

Coloring Time with CodaChrome

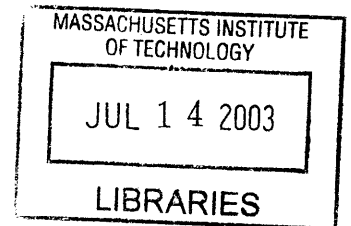
by

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Submitted to the Program in Media Arts and Sciences,
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Master of Science in Media Arts and Sciences
at the
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Abstract

As new computationally enhanced tools become available, there is an opportunity to give more and more people access to new ways for personal, creative expression. We designed a new computational construction kit to allow children and adults to design and build interactive, dynamic color patterns on electronic jewelry and sculptures. We designed activities to introduce CodaChrome, our color pattern creation environment, along with ideas about color and material properties to children in the context of immersive design experiences. The process and product of these experiences reveal the way young people understand abstract concepts related to the notions of space, time and space-time interrelationships. This thesis reports on the design and evaluation of the activities, the development of the CodaChrome system, and the evolution of our methodology for investigating the formation of concepts like synchronicity and concurrency and their dependency on spatial connotations. The presented case studies contribute to the ongoing research on the media-dependence of classic epistemological questions regarding space and time, as manifested in the diversity of children's styles in making and thinking about dynamic color animations on light modules, which can be arranged in arbitrary spatial topologies.

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Chapter 1 Introduction

The story of Alice



Figure 1.1: Alice's synchronized color sequences

Alice, a ten year-old girl, sketches the following drawing (Figure 1.1) to explain how two color sequences played out in time could be synchronized. She says: “One sequence will go through yellow and then switch off (depicted by black). And then, it will go red and then switch off. And then it will go green until it switches off again. Then the other one will go red, it will switch off and then it will go purple and switch off again. And then both of them will repeat all over again”. By looking at her drawing I can tell that she is trying to use the black color as a synchronization point to highlight the color changing. That is why they are vertically aligned; they “go together” in time. On the other hand she is compensating for the use of fewer colors in the second line, by adding three lines of each color instead of two. Given the fact that each line represents an equal time interval, it is obvious that this will not become synchronized. First I describe what I see: “You want the second one to be red when the first one is yellow.” “Yes” “But this is going to be red, while ...” She says: “... while this is green. Then it gets switched up and red and green go together one time and then red and yellow go together another time”. As we go together through a description of the things that will be happening together, I assume the role of a program that is trying to read the lines to figure out how long each color should last. I start by saying: “So, yellow and red start together, and then yellow and red again and then black and red ...”. At that point she stops me: “Oh, wait, that’s not what I wanted. I want the blacks to be together. Let’s put two lines of each color on the second line”. We go through the verbal simulation together and she likes it.

Until now, this representation has almost worked. But, two questions later the activity breaks. “Are there other ways of synchronizing this instead of changing the colors from three to two? Can you make the black last longer to make them synchronized again? Or

maybe the yellow?” At that point she changes the sequence completely to a more random one and essentially abandons the synchronization feature.

Problem Formalization

What is Alice’s difficulty with this drawing? How could it be clearer for her? If she had a different medium to describe her idea, would it help her? And why would it be important to provide such help: could the development of basic analytic skills in thinking about time, which pervades so much of our experience throughout life, be supported by computational tools more effectively than other materials? In particular, the research presented in this thesis is facing the question of how technological tools can help to reduce ambiguity and increase expressiveness and analytical thinking of children when they are thinking about effects or events that evolve over time. Particularly, I will be focusing on the medium-dependence of the tools used for the creation of such events and in particular I will argue in favor of technological tools that enable children to overcome issues in representing dynamic synchronicity, and other concepts inherent in thinking about time, like speed and duration.

These temporal events or effects are realized in the rich and interesting realm of color and light. The basic activity and challenge that the children are faced with throughout the user studies is the creation of a “**color pattern**”. A color pattern is an animated color sequence realized on small and programmable light modules.

The main technological tool that the children use to create these color patterns is the CodaChrome system, which involves hardware and software capable of programming the small, tricolor light modules (LEDs: Light Emitting Diodes) to blink on and off in animated sequence. The metaphors and representations of the temporal concepts involved in the idea of color patterns are designed in the CodaChrome programming environment so as to allow the children to visually and intuitively handle the parameters of their color patterns.

The specific temporal concepts involved in this programming activity are the issues of synchronization and the interplay between the concepts of speed and duration. With CodaChrome the children reveal part of their thinking about these issues in the process of trying to synchronize individual color patterns that reside on different LEDs to produce an overall effect. These LEDs are physically interconnected in arbitrary topologies to form a desired shape.

Design Context

The use of colored light in art has been a very strong element especially with the use of big spotlights covered with colored cellophane and has produced impressive results (Collopy, 2000). But recently it has been transformed in a different scale through the use of the small, inexpensive colored LEDs. These LEDs are now being used in jewelry and clothing, in artifacts like shoes and hats.

Children on the other hand are always seeking new means of expression through ornamentation and clothing. Technological advances allow them to create new forms of costumes, accessories and jewelry as a means of personal expression.

By combining these two facts, a nice space is created that helps the formation of a context for this study and my observations of children trying to create their color patterns: the design of **electronic and dynamic jewelry**. The choice of working with children of ten to twelve years of age and the context of jewelry for the design activity was not a random one. I chose it because the children at the age of ten and later develop a personal style, they are aesthetically opinionated. They are wearing cloths and jewelry because they have the sense that these communicate messages to other people. They are therefore capable of going after jewelry that they might want to wear if they could make it themselves. (Figure 1.2)

CodaChrome builds on the idea of traditional beading where the static pattern is realized by the beads' color and size. The electronic equivalent is the design and use of identical, programmable units (the tricolor LED modules) to create the color patterns. Therefore, the arrangement and the assignment of the colors together influence the appearance of the pattern that changes over time.

Considerations about the Medium

There are a number of different candidate media that would enable a researcher to go deeper into such issues and probably the most powerful one is video. Video as a medium and as a toolset for editing and manipulation, have evolved into the standards of exactly the representations that I am referring to. For example, the vast majority of instances of a software timeline tool stem from video editing tools, like iMovie¹. The assumptions involved in video editing have established a spatial arrangement of time representations. For example, the way to show concurrency is to overlay multiple layers of

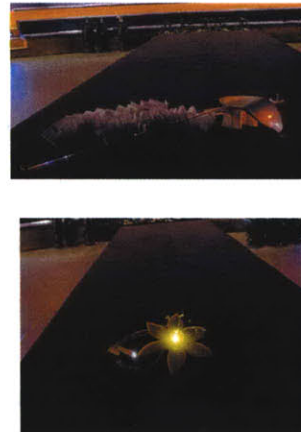


Figure 1.2: Example of electronic pieces of jewelry

media; the vertical line that sweeps all the layers **concurrently**, determines what is going to be played **simultaneously**. Another example is the model of time that flows from left to right, which as Jeanne Bamberger (Bamberger & Hernandez, 2000) notes is a cultural convention that would not work in cultures when reading goes from right to left.

Regardless of the potential of video as a good research tool, I am seeking more appropriate tools and media for children to focus easily on the temporal issues rather than the medium itself. Video is so powerful as a medium that it can easily shift the focus of every activity to narrative or pictorial directions.

Color on the other hand is very powerful as a modality, but less obstructive to the complicated cognitive processes of creating temporal effects or behaviors. Color is not only a more approachable idea in the context of designing electronic jewelry and accessories, but also can resonate more with the activities of young children who are using colored pens, pencils, markers, crayons for drawing on paper, on boards, on glass, on walls – and the list goes on. Can a tool be invented with which children can color time? This question will remain until the last user study in Chapter 5, where the children will color their daily schedule and will “shrink” their day into one color pattern.

My choices

The connection between color and time in the context of this study may not be apparent, especially in combination to the programmable light modules. So, “What’s the big idea” (Papert, 2000) that connects all of the above in a coherent and informative story? I believe that there is great power in the idea that a few LEDs, when combined, can create a kind of display. The combination of the colors on each of the LEDs constructs the greater image displayed. The synchronization of all the LEDs, when they flash the right color and then switch among colors at accurately timed intervals, creates an animated image or video. Great power is included in operations that one LED performs and the motion of the image on any display. In other words, the change of scale between the timing of the LED and the timing of the dynamism in the image are two different things that happen in parallel and are closely linked to each other. This difference in time scale between the one LED and the overall effect of virtual motion on static physical spots² describes exactly the idea behind CodaChrome. The tricolor modules with their respective color patterns, when synchronized properly, will produce an overall effect.

I lead children through this progression from the small, or micro, scale to imagining the overall, or macro, effect. I observe some of their facilities and difficulties, focusing on their understandings of temporal issues necessary for the interchange between the micro

and macro scales. This change in the scale of the programming, translates directly to the change in scale of the child's perception of the activity, which in turns shapes the child's understanding of this micro-world. The process of the interchange of the child's perspective between the micro- and the macro- worlds is described by Edith Ackermann (Ackermann, 2001):

“...both “dwelling in” and “stepping back” are equally important in getting such a cognitive dance going. How could people learn from their experience as long as they are totally immersed in it? There comes a time when one needs to translate the experience into a description or a model. Once built, the model gains a life of its own, and can be addressed as if it were “not me.” From then on, a new cycle can begin, because as soon as the dialog gets started (between me and my artifact), the stage is set for new and deeper connectedness and understanding.”

Concluding, the children through the use of CodaChrome will program each individual LED with a color pattern aiming at an overall effect that will be produced by their aggregate. Therefore, the children, while manipulating the overall effect, will go through the “dance steps” mentioned earlier between the micro-scale –the individual pattern– and the macro-scale –the overall effect– and they will develop connections between properties of the two. For example, they will deal with the issue of synchronicity, when they will try to make two or more LEDs flashing at the same time throughout the pattern. Finally, during their manipulations of the color patterns, they will figure out the connection between its speed and duration, when they will see the color pattern become longer as the speed becomes slower.

Contents

This document is structured in the following way:

Chapter 1- Introduction

The main idea of the thesis is presented here through the narration of an incident with a CodaChrome user. It is followed by the introduction of the key research concepts related to time and design context of the study: the design of electronic jewelry.

Chapter 2 – Background and Related Work

The foundational work is presented here, in a manner that reflects my personal ideas, questions and approach to the current research. It specifically contains related, foundational learning research about concepts related to time, as well as background work about color science and the basis for the color concepts that I will be dealing with in the design of the system.

Chapter 3 – Methodology and Workshop Design

The methodology has evolved considerably over the course of the study. It has been influenced mainly by the design and the results of the user studies and are therefore, presented in conjunction.

Chapter 4 – The CodaChrome System

This section presents the main technological work done on the CodaChrome system, including the hardware, namely the Tower System and the Tricolor LED modules and the software, programming environment.

Chapter 5 – User Studies

The lengthiest body of the thesis is presented here in the course of three user studies. They are described in detail starting from the activity design, the description of the implementation, and finally the results. The three major sections are: The Electro-Jewels workshop, the CodaChrome workshop and the user studies performed with the Light Sculptures. Especially in the third section, the stories of the participants are interchanged with personal reflections and observations.

Chapter 6 – Conclusions

The outcomes of the user studies and especially the results of the third user study are presented in this separate section. Different observations and data across the various studies with the children are assembled here to formulate the conclusions of the current research.

Chapter 7 – Future Work

The valuable experience gained from this research work is gathered in this chapter with concrete examples and ideas of what potential next steps could be taken after the study. The suggestions and reflections are a result of the experience with the system as well as with the design and organization of the user studies.

Chapter 2 Background and Related Work

-Going faster can take more time- From the moment that I was acquainted with Piaget's experiments that could lead to a statement like this, I was captivated. This statement provides for me a powerful urge to search for the concepts and models that could lead a child to such a conclusion. How can a young child form this self-contained and seemingly robust and consistent model of time and speed? What is the intuitive association that produces such conclusions according to a child's judgment? What changes as they get older? Which other concepts form the notion of time as children grow up? And finally, what is the role of technology in the formation and development of such concepts?

As I set off to explore the mesh of concepts and processes behind these questions, a number of powerful books, articles, ideas and people provided the necessary context for my study.

2.1 Jean Piaget and Constructivism

2.1.1 Piaget on Space and Time

Piaget performed a number of experiments with children of different ages that provided insights into the stages of formation of temporal and spatial concepts. His research contains a breakdown of the concept of time into more specific concepts that are formed in a particular sequence and build up into the understanding of "time". These are the notions of succession, simultaneity, duration, and synchronicity (Piaget, 1946).

One of the most well-known experiments was the movement of two turtles with different velocities, so that one would travel longer than the other in the same amount of time (Piaget, 1946). Another was the filling of two bottles with the same amount of water

coming from a tap with the same flow (Piaget, 1946). The two bottles had different shapes and sizes, and the children had a very hard time deciding which one was more full. All variables that would appear in these experiments were controlled, so that the probability of a false result would be minimized. Such an example was the linguistic problem of distinguishing among issues of time and space with words like before, after, longer etc.

Piaget has concluded that the coordination among time, velocity, and space is very difficult during the early years and the time and space framework are interlinked and hard to tell apart, which leads to confusion. Also it is hard to apply egocentric assimilation (Gruber & Vonèche (eds), 1995) to two objects moving at the same time and intuitions can be confusing, especially when the notion of velocity is separated from time and space and not a connection between the two. This last remark has led children to the following misconception: "... going faster can take more time ...". Although it may seem strange, the above description explains how such a thing has come about: 1) if you go more quickly, you cover more space 2) to cover more space, you need more time, therefore 3) if you go more quickly you need more time because you cover more space!

Closely related to the above results were the research findings that the notion of time for young children is not continuous, but has identifiable intervals where time simply runs by and other intervals where time is perceived as idle, as is the case with the perception of age indicated by answers like: "now I have three years of difference with my brother but when we grow up we will have the same age" (Piaget, 1946). This answer reveals also the strong relationship between the concepts of time and space (in a few years the two brothers will have approximately the same height) and actually a lot of the confusion in young ages about time stems from this relationship with space. An additional finding was that the children's answers to what an adult would call "self-evident" questions, although were contradictory to what was being observed, were consistent with each other and with the model that the child had already constructed for the way the observed situation worked.

2.1.2 Constructivism

Piaget's methodology involved the repetition of a number of experiments across different ages (and different developmental stages in Piaget's terminology). The researchers would participate in the experiments in order to probe the children deeper. They would repeat small variations of the experiments to challenge them as a means of expressing the contradictions they faced with their inner model.

Piaget has produced a great body of work during his lifetime (Gruber & Vonèche (eds), 1995). His work was continued by some of his colleagues³. He has studied extensively different concepts and abilities that children develop during aging and has defined the

idea of developmental stages. Children as they grow older, go through consecutive stages of development. Each stage categorizes their basic understanding and skills, as well as the concepts and notions that they find more difficult to comprehend than other.

Beyond the idea of developmental stages, Piaget states through Constructivism that knowledge is constructed at a very young age in people's lives. We are not born with an inherent understanding of various concepts that are part of a child's reality. Instead, we construct such concepts as we go through various stages of building mental models to understand and interpret the world. Such models typically last throughout our adult lives.

Piaget's theory of Constructivism and his foundational work on *Epistémologie Génétique* (Gruber & Vonèche (eds), 1995) have provided significant background for this work. Jean Piaget's great legacy includes classic books such as, *The Child's Conception of Time* (Piaget, 1946) and *The Child's Conception of Space* (Piaget & Inhelder, 1948), where he describes, analyzes and elaborates using a number of experiments on the nature of concepts related to space and time across different ages of children.

2.2 Constructionism

Being a student at the Epistemology and Learning Group at the MIT Media Lab⁴, my research was bound to be influenced by and to acquire some of the characteristics that guide and condition the research conducted within this group. Seymour Papert has played a key role in shaping this research through his ideas, his creation of the LOGO language (Papert, 1980) and one of his corner-stone books: "Mindstorms: Children, Computers and Powerful Ideas" (Papert, 1980) which describes Constructionism in terms of its principles, methodology, technological tools and socio-cultural mind shift needed for more meaningful and natural learning to take place.

One essential Constructionist notion is that some of the most effective learning happens through the design and construction of physical objects that the learners care about deeply. Seymour Papert (Papert & Harel, 1991) tells the important story of the Soap-Sculpture Math class, an idea of how a learning environment could be if the qualities of an art class where the children make soap-sculptures and math would become one. The students though their involvement in design and math activities would provide us with examples of learning-rich experiences, where students would learn, use, and invent math concepts according to their individual pace and learning style for their personal expression through the design of the soap-sculptures.

Another equally important Constructionist idea is the opportunity for learners to reflect on their learning process not only in refining their creations through reconstruction but

also by articulating their ideas when sharing their creations in a social setting.

The creation and application of intuitive, open-ended, and cognitively and socio-culturally resonant tools that enable children and novices to engage with the material quickly and in their own styles is central to the Constructionist methodology. (Turkle & Papert, 1992)

2.3 Messing About with Time by Seymour Papert

Seymour Papert in his paper: “Computer as Material: Messing about with time” (Papert, 1988) describes a number of activities and constructions during an on-going project at the Computer School in New York. The children used tools ranging from the computers and the LOGO programming language to egg cups to “mess around” with the notion of time.

Starting from a simple activity where the children had to produce a time measurement method, they went on to make more reliable contraptions that would perform measurements independent of the conditions of the environment. For example if the method chosen was to count based on one’s heart beat or counting “One Mississippi, Two Mississippi ...”, the result would change according to environmental conditions, e.g., background music.

Papert continues to describe the way the children expanded the clock-making activity once they started having questions about their methods of counting time. The children made self-invented clocks out of various materials and by using LOGO and the computer. Alternative explorations without the use of a computer also took place.

The more their questions, constructions and goals were instigated by their daily activities, and not just school work and life, the more they would bring their activities and contraptions to another level of sophistication, devising complex (sometimes mathematical) concepts to make a valuable addition to their artifact.

