fishtank, a million-dollar museum exhibit that helps children of all ages understand the working of complex systems. Resnick earned a B.S. in physics from Princeton University in 1978, and an M.S. and Ph.D. in computer science from MIT. Before pursuing his graduate degrees, he worked for five years as a science/technology journalist for Business Week magazine.
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Fig. 1 Reactive Playground Project, interactive pathway project (Summer 2005). See footnote 2 for the detailed references. Unless otherwise noted photographs by author.
Introduction

Playgrounds are special places within the urban landscape specially designed for children. Here, they encounter the outdoors and the physical properties of large spaces through play, which allows young children in cities to explore the natural and built environment. In addition, teachers, parents or sports coaches do not set the agenda at the playground. In other words, playgrounds are spaces where children can engage in open-ended play patterns\(^1\) of their choice. The type of equipment such as swings and slides available on the playground provides a framework within which children establish their play patterns.

As digital technologies become increasingly present in children's lives an important question arises regarding their role in playgrounds. This thesis contributes to playground design in a meaningful way by exploring how digital technologies – if at all – can enhance children's open-ended and physically active play in outdoor settings. Can animated playground props support and possibly enhance open-ended and physically active play in playgrounds? This thesis expands the repertoire of objects conceived specifically for children's playgrounds through a review of some existing approaches to outdoor technologies for children and playground designs as well as design explorations with a new category of animated playground prop.

Reactive Playground Project

From June through August 2005, a group of colleagues and I initiated the Reactive Playground Project\(^2\) at the MIT Media Lab. In an attempt to capture the strength of existing, successful playground installations and emerging, popular interactive exhibits, an interdisciplinary group of researchers designed a simple prototype for exploring the problem space of outdoor playgrounds in the digital

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1 Play patterns refers to the sequence of choices and decisions a child makes in creating a game, challenge, or scenario. For example, trying to climb up a slide is one characteristic play pattern, sliding down is another pattern.

2 The Reactive Playground Project is a joint initiative among four research groups at the MIT Media Lab. I am grateful to Marko Popovic, Lis Sylvan, Oren Zuckerman and Orit Zuckerman for a summer of fun. See also, S. Seitinger, E. Sylvan, O. Zuckerman, M. Popovic, O. Zuckerman. “A New Playground Experience: Going Digital?” Extended Abstracts Proc. CHI’06, (Montreal, 2006).
era. We designed an interactive pathway in two sections that consist of a wooden frame with five pressure-sensitive mats. The latter are attached at a distance corresponding approximately to the length of a 4 year-old’s gait. Each mat has a motor with a spinner attached to the wood next to it which turns as the child steps on the adjacent mat.

The simple design with one responsive element enabled many play patterns. We observed all types of running, jumping and walking, fantasy play and more in-depth exploration of the spinners. Just like children use slides as imaginary waterfalls or hiding spots, they used the pathway for everything from simple running to playing choo-choo trains. This diversity of responses seeded further explorations of digitally enhanced outdoor play experiences.

Two Key Principles
Following the Reactive Playground Project, I identified two key principles of successful outdoor play experiences: openness and full-body engagement. My working definitions for these principles are:

**Full-body Engagement**: In playgrounds, children learn to engage the outdoors through active play which entails running, jumping, swinging, sliding and every other form of physical activity. Both playground installations, traditionally mechanical elements such as swings and slides, and the availability of open space encourage children to move around as much as possible and develop their motor skills.

**Open-ended Play**: The term open-ended is used to describe a play activity that encourages a child’s development by promoting his or her own ability to experiment with many different kinds of play patterns. These patterns may include goal-driven scenarios, individual and group play, and all types of designed (e.g. tricycle) and ad-hoc (e.g. a cardboard box) play props.3

Using the two principles of play derived from the interactive pathway project, I aim to explore how digital props can be developed that

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3 In the education literature, a growing movement has been advocating for more play in educational and non-educational settings because of the many derivative developmental benefits. Zigler et al. (2004).
encourage full-body engagement and open-ended play in outdoor play settings.

Architects, planners and artists have spent significant energy on designing the physical, fixed-in-place installations in playgrounds while props remain less explored.4 Children bring objects to the playground and use found props to enhance their play. For example in the sandbox, buckets and more irregular molds allow children to build imaginary worlds. Some of the most commonplace toys are balls, pull-along toys, cars, and tricycles while found objects include rocks, leaves and sticks. This thesis specifically focuses on the “rollers and crawlers” (referring to balls, pull-along toys, etc.) children use in playgrounds because they mediate between the child and larger play installations such as swings and slides. Enhancing these intermediary program elements through digital means reveals new dimensions for playground props.

**Thesis Outline**

In the first three chapters, I develop an ecological approach to designing animated props. Drawing on the lessons from architecture, urban planning and developmental psychology, I suggest a framework for implementing a prototype. Chapter 4 describes the design process for developing one prototype of an animated prop which is part of a category named space explorers. In Chapter 5, I review the prototype and suggest directions for future research on animated playground props as well as meta-reflections on the design process itself as a less rigid and still rigorous approach to designing new technologies for children.

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4 Significant research has been conducted by designers, architects and urban planners about the best approaches to playground design. Devices, layout, natural features and other elements have been considered extensively and evolved over different time periods and cultures, but the props remain unexplored. Hendricks (2001). Hurtwood (1968). Heseltine and Holborn (1987). Alamo (2005).
Fig. 2 Calvin and Hobbes comic strip.
Chapter 1

An Ecological Approach to Children's Outdoor Play

Play presents a key means of "learning about the world" available to children. The child psychologist Piaget was very interested in these dynamic aspects of children's play which he saw "as a biological model of interaction between child and environment." In other words, children are able to learn about themselves and subsequently the world through hands-on interactions which researchers, educators and grown-ups call play. This environmental dimension of children's play is highlighted by Catherine Garvey and more generally the Vygotskian socio-constructivist approach.

During play, objects act as mediating elements between children and their surroundings because they connect the two. Garvey's work specifically mentions the importance of objects as mediating elements between children and their environment because they connect the two:

They provide a means by which a child can represent or express his feelings, concerns, or preoccupying interests. (...) Further, for the child an unfamiliar object tends to set up a chain of exploration, familiarization, and eventual understanding: an often-repeated sequence that will eventually lead to more mature conceptions of the properties (shape, texture, size) of the physical world.6

The adjacent figure introduces the three essential elements of the play scenario Garvey describes, children ↔ props ↔ play setting. Though Garvey does not limit herself to outdoor spaces, they are the setting studied in this thesis. I use the words environment, surroundings and space in different contexts, but the reader should keep the outdoor play setting – the playground – in mind throughout.

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5 Quoted in Heseltine and Holborn (1987).

Developmental Stages of Play

Play patterns can be categorized in many ways in relation to a child's developmental stage, age or exhibited preferences. Differentiating among cognitive, physical, and social styles of play are three often-cited categories. The general phases of physical play are “rhythmic stereotypes peaking in infancy, exercise play peaking during the preschool years, and rough-and-tumble play peaking in middle childhood” according to Pellegrini and Smith. A group of Spanish architects has distilled the psychological data into the following helpful categories:

**Play Stages**

0-3: children experimenting with their bodies, moving alone, playing, experiment touch, sound sight.

3-6: lots of fantasy play, they use “abstract elements, tables, benches, …”

6-8: more physical activities, training themselves

8-10: less adult supervision needed, also physical dexterity, balance, coordination, structured games, rules, social

One of the important themes in this chart is the increased independence of children and the importance of physical skill-building. As children mature, they develop the gross and fine motor skills which allow adults to navigate their environments. Typical play equipment such as swings, slides and monkey bars are all geared towards this type of development. During the preschool years, certain types of exercise play peak, according to Pellegrini and Smith making it especially important to promote continued physical activity during this phase.

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9 The other stages are: “rhythmic stereotypes peaking in infancy, exercise play peaking during the preschool years, and rough-and-tumble play peaking in middle childhood.” Pellegrini and Smith (1998).
Physically Active Play

Physically active play can benefit children's development in significant ways. Pellegrini and Smith's explain that: "Exercise play could be beneficial (…) both because it is nonacademic and also because it is self-motivated, playful, and associated with enjoyment, self-efficacy, and mastery." Physical play can be an important part of the "active engagement" children show in an activity:10

(…) physical activities abound in our children’s world and are crucial to their development because they are taking pleasure in testing their budding abilities, learning how well they work, and practicing their various uses.11

These physical activities have general health benefits, but they also enhance the overall experience of self-directed play. Being engaged with the whole body goes hand in hand with so-called cognitive play.

In Jerome Bruner’s research, quality play time at a young age is shown to increase a child’s aptitude later in life.12 Quality play time means access to different types of play including open-ended situations. So, while organized sports can be very healthy for children they do not replace open-ended and physically active play situations without codified rules. The playground presents the ideal setting for providing this type of self-directed experience.

Open-Ended Play

The term open-ended is used to describe an activity that is not constrained by explicit limits. In this case, open-ended play encourages child development by relying more upon the child than the toy/prescribed activity for learning. Constructivist theory posits that "children have an inner drive to build an understanding of their

10 Pellegrini and Smith (1998).

11 Catherine Garvey introduces five elements of play: (1) “Play must be pleasurable and enjoyable.” (2) “Play must have no extrinsic goals.” (3) “Play is spontaneous and voluntary.” (4) “Play involves some active engagement on the part of the player.” (5) “Play contains a certain element of make-believe.” Garvey and Rubin (1977).

12 Garvey and Rubin (1977), 210ff.

world as they explore and interact with materials. Concepts about how the world works are built gradually and become increasingly complex as the child enters a rich learning environment and exercises his or her freedom to play." During open-ended play children are free to use their imagination to define a play scenario and apply their own unique play patterns, actions and details.\textsuperscript{14}

Some researchers in education have been lamenting the reduction of play time in kindergartens, the removal of dress-up spaces and the exclusive focus on cognitive development with no regard for other forms of activity. A similar wave of focus on cognitive functions took place in the 50s and 60s cold war era to ensure a strong American future. Zigler et al. argue for a whole-child approach to learning rather than just focusing on certain aspects by referring back to Piaget who said that "children actively acquire knowledge through interacting with the physical environment." \textsuperscript{15}

This type of interaction with the world is an inherent part of playgrounds.

\textbf{Props or Not?}

The question of whether children need props to play also requires some attention. Some educators – like the \textit{Alliance for Childhood}\textsuperscript{16} – criticize that children don’t need specially designed objects for play and especially not digital or computational ones. Walter Benjamin thought that specially designed toys were a sign of the increasing disconnect between children and their parents. Specialized – or as he called them "emancipated" – toys are a caretaker-replacement rather than a prop for learning or teaching.\textsuperscript{17}

\begin{itemize}
\item \textsuperscript{15} Zigler et al. (2004).
\item \textsuperscript{17} Translation by author. W. Benjamin. \textit{Gesammelte Schriften} (Frankfurt am Main: Suhrkamp, 1991), 115.
\end{itemize}
In the second half of the 19th century, one observes how the toys become larger, and they lose their subtle, small and playful characteristics. Is it at this moment that the child lives in a separate play room, a closet where she can store, for example, her books separately from the parents' books? There is no doubt that the older, smaller books required the constant attention of the mother, the new large-format books with their boring codling are better designed to replace her while she is away. The toy becomes emancipated; and so it removes itself further and further from the family's control as industrialization takes its course and becomes strange to the children, but also the parents.  

Benjamin understood that children need an external assistant at certain times. Vygotsky "argued that development occurs within the "zone of proximal development" when tasks that are difficult for the child to learn alone can be mastered if the child is guided by someone who is skilled at the task." In play, the right balance of structure and freedom can be crucial to ensuring a positive experience.

Smart play props cannot replace teachers and parents, but they might be able to provide a helpful nudge at the right moment through their autonomous and potentially interactive behavior. In general, manipulating objects allows children to experiment with theories about themselves and the world that they could not test with people or pets. For example, a child destroys a tower after painstakingly building it. This situation could be a re-enactment of the child's own propensity to fall previously. Making the tower topple gives a sense of power and superiority as well as the possibility of reliving the previous experience in an active manner. If the objects were animated in addition to being manipulable, the child could enact even more complex scenarios.

Manipulating objects is one of the outwardly visible signs that play is necessarily a full-body experience. Winnicott explains that playing involves the body through the "manipulation of objects"

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and the intense interest "certain aspects of bodily excitement" entail. Froebel developed a series of "gifts" which were designed as objects that young children could manipulate in order to learn. These "manipulatives" have evolved into a mainstay of the preschool environment. In the playground, physical play and the manipulation of objects can be brought together in an especially engaging way.

A manipulative setting can incorporate different types of fixed and movable parts that range from smaller objects to larger movable parts through manipulable, but fixed parts. These components allow children "to learn the properties of the physical environment and develop skills in manipulating it." In their guidelines for playgrounds, Moore et al. describe six different types of manipulative settings:

1. **Found objects in fixed settings:** small objects and natural materials; small toys (cars, trucks, sand box toys); heavy loose parts (wooden logs)
2. **Purpose-made props:** inflatables, dress-up materials
3. **Modular systems:** large-scale construction blocks
4. **Large wheeled vehicles**
5. **Adventure playgrounds:** open setting where children design and build the entire infrastructure
6. **Natural settings**

This list categorizes custom-made props, found props, large-scale and hand-scale props demonstrating the breadth of manipulative settings which are conceivable for outdoor play situations. Every

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prop enhances different play patterns and accommodate different play styles so that designers can target very specific play values through their choice of props. In adding digital features to the props further play patterns can be encouraged that still need to be developed by researchers and designers.

In any of outdoor play setting, children's ability to engage in the types of concentrated, open-ended play determines the quality of the play. This zone should be a protected area because "(t)he playing child inhabits an area that cannot be easily left, nor can it easily admit intrusions." Thus, any additions through new play equipment or props to these spaces must be derived from a deep understanding of the benefits of open-ended and physically active play in early childhood until adulthood.

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Fig. 3 Santa Maria Maggiore in Rome,
www.colossusblog.com/mt/archives/images/maggiore1-thumb.JPG
Chapter 2

Comparing the Child’s Conception of Space to the Designer’s

The understanding children develop of their play spaces is strongly linked to their play patterns. In *Experiencing Architecture*, Rasmussen illustrates this spatial understanding through an example:

The enormous church of S. Maria Maggiore stands on one of Rome’s seven famous hills. Originally the site was very unkempt, as can be seen in an old fresco painting in the Vatican. Later, the slopes were smoothed and articulated with a flight of steps up to the apse of the basilica. The many tourists who are brought to the church on sight-seeing tours hardly notice the unique character of the surroundings. They simply check off one of the starred numbers in their guide-books and hasten on to the next one. But they do not experience the place in the way some boys I saw there a few years ago did. I imagine they were pupils from a nearby monastery school. They had a recess at eleven o’clock and employed the time playing a very special kind of ball game on the broad terrace at the top of the stairs. It was apparently a kind of football but they also utilized the wall in the game, as in squash – a curved wall, which they played against with great virtuosity. When the ball was out, it was most decidedly out, bouncing down all the steps and rolling several hundred feet further on with an eager boy rushing after it, in and out among motor cars and Vespas down near the great obelisk.
He goes on to explain what the value of the experience is for the children from his perspective as a designer:

I do not claim that these Italian youngsters learned more about architecture than the tourists did. But quite unconsciously they experienced certain basic elements of architecture: the horizontal planes and the vertical walls above the slopes. And they learned to play on these elements. As I sat in the shade watching them, I sensed the whole three-dimensional composition as never before. At a quarter past eleven the boys dashed off, shouting and laughing. The great basilica stood once more in silent grandeur. In similar fashion the child familiarizes himself with all sorts of playthings which increase his opportunities to experience his surroundings.23

Through the "playful" use of the space these children learn to read the spatial qualities of the plaza behind the Basilica. They can estimate distances, materials, and ultimately more abstract qualities of the space.

Children's Conception of Space

Children have a different relationship to their surroundings than adults because of their physical size and cognitive development. In addition, their bodies are still changing causing a constant recalibration in relation to the surrounding world. Our bodies relate in scale to the objects around us for very pragmatic reasons such as usability and access. It would not make sense to place a cupboard two meters in the air in a regular kitchen and yet children experience most of their surroundings in this disorienting way. So children perceive objects as unusually large or small while their bodies catch up to the world around them and their senses become perfectly calibrated to their surroundings. Before they reach this point, their perception of the world is skewed. Pope’s Essay on Man warns us about the dangers of inappropriate sensory input.

From Essay on Man25

The bliss of Man (could Pride that blessing find)
Is not to act or think beyond mankind;
No pow’rs of body or of soul to share,
But what his nature and his state can bear.
Why has not Man a microscopic eye?