After they were comfortable with “messing around” with time, the activities evolved “BEYOND MESSING AROUND”. For example, computers became more accurate clocks but they still needed calibration if they were to be compared with the standard second. This introduced the mathematical concept of the average value.

The role of the computer and the LOGO language proves to be a very central one when dealing with contraptions that needed accuracy as well as a higher degree of adaptability or flexibility. For example, the speed of the LOGO clocks could be easily modified by varying the time of the WAIT command.

Overall both the computer clocks and the other types of clocks formed the basics of

a rich and fulfilling activity for a whole classroom for a number of weeks. The activity transformed into a creative, inventive and fun exploration of the notion of time, messy at the beginning, and rich as well as constructive at the end.

2.4 Edith Ackermann – A Bridge between Constructionism and Constructivism through Situated Knowledge and Media Dependence

The viewpoints of Constructionism and Constructivism are combined in a remarkable way in the work of Edith Ackermann (Ackermann, 2001). Ackermann materializes the ideas behind the child's developing notions as expressed by Piaget and Papert. She provides us with insight about how the two can be viewed and studied as complementary to each other.

In her description of Piaget's viewpoint, she perceives the process of distancing oneself from a situation as a necessary step in learning and understanding, "... there are moments when we need to project part of our experience outwards, to detach from it, to encapsulate it, and then reengage with it." (Ackermann, 2001). Piaget through his developmental stages theory provides a framework for expressing what is cognitively possible at different ages, looking at the aggregate.

On the other hand, part of Papert's viewpoint is based on the idea that the learner dives into unknown situations and by looking at situations and problem under different lenses, is able to bridge incompatibilities in one's way of thinking. Papert looks at the situated or connected intelligence and engages the learner in situations where the key to learning is "becoming one with the phenomenon under study" (Ackermann, 2001).

Ackermann also takes the position that Piaget and Papert take a common view towards the fact that children are "... building their own cognitive tools, as well as their external realities". They also share "an incremental view to knowledge construction." (Ackermann, 2001) Underneath that though, their main difference in what they are seeking to find is how to construct internal stability for Piaget and the dynamics of change for Papert.

Ackermann revisits a classic experiment of Piaget's, the Water-Level experiment, taking into consideration the "constructive role of specific contexts and media, as well as the importance of individual preferences or styles in knowledge acquisition". (Ackermann, 1990) In her attempt to do so, she utilizes new elements introduced by Papert, like the idea of the more powerful manipulative that can lead to richer explorations by giving richer media to the children to represent their concepts and ideas with.

The original experiment was designed by Piaget and Inhelder (1967) to study children's

progressive construction of a stable and external frame –the coordinate system– necessary for describing orientations and movements in space. Children are presented with the following task: they see a cylindrical bottle partially filled with liquid. The bottle gets turned around and covered with a cloth to hide the water-level. The children were asked to draw the anticipated orientation of the water-level when the container was presented in different static orientations (Figure 2.1).



Figure 2.1: Different bottle orientations

Piaget and Inhelder (1967) grouped children’s responses into three main stages, including various substages as a progression towards the development of the coordinate system.

Ackermann uses the Differential Approach (Ackermann, 1990) to pay particular attention to the singular paths and learning curves. She looks closely at how individual children deal with particular contexts and how the different media shape the children’s representation of the phenomenon. The extended set of media that she uses in her experiments includes drawings, gestures, and verbal descriptions. She also extends her study in comparing both experiments in terms of how children translate similar drawings based on the data that they had available.

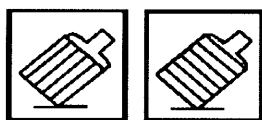


Figure 2.2: “The water is flat and goes towards the neck”

(Images 2.1 & 2.2, are included in (Ackermann, 1990) and copied with permission from the author)

One example out of multiple such cases is shown in Figure 2.2, where it may seem that the child expanded the content of the bottle until the tip, whereas in words the child was saying: “the water is flat and goes towards the neck”. It does not mean that the bottle gets filled up with water.

Some of the concepts and ideas presented here have influenced the design of CodaChrome, its research questions and its tools. They are mainly three: First, the medium that children use to express their beliefs, is important and depending on its affordances it may help children to express their ideas in a variety of imaginative ways. Second, some of the intricacies of space-time interrelationship usually affect the representations that children create especially when their observations include an event that changes over time (like the motion of the water toward the rim of the bottle). This may lead to activities and tools that carry the spatial aspect of temporal concepts into account or eliminate it. Third, this dialog or interplay between the observer and the phenomenon is important to the structuring of the activities with CodaChrome, because of the phenomena that children will have to model. In order to succeed, they will engage in a

dialog with the materials, first assuming the role of the driving force of the phenomenon and then stepping back and seeing it from a distance until the ideas behind its behavior are resolved and incorporated into their model.

2.5 William Friedman – About Time: Inventing the Fourth Dimension

The major focus of the previous sections has been the description of the various underlying directions in the shaping of this research. The already presented work shows not only the framework for this thesis in terms of the learning research, but also the research results on the children's understanding of notions of time. William Friedman's book titled "About Time: Inventing the Fourth Dimension" (Friedman, 1990) addresses the nature of Time. Friedman is a scholar on issues of time and has conducted experiments that dealt with children's representations of time and space. He describes issues related to time by analyzing it from a variety of scientific angles. These are related to how time can be perceived within a culture, how memory can be closely connected to our realization of time, what are the prevalent representations of time, etc.

One of the most elusive aspects of the notion of time is the fact that it depends a lot on human psychological and cognitive processes. Past time may seem to us to become "elastic" over the years; some events might seem long ago and some others like yesterday. Time then becomes dependent on our memory for estimating durations in the past, or dates that certain events took place. For example, we might remember a time of the year based on the weather conditions or the people around us. We might remember with great accuracy the time that an event happened because of the clues that we have kept in our memories to testify that (was it day or night?). The duration of events thus becomes relative to how we remember them; a time filled with memories, activity and changes in everyday life could seem to have taken longer than other moments in time where the everyday routine and the repetitive nature of our activities cramp a lot of days into one single memory. And since time derives from our memories, it can get distorted as "information is lost, schematized, reorganized, or embellished" (Friedman, 1990).

In contrast to the above subjective models of time, there are ways of representing time in a more objective way like with clocks and calendars. Friedman writes: "The clockface has become the dominant image of time, but if we look around us, we find other representations, numerous and varied. These range from the successive frames of comic strips to physicists' diagrams of relativistic space-time and include the circle of the zodiac, historical time lines, and train schedules along the way." (Friedman, 1990) Some of these representations capture time patterns and others not as well. An example of a representation of cyclic time is the week cycle in calendars, clocks, even waveforms. On the

other hand a digital clock or display doesn't capture such time patterns as successfully.

The various representations involve different sets of trade-offs. The idea that different forms of representation favor different kinds of information, is important when considering the mental processes involved. There are many examples of such representations. Scientific graphs and illustrations usually depict time as one axis in a two-dimensional plot. In these graphs time is continuous and endlessly dividable, rather than a succession of states. Calendars mask the continuous change from one day to the next. Musical notation emphasizes order, duration, and simultaneity, but repetition is only symbolically portrayed.

Friedman observes the pervasiveness of spatial representations of time and elaborates:

“... There are exceptions of course, such as the verbal rule for the number of days in each month, our recitation of lists of the days of the week or months of the year, and literary metaphors of time. But the spatial arrangement of symbols is so frequent a format for representing temporal relations that one wonders whether there is something psychologically natural about it. [...] Even at an intuitive level, though, we can see why space is so successful a medium for modeling time. It allows us to freeze a succession of times that never, in reality, coexist. We can scan at will the parts in sequence, mimicking the passage of time, but are able to return again to the start or any other part of the pattern. With ease we can perceive relations that never could be experiences in the flow of time itself because only one part of a time pattern is ever available to sensation.”

A lot of the aspect of what is generally called the “Meaning of Time” remains intensely personal and therefore hard to extend to generalizable conclusions. However, there have been cases where people seem to share associations relating to time. Specifically, Philip Seymour asked a group of one hundred Scottish students to report colors and other associations to the months and seasons. (Friedman, 1990) “Not surprisingly green, yellow, and blue were frequently given for the spring and summer months, brown for autumn, and white and gray for the winter months.” Associations to seasons included climate and vegetation as well as activities, holidays, and moods.

2.6 Color and color theory

2.6.1 Human Vision and Color Perception

To understand better the issues of color, one has to look deeper into the sciences that are related to the human perception of color and human vision. Light is a form of

electromagnetic energy that can be specified by its wavelength distribution. The human eye can see only a small portion of the radiation, within the narrow wavelength band of 380 to 780 nanometers (nm). This radiation, when reaches the eye, produces a variety of sensations. Color is one such visual sensation created by the light of many wavelengths. Therefore, according to the spectral distributions, generally, but not necessarily, people perceive different color. A color stimulus therefore, is specified by visible radiant energy of a given intensity and spectral composition. (Netravali & Haskell, 1995)

The human retina contains predominantly three different color receptors (called cones) that are sensitive to three overlapping areas of the visible spectrum. These three receptors' sensitivities peak at approximately 445, 535, and 570 nanometers, called blue, green and red respectively (Netravali & Haskell, 1995). Each of these three receptors gathers the energy of the incident light at various wavelengths proportionally to their sensitivity at that wavelength. The resulting numbers are primarily responsible for color sensation, which is the basis for the trichromatic theory of color vision. (Netravali & Haskell, 1995)

The two photoreceptors identified in the retina are the rods and the cones. Cones are responsible for spatial acuity and color vision at normal daylight levels, while rods are responsible for low light vision. At light levels of an intermediate range, both cones and rods provide vision. (Netravali & Haskell, 1995)

Color may appear different based on the conditions under which it is observed. The perceived appearance of a color stimulus depends upon many factors. Color perception relates to such effects as simultaneous contrast (the produced effect from placing two colors side by side), successive contrast (the complementary afterimage that appears after an object has been removed from view), accidental color (the result of injury in the eye) and color constancy (the accommodation of the eye to changes for changes in illumination). (Leland 1985).

2.6.2 A Few Definitions about Color and Light

Complementary Colors: A pair of colors is called complementary when the colors produce any tone of gray when mixed in equal quantities. The complements of the colors of light are different from those of pigments.

The nature of black: The impression of black can be created by the absence of light transmission or reflection by a material. No black is absolute: in practice even the darkest material reflects at least three percent of incident radiation. A pure black is rarely found in the natural world, and early conceptions of black seemed to encompass any color that is dark, including browns and blues. A near, but not perfect black can be produced by mixing

complementary colors, or the three subtractive pigment primaries: red, yellow and blue.

Hue: Hue describes what color is present (red, yellow, green, etc.) and this can be related to the dominant wavelength of the light source. (Pennebaker & Mitchell, 1993)

Value: Value describes a portion of the graduated scale with grays of different lightness. The scale ranges from white to black. These values show the progression of lightness at the perceptive level without any reference to the quantity of light that the various shades of gray reflect. (Pennebaker & Mitchell, 1993)

Brightness: Brightness describes the intensity of the light (revealing whether it is white, gray or black) and this can be related to the luminance of the source. (Pennebaker & Mitchell, 1993)

Saturation: Saturation describes how vivid the color is (very strong, pastel, nearly white) and this can be related to the purity or narrowness of the spectral distribution of the source. (Pennebaker & Mitchell, 1993)

Chroma: This attribute describes the intensity of color. It is the difference between a color and a neutral gray at the same value. (Pennebaker & Mitchell, 1993)

2.6.3 Introduction

It is not by pure chance that just about everyone can answer the question: “What is your favorite color?” In our daily life we use a variety of color-coding systems that have been developed because of the simple and effective way of communicating simple and comprehensible messages. Color can serve as a medium for communication in multiple levels ranging from strict function, like the color-coding of safety signs, to pure expression. Even more important than the reasons above, color became prominent in CodaChrome because it is a powerful and expressive medium.

2.6.4 Color as an expressive medium for children

Color has always been part of ornamentation and jewelry making partly because of the materials used in their construction, like the precious or semi-precious stones that produce an abundance of different colors based on their texture or light effects. Modern jewelry designers use colored light as another one of the materials at their disposal (Watkins, 2002). This recent trend in the use of colored LEDs has penetrated the accessory and fashion design, and has been commercially successful in children’s fashion, e.g. children’s shoes with flashing lights.

Children have been using colored markers and paints in their drawing activities and art

classes for a lot of decades. Although markers and paint are widespread in various children activities, children don't have equal experience with using colored light. The tools they are using (the markers, crayons, pencils) cannot be mixed to make their preferred color with the exception of water colors. All these alternatives are restricted to a certain degree by the original set of available hues and tones, regardless of how large or small it is.

Children nowadays are also exposed to drawing activities using computers, where the use of various color palettes helps the creation of more meaningful color combinations and drawings. But how often do children get to wear the outcome of such activities the way that they would wear a piece of jewelry. Similarly, when children engage in the crafting their own piece of jewelry, little of the interactivity and dynamic effects accomplished on the computer can be transferred onto such objects.

My first and foremost drive has been the development of the right toolset for children to engage in a dual activity: first, they will make their own colors, and second, they will use these colors to express themselves in a variety of ways. With CodaChrome, children will have the chance to blend the interactivity of computation, the expressiveness of colors and the creation of personalized artifacts in one activity. It will enable children to make their own jewelry, or to create representations of their daily schedule, or in general, to describe temporal relationships through the creation of animated color sequences.

If children had the tools to help them utilize colors as a means of expressing different aspects of their lives, how would they use them? What things would they express or model with color? And as the title of this thesis states: How would they color time? Would they use color as a way of expressing parts of their day or week? Does such a concept of using color to describe their day resonate with them?

This changing nature of the color pattern over time enables people to create temporal points of reference. For example, someone might say: "I remember that when that LED was green the one next to it was yellow and when both of them were red, a sound was heard" or "The moment that this one goes on, I want the other one to go off". The use of color as a temporal point of reference can extend our means of expressing temporal information or relationships.

Additionally, the use of color by children could also be studied as an extra source of information about their way of thinking and the activity they engage in. Johannes Itten in his book "The elements of color" (Itten, 1970) describes results from his studies of subjective color and color combinations and finds them closely related to the individual. He concludes by connecting his results to the education of children. He highlights the importance of their individual artistic preferences in the learning process.

“Education should naturally give every child the opportunity to evolve organically out of himself. Therefore, educators must be able to recognize the aptitudes and potentialities of their pupils. Subjective color combinations are one key to identification of the individual’s natural mode of thinking, feeling and doing.”

Although the last point appeals more to a psychological approach in the design of tools and activities, it is nevertheless an interesting additional viewpoint to the children’s ideas about color. Another viewpoint is Munsell’s idea that children should be restricted in using solely low-chroma pigments, because they were not skilled enough to properly control high-chroma pigments. Should all of the above be true, an extensive study is in order about the tools and functionality suitable for expanding the children’s natural tendencies towards color as a personal expression. It might also prove useful in the structuring of meaningful educational activities for a wider group of children. A small part of the CodaChrome user studies has revealed different styles of color combinations used by children while describing daily activities.

2.6.5 Color in CodaChrome

My goal here is to address issues that I was faced with in designing the CodaChrome palettes. Through the evolution of my knowledge around color issues, I have identified some of the important ideas that in my opinion that guided my steps through the fascinating space of color.

Part of my original descriptions of the CodaChrome system, included the creation of color patterns by drawing a line on a color palette. I didn’t know at the time, how many definitions the term “closeness” of two or more colors might have. The prominent color palettes that I had encountered until then were the RGB palette, based on the Red, Green, and Blue primary colors, its complementary CMYK palette (Cyan, Magenta, Yellow, Black), and the HSB palette, which stands for Hue, Saturation and Brightness.

These palettes are usually just two-dimensional projections or approximations of how the three-dimensional color space is structured. In other words, they don’t convey much information about the shape of the color solid –a three-dimensional representation of a color space– and the arrangement of colors in it. For example, the color solid for the RGB color space is a cube that has white and black in opposite corners, and the primary and secondary colors appropriately arranged on all the other corners. The spatial arrangement of colors in relation to each other makes it possible to indicate progressive passages from one color to another with a minimum degree of ambiguity.

The RGB color palette was the first color space that I was acquainted with. The RGB

color space is used when dealing with the computer screen and consequently used by all the graphic design software that I had interacted with. The LEDs are programmed using the RGB description of colors.

A quick look on an RGB palette will reveal its bias towards its primary colors, manifested by red, green, blue, and their gradients taking up most of the space. A line on this palette will inevitably produce a color sequence, which will be biased towards these three colors.

2.6.6 Systems of Colors and the Munsell Color System

The goal of most color systems has been the modeling of the “human color transfer function”, that is the way that the human visual system (HVS) transforms a radiation stimulus into color appearance. Such systems typically apply scaling factors to color attributes based upon measured parameters of human psychophysics (Jacobson & Bender, 1996). Some systems have been based on different primary colors, others are just arranging the primary hues differently on the color circle.

Some of these color systems are influenced more by the psychology of color perception. Psychologists like Ewald Hering have expanded the scope of color science by expressing the view that despite the facts about measured light and retinal response that produces color, its experience remains subjective and personal. He also devised a system of color organization around a triangle, with pure color at one angle, white at the second and black at the third, which became the basis of Friedrich Wilhelm Ostwald’s color system and later of the Natural Color System (NCS) of Sweden.

Faber Birren has studied color perception and the way it is influenced by the context in which the colors are seen. Birren created the Color Triangle based on the idea that “in perception the visual process (particularly the brain) tends to classify the world of related colors into seven forms.” The Color Triangle indicates white, black and pure color as primary sensations. In secondary forms white and pure colors produce tints; black and pure color produce shades; black and white produce gray; and black, white and color together produce tone. (Birren, 1987)

Other systems include the chromaticity diagrams, which are mathematical representations that relate to color-matching properties of the eye to ensure exactness. These chromaticity diagrams have an objective basis of analysis, free of visual limitations. The CIE system was recommended by the Commission Internationale d’Éclairage (CIE), is important to scientists that need a mathematically precise system that correlates color to the properties of the eye and the wavelengths of light. The system is based on additive color mixture and its advantage is that the position of every color in relation to each primary is calculated

and can thus be accurately noted. The disadvantage is that the distances between hues are strongly distorted in parts of the spectrum.

Munsell Color System

The Munsell Color System (Figure 2.3) arranges colors in scales of visually equal steps.

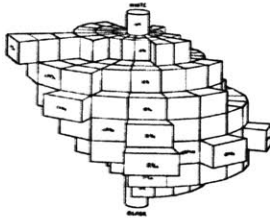


Figure 2.3: The Munsell Color Solid

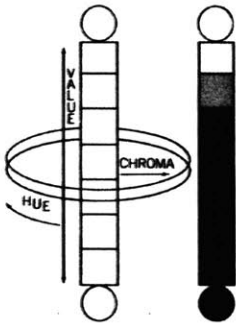


Figure 2.4: The Hue, Value and Chroma coordinates.

(Creative Color, (Birren, 1987))

The color system is organized in a number of charts separated by basic hue, called the Munsell Book of Color (Munsell Book of Colors, 1942). A color solid constructed out of these charts resembles a distorted sphere. The three coordinates of Munsell colors are: Hue, Value, and Chroma. The equator is the basic circle of pure colors. There are five principle hues: red, yellow, green, blue and purple and five intermediate ones: yellow-red, green-yellow, blue-green, purple-blue and red-purple. The hue circle is arbitrarily divided in 100 steps. The perpendicular axis is the black-to-white scale (value) that ranges from 0 (pure white) to 10 (pure black). From the value scale outwards is the open-ended chroma scale that could reach 14-16 depending on the strength of the colorant, such as yellow. A color is described in the Munsell system as H V/C, where H represents the name of the Hue, followed by two numbers representing Value and Chroma (Figure 2.4).

Two aspects of the organization of colors in the Munsell system produce interesting properties for the design of color palettes in CodaChrome: the visually equal distance between the Munsell colors and the careful arrangement of the colors onto the color solid.

A first major implication of these properties is the ability to draw a line through the Munsell color space that will yield colors with visually equal

distance from each other. Furthermore, these colors are going to produce a balanced result. There are three distinct color paths that produce such balanced results:

First, a vertical path can extend from black through a basic hue to white. Equal departures either way from the middle hue must balance, e.g. R 5/5 (red) will extend from black to white, whereas R 3 will extend until R 7, etc.

A second path follows the equator where the hues can be combined with their neighboring colors, either one or two positions away, e.g., R matches RP and RY (its shades) or P and Y. The path can extend to the opposite side of the hue's circle to the complement of a hue—instead of neighboring colors—e.g., R can match its complement BG (blue-green).

The third path extends across space because it is neither horizontal nor vertical, but inclined. So if the point of origin is middle Red, it can pass upward out of Red toward lighter Purple and downward from Red into darker Yellow. This is just one example of the many positions that this line can assume.

The above paths provide us also with information about the area that each color should extend in order to appear balanced in the mixture. If a color is strong it should be mixed in less area with other colors that are not so strong to produce a balanced result. Therefore, in the example of the third path, if we draw a line between bright yellow and its opposite purple-blue we will get the result of the rule above, i.e. Y 7/9 & PB 3/4. In order for the two colors to appear balanced, the area with the stronger color (yellow) should be less than the weaker color (purple-blue). One quantitative way of formalizing this difference is given by the inverse proportions of the products of Value and Chroma (Birren, 1969). In the case of the two colors mentioned earlier, yellow and purple-blue should be used in proportions equivalent to $(3 \times 4 =) 12$ over $(7 \times 9 =) 63$. (Figure 2.5)

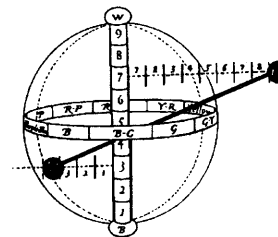


Figure 2.5: Balanced color combinations on the Munsell color sphere

(Munsell: A Grammar of Color, (Birren, 1969))

2.6.7 Color Harmony, Color Experience and Expression

Harmony is usually talked about as a pleasing combination of two or more colors. Harmonies are subjective; there exist some color combinations that some people find agreeable, while others find the opposite. There are scientists who argue in favor of the objectiveness of harmony based on physiological phenomena in color vision. In particular it is argued that the eye's afterimages and the studies of color luminosity encompass the rules for the harmonic –balanced– relationships among colors. (Itten, 1970) The definition of harmony seems elusive because of the subjectivity of color perception among different people. One person may differ from another in color perception due to differences in the psychophysical response, or even due to cultural differences. (Bender, 2001)

Although our perception of color may differ from person to person, experimental research suggests that our reaction to color relationships is universal. Consequently scientists argue that color harmony and its rules can be defined objectively. These color relationships are the “patterns of color combinations that constitute experiences of color, each with their own ‘character.’” (Jacobson & Bender, 1996) Specifically, if we put two colors together, side by side, some interaction will be caused between them. For example, if two complementary colors are seen together, the contrast effect created between them will highlight both of them. If the combination of two colors is not “harmonious”, then

both colors will appear dull.

These “experiences of color” are color combinations that either interact with each other to produce harmonious effects, as the contrast of complementary colors, or dissonant effects, which –as in music– produce unresolved tension to the observer. They could consequently be described as “active” or “quiet” or “loud”.

Scientists argue in favor of the existence of universal rules on how people react to experiences of color, because when asked to describe such experiences, they invariably characterize the result. Therefore, “the relationships among internally generated colors are, in many respects, universal, and this relatively free from individual and cultural influences”. (Bender, 2001) The subjective and personal judgment comes at a later stage, to characterize such an experience as “pleasing” or color combinations as “beautiful” or “ugly”. (Jacobson & Bender, 1996)

Concluding, the parameters that vary how people will react to different experiences of color can be studied. The results of color interaction can influence the design of tools for the creation of powerful visual communications with color. (Jacobson & Bender, 1996) In the case of CodaChrome, if such relationships among color combinations had been incorporated into the creation of the color palettes, the children would be able to choose from custom palettes depending on what message they wanted to convey through their color patterns.

2.7 Tension

The directions analyzed above provide a very rich foundation for my research, but in the process of trying to remain true to all of the above I found myself revisiting my research directions multiple times without ever feeling that I am true to all of them. To be more precise, here is what I mean:

In the original research conducted by Piaget (section 2.1.1) and his experiments revisited by Edith Ackermann (section 2.4), the objects used in the experiments were objects of the children’s everyday life. The results were made even more compelling when the children under the pressure and the paradoxical nature of the experiment would observe different things than if they were asked more casually about what they see. The same everyday objects –versus the new technological tools that children hadn’t seen before, like the Tower system– was maintained in Ackermann’s experiments, only the children had a different medium of expressing their thinking. But the observed object remained the same and very close to what they see daily, a glass bottle filled with water.

On the other hand, in my studies I talk about new artifacts that the children are making

and we are observing their making of these objects. Adding to that, the objects are built by technological tools that are currently being developed and introduced to the children for the first time. So where is the recognizability, or persistence of objects, that could justify the Constructivist foundation that I am claiming?

Equivalently, on the Constructionist side of my research, the questions that I was getting at could become the focus after a very long relationship with children where the construction activities would evolve over a long period of time. Then the social setting of the workshops and the nature of the activities will have contributed to the development of a common vocabulary and new approach to thinking about temporal issues among the participants.

It already becomes apparent that much of this tension translates into other types of dilemmas during the methodological evolution of the study that will be described in the next chapter. As a forward to it and to conclude this path through the inspirations and foundations of my research, I will foresay this: The connection between all of the above started to take shape for me after the conclusion of my user studies.

Now it is more clear to me that because of the nature of my questions, I needed a better and longer relationship with the children to arrive at the temporal issues at a commonly formulated pace. From a combination of a clinical structure of my later user studies and a different type of construction than creating an object from scratch, I found the connections with Constructivism in the structure of some of the experiments reported. I discovered the connection to the Constructionist aspect of my research when I redefined the idea of a construction personally meaningful through the creation of behaviors and dynamic events on already constructed pieces. I discovered Ackermann's work as the connecting link between the theoretical work and the path that I had chosen (out of a lot of different paths that I could take) in the situatedness of this medium within the creative and expressive tools that can appeal to children, teachers, pedagogues, and learning scientists alike.

Chapter 3 Methodology and Workshop Design

The questions guiding this thesis have evolved during the progress of the research conducted and have been mainly influenced by the three user studies described in detail in Chapter 5. The user studies have also played a major role in the evolution of the research methodology. Their contribution becomes clearer upon examination of their design rationale and structure. This evolution reflects the tension among the different experimental approaches described in the previous chapter.

Due to the fact that this work is based on theoretical directions that employ different experimental methodologies, the definition, structure and result interpretation of the present user studies has not been self-evident. In this chapter, I will present my methodology as it evolved over time to address the requirements of my research questions. The text follows the chronological path of the three user studies, and describes workshop design decisions, their foundation in existing research, and their successes and failures in providing me with data regarding my research questions. Each one of the three main chapter sections is concerned with a particular user study in chronological order. Necessary context for each study is provided and results are discussed with particular emphasis to unresolved issues that caused a redesign of each subsequent study.

3.1 Introduction

Constructionist research is usually conducted in the form of workshops, where participants engage in construction activities and utilize various tools and materials ranging from everyday objects to sophisticated technological tools. The design of a Constructionist activity aims at creating a genuine experience for those involved, by engaging them with powerful ideas in the process of an authentic design and construction challenge.

These open-ended activities enable the participants to engage with the material at their own pace and to approach the construction challenges with their own learning style. The

activities usually involve groups of people who work either in individual or collaborative projects. During the workshop, the participants come up with the ideas and designs for their projects and, within the social setting of the workshop, they face the challenges of its construction with the help of the facilitators and the other participants.

During this construction phase, workshop participants approach techniques used by professionals when dealing with problems and challenges in their work. In this process, the participants learn or develop some of these required professional skills. A lot of the workshops involve the use of the necessary tools in a collaborative setting with professionals in a mentor-apprentice relationship (Lave & Wegner, 1991).

The Epistemology and Learning group at the MIT Media Lab has a long tradition of designing and organizing constructionist workshops based on the above principles⁵. Within the Epistemology and Learning group, I have been working with the group called Grassroots Invention⁶ at the MIT Media Lab, which has participated and co-organized various workshops among our collaborators. One such collaborator is The Ark⁷, a premiere cultural center for children, located in Dublin, Ireland. The Ark's mission is the creation of artistic workshops for children based on the background, craft and practice of visiting artists. They also organize performances and festivals for children with their participation.

The history of this collaboration is partially exhibited through two major workshops organized in close relationship: the “Bless the Beast” and “Electro-Jewels”, the second of which was the setting for the debut of the CodaChrome system. The “Bless the Beast” workshop was run first and set the path for the next one, “Electro-Jewels”. Both workshops are described here, and “Electro-Jewels” in particular constitutes my first user study.

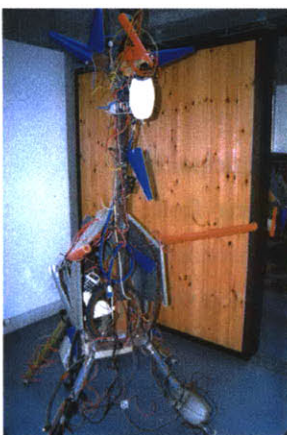


Figure 3.1: A full-sized “beast”

3.2 “Bless the Beast”

“Bless the Beast” took place in the summer of 2001 and was inspired by a collection of famous Picasso sketches of fanciful “creatures” based on real animals. The participants worked with an Irish sculptor to make three-dimensional versions of these animals out of welded metal frames (Figure 3.1), found and recycled objects and electronic components (Figure 3.2). The techniques and materials used were heavily influenced by the sculptor's personal style.

The workshop ran for six weeks and the twelve resulting large-scale sculptures served as examples during the seventh week of the workshop

when small programmable computers, called Crickets (Martin, Mikhak & Silverman, 2000), were integrated into the mix of material. The children worked with the artist, named Joe Butler and the MIT team, Dr. Bakhtiar Mikhak and Chris Lyon, to create tabletop versions of the “beasts” (Figure 3.3) that were brought to life through simple robotic movements programmed in a visual programming language called LogoBlocks⁸.

“Bless the Beast” established a set of characteristics for the collaboration among teams of facilitators as well as an organizational setting for the workshops. In particular, it articulated an approach to collaboration between the two organizing groups by bringing together artists and technologists to work closely and collectively to construct the identity of the event.

Integral to the “Bless the Beast” was the concluding public exhibit of the art works created during the workshop, which gave the workshop a distinct character from traditional educational workshops. The exhibition featured a combination of the style, work and use of materials by the participants and the functionality and aesthetics of the technology.

3.3 “Electro-Jewels”⁹

Based on that established style of collaboration, the second workshop called “Electro-Jewels” was organized during the summer of 2002 by three groups: Everyday Learning¹⁰ at Media Lab Europe, The Ark, and the Grassroots Invention Group at MIT. These groups collaborated to identify the supporting ideas and concepts and to develop the activities around the technological tools and craft materials. As the title suggests, the theme of this workshop is the combination of jewelry design and electronics to create dynamic, electronic jewelry.

The target group chosen for this was ten pairs of parents or grandparents and children from ten to fourteen who would work together. The reason for choosing pairs of participants was to make sure that the expressiveness of the tools was evident for both ages of novices and to understand how “generation gaps” might be crossed as they helped each other to learn about these new cybernetic materials.

Three main strands of activities were identified, each one with a different viewpoint towards jewelry design. One was the communicative aspect of jewelry and the social connotations that jewelry has taken across time. It also signified specific cultural influences to the style and fashion of entire eras. Expanding on the theme of time, the second group

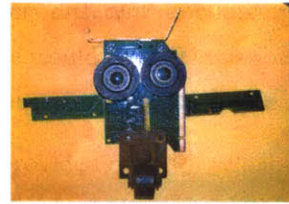


Figure 3.2: The children made small tabletop sketches out of found materials.



Figure 3.3: Some of the tabletop “beasts” became animated with Crickets.

of activities was related to various concepts of time, specifically to issues of visual rhythm, such as flashing colored lights perceived as a form of signaling to others as some kind of (secret) message. CodaChrome was part of this second group since it focuses on issues of synchronization of the color patterns and on the dynamic effect of color changing of the light modules. The third group of activities was related to monitoring and visualizing body activity in an interplay between information that people choose to communicate to others, or prefer to keep private.



Figure 3.6: The final fashion show



Color and its relationship to electronic jewelry played a key role in the activity design. During preparation, all the teams were presented with background information regarding contemporary jewelry design. From this background research, it became evident that the colored light had a very special and pervasive role in the upcoming designs, especially since the colored LEDs could be controlled by the technological tools used in the workshop. This prominent role of color in designing the activities for Electro-Jewels was my main motivation to explore the powerful ideas of color and color theory that evolved over the course of my research.



Figure 3.5: A number of artifacts were made using a variety of tools

The design of the activities and the organizational discussions of the workshop took place in Dublin, Ireland, where Media Lab Europe and The Ark are located. I spent part of the summer (around seven weeks) in Dublin, hosted by the Everyday Learning group at Media Lab Europe.

One of the distinctive characteristics of the workshop was the involvement of professional jewelry designers who would work with the participants. Unfortunately, the organizational discussions did not involve

the particular jewelry designers who came to participate in the workshop later on¹¹, but as is typical for such workshops there was a lot of improvisation and inventing-on-the-fly as the workshop proceeded, such that the involved designers' views, skills, and ideas were reflected in the work.

Electro-Jewels was implemented over two weeks in two sessions, each four-days long, with two different groups of participants but a common theme and workshop design as described earlier. Three jewelry designers participated in the workshops, each with different expertise: military folk art, diamonds and precious stones, and glass beading.

The space was versatile and open and could easily be arranged to match the flow of activities in order to enable better facilitation. The participants were able to leave their work in progress and continue the following day. The four hours allocated per day contributed significantly to the deeper involvement of people since a lot of time was available for experimentation with newly acquainted tools that were time-consuming to handle. (Figure 3.5) Many participants lingered beyond the designated time so as to remain immersed in their designs and constructions as the work proceeded. People were particularly excited with the ability to make fine designs and cut them accurately on acrylic, although the laser cutter was not on the premises and so others implemented these realizations at Media Lab Europe and the participants collected their cut pieces the next day.

The duration of the workshop was long enough to let the participants relax and not feel pressured to produce artifacts right away. On the contrary, they had a lot of time to check the various materials and explore the possibilities of their use in their designs. To help with the progress and to stimulate creativity, there were two "show and tell" sessions, where all the participants would gather around and show their intermediate artifacts and share their ideas and experiences, one in the middle of the workshop and one at the end where they would show their final pieces to a broader audience (Figure 3.6).

As I mentioned earlier, there were three main groups of activities that people would pursue and three different technological suites that mainly dominated each one. The first group, the communicative aspect of jewelry, was going to be pursued by using two circuit boards that would communicate wirelessly and flash when they would come close to each other. The second group was the CodaChrome system based on the Tower system, a small modular controller based on a PIC foundation and extended with a colored light module, which would flash different lights according to a combination of cues. (The Tower system and the tricolor modules are described in detail in section 4.1) The third group, the heart sensors and biometric feedback was going to be implemented using the Crickets (Martin, Mikhak & Silverman, 2000).

The technological tools at the disposal of the participants had very different functionality, form factors and user interfaces. So, it was inevitable that people would engage in various degrees of interest, complexity and dedication with the different technologies available.

The interaction with the participants was very important and provided me with valuable information on issues regarding the use of the programming environment, the desired software functionality, and the types of materials that people engage more with.