For this plain reason, Man is not a Fly.
Say what the use, were finer optics giv’n,
T’ inspect a mite, not comprehend the heav’n?
Or touch, if tremblingly alive all o’er,
To smart and agonize at ev’ry pore?
Or quick effluvia darting thro’ the brain,
Die of a rose in aromatic pain?

24 Vygotsky describes this phenomenon as well: “(...) children at different stages of their development do not yet possess a system of communication with adults which is sufficiently compatible. This means that a child at different stages of his development does not generalize to the same extent, and consequently, he interprets and imagines the surrounding reality and environment in a different way.” In R. Veer and J. Valsiner, The Vygotsky Reader. (Cambridge, MA and Oxford, UK: Blackwell, 1994), 345.

Most urban spaces cannot be interpreted at child-scale. This fact is powerfully conveyed by city maps where the smallest elements shown are usually buildings. Playgrounds have an intermediate scale that does not necessarily predetermine the users’ age or physical characteristics. While certain zones like the sandbox usually become a playing field for younger children, older children occasionally play there and parents also lend a helping hand.

Metaphorically and literally, the playground acts as a stage-setting for children’s play in an outdoor context. In this context the connection between stage set, i.e. the sandbox, and props, i.e. the shovels and molds, lends meaning to the space which the children interpret and reinterpret throughout their play. Further, the spatial relationships among the objects and the children assume meaning based on the types of play patterns taking place. These relationships resemble the technique with which filmmakers

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26 "The map’s scale (...) has a way of determining – all by itself – what can be seen and what can’t. For instance, at small scales kids just...disappear. They get swallowed up in the worlds of their parents." Wood, “The Power of Maps” in S. Aitken, Geographies of Young People (London, New York: Routledge, 2001), 22.
bestow meaning, the “mise-en-scène.” Modifying spaces by “putting things in the scene” provides the basis for meaning interpreted by observers. Monaco in *Understanding Film* thereby differentiates film from other media because “it is not composed of units as such, but is rather a continuum of meaning.”

Urban spaces at various scales have been interpreted as providing a similar ongoing visual experience and narrative. Mitchell reinterprets mise-en-scène for the city:

(...) the interconnected spaces of a city construct a mise-en-scène through both the synchronic effect of simultaneously visible elements and relationships and the diachronic effect of elements and relationships presenting themselves sequentially to moving observers.

Objects further enhance the meaning of spaces through their appearance and position in the environment.

In addition to bestowing semantic meaning, objects can also intermediate the sensory experience directly. As the character in the film or the observer in life moves through the city, she collects a mountain of sensory data which in turn is processed in the mind. In the case of a blind man, a cane literally transfers the information about the environment to the body and becomes an extension of the latter’s sensory tools. In Bateson’s words, “Suppose I am a blind man, and I use a stick. I go tap, tap, tap. Where do I start? Is my mental system bounded at the handle of the stick? Is it bounded by my skin? Does it start halfway up the stick? Does it start at the tip of the stick?”

He unlocks this conundrum by explaining that the context of the inquiry should determine the definition of the unit under discussion:

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sensory experiences of space with and without the intermediation of objects:

(1) direct experience of spaces through senses

(2) indirect experience of space with intermediating objects

(3) interconnected relationships leading to entirety of the sensory landscape of play
The stick is a pathway along which transforms of difference are being transmitted. The way to delineate the system is to draw the limiting line in such a way that you do not cut any of these pathways in ways which leave things inexplicable. If what you are trying to explain is a given piece of behavior, such as the locomotion of a blind man, then, for this purpose, you will need the street, the stick, the man; the street, the stick, and so on, round and round.

In designing for children's play, the unit of inquiry encompasses the child, the objects and the play space and not the relationship between the child and the space or the relationship between the child and the object separately.

An illustrative example makes the argument clearer: If one imagines a child pulling a duck on rollers behind itself she can feel the ground through the string. Her own speed of walking and the nature of the ground co-determine the state of the string. The relationship between the child, the string and the ground is analogous to the blind man, his cane and the world. The world becomes knowable with the assistance of the prop and enhances the experience of the environment. At each linkage point – hand to rope, rope to object, object to ground – sensory information is passed on to the next stage until it finally reaches the child who begins to perceive attributes of the surrounding spaces. The attributes can be related to the topography (flat, hilly), the tactile characteristics (muddy, sticky, rocky), or the arrangement of objects in space (obstructions). Passed through the rope, these features add another dimension to the child's experience of the space and can then be added to the child's own ongoing narrative of the encounter with the outdoors.
The Architect's Perspective

Architects and designers have often attempted to design special places for children's play. The architect Aldo Van Eyck describes vividly how heavy snowfall transforms the whole city into a playground for children: “But what the city needs for its children has to be more durable than snow.”30 The spatial transformation achieved through the snow should be captured in our playground designs and the props found therein.

Infrastructure for playgrounds and outdoor games has a long history that differs among cultures. The most familiar play installations we find in playgrounds today, such as swings and seesaws, originated for the amusement and physical training of the wealthy. Play was an adult activity among the upper classes with ample leisure time. In the 19th century, the public play yard was

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designed in response to a lack of open space in urban settings depriving city children of physical activity outdoors. Urban planners now consider playground spaces generic utilities which should be available to all city residents.

Various design approaches have determined playground forms. For example, the 1970s gave rise to adventure playgrounds where children design and build their own play environments. Today, we see many examples of designers and artists developing playful and stimulating outdoor spaces. These designers have also regained an appreciation for the development of stimulating environments that consist of more than mechanical equipment:

The trade-off imbalance which has been going on all this century between natural environments converted to urban development and their substitution by standard type playgrounds has been totally in conflict with the best interests of children. This tide of change cannot be stopped, but much can be done to re-establish a balance on the playground… there is a need to depart from the stereotype acquisition and placement of ‘play structures’ in flat open spaces.

This critique suggests that designers should better integrate the play structures into the spatial concept of the playground because they are linked in how they impact children’s play.

And many sensitive designers have focused on equipment that increases motor and cognitive abilities in children. Guidelines developed by Heseltine and Holborn focus especially on the value of play achieved by a specific design. Their measures for the quality of play are:

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Many of the most popular installations like large swings, merry-go-rounds, and slides mostly challenge children's gross motor skills. Increasingly, cognitive games have found their way into the playground though from observation and anecdotal evidence these installations fall behind the typical playground equipment when it comes to children's interest.\textsuperscript{35}

Bodily activity and exploration with materials is important in all playgrounds and differs depending on the types of equipment available. A study on the impact of play equipment on children's activities found that the type of playground provided to children does impact play patterns. When there are more sophisticated installations children play more on the equipment. However, they also engage in less social play.\textsuperscript{36}

Some architects observe that highly physical play activities often require less infrastructure because a good open space can fulfill the children's needs. However, "it is always advisable to ensure some form of modular play equipment, structures and varied terrain, all of which provides a range of possibilities for interaction and dynamic games."\textsuperscript{37} These dynamic games should be zoned for different areas throughout the playground so as not to interfere with the other types of more quiet and reflective play. Alamo advocates separating group play zones from individual play zones; noisy and


\textsuperscript{37} Alamo (2005), 269.
physical games from quiets ones. This type of separation is not just functional, but also increases the legibility of the space: "Ensuring a certain degree of organization in a playground is a necessary aspect so that children learn to find themselves within a space and get their bearings among different play areas." To achieve this legibility, designers need to think back to their roots as organizing human activity – in this case play activity – when conceiving of successful outdoor playgrounds.

Alamo’s book Design for Fun includes many truly inspired examples from around the world which successfully address these design goals. However, in some cases the design aesthetic is clearly adultist in nature in its emphasis of sculptural qualities, for example. How children’s design aesthetics differ from those of adults goes beyond the discussion here, but it should be stated the two do not always overlap:

A rich and plentiful world is not necessarily a good environment for children; on the contrary; it shows rather how much adults strive to be the centre of attention. A child-oriented environment allows children the freedom and space to create, shape and form things – it allows change and decorations that we might consider destructive, ugly or kitsch. A child-oriented world has its own aesthetics.

Even for the most talented grownup designer it may not be easy to judge what would be appropriate which could be the essence of the challenge to create appropriate play props and spaces for children.

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38 Alamo (2005), 274.

Bringing it All Together: Convivial Spaces for Open-Ended Play and Fully-Body and Mind Engagement

The Reggio Emilia school system combines the desire to build child-centered spaces with high-quality design in a unique way that emphasizes creative expression and supports children’s natural exuberance. Since the 1970s, the medium-sized town of Reggio Emilia in Northern Italy (population approx. 150,000) has been building and designing very special school buildings and connected educational programs for young children up to the age of six. The spaces support a learning environment “where knowledge is seen as constituted in a context through a process of meaning making in continuous encounters with others and the world, and the child and the teacher are understood as co-constructers of knowledge and culture.”40 In Reggio’s practice, the spaces of learning are interlocutors for the children and teachers and are designed to “allow for maximum movement, interdependence, and interaction.”41

One of the original examples the Diana School is located in the heart of the downtown on the edge of the public gardens. Some of the early photographs documenting Reggio’s successful approach depict the unique spaces within this school. Each classroom includes an “atelier” and the school houses a larger public “atelier” which is the center of creative activity.

Diana’s contemporary counterpart, the Nilde Lotti infant-toddler center was designed by Tullio Zini and completed in 2003. In contrast to the older Diana School, this building includes many architecturally unprogrammed spaces that can be adapted


to whatever activities are taking place empowering children and teachers to shape their environment, which is directly linked and customized to the activity at hand. As a result, it feels like the whole room can be incorporated into a creative activity in addition to the ever-present “atelier” spaces. The indoor and outdoor zones are visually and physically connected through large glass elements and a central winter garden.

At all the schools, several elements recur across age groups, schools, and classrooms. For example, the use of light tables and overhead projectors to transform objects and create shadow plays has been incorporated into every stage of teaching. Using a very simple technology such as light, children can transform everyday objects into magical creatures.
Through the design of specific play spaces and the provision of rich materials the infant-toddler centers of Reggio Emilia inspire a tactile approach to designing tools and spaces for play and learning. All of Reggio's tools enhance the sensory richness of the creative and open-ended experience. Materials affording diverse tactile experiences allow the children to express their artistic and analytic capacity to study the world around them and visualize their ideas.

This attention to diverse encounters with materials relates to from Reggio’s philosophy of the “Hundred Languages of Children” which acknowledges children’s unique play and learning styles and the subsequent need for multi-faceted environments. The spaces of learning and playing at Reggio reflect this philosophy. Even though most children play with a variety of materials on a daily basis, their experiences, as those of grown-ups, are mediated by increasingly uniform and standardized materials. Research conducted by the Reggio Emilia Schools in conjunction with Domus Academy in Milan criticizes the relative homogeneity of the surrounding environment: “the coldness of metal, the linear cleanliness of plastics and wood smoothed by machine precision, creating a material landscape in which contrasts are generally reduced or, at most, handled with difficulty.”42 Children, more than adults, use their hands to gather tactile information through sensory stimuli: “Children touch, caress, rub, and play; with one hand or two, with their fingertips, palm, the back of their hand, the knuckles, the edge.”43

Many of the materials used in the classroom are collected by Remida (founded in 1996), which organizes and reuses clean waste materials from companies in the region. All materials are donated and range from fabrics to metals, electronics to paper. The exhibit shown to the left was prepared by an artist to demonstrate the breadth of materials available at the center.

42 The Reggio Emilia Schools in Italy are internationally acclaimed infant-toddler centers and preschools dedicated to building successful learning environments for children. Their research is specifically aimed at developing better physical spaces which they call “relational space” for children to flourish. G. Ceppi and M. Zini, eds., Children, Spaces, Relations. Metaproject for an Environment for Young Children. (Milan: Reggio Children, 1998), 72.

43 Ceppi and Zini (1998), 76.
Teachers and educators can “shop” for free at the Remida Centers for their school activities. Today the network of recycling centers consists of locations in Italy, Australia and Denmark. Since 2000, Remida has been organizing a set of activities around a particular theme, for example, totems. The annual Remida Days are usually coupled with public installations in the downtown area which bring the schools closer to community life.44

Capturing the spirit of Reggio in the design of props and spaces for play shows how theories of play (and education) can be interlaced with a designers’ work. It closes the gap between theory and practice in a unique way. Incorporating new technologies into these designs adds another layer of complexity to the mix, which is described in the next chapter.

Fig. 13 “Shopping” at the Remida center in Reggio Emilia.

44 Remida Series, *Remida Day muta...menti* (Reggio Emilia, Italy: Reggio Children, 2005).
Fig. 14 Water games created for the 2004 Barcelona Forum of Culture. www.iua.upf.es/eic/jocs/aigua/, www.barcelona2004.org/cat/ Photograph provided by N. Pares.
Chapter 3

Adding New Technologies to the Mix

Impact of Digital Technologies on Children's Play

For today’s children, so-called “millennials”, digital devices and computation-based toys are taken for granted. In some cases – like the Sony Aibo – the objects can be highly complex while others are simpler. Defining technology is not the goal here, but I am using it to mean computational elements that surpass traditional, analog toys.

Very little interaction with these objects takes place outdoors or involves full-body engagement. In fact, most digital devices such as computers, handhelds or robotic toys like Sony’s Aibo or Robosapiens do not encourage full-body motion or open-ended play. The Toy Robots Project at Carnegie Mellon, for example, has set the following goals:

1. Excite and inspire public interest in robotics and in science and engineering in general
2. Educate users in robotics, engineering and the natural sciences
3. Utilize commercial sources of funding for robotics R&D
4. Provide a challenging and rewarding work environment for roboticists
5. Exploit high-volume manufacturing in the commercial sector to mitigate robotics costs

45 The Pew Internet and American Life Project discovered that more than half the teenagers online develop or reconstitute online content for their specific needs. The physical context for creating this content remains a computer lab, a children’s room or some other enclosed space.

These goals are very focused on the field of robotics, which is the researchers’ domain of interest. This approach does not acknowledge the environmental aspects of children's play.

Many “emancipated toys” – whether digital or otherwise – are designed for children to fulfill specific goals ranging from marketing goals to educational ones. As a result, designing digital devices for children often implies making the adult world smaller, cuter, more colorful or simpler and less functional; that is, they lack a certain open-ended nature which accommodates different styles of play and what Resnick and Silverman call “low floors and wide walls.”

We see our construction kits as defining a space to explore, not a collection of specific activities. And our hope is that kids will continually surprise themselves (and surprise us too) as they explore the space of possibilities. When we created Programmable Bricks, we didn’t imagine that kids would use them to measure their speed on rollerblades, or to create a machine for polishing and buffing their fingernails.

In this description, the authors are referring to various tangible and software-based construction kits. Low floors allow beginners to immediately make creations. And wide walls make it possible to invent and reinvent new activities with the available features.

47 Note, that this thesis is not a techno-skeptical piece, as researchers have repeated technological determinism does not lead to useful findings. And, children and young people are increasingly found to have sophisticated and differentiated uses of technology that do not have negative impacts on them in the broad-brush way some popular claims imply. S.L. Holloway and G. Valentine, Cyberkids: Children in the Information Age (RoutledgeFalmer: London, 2003), Conclusion. J. Suoranta and H. Lehtimaki, Children in the Information Society, The Case of Finland (New York, NY: Peter Lang Publishing, 2004).

Technologies Expanding the Scope of Outdoor Play Experiences

Some examples from different disciplinary angles show what potential new technologies have for enhancing open-ended and physically active play:

Ambient Spaces

Y. Rogers, Ambient Wood, Equator Project: The Equator Project comprises many different research efforts among them the Ambient Wood outdoor field trip for school children. In order to enhance the field trip, tools were built which would provide digital information to the children while they were exploring the outdoor environment. Rather than separating field research from other resources the goal was to enhance the experience through written and audio information or through tools like magnifying or framing certain elements in the forest. In some sense, these tools function as digital props in the off-the-grid outdoor environment and become meaningful through the potential they have to unlock the secrets of those spaces. Outside of that context these tools would not be beneficial to the children. The technologists tried to take children's needs into account and enhance their outdoor experience in a meaningful way. The end-result is an augmented outdoor installation accessible to children as they wander through the forest.

Full Body Engagement

H. Lund and Playware: A Danish group of computer scientists and roboticists developed Playware as a system of "intelligent hard- and software that aims at producing play and playful experiences among users." Inspired by hopscotch and other floor games this digital iteration opens many possibilities for reconfiguration. These elements could also be added to existing playgrounds to enhance that outdoor environment.
Interactions in Spaces

Interactive Water Installation: In Spain a group of computer scientists and interaction designers created an interactive, outdoor water play installation for the "Universal Forum of Cultures" held in Barcelona, 2004. Users could activate the fountains by forming rings and spinning around them. This natural interaction was facilitated by an artificial vision system. These designers developed a full environment instead of individual augmented elements to be added to the space. They selected the rather universal game of holding hands and running in a circle. From this interaction they derived the technology and the spatial arrangement of the installation and truly captured the essence of the Forum. None of the digital infrastructure interfered with the naturalness of the interaction and the intuitive nature of the design was confirmed by the popularity of the exhibit.⁴⁹

Fig. 17 Water Games, interaction patterns, the water fountain is activated when the children hold hands and start to move in a circle requiring them to coordinate and agree on a direction and pace. Photographs courtesy of N. Pares. See also Pares et al. (2005).