The observation in such a setting where there are a lot of people around, all engaging in various activities at the same time, is quite “messy”. The workshop was mainly videotaped by one person who wasn’t involved actively in the workshop. This static camera would capture different loci of activity around the room and some conversations. There was a second camera, a mobile one that made it easier to capture parts of conversations. On the other hand, because the persons with the mobile camera were part of the workshop, they would be frequently interrupted to provide help at some point or another, and so the footage would seem fragmented, though often it included the most interesting details of constructive processes and dialogs.

Asking children and adults about the timing of the color patterns requires a lot of concentration on their part, especially since I would be trying to probe them to see whether there are inconsistencies in their reasoning and design. This type of focus is very hard for the participants to achieve where interruptions are frequent. For example, during the first week of the workshop one of the participants used the CodaChrome system to make a fancy hat. The construction piece of the hat was elaborate and occupied most of the two days of the whole construction leaving a few hours for the programming and under the pressure of the final fashion show.

3.3.1 Summary

Electro-Jewels was for me a big help towards my research, because of its wealth of valuable information regarding the workshop design, the starting points that people found useful when trying to design electronic jewelry, and the design process that most of them took in order to produce a piece that would do justice to their original idea.

Moreover, I realized that my next user study must be either longer or more focused – longer so that the participants would have more time to refine their designs and still have time to focus on the programming activity.

Although this workshop helped me confirm that the design I had in mind for CodaChrome would work because people could start using the software right away, it did not provide me with enough data about the timing concepts that I had in mind. I needed more time

with each one of the participants individually to dive deeper into their understanding of timing issues.

3.4 CodaChrome Workshop

Electro-Jewels provided valuable input for the design of my second user study, another workshop with the theme of designing electronic, dynamic jewelry using the CodaChrome system. The second user study was made possible with the help and cooperation of Kay McGarrity, a teacher in the Watertown Middle School in Watertown, Massachusetts. Ms. McGarrity has a long-standing collaboration with the director of the Grassroots Invention Group, Dr. Bakhtiar Mikhak and has collaborated with him and with other researchers from the MIT Media Lab in activities with her students in various research projects.

After the initial contact with her about the CodaChrome project, we decided to perform the second user study with her and her students. All of them were very excited to participate in this user study, the planning of which started in early January and continued to evolve until the end of February when it took place. The participants were seven children from Ms. McGarrity's sixth grade, ten years of age, four girls and three boys.

The children after an introductory session at their school came to the MIT Media Lab for a two-day workshop, and spent about four hours each day on making their jewelry pieces. The workshop ended with a photo-shoot where they posed with their pieces for a group and individual photographs and narrated the "making of" their pieces in front of the camera.

3.4.1 Design Goals

This second user study was designed in close relationship to the Electro-Jewels workshop. The two user studies had a lot of the organization and activity design in common; the most important common theme was the similar design target: the design of electronic jewelry. It also had a focus on the construction of the pieces and the exploration of temporal notions using the corresponding representations in the CodaChrome environment. Electro-Jewels had a strong influence on the organization of the CodaChrome workshop: Both workshops shared common themes. Moreover, feedback from Electro-Jewels participants was used constructively throughout the design phase of CodaChrome.

One of the lessons learned out of the first user study was the participants' difficulty to digest the ideas, concepts and new materials in the short period of time between original introduction and incorporation into a personal design. This combined with the fact that the workshop would last half the time the first one did, made me want to give the children

a head start in thinking about their designs. For this reason, we decided to perform an introductory session at their school two weeks before the workshop. The idea behind such a session was to engage the children in conversations focused on their potential personal connection to jewelry and also to introduce preliminary design ideas for such artifacts. We wanted to challenge their concept of what jewelry is. Second, we would get them acquainted with the technology and the software, so that they knew what they had to take into account while designing their jewelry. Third, we wanted to introduce materials that they probably would not have thought of and had impressive properties. Finally, such introductory sessions would cause them to get an early start in their design before the workshop and would minimize the probability of a “black-out”, that is lack of inspiration during the actual workshop sessions.

The workshop activity had two integral parts: 1) The construction of the jewelry piece (based on their design after the introductory session) and 2) programming with the CodaChrome environment and the conclusion of the design with the color LED effects. Some children decided to do it interchangeably (construction and program), and others chose to finish their piece first and then program it.

During the second day and while the children were finishing their pieces, they would engage in a ten minute interview with me at a nearby room. My questions focused on their design, their experience with the software, their experience with materials and construction and the way that the dynamic color patterns were used to finalize the design.

At the end of the workshop we had a photo-shoot where all the children would wear their pieces and stand up to say a few words about their experience. The pictures were going to be “tokens” to take home as a reminder of the workshop, since, because materials were limited in supply, they wouldn’t be able to take the pieces they created.

3.4.2 Results

The children at the end made great pieces and they showed a variety of ideas (Figure 3.7). They were still focusing on the construction activity more than they were focusing on the programming of the tricolor modules and thinking in terms of the temporal aspect of the patterns. This second user study produced very nice examples of the children’s design phases and the evolution of their designs.



Figure 3.7: Examples of the artifacts created during the CodaChrome workshop

By the end of the workshop, I had a few interesting conversations about the issues of time that I was looking for, but as it turned out, the children were so absorbed by the construction of their pieces that the actual programming ended up being of less importance and would only be undertaken at the end of the construction phase.

That is why I chose as my final step in the organization of my user studies an approach closer to a more clinical method of observation, where I would spend more time with each one of the children during their efforts to program a piece with a color pattern they invented and liked. For the design of the third study, I used my perception of their developed understanding of what the CodaChrome system was used for, and their experience with the programming environment.

3.5 Third user study: Light sculptures

The final stage of the methodology evolution involved one-to-one sessions with four of the children who participated in the CodaChrome workshop to program two prefabricated pieces trying to implement a dynamic effect that they could think of. The two pieces were modeled after an hourglass and an abstract clock in an attempt to shift the construction activity towards time issues (Figure 3.8). The two directions they followed were to either model the sand of the hour-glass with lights, or color the abstract time piece with their everyday schedule, in effect their actual daily passing of time. The description of the artifacts and the activities in detail are illustrated in Chapter 5, User studies.

During this final user study I was able to get a better understanding of the children's ideas and the way that they interpreted synchronization issues. Moreover, I gained valuable information on the dynamic behaviors that



Figure 3.8: The two time pieces modeled after an hourglass and an abstract clock

the children wished to implement with the color patterns.

I asked the children to find dynamic events in nature and try to simulate them in an abstract way with one of the provided objects. The second activity was to program the second time-piece with their everyday schedule narrated or encapsulated in a much shorter amount of time. In this fashion, the children had to think about their memorable daily events, their relative importance and their corresponding color representations using a color pattern for the whole day. They also had to reflect on what events to incorporate and think about required event representation granularity within a full day.

3.6 Conclusion

This last user study was influenced by the clinical approach of the Constructivist studies where a lot of the data are created during the conversation between the child and the researcher. This conversation involves carefully posed questions to the children, according to how they react during the experiment to things that seem to startle or confuse them. Similarly, even if the children don't seem confused, the questions are probing the children for a clearer description of what they think is happening while they are observing some event during the evolution of the experiment. Similar questions and observations could be the focus of experiments and workshops organized for adults, in the same spirit of the Electro-Jewels workshop.

Chapter 4 The CodaChrome System

In the previous chapters there have been many references to the CodaChrome system since it is the main technological tool for the creation of the electronic jewelry and the programming of the animated color patterns. This chapter aims at giving a more detailed description of the CodaChrome system, both its hardware and software components. Particular emphasis is placed on the development of the CodaChrome programming environment since it is the main technological focus of this thesis.

While programming their color patterns through the CodaChrome environment, the users have at their disposal multiple widgets. The design of CodaChrome and especially the widget design are grounded in a set of design principles that have the right selection of representations and controls to resonate with users' personal intuitions without compromising the nature of their design process or the desired complexity inherent to the object.

The design of CodaChrome is always aiming at capturing the user's intuitive approach to the interaction of the color patterns through visual programming. The main trade-off in this regard is the degree to which a system remains open-ended while realizing a coherent visual interaction model. The system structure remains adequately open-ended to enable researchers to customize and change the tools to better fit their specific research questions and engage in and contribute to the evolution of the tools.

I will start with the hardware part of the system and I will describe the modules needed for the physical construction and then I will present the architecture of the system to explain how the system is structured

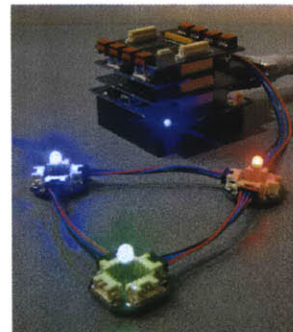


Figure 4.1:
**CodaChrome hardware
configuration**

and finally I will present the programming environment, the desktop application of CodaChrome.

4.1 Hardware

The hardware part of the CodaChrome system enables the physical construction of the electronic pieces of jewelry. It is based on the Tower System with its integral for this application module, the tricolor module with its programmable LED. The Tower system (Lyon, 2003) has been developed by my group, the Grassroots Invention Group at the MIT Media Lab and in particular by Dr. Bakhtiar Mikhak, Chris Lyon and Tim Gorton and its design enabled me to use it for CodaChrome because of its modular architecture and the fact that it is easy to program and change according to the needs of my system.

4.1.1 The Tower System

The Tower enables the design of a system that is not only modular and programmable, but is also easy to change and can be interfaced to sensors. It is a modular electronics design environment that was developed based on the principle of easy snap-together design of complex electronics systems. The Tower is comprised of a Foundation module (Figure 4.2) with the core processor on it, and other boards that stack on top of it, extending its functionality with a wide range of features including sensing, actuation, data storage, and communication.

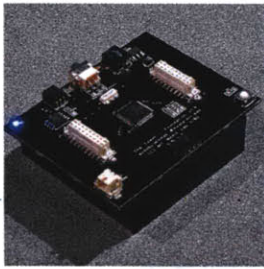


Figure 4.2: The Tower PIC Foundation

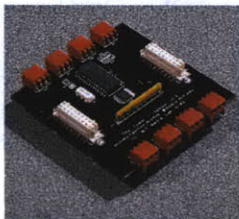
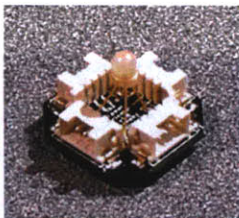


Figure 4.3: Tricolor Module and Sensor Layer

4.1.2 Tricolor LED modules

For the CodaChrome system, the Tower system was extended with a special “Tricolor” module¹² (Figure 4.3). The Tricolor module has a single full-spectrum LED capable of displaying million of colors, and its small size makes it easy to embed in a variety of materials.

Each Tricolor module has four connectors that allow it to be connected to other modules and to a junction on the Tower itself, allowing for the creation of interesting chains and three-dimensional topologies. Since each Tricolor module resides on the primary Tower data bus, the Foundation retains independent control over the color displayed by each module. A sample configuration of the Tower with three Tricolor modules connected is shown in Figure 4.1. In addition to the Tricolor modules, the

CodaChrome system also uses the Tower's preexisting Sensor and EEPROM data storage layers.

4.2 System architecture

The CodaChrome system consists of the hardware described in the previous section, desktop software written in Java, and firmware and software on the Foundation itself (Figure 4.4).

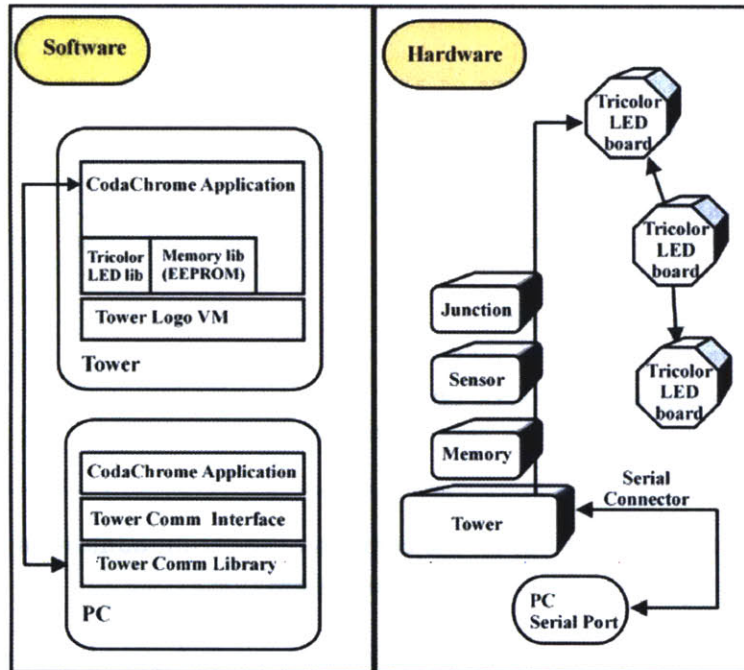


Figure 4.4: Diagram of the System Architecture

The CodaChrome application running on the desktop computer uses the serial port to communicate with the Tower. The Tower Foundation runs a Virtual Machine (VM) that interprets a variant of the Logo language, using simple libraries to communicate with attached layers. On this platform, a Logo program¹³ manages the communication with the desktop and according to the directives it receives from the application, it performs a number of local functions (see Figure 4.5). The necessary commands for this communication were formulated in an interface to separate and abstract the CodaChrome application from the Logo software. The application uses this interface to send commands to the Tower and to retrieve information about the connected Tricolor modules and the values of attached sensors. A sample of such commands is shown in the figure below.

```

public int[] getLEDIDs();
//get the IDs of the connected to the Tower Tricolor modules

public int getLightSensorValue(byte num);
//return the light sensor value from the Tower

public byte getOpticalValue();
//return the optical distance sensor value

public void setTricolor(byte id, byte r, byte g, byte b, byte time);
//the basic primitive that makes the transition from the current color to the
specified RGB value (r,g,b) in the designated amount of time (time)

public void play();
//start looping the color patterns on all the Tricolor modules

public void stopPlay();
//stop the looping of the color patterns

public void download(LEDLoop[] loops);
//download the vector with the RGB values and the transition times for all the
Tricolor modules

public void setBoardID(byte newID);
//set the unique ID to each Tricolor module

public boolean isLEDConnected(byte id);
//check if Tricolor modules have been disconnected

```

Figure 4.5: Sample methods for the computer-tower communication in the CodaChrome system

The above interface describes a protocol for the communication between the Tower system and the desktop application. In more detail, the above command: **getLEDIDs()** is used by the CodaChrome application regularly to retrieve the IDs of the connected Tricolor modules and to detect changes in the chain of connected modules (whether some of them have been disconnected or new ones attached to the chain). When the command: **download(LEDLoop [] loops)** is initiated, the Logo software will store all the values it receives into the Tower memory layer. On the **play()** signal it will start to read the values stored in the memory layer earlier and will run the color pattern. Specifically, the Tower will read these values sequentially and their respective fading times, and will then initiate commands for all the programmed LEDs to run their individual color patterns. These commands are consecutive **setTricolor** primitives and its parameters are: board-id, red, green, blue, and fading-time. Once the patterns starts, the Tower can then be disconnected from the computer and run independently.

4.3 The CodaChrome Programming Environment

The software for programming the color patterns on the tricolor modules is a desktop application written in Java¹⁴. Its main features stem directly from its requirements defined during the design phase and include: 1) various color palettes for the definition of a color sequence, 2) timing and speed controls tools for the adjustment of the play-back rate, 3) sensor controls for the adjustment of sensor related parameters and the play-back rate of the color sequences based on sensor input, 4) visual indication of the connected tricolor modules and their color patterns (if they have been already programmed), 5) drag and drop functionality for programming these connected tricolor modules and 6) multiple ways of storing the color patterns for later use.

The CodaChrome application was developed during two phases, one prototype version during the early stages of the CodaChrome system and the other, more recent one, which shows a complete design of the system and incorporates the feedback provided by the user studies.

The first two user studies designate these two phases, one performed with the prototype (version 1.0) during the summer of 2002 and the other with the new redesigned CodaChrome environment (version 2.0) on February 2003. There have been revisions on version 2.0 that will be discussed in detail through the rest of this chapter.

4.3.1 CodaChrome Programming Environment – Prototype Version 1.0

The prototype CodaChrome application was used during a two-week workshop that formed the preliminary user study called “Electro-Jewels”¹⁵ (described in detail in Chapter 3). During Electro-Jewels only parts of the CodaChrome system were in place and were put to use for testing purposes. This prototype version had most of the hardware and firmware in place and only pieces of the software programming environment.

The functionality that was part of this prototype was mainly focused on the serial communication between the desktop application and the tower, as well as the smooth detection of any addition or removals of LEDs from the connected chain. Therefore, more emphasis was put on the back-end of the system, rather on the user interface and the programming tools.

The minimalistic programming environment shown in Figure 4.6 had the necessary functionality to detect the presence of the tricolor modules and program them with color sequences in an elementary way. Apart from the communication with the Tower system and the indication of the connected LEDs, it provided two color palettes and a speed slider for the programming of the animated color patterns.

The labeled icon represents each connected LED with its unique ID number and functions also as a button that leads to the programming tools. The color palettes used in the prototype version were two, one with discrete colors and another with a continuous spectrum (Figure 4.7 & Figure 4.8). The discrete one is based in the RGB color space and could create color sequences with equal duration among colors based on the user's input. The continuous spectrum one creates color patterns according to a line that the user draws on it by dragging the mouse. The speed between the fading colors depends on the users changing speed while making the dragging gesture. Both color palettes had a speed control that controlled the playback speed of each color pattern individually.