⁴⁹ Telephone conversation with N. Pares, 1 March 2006.
Several lessons can be drawn from these examples. First, simple interactions such as holding hands around a fountain can support very creative and imaginative games. Second, digital interventions can enhance the spatial experience without detracting from feeling grounded in a three-dimensional outdoor space. Third, digital props can support and encourage physical interaction that resembles the physical activity children enjoy in playgrounds.
Digital AniMates as Playground Props Inspiring Full-Body Engagement and Open-Ended Play

In an attempt to add to the repertoire of examples described above, I would like to propose a new category called “space explorers” for preschool children which derives from the pull-along toys many of us remember from our own childhood. What are space explorers? They are animated objects that reveal important information about spaces through open-ended and physically active play.

Ackermann uses the term “AniMates” to describe props that raise different issues in play through their ability to act autonomously. The distinguishing characteristics of these props are: (1) their autonomous nature, (2) ambiguous existence between animate and inanimate, (3) their own special personality, and (4) the potential for interactivity. As a result, these objects do not become unconditionally subservient to their playmate raising issues of “agency, identity, attachment and control.”

Successful AniMates are “good dancers” which requires some form of reciprocity between the child and the prop: “To be fun, the tech-toys and toy-bots of the future will have to be “good dancers”, i.e. good at negotiating gives and takes.” This back-and-forth could be called “responsiveness” or “interactivity”.

In a playground setting, the digital incarnation of these objects presents a new opportunity that has not been explored. Existing games like playing ball already involve transactions among players raising issues of agency and control through simple games of catch. In the case of animated props, these issues can be explored even further because the object itself has some autonomy or “inner” goals and behaves differently over time. Thus at times, the object plays the role of main character relegating whatever it impacts to the status of recipient. At other moments, the relationship is reversed and the previous recipient takes action.

This type of interaction has connections with the anecdote recounted by Rasmussen of the boys in Rome. The children made the ball impact the Basilica’s plaza and thereby engaged the space in play. In this case, another layer of response from the object itself

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is added. For example, the ball could “decide” to take the other way and not roll down the steps.

In the case of animated playground props several specific scenarios will engage children in their three dimensional surroundings. First, if the child copies the space explorer’s movements it may become more physically active and re-experience the space through these new movements. Second, following another object may lead to a different view of the playground if the object has specific zones it inhabits. Third, watching the object touch and bump into things externally manifests how many children engage with their surroundings. Finally, the object’s movements are open to narrative interpretations of the ball’s role in a fantasy scenario.

The design of the object in terms of actuation, shape, materials, colors and sensory capacity play an important role in enabling these interactions. However, the scenarios and underlying goal of supporting open-ended and full-body play in outdoor spaces precedes any technical requirements.
Fig. 18 The pull-along toy, the ur-form of the pull along companion toy, which younger children use to accompany them on their explorations. This object is shown here as a metaphor only and not to insinuate one specific type of form or interaction.
Chapter 4

A Design Process

Immersive investigation utilizes direct engagements with subjects in order to work past the designers’ own misconceptions and to establish an intimate understanding of the complex relationships between provider, subject, budget, infrastructure and community.51

The following episodes describe the exploratory design process employed to develop the category of space explorers introduced at the end of the previous chapter. This method involves iterating and reflecting throughout the design process together with a constituent group rather than completing and fully developing one design before engaging the users and context. The chronological account provides insight into the process and the design challenges raised by the provocative notion of space explorers. Each account is connected to methodological, theoretical and practical concerns about developing autonomous objects for enhancing outdoor play.

Episode 1: What are space explorers?

In trying to develop a prop from the suggested approach, a new category emerged called "space explorers" for preschool children, which derives from the pull-along toys many of us remember from our own childhood. What are space explorers? They are animated objects that reveal important information about spaces by adding another layer of complexity to the triangle of children ↔ props ↔ play setting.

In literal outer-space exploration, the spherical robot plays an important role. There are several examples of inflated or solid spherical robots which have been developed for understanding distant planets.

NASA Tumbleweed
NASA developed the Tumbleweed inflated ball which is so light that the strong Mars winds carry it across the planet where it collects data. In case it needs to change direction, it deflates and waits for the next gusts.

Swedish Orb
A group of Swedish researchers at Uppsala University in Sweden first developed the orb as a spherical robot for probing planets. They formed the company Rotundus in 2004 which has adapted the technology for surveillance purposes.52

Julius Popp
Developed both as an observation robot and as an art piece the German artist Julius Popp developed a spherical robot which can accompany humans or travel the surface of distant planets.

EGGWAY
Jessica Banks at MIT’s CSAIL laboratory designed EGGWAY as a simple helper-robot which performs basic tasks for humans. The robot’s spherical shape allows it to move within human interior spaces and goes against walking or other more anthropomorphic robots.

52 Rotundus, http://www.rotundus.se/
**Gyrover**

Developed at Carnegie Melon, Gyrover is a one-wheeled robot that can steer, stand and travel very quickly across extremely rugged terrain. The robot is equipped with minimal sensing and on-board computing, but these functions are being developed for future use.

**Personal Mars Exploration Rover (PER)**

Some literal attempts have been made to adapt these scientific objects for children, but they are often focused on the engineering lessons or the introduction to space exploration in general. At Carnegie Mellon, the Personal Exploration Rover was developed by a group attempting to introduce engineering and innovation concepts to children.53

While the PER uses the vehicle-style autonomous explorer as a model, the spherical robots also provide a strong precedent. Using wheels and balls for children’s play is time tested – balls are still one of the most commonly found mobile objects on the playground. And there are several commercially available remote-controlled and uncontrolled spherical toys for children.54 The age-old game of the hoop and the stick is an example of a wheel-based toy. These shapes have also been adapted for adults in extreme sports such as Rhoerenrad or Zorbing!

Starting from the universal spherical shape and adding the idea of an exploration device, a basic scenario for a roller would be:

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Basic scenario:
Children encounter the space explorer in a playground setting where it is activated by their presence. The types of ensuing behaviors include expected and unexpected outcomes, for example: the spherical object may initially roll down a hill as expected only to turn around and return towards the child.

Lessons for Playground Props

It is impossible to know how the children in Rasmussen's story about Rome would have perceived an animated object, but several characteristics distinguish space explorers from previous playground props:

1) Autonomy
First, the object is autonomous or moves of its own accord without needing a push from the outside. In other words, it is a "self-regulating device". Ackermann explains that these types of devices include "a mechanism able to read or sense certain features in its environment (such as light, sound, or obstacles), to measure or evaluate their value in relation to an internally fixed referent, and to adjust its behavior accordingly." As a result, children (and grown-ups) develop psychological and physical explanations for the object's behavior, which are continuously updated throughout the interaction with that object.

2) Animate/Inanimate
The first feature leads to a second characteristic, a certain blurring between animate and inanimate which is fascinating for children whose understanding of what's "alive" is still being formed. In a short exercise with a group of children at a preschool, one of the children confirmed this notion when he said that the ball should "roll it by itself."

As Turkle's extension of Piaget's earlier studies shows, digital objects are especially interesting in this context because of their increased "holding power." According to her observations children attribute life and consciousness to objects for different reasons at different developmental stages. Computational objects are also assessed differently at successive stages.

3) Personality
Third, the roller has a personality which the child can interpret based on how it moves in the space. If it likes to hide in the corner the child might think it is shy. (A more detailed discussion on the issues raised by this feature follows in episode 5.)

4) Personality and Interactivity
Fourth, the object can respond to specific actions of a child with specifically programmed reactions. At a certain distance, it can be a follower. At another it might ignore the child. The specific interactions relate to particular play scenarios and serve to engage children in different activities over time as they explore their playground. The play scenarios are derived from a deep reflection as a designer and observer of children's play patterns. These characteristics are developed further into specific interaction patterns which address different play scenarios in Episode 5 of the design process.

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Episode 2: Listening to Children

Designers make assumptions about how the groups they address will receive or use an object. When focusing on young children, the designer is especially challenged because her frame of reference differs vastly from a child’s. Cycling through different active and observing roles can assist in making choices: “In iterative design, there is a blending of designer and user, creator and player.”

Druin suggests three specific research and design methodologies for working with children to develop appropriate technologies:

1. Contextual inquiry is a form of detailed observation technique which is very important in capturing the non-verbal expression of young children especially.

2. Technology immersion gives children the opportunity to experiment with many more technologies than they would encounter in their everyday environment thus allowing researchers to see how creatively children can use the proposed systems.

3. Participatory design stems from the desire to work with children rather than for them and comes from a longer tradition of other attempts to incorporate end-users of designed products into the development.

Contextual inquiry resembles the type of close observation many designers of urban space engage in to understand the movement patterns in everyday life. William Whyte’s work on small urban spaces in New York and his methodological notes on work in the field are very much focused on understanding people’s behavior in spaces that reveal details on their social relationships. Adding the...

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role of space to the observational inquiry enriches the understanding of technology which the researcher stands to gain.58,59

The goal to ground the entire project in observation and lessons from the field initiated the first phase of observation with a group of preschool children at their playground and in their classroom. The inspiration – more so than design images – gathered there provided the initial impetus for developing the design explorer category.

In a first exploratory phase, two researchers visited the childcare center and spent two afternoons with the preschool class drawing the playground and discussing favorite activities. (The field research protocols used for this thesis and described here in Episode 3 were reviewed and approved by the MIT Committee for the Use of Human Subjects, Application No. 0505001241, MIT Media Lab Reactive/Active Playground Project). Following the exercise researchers also observed the children in the on-site playground. The sessions were held in a corner of the classroom around a small table with space for two to three children at any point in time. In one instance, the table was moved to the window from which the playground can be seen. The children were invited to participate in the activity on a rotating basis and as part of their regular free activity hour in the morning. The researchers took turns in introducing the children to the activity and observing in a total of 6 groups of 3-4 children.

58 Carolina Simon completed a detailed observation study of three tot lots in Cambridge, MA. The study is a successful example of how observation and surveys can be used to assess the success of an outdoor space. Inspired by William Whyte’s study of small urban spaces in New York city the work successfully transplants his method. C. Simon, Small Urban Spaces: Programming for Good Tot Lots (MCP Thesis, MIT 2003).

Fig. 23 Views of the playground of the child care center.
Lessons from Playground Observations

The sessions provided a constructive basis for continued work with the children. At this stage, they did not engage the question of “what if” through words, but rather described fun activities or places which they seemed to associate with the playground. Also, in some cases the children did not feel like drawing the playground and the children were not explicitly restricted from other topics.

From the overall session several favorite areas in the playground emerged. In general, all corners of the playground seemed very well used. The circular track for riding tricycles, pushing trucks and running was very popular among all the children. They seem to especially enjoy it between focusing on particular areas of the playground. The playhouse served as a basic prop for fire engine, house, and for “cooking” mud soup. One girl drew the house with many windows, but still noting that it was the playhouse outside. One of the children drew the slide with all its colorful elements from a very provocative angle when asked to draw his favorite playground element.

The preferred activities observed in the playground involved playing together with friends and more structured games. A set of tree stumps of different heights arranged in an area served as a great basis for group games of various kinds. Trying to stay on the stumps according to certain rules and moving from one to the next quickly in a circle was observed though the particular rules of the game did not manifest themselves clearly. Another narrative-based game was to “transform” the playhouse into a fire truck: “quick, get in the fire truck, we’re leaving”. One of the children was very keen on finding the few flowers living in the playground while the teachers attracted some attention with their discussion of the ant farm. Three of the children also drew flowers or other natural elements of the playground space.
Fig. 24 Children’s drawings juxtaposed with two detail images of their playground. These are not supposed to indicate the one-to-one connection, but rather the fact that children connect with certain play zones and identify them as important.
Episode 3: Initial Design Probe

The goal of the initial demonstration with a self-propelling ball was to consider its value as a play object, which would have required extensive technical development. As a way of pre-testing the value of such an object a small Wizard of Oz demonstration was tested with the same group of kindergarten children.\textsuperscript{60} The children’s initial reactions were gathered using this methodology for several reasons that take the ethical considerations of this type of experiment into account:

(1) The children would not have been able to experience the full range of behaviors in a very experimental prototype.  
(2) The “wizard” can more easily adapt to unexpected reactions on the fly.  
(3) The time-frame for building the prototype would have delayed feedback from the children thus making it harder to incorporate their reactions into the design.

Workshop

In order to simulate different behaviors a researcher used a remote control to steer the ball towards or away from the children. Although the interactions were not triggered by the device itself the excited reactions described in more detail below provided enough evidence to move forward with more sophisticated iterations.

During one afternoon (July 13, 2005, 3:30-4:30), two researchers spent approximately 15 minutes each with three groups of children from the childcare center. The groups of five children (boys and girls mixed) came to the activity room which is used for special events and play-time when the weather does not permit outdoor play. The entire interaction was video-taped for a more detailed evaluation later.\textsuperscript{61}

First, the children answered a few questions while holding a regular playground ball and then passed it on:

(1) What do you like to do with the ball or when you are playing games with the ball?

(2) What would be the craziest thing you can imagine a ball would do? Or what would a funny ball do?

Second, the children were introduced to the prototype. In each group, a different type of behavior was tested in order to gain some insights into their response to the object.

Group 1: In this case, the ball exhibited surprising and funny movements at first and then the remote control was uncovered and discussed with the children.

Group 2: This group was shown the “surprising” behavior of moving towards the children spontaneously. The remote control was hidden.

Group 3: The final group was asked to stand at the other end of the room, clap and wait for the ball to come.

Lessons for Designing “Roller and Crawler” Playground Props

The exercise proved a valuable starting point for further research because it showed the children’s initial excitement at the sight of a responsive object. Showing them this demonstration and observing them at play was a good starting point for refining the behaviors developed in great detail in episode 5. The exercise did not connect as well with the outdoor playground space as initially intended, but the room was large enough to engage the whole body. The room is used for physical activity by the childcare center teachers.
The children had some ideas for crazy movements though the question may have been too vague. In general, the children age 4-5 gave typical answers about the expected behavior of the ball. They enjoy kicking, throwing, running and rolling the ball. Among the unexpected answers were suggestions that the ball start "dancing crazy" or "falling from above" or "roll it by itself."

Studying the behaviors of the ball itself proved more difficult due to the technical limitations of the remote controlled version. The very detailed responses were in part a reaction to the clear need for precise and well-calibrated signals from the object which the children would enjoy and understand. This exercise also clearly showed that just providing the children with a remote control would not fulfill the expectations for a responsive playground prop.

Several observations about the movements of the ball and the games the children started can be made, however. After a short moment of surprise, two of the three groups observed ran towards the ball and began holding it or pounding it. In some cases, they were holding it gently and in others they were actually pushing it around in a tight circle or punching it. This group situation became quite exuberant in one case, but only for a short moment. In watching, the situation resembled exercise play in the playground. There was giggling and laughing throughout the session and - with the exception of the very first moments - very little hesitation to run after the object.

The main insights from this workshop were: (1) the behaviors should be very well calibrated to the children, (2) the very large beach ball was slightly too large to function in a ball game so holding it and pushing it from below was the only opportunity for the children to move it, (3) a larger-scale space with no obstacles would provide more opportunities to explore how the object would set off a playground and enhance the children's spatial experiences.
Episode 4: Moving Muscles for Autonomous Rollers and Crawlers

From the initial workshop, it became clear that selecting an appropriate motion principle would be important. The following criteria were used for developing a mechanism which are very focused on the kinesthetic quality of the movement:

1. type of movement generated
2. novelty of the application
3. potential for blurring the boundary between animate and inanimate, which relates to open-ended play

Many examples of spherical propulsion systems exist and some examples are described here. However, they do not produce a movement that is inherently intriguing.

Pneumatics or artificial muscles as they are sometimes called have some of the unique kinesthetic qualities that became important for the prototype design. Though very mechanical in some ways, the exhibited movement looks and sounds like breathing. This generates a slower and jerky movement in an autonomous object which can be intriguing and even funny. Other forms of actuation would not be able to achieve these same effects which create the infrastructure for the play patterns interesting to children. In addition, using them in an autonomous system makes the motion look like it comes from within the structure and not from a separate compressed air source.