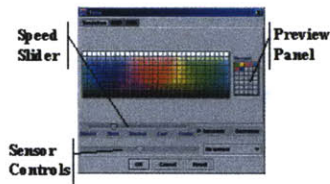


Figure 4.7: Prototype Discrete Palette

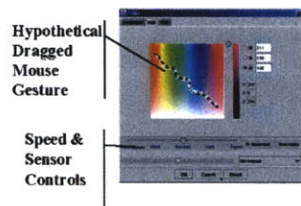


Figure 4.8: Prototype Continuous Spectrum Palette

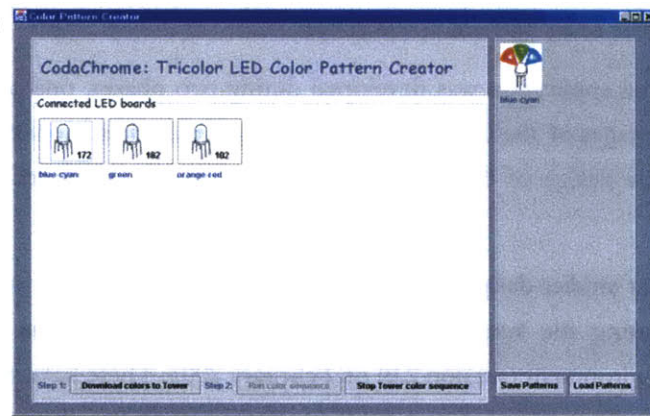


Figure 4.6: Prototype of the CodaChrome environment

The first version of the CodaChrome system had also the capability of adjusting the playback speed based on sensor input, like for example light, temperature and distance sensors attached to the Tower. The parameters that are controlled by the sensor are the speed acceleration or deceleration by a factor of one to five. Although this functionality had been taken under consideration during the design of the system and was implemented in the firmware, it was not fully incorporated into the end-user interface.

Once a dynamic pattern has been created it can be duplicated on other LEDs or saved in a collection of stored patterns, as illustrated on the right side of Figure 4.6. The saving and restoring of color patterns is made exclusively by drag-and-drop. The saving of patterns enables also their duplication on multiple LEDs. Apart from saving separate patterns, the whole arrangement of LEDs and their patterns can be saved into a local file and recalled at a later time.

4.3.2 The CodaChrome programming environment (version 2.0)

The CodaChrome environment after the use of pieces of it in the preliminary user

study, was fully designed and developed and is currently at its second version. Careful consideration was given to the observation and the results from the user study, some of which were addressed previously. Consequently the changes from the previous version of the CodaChrome environment are towards three directions: 1) additional functionality by providing more tools for the programming of the tricolor modules, 2) extend and enrich the user interaction 3) provide more concrete and coherent visual feedback about the color patterns that reside on each LED. The second version of the CodaChrome environment is shown in Figure 4.9.

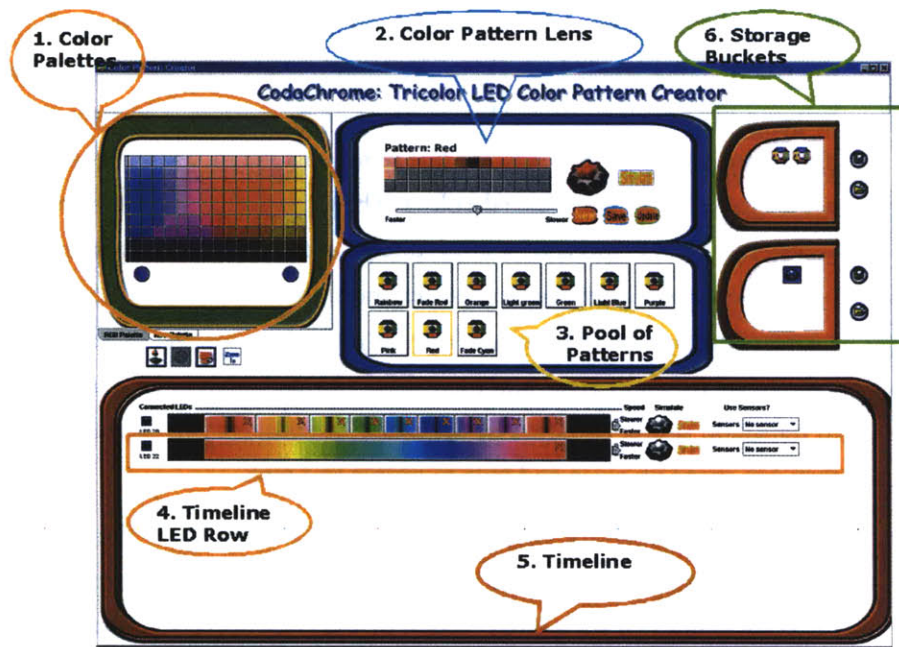


Figure 4.9: The new CodaChrome environment

1. Color Palettes (version 2.0): Some of the changes from the previous version are easy to pinpoint by comparing the two pictures. First of all, starting from the left top corner, the tools for defining the color sequence are always visible and not attached to specific LEDs. Here, part of the discrete palette (RGB palette) is shown. Next to the RGB palette tab are the tabs for the other palettes like the continuous spectrum tab.

Discrete RGB Palette (Figure 4.10): The discrete color palette, based on the RGB color space, is used for entering a number of specific colors from a broad color and shade selection. The sequence that the user picks the discrete colors from the palette specifies the color sequence with equal time intervals between colors. On the Color Pattern Lens (No 2 on

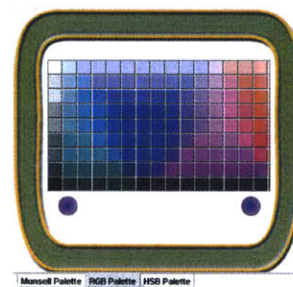


Figure 4.10: The RGB Discrete Color Palette

Figure 4.9), there is a table that gets updated with every new entry acting as a static representation of the color sequence. This mode is useful for creating sharp transitions between colors, and for easily synchronizing dynamic color patterns due to constant color transition durations. The arrows scroll the arc of the palette to the left and right to reveal all its colors.

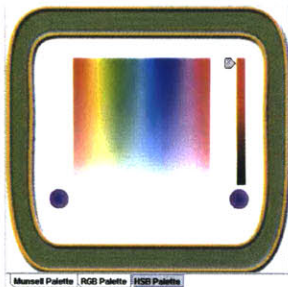


Figure 4.11: The HSB Palette (Two Facets)

Continuous Spectrum Palette (Figure 4.11): The next widget produces a combined definition of color sequence and transition time in one gesture by dragging the mouse on the palette. The color sequence is defined by the palette color gradations along the mouse trace. The transition time between two colors is defined by the speed of the gesture. This process is illustrated in Figure 4.8, where the line represents the mouse trace and the white marks show the selected colors. Their relative position is variable depending on the speed of the gesture at each interval. Longer spaces between marks correspond to shorter transition times. In this example, the resulting pattern will change from bright red, to orange, to yellow, to light green, to bright green and then to light blue. At that point it will start to transition slower (denoted by the dense white marks) to dark blue and then will speed up again and fade to purple and pink.

The arrows are used for swapping among different facets of the palette, and thus being able to see the full spectrum with saturation mapped on the vertical slider or see a cross section of the color space at a certain hue and all the spectral hues mapped on the vertical slider (Figure 4.11).

This mode is more suitable for creating smoother transitions because the colors are selected out of a continuous spectrum at a sampling rate fast enough to generate enough color samples even during fast user gestures.

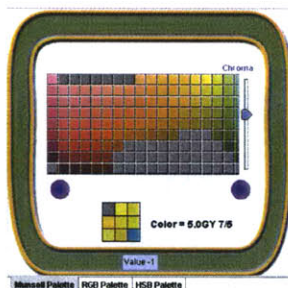


Figure 4.12: The Munsell Color Palette

Munsell Palette (Figure 4.12): This palette is based on the Munsell color system that has been described in section 2.6.6. It is arranged in increasing value from bottom to top and in increasing hue values from left to right. The chroma has been mapped onto the vertical slider next to the colors. On the bottom of the palette, the grid of colors practically constitutes the tool that facilitates the navigation through the color space, by highlighting the relationship of each color to eight other colors of the same color space. The reference color is at the middle of the grid and starting from the upper left corner and going clockwise, the colors

appearing are (based on the reference color): 1) Neutral, 2) Value+1, 3) Chroma+1, 4) Hue+1, 5) Complementary, 6) Value -1, 7) Chroma-1, 8) Hue-1. The Munsell notation of the base color shows next to the grid. The arrows are used to reveal all the colors of the Munsell color space.

2. Color pattern lens: On the center top part of the screen exists the color pattern lens, the area where details about the selected color pattern appear. The name of the pattern is on the top, below is the color sequence that gets updated in real time, and below that, the speed control. More to the right are the controls for saving a color pattern, update an existing one, and create a new, blank one. A completely new feature has been added here, that is the simulation button. It is basically a virtual equivalent of the real tricolor module and it can simulate the color pattern currently being defined or updated. When the color pattern is ready, it is saved for later use in the programming of the tricolor modules.

One of the major revisions was the separation between two entities that were blended into one in the previous version, these of the color pattern and the tricolor module. Previously one tricolor module could have just one color pattern attached to it. Now the color patterns are created independently of the tricolor modules that will eventually reside on. As a result of this, the speed control of each color pattern is now found at the color pattern lens area rather than attached to the palettes.

3. Color Pattern pool: The already saved patterns appear in the area directly beneath, in the pool of color patterns. They all have the same iconic representation and a name usually different from the other ones. This name can be changed at any time by double-clicking on it. That way we don't need copy-paste mechanisms for adding the same pattern to multiple tricolor modules. We can just drag the same original pattern onto the multiple LEDs and that is equivalent to creating new instances of the same entity that will reside on multiple LEDs.

4 & 5. Timeline component: The center-lower part of the screen is occupied by the main programming module of the system. When an LED gets connected to the Tower system, the CodaChrome software will detect and create a row of various components to represent and control it, as shown in Figure 4.13.



Figure 4.13: Picture of a single row.

Each row consists of its ID number and the LED icon, the black area where the color patterns are dropped for the programming of the LEDs, a speed control for the whole

LED (all the color patterns that comprise the color pattern on this LED will be affected by a change in the row speed control), a simulation button similar to the one on the color pattern and the sensor controls.

The speed control will change the individual playback rates of all the color patterns on that row uniformly. Nevertheless the relative duration of each color within the color pattern will not change. The change in duration will appear on the user interface as well. If the whole row is changed to go slower than it already is then all the color patterns will appear to get longer and the opposite happens when the speed changes to faster.

The timeline component can hold up to eight of these rows that is the limit of the LEDs that can be connected to the Tower system. If there are more than 8, then the excess ones cannot be programmed. In the timeline component the LEDs are programmed by using the drag-n-drop of the color patterns previously defined to the LEDs. This is a tool for attaching color patterns but also a way of making subtle changes to the timing of a color pattern by changing the boundaries of the components. Each component on the timeline is colored with its respective color pattern in proportional length to their duration. So there is a complete mapping between the components, their length, the color pattern duration and the color changing marks. That is particularly important in issues of synchronization of the color patterns among the LEDs.

If long color patterns are dropped onto a row in the timeline component thus causing them to become invisible, the timeline will change its scale by a predefined percentage, it will zoom out. The opposite effect has the “Zoom in” button that appears on the CodaChrome screen next to the Download to Tower and Run Color Pattern buttons.

6. Save Buckets: The saving and restoring mechanisms were extended to support the saving of individual color patterns, of programmed LEDs as a whole, and of the workspace (instead of just the programmed LEDs in version 1.0). The area on the right part of the CodaChrome screen shows two “buckets” that resemble the idea of two different collections of saved color patterns and compiled LEDs. To save the color pattern, the user needs to drag it from the pool of color patterns and drop it on either of the “Buckets”. When the iconic representation of the LED is dragged from its label, it can also be dropped on either of the two buckets. The two buckets will be saved in two different files on the hard drive and therefore can be retrieved independently of each other. The reason for the existence of two buckets is due to the flexibility that such redundancy provides. For example one bucket could be the place where a standard set or library of ready-made pattern is always loaded for use in programming, and the other bucket can be used for saving the new patterns that were created. Alternatively the two

buckets can be used for saving the two different entities, the color pattern on the one and the programmed LED on the other. This is the case shown on Figure 18, where the first bucket contains two color patterns saved and the second bucket contains one compiled LED. The different icons are a visual clue for the different entities saved in the buckets. The various instances of each are distinguished by their name that is the tooltip text on these icons.

The saving and restoring of the whole workspace is done by the standard keyboard shortcuts (CTRL+S, CTRL+O).

4.4 General Remarks

The above features provide the necessary functionality to allow for more control and fine-tuning over the creation of the color patterns. It provides visual feedback on how the result is going to look like, since the LED tracks as they are stacked vertically represent the parallel development of the color patterns in time. Time flows from left to right.

On this timeline, the color patterns can be adjusted to fit the overall synchronization among the LEDs. Their adjustment usually involves fine trimming or extension of the color patterns duration. That is done by just dragging the edges of each color pattern, providing that there is enough free space and there is no neighboring color pattern to block its extension. When the boundaries of a color patterns change, the playback rate gets readjusted to produce the designated duration. So the color pattern will uniformly scale in speed to match the desired outcome.

Chapter 5 User studies

The data that I have been presenting throughout this thesis have been the outcome of the three user studies conducted over the course of almost a year. Their historical evolution is also described in the third chapter from the viewpoint of the methodological progression of the studies. Some of the information presented already there will be repeated in the present chapter to provide a more coherent and non-interrupted reading.

The first user study was Electro-Jewels, a workshop on designing dynamic, electronic jewelry. Electro-Jewels was a preliminary study as far the implementation of the CodaChrome system was concerned since it took place during the first prototype stages of the software. Yet, it constitutes an important milestone in the definition of the subsequent user studies and it provided the starting point for the methodology evolution, as described in Chapter 3.

Electro-Jewels helped not only in defining future development directions for the system and research but also it allowed for the continuing development of the tools and the activities during the whole two weeks of the workshop. The results of this particular part of the study informed the design of tools and the design of the actual artifacts in situ.

The two user studies that followed the Electro-Jewels workshop provided valuable insight and interesting evaluation results, especially from children who used the CodaChrome system as it was being developed.

The second user study took place during February of 2003 with seven children from Ms. McGarrity's sixth grade class at the Watertown Middle School, in Watertown, Massachusetts. They used the second version of the CodaChrome environment, although a few features were not completed at the time. This CodaChrome workshop had a set of activities similar to Electro-Jewels. The context was the design of electronic jewelry using

the CodaChrome system. The goal of this workshop was to test the features of the new version of the CodaChrome environment and to verify that the interaction design and the functionality of the system was consistent with what the children would find easy and intuitive to use. This user study also gave more insight to the design and creative process of the children specifically showing different design challenges children faced and how they changed them to succeed in their goal.

The third set of user studies explored more the issues of time concepts and colors, through the use of two prefabricated objects modeled after an hour-glass and a clock. This user study is essentially a continuation of the previous one, since it is conducted with some of the children that participated in the original CodaChrome workshop. There are a lot of differences though, partially due to the one-to-one nature of the study. I visited their school three times over the period of two weeks and worked with four of them. I changed the activities each time to match the children's personal preferences and inclinations. The main idea of the activities for this last set of meetings was to program the two prefabricated objects in a way that resembled either natural phenomena or their daily routine. This last user study produced very thoughtful and detailed conversations revealing their thinking about temporal concepts. The children described temporal behaviors or events that they wanted to attribute to the features of the two prefabricated objects, while using the CodaChrome environment.

5.1 First user study: Electro-Jewels

“Electro-Jewels” was organized in the summer of 2002 by three research groups: Everyday Learning at Media Lab Europe, The Ark, and the Grassroots Invention Group at MIT. These groups collaborated to identify the main workshop themes and also to develop the activities around the technological tools and craft materials. As the title suggests, the theme of this workshop was the combination of jewelry design and electronics to create dynamic, electronic jewelry. Ten pairs of children and adults from ten to fourteen worked together on individual or collaborative projects with the help and guidance of three professional jewelry designers.

5.1.1 CodaChrome Activity Design

Out of the three strands of activities identified for the workshop, CodaChrome focused on issues of synchronization of the color patterns and on the programming of dynamic effects. These types of activities were connected to the research theme of the workshop that related closely to the notion of time and temporal concepts. (3.3 contains a detailed description of the activities).

A key role in the design of the activities was the idea of color and its connection to the electronic jewelry that was going to be created at the workshop. During the preparations for the workshop, the bibliographical research produced a lot of designs that highlighted the importance of the colored light, especially since the colored LEDs (Light Emitting Diodes) could be controlled by the technological tools used in the workshop.

As already described, the workshop activity was based on the creation of animated color sequences (color patterns) with the assignment of RGB (red, green, blue) values to very small lights (LEDs) that were physically interconnected.

Some of my questions while I was designing the activity were the following:

- Where does the difficulty reside in using the CodaChrome software when people have to take into consideration the synchronization among a number of dynamic patterns (more than two)?
- What tools are the most natural for people to use for defining and manipulating more effectively the color sequences and their transition times?
- How can CodaChrome help people describe a phenomenon that evolves over time? How can they represent it and reproduce it by using the software?

Initial ideas for introducing the activity

The CodaChrome system introduction was designed to highlight some of the underlying concepts of the system design, such as: animating color patterns, timing and frequency of the transition of colors with the use of paper-based activities and color wheels. In the beginning, people experimented with different cutout patterns on color wheels (Figure 5.1) and mixed different colors to see the resulting combination effects. Some of the cutout shapes on the color wheels were non-regular, as if they were created with a gesture of the hand rather than resembling a particular geometrical shape. The cutout shapes were the first representation of a color sequence.

The second step was to introduce the idea of color animation by generating transitions between colors in a color sequence. Inherent to the concept of animation is the concept of time, which was also introduced in this activity specifically by the time needed to fade between colors. Therefore, a connection had been created between the color sequence and a timeline of transitions. The second part of the activity involved the hand rotation of the color wheel in order to generate an animated color pattern along the cutout shape.