Most pneumatic muscle implementations stem from robotics applications. In the 1950s, the first pneumatic actuators were developed for artificial limbs (McKibben muscles). Today, commercial versions for robotics applications are available through Bridgestone Rubber of Japan and the Shadow Robot Group in the UK as well as the Images Company.62

The Festo Company produces pneumatic actuators for industrial purposes, which integrate sleeving and air bladder and include sophisticated connection systems. These products are

62 One example of McKibben muscles: http://brl.ee.washington.edu/Research_Past/Biologically_Based/Device_01_Mckibben/Mckibben.html
replacing hydraulic systems in large machinery because of their clean and powerful actuation.\textsuperscript{63}

Another approach to muscle-like actuators are pleated muscles which have been used in small-scale and large-scale applications. The Free University Brussel has been at the forefront of developing this technology both for robotics and large-scale architectural applications.\textsuperscript{64} To date, Festo and Shadow Robot Company have developed industrial and robotic applications at different price points and for industrial and robotic applications respectively.\textsuperscript{63} Outside of these realms, the Technical University of Delft Hyperbodies Research Group has explored the life-size, architectural qualities of pneumatic muscle actuation.


\textsuperscript{64} VUB, Bruxelles, Belgium, http://www.vub.ac.be/
Motion Principle

The decision to use pneumatic actuators led to the selection of a wheel structure instead of a sphere in the initial prototype enhancing stability. The muscles displace a central weight thereby setting the entire wheel in motion. Six muscles in total actuating in pairs or individually enable gradual steering.

Fig. 25 Massing diagram of the major components of the prototype.

- structural rings
- compressed air tank
- electronics
- batteries
- pressure regulator
- air compressor

approx. massing for mechanical components for wheel prototype

Fig. 26 Prototype as implemented with three muscle pairs and central element.
Designing Muscle Power

The muscles needed to develop an autonomous rolling system led to a special design for integrating muscles and valves. This innovation improves on commercially available products which consist of valve manifolds, tubing and connectors at the muscle ends. The integrated system is light-weight and takes advantage of the space inside the muscles which only contract 30% thus leaving most of the interior space unused.

A new boss system (valve mounting technique) was needed to successfully integrate the muscles with the valves because traditional valve manifolds are too bulky. Surface-mounted and socket-based boss systems were developed for the smallest available 3/2 valves (produced by The Lee Co.). The adjacent diagram shows the functionality of the solenoid valve in a section. The three openings – normally opened, common and normally closed – connect the circulation system of air, the air supply and the interior of the muscle allowing air only to enter the muscle when the valve is activated. In the final pneumatic muscle design an aluminum surface-mounted piece was designed to connect muscles and compressed air because it proved the most reliable and air-tight.
Fig. 28 Building the integrated pneumatic valve-muscle units.
Fig. 29 Diagram adapted from The Lee Co. for the solenoid valve used in the prototype.
**Transparent Structure**

In order to draw attention to the muscles, a transparent poly-carbonate structure (16” diameter) was selected. Hanging by the muscles from the rigid structure are the air tank, compressor, batteries and electronics. The structure cannot be deformed, an advisable design choice in the first prototypes.

![Fig. 30 Rendering and diagram of structural system, 16” diameter.](image)

**Lessons from Building**

Implementing a muscle-actuated system led to challenges which have been clear to roboticists from their work with McKibben muscles for many years. In this case, the on-board compressor’s noise truly detracts from the aesthetic experience of the object. Cost and size constraints for compressed air systems make it difficult to envision a viable small-scale option. Using an on-board air tank was considered, but limits the overall range of the system because of constant recharging needs.
The integrated valve solution and custom-boss system proved successful and robust. This solution could be applied to muscles for other applications as well and presents a considerable innovation for systems intended to function autonomously.

The greatest benefit from the muscles lies in their kinesthetic quality which other designers have recognized as well. Architects at the Technical University Delft already hinted at the exciting potential with the programming of their Muscle NSA. “The "muscle" was a piece of architecture with "emotional states" that were programmed based on "e-motive scripts [based on rules, operations and formulas with a multitude of variables] running in real time.”65 The project exhibited several behaviors which blurred the line between animate and inanimate:

1. volumetric alterations of the external form using the muscles
2. emission of combined pre-designed sounds and at runtime generated wave samples, combining the “breathing” of the object with other ambient sounds in the physical space
3. real time graphical display of the computational process

The designers referred to the space around the muscle body as an “invisible playing field” within which the experience of this strange object takes place. Capturing the same magic for a play setting should be the goal for implementing pneumatics in children’s applications.

More potential for implementing pneumatic props should be explored. LEGO pneumatic elements are available, but they have no anthropomorphic qualities at all.66 Other construction kit additions are conceivable and should be developed.

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66 Lego pneumatics example, http://mapageweb.umontreal.ca/cousined/lego/3-Physics/Pneumatics/
Episode 5: Developing Interaction Patterns

The initial characteristics suggested for space explorers are autonomy, animate/inanimate, personality, and interactivity. Autonomous movement was achieved in an initial prototype through pneumatic muscles which also allude to the ambiguous animate vs. inanimate state of the object. Pneumatic muscles are a great technology to smoothen the appearance of self-propelled movement in a robotic device. This aspect is of great value as young children are still shaping their notions of life.

The built prototype did not serve the purpose of testing interaction patterns which would be made possible by the four characteristics of an animated playground prop defined in episode 1. The object moved autonomously providing sufficient proof that pneumatics are an effective way of showing inner-propelled movement in an object. The muscles were effectively routed to displace the central weight and offer observers an exciting impression of autonomous motion which differs from other such objects. The next steps of control and sensing were severely limited due to lack of time and the complexity of the problem. Nevertheless the ability of the object to project notions of a gradual and intriguing motion make it an exciting precedent for continued work using pneumatics and for explorations of other autonomous playground props that are capable of interacting with children in outdoor play spaces.

On Space and Personality

Simple behaviors have the potential to make a significant impact on an observer. Farber and Resnick’s experiments with LEGO-Logo creatures attest to the fact that repetitive and basic behavior patterns may evoke deeper psychological discussions. These studies relate to Braitenberg’s Gedankenexperiments about simple computational objects that could evoke psychological reactions in people.

The three-dimensional context can provide an important cue for psychological and physical explanations for an autonomous object. Even very simple responses to the surroundings prompt

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onlookers to attribute fears, goals and aptitudes to autonomous and animated creatures. For example, avoiding dark places could be interpreted as shyness.

Each personality described in the table engenders a different interconnection between child, object and subsequently space. The friendly ball gives the child a stable reference point in space as it follows you around. The constant link to the object allows the child to explore uncharted territory with one known, namely the connection between the roller and the child's location in space. Just like non-digital pull-along toys the friendly crawler transmits information about the landscape through a constant link to the child even though it is invisible.

The hurried and sluggish rollers illuminate the landscape under different circumstances. When riding a train at top speed or at a slow pace different characteristics of the landscape emerge to the riders watching through the windows. Similarly, a fast-moving roller induces running in the child who then experiences an environment at that speed. While children run around without the accompaniment of an object their experience becomes tangible through the connection with the object. Their own pace becomes something observable through the objects motions.

This type of behavior relates to Papert's notion of body syntonicity. This case extends the concept from learning about the functioning of an object through your own motion to the understanding of spatial relationships. As the object moves across the outdoor space the child is learning about the space through its
Some Personalities

This is the “friendly” explorer which moves towards a child or a group of children when it comes within a certain distance of them.

The “hurried” explorer moves very quickly enticing onlooking children to follow it at a faster pace, almost like experiencing the passing landscape on a bicycle. This interaction encourages physical activity and running.

This is the “slow” explorer which decreases the pace of play and focuses the children’s energy on details in the landscape.

The “tracing” or “slime-bug” explorer leaves traces behind for the children as evidence of their trajectories. For example, it leaves tracks in the sand, grass and snow that are created by the treads on its exterior surface. It has the ability to leave trails of sand and water on the ground that are ephemeral, but sufficient to leave marks on the landscape for the children to study.

Sometimes the explorer, the “unpredictable” explorer, moves contrary to expectations, i.e. it does not roll away when you kick it or it does not respond specifically to the topography. The motions are not intended to be aggressive or frightening, but evocative and surprising.
motion. Just like the blind man learns about the world through the transfers being related from the ground through the cane to his mind the object provides cues about the spatial surroundings and the child's relation to them.

The most tangible of all the personalities is the tracer who leaves a mark on the ground. Either by sprinkling powder or rolling on a special surface (sand, snow or otherwise) the object leaves a trail on the ground which provides evidence of the movement patterns. Children can relive their experience by retracing the steps and see the direct marks left by objects on their environment thereby enriching the natural interaction.