Figure 5.1: Color wheel and various cutouts

The next set of preliminary activities was more closely related to the actual technological modules of CodaChrome. We prepared a very simple design using traditional jewelry making materials. Specifically, we used wire, a blue-colored bead and a green-colored bead. At the center, we placed a tricolor LED module. The participants used the CodaChrome application to make the LED module gently fade between blue and green (the color of the beads on either side).

5.1.2 Workshop Activities & Artifacts

As already stated, the workshop was comprised of a set of three separate activities based on the different technological tools. During the first week, the participants were briefly introduced to the materials and were given the time to move around the workshop space and explore the materials and tools. In the first two days, they learned about contemporary jewelry design and different styles of making traditional jewelry, and they heard the professional jewelry designers describing their materials and design processes. Participants even brought their own jewelry and talked about the personal interpretation of what wearing that piece of jewelry meant and the feelings and experiences they had associated with it. The first two days of the workshop were dedicated to creating an object and reflecting on the design and construction process at the first show-and-tell session. The two latter days were dedicated to the creation of the final pieces, which could either be a continuation of the previous work or a completely new design.

The participating pairs chose to create either one or two objects, but they worked together in either case. The range of creations was broad both in terms of jewelry type and material use. The design of the pieces was influenced by a variety of jewelry posters presented to the groups during the introductory sessions, ranging from traditional Egyptian jewelry to contemporary whole-body pieces. An example of a creation that resembled traditional jewelry was a bracelet enhanced with simple LEDs as shown in Figure 5.2. Another more unusual piece was a medallion that used just an electro luminescent wire (Figure 5.3). It showed creativity and playfulness, especially since the center photograph was cutout from a magazine that belonged to the young boy who designed the artifact. Figure 5.4 shows a piece made by one of the workshop artists using the CodaChrome system. It was a combination of three different pieces of



Figure 5.2: Electro-Bracelet



Figure 5.3: The medallion



Figure 5.4: Study on light effects

acrylic exploring the idea of diffused color light. It wasn't modeled after a specific piece of jewelry, therefore it did not have a name. I have assigned the "study on light effects" name due to its descriptive nature.

Figure 5.5 shows an electronic band to be worn across the body. The detail shown on the smaller picture is the centerpiece, a piece of black acrylic with cutout animals mounted on a small motor. Behind the centerpiece, one LED would fade through a color sequence that would be synchronized with the rotation of the centerpiece. The colors would change when a different animal was shown: the crocodile would be green, the duck orange, the lizard brown and the cow pink. This was based on the idea of projection: The LED behind the centerpiece would project the cutout animal shape on a wall.

One of the most impressive pieces created during Electro-Jewels was the hat shown in Figure 5.6. One of the adult participants came at the beginning of the third day with the hat designed on a piece of paper. She had figured out the materials and color patterns that she wanted to use to make it. Afterwards, when we were talking about the design process of the hat, she told me that she had a long commute and so she and her daughter used to time to talk about what they were going to make, and had a lot of great ideas this way. It was a very helpful point of reference for me because it led to the introductory session of the CodaChrome workshop.

The design process she followed is depicted on the three panels of Figure 5.7. She started from the structure of the base: she cut the shape on a flat piece of acrylic and then heated it with a heat gun and then bent to take the shape shown in the picture (her description was that she wanted to make an extravagant, Napoleon-style hat). The nice properties of the acrylic were perfectly demonstrated through this piece to the second week participants that saw its property as a waveguide for visible light. It was inspiring to see its use in creating the colorful, lit-up rim of the hat. The pattern created with the initial prototype of CodaChrome was programmed to have the effect of the wave, where the pattern would start at the front dangling LED and then continue as a wave towards the back of the hat, blending perfectly with the topology of the LEDs. The Tower was hidden and attached with Velcro on the top of the hat, where she had cut a hole for accessing the on/off button. The color pattern of the hat was accentuated with the front dangling LED (attached to a wire that



Figure 5.5: Chest Band

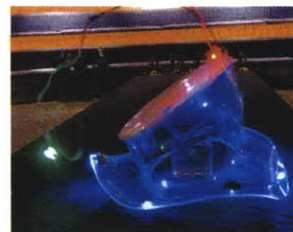


Figure 5.6: The hat



**Figure 5.7 a & b & c:
Making of the hat**

would make it move with every step).

Reflections



Figure 5.8: The Tiara

Figure 5.9 shows one of the participating pairs, a father with his daughter, after the final show talking about their work. The girl made a headpiece –a tiara– with CodaChrome shown in Figure 5.8. She used three LEDs in a triangular topology, each of which was attached to a small acrylic tube that would diffuse the light in outwards directions. Her father created an interactive tie.



Figure 5.9: Father and daughter talking about their creations

We observed a variety of interacting and collaborating pairs in addition to the prevalent collaborative relationship that developed between each parent-child pair. The pair in Figure 5.9 illustrates one example of such interaction, where both father and daughter worked on individual pieces, but the father was helping his daughter define and build her piece and worked on his project at the same time. Other types of collaboration that emerged from the workshops were the collaborations among children from different pairs. They would share their ideas, ask questions to each other about the pieces they were thinking of making, and work together especially if they needed help with the tools and materials. In one case, the two children worked together to produce two complimentary pieces, armor and sword, that were made out of the same materials and were decorated in a similar manner.

5.1.3 Preliminary Results and Evaluation



**Figure 5.10:
Participants talking
about their creation
in “show and tell”
sessions**

The results of this particular part of the study influenced the re-design of the software environment, the activities, and the organization of the subsequent workshops. It was the first attempt to identify the types of interaction among the participants, the produced artifacts, and material choices. It also provided the next user studies with valuable input for the design of the activities during the workshop, and their day-to-day planning.

Conversations during the workshop provided a great deal of insight on the way participants approached the creation of light patterns. During such conversations, I discovered that their descriptions varied according to the number of Tricolor modules that were deployed in a piece and according to the complexity of the synchronization among the light patterns. The

prevalent relationship among color patterns in a piece was the shifting of one pattern from one LED to another over time. For example, they would not try to make an image of some sort (using the LEDs as static pixels) nor would they try to make patterns with flashes of color at regular time intervals.

People were specifically interested in being able to control the overall coordination among the color patterns, which was a complicated task and became easier in the later versions of the system with the addition of the global timeline. Frequently, the participants would only describe the behavior of the one tricolor LED module whose state changed per time “tick”. But it was difficult to explain which state should the others keep at the same time “tick” so that the whole light pattern would repeat itself over time.

A few of the present features of CodaChrome became imperative to implement as a result of this study. Most of the following features were known issues before the workshop but other organizational issues took priority over them, like the testing of the hardware and the design of the CodaChrome activity (including the introductory activity). Some of these features were:

- The timeline component: an interactive software widget that would show the overall synchronization of color patterns among the different LEDs.
- The reuse of already created color patterns either for copying and pasting in multiple LEDs or for being able to perform incremental modifications. For example one LED contains a color pattern that defines the animated sequence of five colors. One could try to duplicate this pattern onto a second LED only with this change: the fifth color in line instead of being blue, it should be yellow, so that when the pattern loops it will be synchronized with the first LED only slightly different. Without the ability to copy-paste and update the existing patterns, one should replicate all the colors in the color sequence except for the last one. The new environment would provide the user with more tools to easily manipulate and change existing color patterns.
- A detailed view of what the individual color patterns look like and a companion simulator.

5.2 Second user study: CodaChrome workshop (February 2003)

The second version of the CodaChrome environment incorporated all the changes and new features that were specified as a result of the Electro-Jewels workshop as well as features that represent different directions of research questions related to how children understand and use different representations of temporal concepts. During the CodaChrome workshop version 2.0 was not completely ready yet; it had a few differences

in the layout of the screen and the color patterns when dropped on the LEDs were white instead of colored with the color sequence. Also the user interface sensor controls were not completed.

The second user study was organized and run in collaboration with Kay McGarrity, a teacher in the Watertown Middle School in Watertown, Massachusetts. We started planning the CodaChrome workshop in early January and continued to do so until the end of February when it took place. The participants were seven children from Ms. McGarrity's sixth grade, ten years of age, four girls and three boys. I will refer to them with the following false names in order to hide their identity: Mary, Joan, Susan, Alice, Joe, Martin, and Fred.

The theme of the workshop again was the design and making of dynamic electronic jewelry. The children after an introductory session two weeks before the workshop came to the MIT Media Lab for two days, four hours per day to make their pieces of jewelry.

5.2.1 Design Goals

This second user study inherited a lot of our experience gained during the Electro-Jewels workshop. One common aspect between the two workshops, apart from designing electronic jewelry, was the focus on the participants' thinking about the notion of time and related temporal concepts.

The CodaChrome workshop had the following differences from its predecessor:

- The audience was homogeneous in age and background, as all the participating students were in the same class studying with the same teachers.
- The children had already been introduced to their constructing activity and the technological tools before the workshop. During the preliminary session they designed their piece of jewelry on paper with descriptions of the materials as well as the color patterns that they would program it with.
- The list of materials although long (as described earlier) wasn't as extensive as the list of materials used in Electro-Jewels, where the materials were the aggregation of all the raw materials that the three different artists would use.
- The technological materials and tools (namely the tower and the tricolor LEDs) were predefined and standard so the form factor, functionality and restrictions were given and taken under consideration during the design of the pieces.

These conditions provided me with several opportunities to work with the children directly to understand better their way of thinking about the concepts that CodaChrome

highlights. Since this interaction was taking place during a construction activity, the design process and their work toward their final pieces influenced the children's ideas and thinking about the color patterns and their timing.

The children were able to find meaningful ways of incorporating the small light modules into their jewelry pieces throughout the design process, as they have seen in many of the commercially available jewelry targeted to young ages.

But although the use of colored light modules was resonant with children because of their experience with these commercially available objects, the idea of programming them with an animated color sequence to produce an overall effect was new as well as very difficult while each of the children followed its own path to becoming familiar and adding to their own personal toolset, the capabilities of this powerful feature.

Over the next sections, I describe exactly these processes that helped them understand and creatively combine technological tools, traditional jewelry-making materials, general art and craft materials, and their ideas and creativity to essentially discover their own individual way of understanding and utilizing this new medium available to them. In describing each case, I will be giving examples of an original design they made two weeks before coming to the workshop and the impressive consistency they showed in its making.

We decided on an introductory session with the participants before they would come to the workshop. Two main reasons contributed to such a decision: first due to the difficulty that Electro-Jewels participants had to digest the ideas, concepts and new materials in a short period of time and second due to the shorter duration of the overall workshop (two days instead of four).

The ideas about the structure and character of such a preliminary session were to engage the children in a conversation of their connection to different pieces of designed jewelry and to start with some design ideas for concept designs, in general expand their notion of what jewelry is. We also wanted to show the range of materials while the children would be making their pieces. The outcome of this preliminary study was a set of drawings, sketch designs that would be used as the basis of their workshop constructions.

5.2.2 Preliminary session

Another lesson learned from Electro-Jewels was that people related differently to their designs once they had made an affective connection to pieces of jewelry that they owned and were very fond of. So I wanted to reinforce this connection as a way of cultivating the idea of the sentimental value a piece of jewelry has and why we choose to wear it. My

goal was to encourage the children to make an affective connection to the artifact that they were going to build from the beginning of this process. Their teacher and I started by showing sample presentations of our own jewelry depicting our connection to the piece. Examples were whether the jewelry was a present or whether it was a piece of memorabilia from a place visited in the past. We were happy to see that they didn't copy our way of talking about their piece, but were focusing on the parts that they found important. Some examples are: "I like this watch because I am wearing it for three months now and I haven't lost it nor have I broken it!" or "my best friend gave me this bracelet and she has one that looks exactly like this" or "can I talk about my shoes? I wear them all day, I want to decorate them with lights!". After each one took turns in describing one's piece, they questioned the purpose of this exercise, remarked that this was a great opportunity to talk about what everyone interpreted as jewelry (even if they were accessories), commented on appropriate occasions for wearing each piece and gathered information about materials usage.

I had brought with me a lot of pictures of funky or conceptual designs of oversized jewelry or body pieces that showed a wide interpretation of what jewelry really is. Others had lights directly incorporated in them and others were just not worn outside an art or fashion design studio. My goal was to excite their imagination as well as gauge their creativity and attention to detail. I was surprised by their reaction to jewelry interpretation, eye for detail and ability to uncover "hidden meanings" in the pictures. Figure 5.11 lists some interesting comments and reactions that I recorded during this exercise. Although not directly related to the subject of this thesis, nevertheless they give us a glimpse into their alternative viewpoint.



"- It is a hat because it covers the head"

"- No, it is a necklace because it stands on the shoulders"

"It is a broach, no a hair pin ..."

"It is something that stands on a table decorated with stones"

"Is it a ring? But which part is a ring and which isn't?"



Figure 5.11: Pictures of contemporary jewelry design and the children's reactions

I also wanted to give them a head start on the materials that would be used during the workshop. One of the advantages of the workshop being situated at the lab is the abundance of materials and prototyping tools such as the laser cutter that can produce prototype artifacts in a very short amount of time. During Electro-Jewels, people would

use a saw to cut acrylic for their designs. I brought with me transparent acrylic with a precut design on it to show how the light gets diffused through the material and shines through its cuts. Other things that I brought with me included (Figure 5.12):

- A book of faces made out of everyday materials and objects. Some of the designs were in abstract form and some were more tangible and easily understandable.
- Cut-out color wheels to start the discussion about their color preferences and color combinations.
- Jewelry wire and beads to show the structures that can be to cover the LED board as well as the matching colors and shapes that could produce a balanced design.
- Other types of beads that had interesting reflecting properties.
- Ready-made color patterns on connected LEDs that I had snapped together and programmed. No further details on the hardware components were given though at that time.
- The CodaChrome environment on which I gave an overview for about ten minutes.
- Colored markers and paper.

After I showed all the different things I had brought with me, their next question was: “Can we start designing our pieces now?” I therefore drew the conclusion that no extra session was needed and they were ready to start designing. The following dialog indicates that they actually went one step ahead, already asking about more advanced tools and materials:

S: “I want to make a pair of earrings and it is very hard to design one with these wires connecting the LEDs together. How come this is not wireless?”

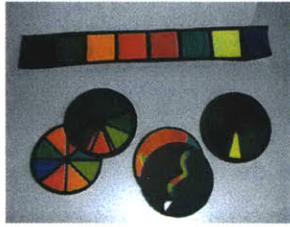
M: “Well, it doesn’t always work correctly, the wires connect it to the batteries for power, ...”

S: “But there are small batteries, the round ones that go into watches that would fit behind the ear to make an earring.”

Yes, they were ready indeed!

5.2.3 Materials

A wide variety of materials were used for the creation of the jewelry pieces ranging from classical jewelry material, like wire and beads, earring clips, general art material like felt,



glitter glue, Velcro, Styrofoam balls, wooden sticks etc. The pictures in Figure 5.12 show more of the materials used for the final pieces that provided a type of inspiration to the children, like for example metallic grid, colored tapes, Fimo (clay-like material that becomes solid with heat), colored strings and adhesive decorations.

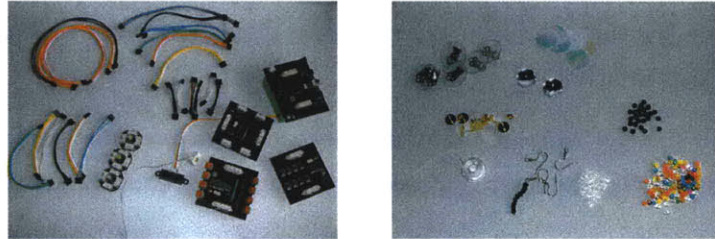


Figure 5.12: The materials used for the CodaChrome workshop (above and left)

The materials list was extended with what turned out to be the dominant material of the workshop: the transparent acrylic. It was mostly used in the form of rods of different diameters. The thin ones were heated and bent in shape whereas the thick ones were used in short pieces and were attached directly to the LEDs. The thick rod captivated the children and especially Martin. He spent a lot of time moving around the lab looking at various light sources through this rod and examining the different effects that were produced. Flat rectangular pieces of transparent acrylic were used for one of the pieces. They were cut in the laser cutter and sandblasted to look translucent. The design process of this shoulder piece is described later along with the other artifacts produced during the workshop.

The tools that were used in the construction activities were a heat gun, a hot glue gun in addition to scissors, pliers, and box-cutters mainly handled by adults.

5.2.4 The Workshop

The present section contains a detailed description of the workshop with the main focus on individual work progress. Stories related to before-and-after comparisons in addition to problem-solving observations will also be presented.

The importance of these short stories in the following description lies

also in the evolution of their thinking about how to incorporate the key feature of their work, the animated color patterns. The various anecdotes and final pieces contain valuable information about how the children assimilated the ideas and capabilities of the colored lights and their changing colors in a programmatic way.

Right after the introductory session at the school most of the children completed a preliminary design sheet briefly describing their intended jewelry piece. These design sheets were handed to me on the day of the workshop. Scanned views of these sheets will appear in subsequent sections.

Present during the workshop were their teacher, Ms. McGarrity and Andrew Sempere, a researcher from the Grassroots Invention Group working on similar research issues; Andrew –an artist by training- provided help and artistic advice. Another two facilitators that had more the role of observers were present during the workshop but not continuously.

Starting with the physical construction, the children began their pieces by getting familiar and comfortable with the materials. Using their original designs in addition to the Tower and tricolor LEDs they got quickly engaged in the construction activity. Their observation provided me with very interesting data about their individual style of thinking and problem solving: Some of the children found exactly what they had described in the pool of available materials but others didn't and they had to find an alternative way of implementing their idea. All of the children had to make design compromises to comply with the fact that they couldn't permanently glue the LEDs on their pieces and they couldn't hide the Tower in an unreachable corner of their piece. We had to have access to them for debugging purposes. Access to the on/off buttons of the Tower as well as the batteries was also necessary.

5.2.4.a Mary

The children that found matching materials made a lot of progress over the course of the first day and they had more time to refine their color patterns. That was the case with Mary. Mary in her paper design made an earring that resembled a flower. It had clip-ons, the LED in the middle, beads as decoration and flower petals made out of wire and blue felt.