These characters range in their spatiality along a continuum. The tracer creates a more visible and clear connection with the environment than the unpredictable crawler who may be more interesting as a result of how it exhibits a will to explore according to its own rules. Nevertheless all the objects reveal characteristics about the space through an invisible link with the child's motions. When the child moves the object moves in relation to her only faster, slower, or leaving a trace on the ground.

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68 Curlybot uses notions of body syntonicity in an interaction with a very simple computation manipulable that learns gestures. The small creature can record a gesture and then play it back repeatedly. This type of interaction with a computational object enhances the interaction and expands the notion of computation beyond the computer screen. http://tangible.media.mit.edu/projects/curlybot/
Personality and Interactivity: Same or different?

The personalities described are essentially character traits that have been derived from the behavior, but do not necessarily amount to the type of give-and-take interactivity suggests. In this case, the response of the object relates to the actions of the child and more. The responses add another layer to the relationships between child and object. Suddenly, there is a relationship of give-and-take between the child and the crawler. There are more unexplored scenarios within this category which also presuppose a more intelligent object counterpart.

Lessons for the Future

Other types of autonomous playground props should be conceived that capitalize on the intriguing self-propelled motion enabled by an autonomous pneumatic muscle system. The ability to move through space and in relation to space engages children in the triangle described in the first part of this thesis, namely children ↔ props ↔ play setting.

One possible idea (see full-page image) would be a caterpillar-like motion generated by the muscles contracting along the sides of a sequence of air pillows which also act as miniature air tanks. This crawler mimics the pull-along toys quite literally, but adds an intriguing autonomous motion. Its slow movement further creates incentives to explore the ground and topography of a space. An initial iteration of the design can be seen in the adjacent figure.

If children are to find objects like this one in our playgrounds of the future they need to be enabled for exciting interactions. In exploring the interaction patterns with such an autonomous device the stages of interaction should be considered in future implementations.

While the child may be interested in the object as such in the beginning, questions of how the motion is generated and what experiments it might enable should arise. If the object is truly successful it should enable this type of rotation in play styles from accepting the object as magical to taking it apart as an engineering discovery.47
In all cases, the interaction will be place dependent. To quote Bill Mitchell – the game of golf depends on the existence of a golf course. Without the existence of this highly manicured space the meaning of the word “birdie” would not exist. In a similar way, children will encounter objects and digitally enhanced objects too in their play spaces of the future. As a result, designers should consider how these objects will relate to those spaces and increase the children’s ability to experience the world around them for the rich and exciting place it is while they still look back to their pull-along toy for comfort.
Each segment is made of a semi-transparent bubble (likely made out of a soft, but robust material like technogel, www.technogel.it) which serves as the air reservoir for the muscle actuation. The electronics will be contained in one of the caterpillar segments. One set of muscles on the top and one set on the bottom will serve to curl the caterpillar up and then move forward.
Fig. 33 Collage of materials for a rich tactile experience inspired by Reggio Emilia and collected at Remida.
Conclusions

(or) “In spite of the Limitations of a Prototype, the Journey Was Worth It”

The muscle-ball prototype has fulfilled some of the anticipated characteristics of a successful space explorer. First, it moves autonomously, but is not yet able to travel terrain. The movement is jerky because the objects internal sensing abilities are still too primitive.

Second, the internal muscle structure evokes the animated characteristic which led to the selection of the muscles. However, pneumatic systems in autonomous objects are excessively cumbersome. On the one hand, the compressor, air tank and valve-systems do not lend themselves to designing an autonomous object. On the other hand, integrated valve-boss holder system has proven successful. This innovative approach makes it possible to conceive of smaller, construction-kit-like pneumatic elements which improve on previous LEGO hydraulic systems, for example.

Third, the personality of the object at this point derives from its transparent nature and evocative structure. Making the object transparent was a conscious decision made in order to display the internal muscle architecture. The rigid structure was a starting point for the first prototype which can be reconsidered in subsequent prototypes. While the beautiful lattice structure can be taken apart, it forms a rigid cage. In future designs, flexible structures and malleable surfaces offer rich alternatives to the original lattice. The exterior surface materials do not necessarily have to be transparent and in fact can evoke many different personalities in their own right. Tactile and visual characteristics are described to children and contrasted with their opposites.

Finally, the interactive nature of the object requires further development. Additional sensors on the object and in the hands of the children would be needed to enable certain responses. The implementation should be contingent on the interaction patterns considered important in the set of proposed scenarios.

Given the experiences prototyping the first pneumatic roller two aspects of an enhanced playground prop are important: first the surface features, second, its behaviours. The surface features
include the sensory characteristics and technical capacities of the objects. Materials, mechanical features, design drive the sensory experience of the object. The technical features are comprised of the motion mechanism, sensing capabilities and built-in intelligence. The material studies of the Reggio Emilia schools provide a methodology for studying the tactile and visual qualities of the materials which might be used in a given object. These diagrams can be seen here in addition to a collage of materials available at the Remida Recycling Center in Reggio Emilia. The diversity of materials can be an enormous source of inspiration for designers working to develop engaging objects for children. The behaviours are the second important category because they determine the personality and the objects relationship to the spaces of play. Depending on how the object moves through the space the child will gain a very different understanding of the environment.

Fig. 34 Reggio Emilia tacility diagram and materials studies. See Ceppi and Zini (1998).
Meta-Reflections on a Design Process

Approaching the design of technologies for children from an environmental framework provides a promising avenue for enhancing outdoor play. This theory addresses not only the relationships between child and play object, but also the relationships between three protagonists, namely children – play objects – spaces. Together these three actors co-create a quality play interaction that benefits the children’s development.

If the play props are enhanced through digital technologies these relationships become increasingly complex. At the same time, the added features may detract from the experience. Children are happy to play with a brown box and may not benefit at all from augmented objects. However, their lives are increasingly mediated – whether through television, mobile phones or other technologies – and therefore it is necessary to consider their role in outdoor play spaces as well.

The nature of the technologies presents the greatest challenge for the designer of current-day enhanced play props. In her 2005 second edition of The Second Self, Turkle describes how the functioning of computational tools has become obscured since the 1980s. Increasingly, users do not know how things work they just control the parameters which are made available to them through the designers. She contrasts “transparent algorithm” with “opaque simulation”.

For very young children, part of the interest derives from the “magic” of the computational object’s autonomy. However, Piaget’s and his successors’ research shows that children (and grown-ups) personify objects even when they know them to be machines. An experience can be rich and complex even when the object is transparently simple, constructed, and obviously running on a program. Understanding the delicacy of this relationship should be the role of the conscientious designer. It is important to know that one is manipulating sensitive relationships that can benefit or harm the counterpart in the relationship.

The rolling space explorers are only one possible instantiation of the category of playground prop this thesis

addresses. Many of the characteristics described in episodes 1 and
5 could be applied to other kinds of props. These technologies thus
are not an end in and of themselves. Instead they become part of
the web of relationships tying children to their environment. In order
to enrich the experience for the children, these connections must be
studied and observed by the designer. Towards that end, the circle
of relationships between children ↔ props ↔ play setting becomes
the key framework for working and conceiving new and enriching
animated play props.

These ideas have arisen from a design exploration which
involved listening to children and independent design work. It is
important to note this profound difference to other approaches where
an independent usability study follows the design process. In an
attempt to combine analysis and design, this thesis attempted to
provide designers other avenues for exploring new digitally enhance
playground props for children of the future.
children

playground space, space for outdoor fully-body play, includes natural and built spaces such as urban environments

mise-en-scene for play
Epilogue

In the context of this discussion, robotic toys such as Robosapiens could be interpreted as harbingers of children’s increased interaction with robotic companions rather than playing outdoors and with other children. In an attempt, to open other directions for discussion I have placed the Robosapiens outdoors and allowed him or her (that is for another discussion) to interact with children in the playground. This context changes how children will interact with the object and interpret the space of which it is now a part.

Considering the potential for exploring more urban spaces in the companionship of an animated object or with a mediating device is a challenging enterprise. And it will most likely take many years before they become a reality. In the meantime, however, I think designers of children’s spaces and technologies would benefit from integrating their thoughts on how to design successful play spaces with the potential emerging technologies might hold for children in the future.
Fig. 35 P. Brueghel the Elder, Detail from Child’s Play, painting, 1560.
Bibliography

Child Development and Play


Designing Playspaces


**Technologies for Children**


Children's Geographies


**Other Works**