By the end of the first day she had a pair of these earrings ready and was able to program them with a color pattern. Her design and artifact by the end of the first day appears in Figure 5.13.

My Jewelry design

What piece of jewelry are you thinking of making? Earrings

Sketch your idea and show where you will put the colored lights and how they are going to change with time:

If you prefer, you can write a description of your color pattern in words:
purple to blue to green to yellow

What materials do you plan to use? (e.g. plastic, wooden sticks, paper, jewelry wire, glass beads etc.)
earring clip, rhinestone, wire, chain/thread
light, cloth

How would you wear this piece of jewelry? (e.g. clothes, shoes, hat etc)
Earrings

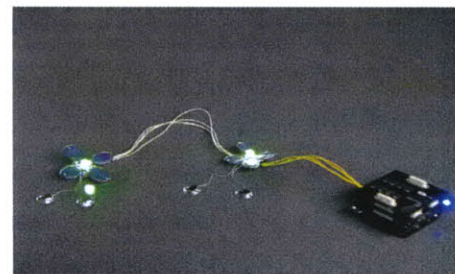
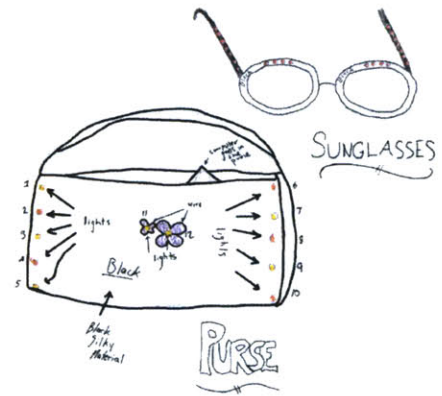


Figure 5.13: a. Mary’s earring design on paper (left) b. Mary’s earrings at the end of the first day (bottom right) c. Her extended design of a purse and glasses with matching decorations (upper right)

The felt was purple rather than blue, but everything else was the same way she designed it. The color pattern was also what she had in mind, purple-blue that fades into green and yellow and then purple-blue again. Her reason for this color transition was to match the appearance of an actual flower that is usually green and yellow in the middle. The purple-blue color was also in the pattern to help the blending of the pattern with the color of the felt. Her follow up design included a purse and sunglasses with matching decorations, but when she finished with the earrings she didn’t want to continue making the other two pieces that were complicated and involved materials that weren’t readily available (cloth, needles and string).

During the first day Mary asked for the help of the other people present when she wanted to make the loops of the petal borders using straight wire. She needed something to bend the wire. She asked: “Does anybody know how to make a flower out of this wire?” Her teacher replied: “How about twisting it around your finger or something else that is round?” She tried turning it around different objects but they were too small. At the end I gave her the cylindrical box of the paper glue. She said that is was exactly what she was looking for.

5.2.4.b Fred

Help, advice, and collaboration were some of the characteristics of the children team building during the course of the two days. They were asking for the advice of the adults but also help from the other children to complete the task at hand. Some of them were able to suggest good alternatives to their classmates when they needed to work around a problem.

A good example of collaboration between two of the participants was Fred and Martin. Fred had designed a mask in his original design that would be made out of wire wrapped in a head shape. But he had problems figuring out which was the best structural material. All the wires we had tried even the thicker ones were not strong enough to maintain the head shape he wanted. Figure 5.14 shows his design and his first attempt at the structure (Figure 5.15).

My Jewelry design

What piece of jewelry are you thinking of making? A head mask

Sketch your idea and show where you will put the colored lights and how they are going to change with time:

If you prefer, you can write a description of your color pattern in words:

What materials do you plan to use? (e.g. plastic, wooden sticks, paper, jewelry wire, glass beads etc.)

Wire, glass _____

Beads, and _____

lights _____

How would you wear this piece of jewelry? (e.g. clothes, shoes, hat etc)

Mask _____



Figure 5.15: When Fred tried to make the frame, he said that it is hard to make the features and the whole structure solid.

Figure 5.14: Fred specified a mask that would be made out of wire wrapped in a head shape.



Martin who had been watching him having difficulties with this approach came to think of other alternatives with him. He found the metallic mesh and tried to see if it could get the shape of his head, but because he couldn't think of a way to bend it in shape said, "it will not work" and started looking elsewhere for a solution. (Figure 5.16a)



When I proposed using it with a piece of felt behind it to make it easier for the face to handle the pressure of molding, I got a few good punches myself! (Figure 5.16b).

**Figure 5.16 a,b:
Fred and Martin's
collaboration for a
steady frame**



Figure 5.17: Fred's mask at the end of the first day.

After Fred had worked around his structural problem, he was improvising on the same theme of the mask but kept trying until he found the right material for all the features he had thought of. At the end of the first day, the mask had a shape and a texture too, made out of Fimo (Figure 5.17).

5.2.4.c Joan

By the observing the children at their school and during the workshop, I found that they their style of navigating through the activity had remarkable similarities to their personalities. Joan was very quiet all along even since the introductory session. She spent a lot of time in front of a white piece of paper as if she couldn't think of anything to draw. She stayed silent and looked as if she was drifting and thinking of other things, until the end when she handed in her design. It was simple yet effective. It consisted of two communicating pieces (a bracelet and a ring). Communication was manifested with a small chain that connected them physically. It also manifested the communication through the lights of each piece that would go on and off synchronized. (Figure 5.18)

She changed her design at the workshop and decided to make a necklace instead. Her design decisions were successful. Without much help from the other children she produced the design of Figure 5.19 a,b & Figure 5.20 by the end of the first day. She used different transparent materials to make her necklace: the thick acrylic rod I have already mentioned and a small decorative bottle that she attached on the acrylic. She then filled the bottle with small white glass beads and closed it. The wire with the beads to

strap it around her neck was attached to the top of the bottle. The LED was added to the bottom of the acrylic rod, so that when it was lit up it would shed light through all the above surfaces and materials. She made a separate pouch for the Tower and its batteries. I prompted her to search for ways to make the pouch in such a way that it wouldn't require glue to keep it together, because "I might have to change batteries". She produced a pouch with ends made out of Velcro and a handle to hold it that worked extremely well!

My Jewelry design

What piece of jewelry are you thinking of making? Bracelet & Ring

Sketch your idea and show where you will put the colored lights and how they are going to change with time:

If you prefer, you can write a description of your color pattern in words:
It would change from lighter colors to darker colors

What materials do you plan to use? (e.g. plastic, wooden sticks, paper, jewelry wire, glass beads etc.)
glass beads
wire
plastic

How would you wear this piece of jewelry? (e.g. clothes, shoes, hat etc)
on my wrist and finger

Figure 5.18: Joan's paper design of the communicating bracelet and ring

It was clear throughout her design that Joan was using the tricolor LED and the color pattern mainly to generate color combinations matched to the color of the necklace. In her drawing, she described the color pattern only in terms of its color content: "It will change from lighter to

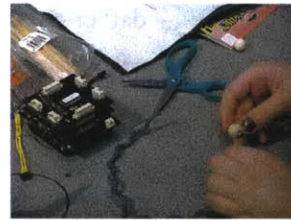


Figure 5.19 a: Joan made the connection of her necklace with two wooden balls and a piece of the very thin acrylic rod after she found out that they were a perfect fit.

b: Her piece at the end of the first day.



Figure 5.20: Joan with the pouch for the tower

darker colors”. The speed and timing issues for her didn’t really matter, and the timing of transitions from one color to the next were rather irrelevant for her design. Indirectly during the programming of the LED she expressed the preference of leaving the speed at the default rate, because the colors changed slowly enough for someone to be able to see and to distinguish them. Her original design focused on matching jewelry pieces (bracelet and ring). In the same fashion, her color pattern focused on matching colors.

There is nevertheless a difference between what she expressed on paper (the difference being in the brightness level of each color rather than the color itself) and what she made finally while she was using the CodaChrome software: She actually chose different colors at almost the same brightness level instead of choosing one color at different brightness levels. Her description and reasoning for her color pattern was that she wanted the color pattern to match the colors of the beads on the necklace (which were all dark in color), a kind of dual presence of the color sequence, one static as that of the beads on the necklace and one dynamic on the LED. At the end she continued to have the same robust idea about how she wanted the color pattern to look like. Her interest was not so much the timing aspect of the color pattern, but rather the colors and color combinations within her piece.

5.2.4.d Susan

On the other hand, Susan had an impressive start during the introductory session where she would ask very relevant and valid questions about the tricolor modules (i.e. why aren’t they wireless, how the current design is limiting her design etc.) but settled for a simple piece at the end. At first, she designed on paper a bracelet with nice decorations and reasonable detail. As a follow up on the bracelet sketch (Figure 5.22), she designed an entire quite elaborate outfit to be created with the CodaChrome system (Figure 5.21)

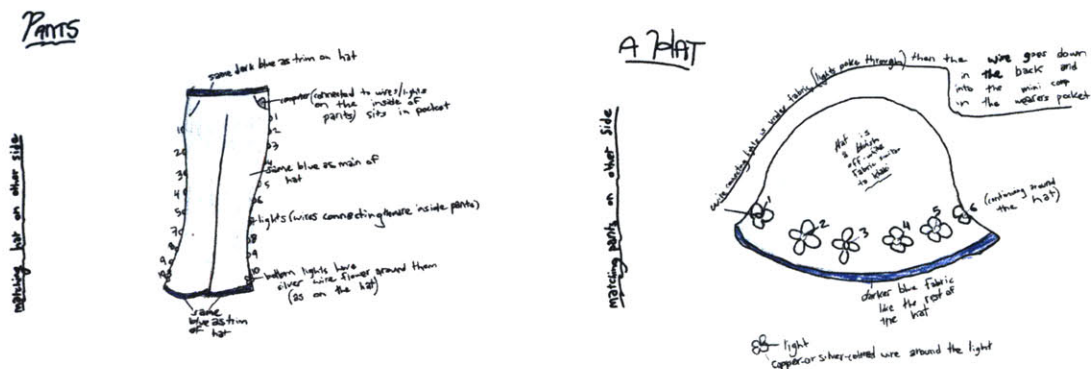


Figure 5.21: Follow up sketch of a matching hat and pair of pants all decorated with CodaChrome

artifact and did not engage in further refinement.

She was able to program her bracelet with the desired color pattern on the first day. She mastered the software easily. She was able to figure out what she wanted the color patterns to be and created them very quickly. After finishing the bracelet, she made a door sign out of plastic that she decorated with additional LEDs. Both her pieces appear on Figure 5.23.

She had a very practical thinking and a symmetrical almost algorithmic aesthetic perspective. Figure 5.23a shows that her designed color pattern consists of a color sequence rotation every time tick. Her practical thinking was also demonstrated when she was interacting with the software while creating her color pattern. She was soon pleased with the results of what she was trying. But once she knew that she had made the color pattern, she would not elaborate more, that is she would not try more complex combinations, color sequences or fading effects. Closer to the end of the workshop, when I showed her a few of the demo sequences, she was interested again and used it to update the patterns on her sign.

Susan helped me realize an important issue with the CodaChrome environment. It is easy with this system to create interesting color patterns in a very short amount of time. In certain cases, this feature provides instant gratification to the users and does not encourage them to engage in further exploration of the timing issues. A more challenging environment could potentially lead the children to target their thinking more towards the timing aspects. CodaChrome can be used to create more complicated color patterns (connecting LEDs into a collective design). Yet, this feature can be obscured by the low learning threshold of the system.

Because of Susan's exceptional interest and progress, I chose her to be one of the four children who participated in my next user study. Seeing her original design and later progress, I thought that she would be a good candidate for the next phase since the activities would require the creation of intricate and complicated color patterns. Moreover, during the workshop, the construction activities did not seem to match her paper designs, as if the failure to produce her design made her loose interest altogether. In the third user study, the emphasis would not be on the physical construction activity, but on the creation of complex color patterns. My thought was that such tasks were more likely to keep her motivated because she would have a harder time mastering the necessary programming capabilities, especially in issues of synchronization.

5.2.4.e Martin

Martin was an exceptional participant: During our introductory session he stood out because of his coherent and accurate way of explaining his thoughts. Unfortunately he did not conclude or deliver any original sketches after the preliminary session. Yet, judging from a few ideas that he explained during the introductory session, he had various ideas most of them revolving around decorating his wristwatch. At that time he also listened to my suggestion about using the laser cutter to cut acrylic. So when he came to the workshop, he had already designed his piece, and he handed me the design of the cut-out acrylic that would be his shoulder pad (Figure 5.24). He had already figured out where the LEDs would fit and what would their pattern be. His idea used eight LEDs that would get attached to his shoulder piece along the rim, only on the front side. The acrylic should have a translucent texture to show and diffuse the colored light. (Figure 5.25)

Due to the fact that we weren't able to cut Martin's piece with the laser cutter until a while later he was forced to do other things in the meantime, like exploring the space, providing his friends with ideas about their designs and trying out the software with his idea for a color pattern. As a result, I had more time to interact with him and engage in conversations about his color pattern. He had also spent a lot of time with the CodaChrome environment and I got a lot of interesting and valuable feedback about the software.

Martin had a very clear picture of how he wanted to program his tricolor LEDs. He explained the intended effect as follows:

“I want the colors to start from the back of the shoulder pad and travel across the front and the same will happen for both sides. Then the colors will arrive at the two LEDs that will be in the middle, they stay there a bit and then go back behind again.”

From this high-level description of the overall effect he had to make the necessary transformations in order to break it down to what color pattern each of the LEDs should have in order for this moving pattern to appear synchronized.

He had a lot of experience in using computers and one of the things that

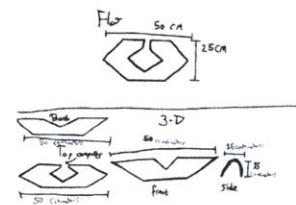


Figure 5.24: Martin's shoulder pad design with its dimensions on the top, side and front/back view.



Figure 5.25: a. Martin's shoulder pad at the end of Day 1 and b. after it is finished. c. Martin wearing his shoulder pad

he did right away with CodaChrome was to play with the palettes and see how each one of them worked. Then he created a pattern and wanted to see how it worked. After doing small exercises like these, he was ready to program all eight connected LEDs. Figure 5.26 shows a snapshot of the CodaChrome environment after he had programmed all the LEDs.



Figure 5.27: Martin while working on the CodaChrome software

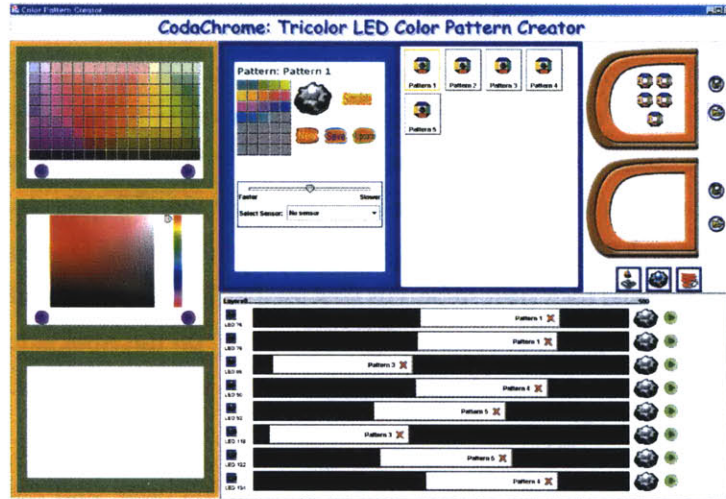


Figure 5.26: Snapshot of CodaChrome screen with Martin's program

In the picture above, the eight horizontal lines with the black background represent the LEDs connected to the tower system. Since the shoulder pad had symmetrical color patterns on both sides, two LEDs were going to share the same pattern. Martin therefore made the same color patterns start and stop at the same time. Figure 5.26 shows that every two LEDs that have the same color pattern start and end at the same vertical line on the timeline component. This imaginary vertical line across all LEDs represents the same moment in time. Time runs visually from left to right. In the picture above the LEDs do not appear with the same order as they are connected in reality, therefore it may be hard to see the pattern synchronization. The first two LEDs contain both Pattern 1 and are aligned. The third and sixth LED both contain Pattern 3 and are aligned as well; the fourth and eighth are both Pattern 4 and aligned; the fifth and seventh are both Pattern 5 and aligned.

Martin was very consistent in matching the lengths of all the patterns that should represent the same length of time. Whenever for some reason a color patterns didn't turn out to be the same length as the others when dropped on one of the LEDs in the timeline component (probably caused by accidental differences during its entry) Martin always tried to drag the end that he wanted to match with one of the others.

Up until then, Martin had used the programming capabilities of the software in the way that I had thought, e.g., by stretching the patterns when he wanted to make them last the same. His overall goal was to shift the color pattern to create a moving macro effect. At the end he was indeed using the software as a tool for expressing what he had actually envisioned.

But up until then, there was no evidence that another type of programming environment or medium would produce different results. In the process of trying to have Martin talk about his color pattern, I tried to have him draw it on a piece of paper thus making him come up with another representation of his own for his color pattern.

We drew a rectangle to represent the tower and eight circles representing the LEDs. His task was to use color pens and try to draw his idea of a color pattern on paper. However, the result on Figure 5.28 calls for a different description than the one he had already mentioned. The interesting thing was that even while he made the drawing he still repeated his original description!

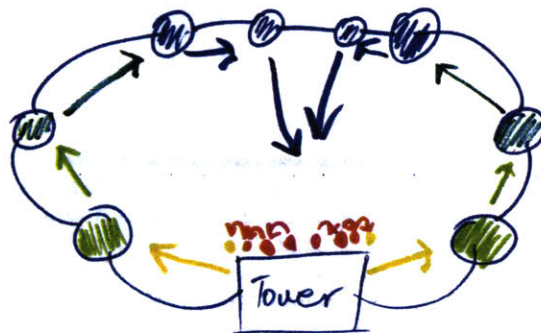


Figure 5.28: Martin's paper description of his color pattern, quite different from the one he verbally explains

He equated his original color sequence with the order that he was coloring the circles instead of the order that the colors would actually appear assuming that the paper drawing was a snapshot of the real pattern. During his description he said that green comes first and then it moves down to the second LED and then comes green-blue. Yet, he actually drew them as if first the green-blue moved down to the second LED and then the green appeared. His idea about the daisy-chained colors, even with the inversion that I just described remained the same. Moreover, he drew the remaining colors on the Tower rectangle representing what he had already described: The colors were somewhere on the back of his neck where the tower was and from there they would come towards the front

when the timing was right.

5.2.4.f Alice

Alice's problems were similar to Martin's with this disconnect between the paper representation and his conception of the color pattern.

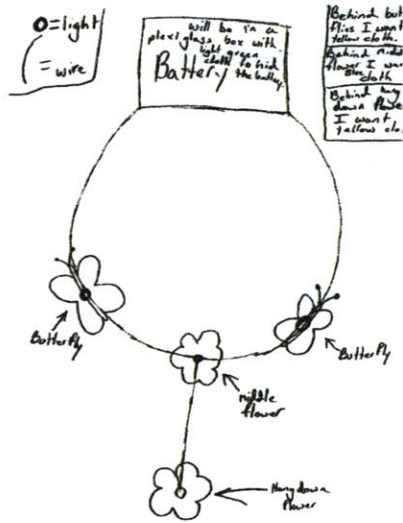


Figure 5.30: The resemblance between her design (bottom) and her construction (top) is apparent

My Jewelry design

What piece of jewelry are you thinking of making? a necklace

Sketch your idea and show where you will put the colored lights and how they are going to change with time:

If you prefer, you can write a description of your color pattern in words:

The top two will change from red to purple, the middle will change from blue to green, and the bottom will change through all colors.

What materials do you plan to use? (e.g. plastic, wooden sticks, paper, jewelry wire, glass beads etc...)

cloth or paper, jewelry wire, alexi glass

How would you wear this piece of jewelry? (e.g. clothes, shoes, hat etc)

around your neck

Figure 5.29: Alice's design of the necklace

Alice's design sheet (Figure 5.29) had the following description for the color pattern:

“The top two will change from red to purple, the middle will change from blue to green and the bottom will change through all colors.”

When it was time to program her piece, she had refined the color pattern to the

following:

“The top two will change from yellow to red to green and the bottom will change through red and purple.”

When I asked her more about the pattern, I realized that she wanted to make the two patterns last the same so that they would become synchronized after they would start looping. I asked her to draw it on paper to see whether that would help her or make matters more difficult for her (I had already the example of Martin in mind). I wanted to see how she was going to draw the synchronized part of the patterns and how she would compensate for the fact that the second pattern had fewer colors than the first one. She drew the pattern as shown in Figure 5.32. The top two would change from two lines (time units) of yellow to 2 lines of red to two lines of green, but she didn't want the colors to blend, so she inserted one line of black to separate the colors. Then she drew the second line representing the bottom LED to have three lines of red, one line of black separator and then three lines of purple. When we tried to see which two colors would appear together, she saw that the colors were not synchronized, that they overlapped with the black separator. Then she changed the second line to have two lines per color so that the colors are synchronized. Only after going through the exercise of trying to see what colors would appear together did she describe how she wanted the overall effect to be: first yellow and red appeared together and then red and purple. At the next cycle of the pattern, green and red would go together and at the next cycle they would change again. She wanted to create a periodicity that would repeat itself every other cycle!

Then I asked about the possible changes caused to the pattern if instead of changing the duration of the second line of colors to match the first she changed the duration of the separators. At that point she didn't want to continue with the exercise and just decided on an almost random sequence of colors (the last line in the picture) that resembled her original design: the bottom LED goes through all colors.

Alice exhibited the following misrepresentation while transforming temporal to spatial relationships: She started to represent time with discrete time units of equal duration. Yet, while drawing the second pattern, she reverted to a continuous representation equating the time



Figure 5.31: After she programmed her piece (top), she started making matching pieces like this hat and veil (bottom).



Figure 5.32: Alice's paper design of her color pattern

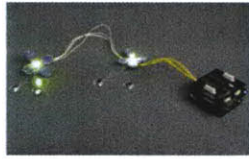
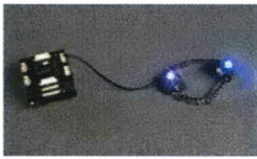


Figure 5.33:
Intermediate steps of
all the pieces created
during the first day

duration of the pattern with its overall drawn length as opposed to the number of discrete time units contained. This was clearly indicated by the relative placement of the separators which were meant to be aligned in a continuous representation but ended up being misaligned in the final discrete representation.

5.2.4.g At the End of Day 1 and Day 2

At the end of the first day of the workshop, all the participating children and adults gathered together to regroup, see the progress of the day, share their thoughts about the next day, share thoughts and ideas about their work in progress and see what types of materials and tools were required for finishing their pieces. During this regrouping the children asked questions about other projects, received comments and suggestions about their own, and they realized the remaining steps by describing what they needed for the next day in terms of materials and programming time.

Figure 5.33 shows what had been accomplished at the end of the first day. Most of the children left the programming part for the next day.

The second day continued with the programming and the interviews and ended with the photo shoot. Figure 5.34 is the photograph of the whole group wearing their pieces. Figure 5.35 represents all the artifacts in their final form.

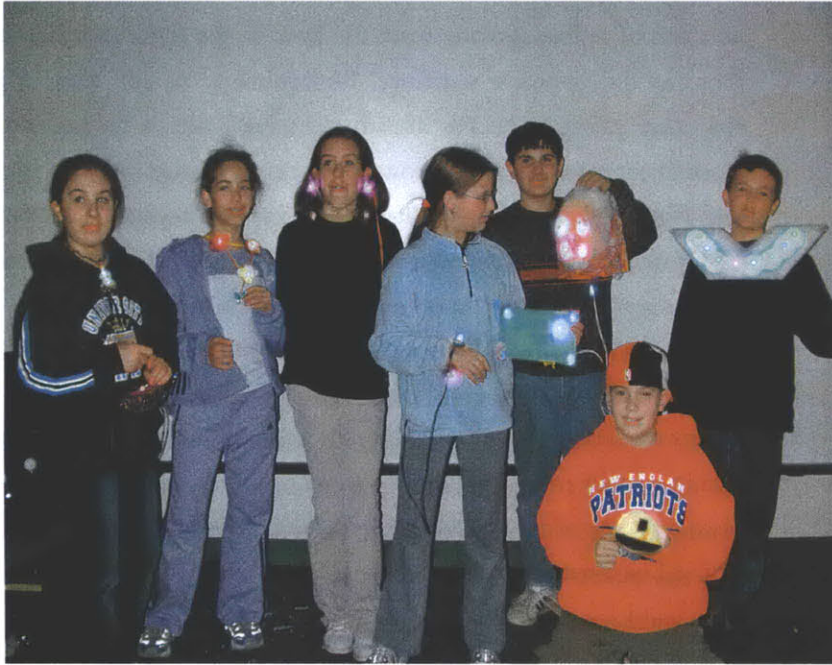


Figure 5.34: Group Photograph at the end of the CodaChrome workshop

5.2.5 Summary

The CodaChrome workshop exposed me to the children's point of view on many different issues. I found very interesting their creativity and problem-solving abilities while dealing with unknown and unanticipated materials (i.e. use of Velcro instead of glue and use of metallic mesh for the mask instead of wire). I was impressed by the consistency from drawn design to final artifact.

By observing their design of the dynamic color patterns, I was able to find common attributes among the children. There were the artistic types (i.e., Joan) who would be mostly interested in the color content of the patterns and the matching of the colors among the LEDs and the rest of the piece materials. Timing and dynamic behavior were of little value to them. There were the Impressionists (i.e., Fred, Mary). They used the color patterns to create an overall effect that would enhance the nature of their piece (scary mask, earrings that resembled blooming flowers.) Finally, there were the "algorithmic" types (i.e., Martin, Alice and Susan) who attempted to represent a macroscopic effect by reducing it to the behavior of each individual LED. Only Martin though achieved this in the final artifact while Alice and Susan indicated this inclination in their paper designs.

Finally, some common misconceptions and misrepresentations that occur in spatio-temporal transformations were clearly exhibited. Specifically, Martin describes his pattern

as a line of colors moving from the back to the front and then he draws them in the opposite sequence. Nevertheless, he still tries to produce the same effect as he has already described, which he makes with the CodaChrome software, as shown in the comparison between Figure 5.26 and Figure 5.28. It seems that the static spatial topology of the painted LEDs is becoming mixed with the description of the dynamic color pattern and that is confusing to the children. Moreover, when the drawing is made, it is difficult to change it to reflect the precise timing, and in both the cases of Martin's and Alice's they got discouraged enough to quit trying. Alice changed her pattern and Martin preferred the CodaChrome software. One of the possible reasons is that CodaChrome contains the combined representation of both the micro-scale, i.e., one color pattern, and the macro-scale so that it is easy to infer what is the relationship between them.

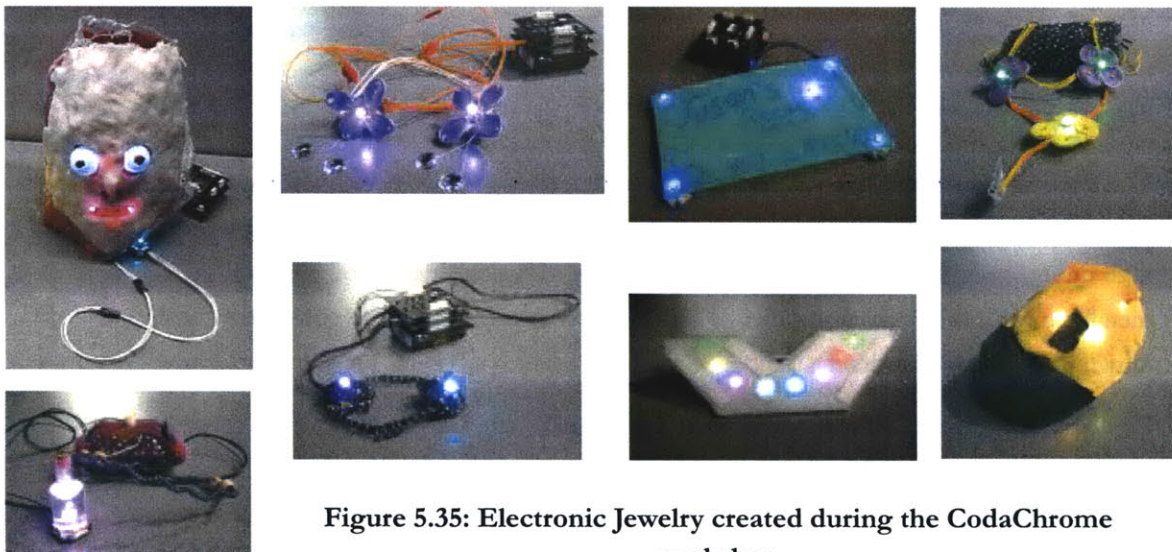


Figure 5.35: Electronic Jewelry created during the CodaChrome workshop

5.3 Third user study: Light sculptures

The success in the creation of well-thought artifacts during the CodaChrome workshop persuaded me to meet again with the children who participated in the previous workshop, focusing more on one-to-one interactions. These individual meetings would provide a more in-depth understanding of how they would think while making the color patterns and how they would use the software to create complex color patterns expressing temporal relationships.

As described in the previous chapter, the children spent a lot of time thinking about how to make their color patterns during the CodaChrome workshop. But for most of the children the focus was on the construction of the whole piece, of which the color patterns were just one part. For example, in one of our later meetings with Fred, when I asked him about reprogramming his mask with another expression (5.3.5), he said that all other expressions would not really work because the mask “by design” was made to look scary. The most he could do with it was to make it look “gloomy”. This is just one of the examples that highlight the children’s main goal when they came to the workshop: to implement their design as they had envisioned it.

On the other hand, remaining true to their design they were paying uneven attention to the construction and programming. Most of the designs in the CodaChrome workshop had a bigger physical construction phase rather than a programming one. That was the reason that led me to this next phase in my user studies where I would restrict the physical construction and focus more on the programming activity.

To return again to the methodological tension that I have described in chapters 2 & 3, this shift in the focus of this next set of user studies might seem further away from Constructionist principles than the other ones. Since the two objects that the children were going to program were made by me, there existed the danger of them feeling personally detached to the activity of programming something that they hadn’t made themselves. These objects (time pieces) were modeled after an hourglass and an abstract clock. Furthermore, the children would not be working within a group of people where they could exchange ideas, inspirations and skills.

During three consecutive sessions I worked individually with Martin and Susan, and I worked with Mary and Fred together during our last session. In an ideal situation, I would have chosen to work with all the children from the CodaChrome workshop. Unfortunately, that was not possible due to time restriction and that is why I chose these four children. My reasons for choosing them were basically their different characteristics that I mentioned in the conclusion of the previous chapter: their individual characteristics

that revealed parts of their thinking and their approach to these new design ideas about dynamic effects. Martin and Susan approached their challenges with an algorithmic model in mind, whereas, Fred and Mary were more interested in the connection between the materials and color patterns to produce the desired effect, or to convey their message.

The participants were the same children as in the CodaChrome workshop. They had already worked with me in designing and programming their piece and I had a little time with them one-to-one even in the previous workshop, during the interviews, where I would ask them about their constructions. I had been careful in creating my time pieces to use materials they had already seen and used before. The time pieces were made out of acrylic cut and sandblasted to produce different textures. This process was familiar to them since we had done the same to Martin's piece and most of them had come with us and seen the machines and the process while we were making it. In this user study, they were even critical of my design of the time pieces and proposed alternatives. For example, Martin said he liked it probably because "it looks like one of the futuristic buildings in SimCity". And then he responded:

"I think it looks very interesting. I like how you made the base [made out of dark acrylic] to look like stone."

He was still able to describe how he would change it to resemble more the idea of an abstract hourglass, made out of acrylic:

"We could disguise the wires and make them part of this [showing the two vertical pieces that kept everything together] and make it a double-layer. [...] And we can have sensors so that it knows when you flip it over."

So, the children would find different ways of relating to the objects of the study either through their shape, or through their construction materials. The children would get attached even more to the programming activities by mapping personal activities on one of the sculptures. To summarize, the children in the previous workshop would be stimulated to think about time concepts via the personal connection that they formed with their artifact during the construction phase. In the workshop on the other hand, the children would be stimulated to talk about time while reflecting on their everyday routines and phenomena they would observe in their everyday lives.

5.3.1 Workshop and Activity Design

When I decided on a more focused programming activity with individual children, I had a number of different scenarios in mind. One was for them to reprogram the artifacts they made during the workshop. Another was to make one or two pieces myself, abstract and simple, that could engage the children in interesting programming activities. My

inclination was more towards the second alternative.

The idea of making a tabletop light sculpture reemerged because it can be perceived as a decoration somewhat akin to the jewelry pieces. From the workshop activity the material that stood out from the others and most of the children found engaging was the transparent or sandblasted (translucent) acrylic.

The form and shape were the most challenging aspects in the design of this piece. Two prominent concepts shaped the two objects that were later used in this user study. One was the idea of creating or projecting a physical pace with the tricolor modules using the inherent time dependence of the color pattern. A physical object that represents the physical instantiation of a rhythm is an hour glass. That was the inspiration for the first piece. The children could use it to program color patterns that contained transitions that could potentially map directly to the properties of an hour-glass: the simulation of the falling sand with colors in time. The abstract hour-glass is shown in Figure 5.36.



Figure 5.36: The first time piece used in the study modeled after an hourglass

The second piece was inspired by an abstract clock onto which the children could map their everyday schedule. This time piece could have two LEDs representing the two digits of a digital clock, one “counting” hours and the other minutes, or in more abstract terms, one counting parts of the day (i.e., morning, afternoon, evening) and the other showing the range of activities or thoughts or feelings during these periods.

Alternatively, the time piece could be designed with four LEDs on a circular base. The fact that there are long separations among the four LEDs would cause the children to incorporate more complex dynamic patterns to show the direction of motion or even more complex relationships among the light modules.

The actual piece was constructed using the second rationale, the four LEDs arranged on a circular surface, as shown in Figure 5.37.

This user study had no construction activity in that the children would not change the physical properties and configuration of the time pieces. The children would only be asked to construct an original color pattern of their own interpretation.



Figure 5.37: Second time piece inspired by an abstract clock

The activities would be closely related to the concepts behind the two time pieces. They would use the hourglass to think of events or situations that

showed some uniform, sudden or slow transition. Then, they would try to model them. Martin for example, simulated the sand in a real hourglass. Susan modeled a color pattern with an “upward motion”. Mary recreated a sunset. They would use the abstract clock to think of their daily schedule and try to narrate it or encapsulate it in a much shorter time interval. For example, they would divide the parts of the day on the four LEDs and change the colors on each one according to their activities during that time period.

The creation of the color patterns based on children’s daily observations would provide the necessary connection between their experience and the activity that they would engage in. Especially in the case of the abstract clock, they would be expressing their every-day activities along with their own personal interpretation using different colors. This would lead to more enlightening and targeted ideas about the way children like to represent their day and what are the different sets of criteria they use to color-code their activities.

5.3.2 Martin - Hourglass

Martin had already shown signs of his algorithmic thinking when he described the motion of the colors on his shoulder pad. I also had the most convincing evidence from him that his paper representations were not working, and I wanted to see –since he had the experience of using the software– how he would use it to face some of the design challenges.

Martin focused on making the hourglass piece look like a real one. His first reaction when he saw it was: “I like this; it reminds me of a futuristic building in SimCity!” I started by explaining to him what I had in mind when I was making the piece to get him involved in its understanding, and then I showed him a simple color pattern that I had copied to all the LEDs that would go through a sequence of seven colors. I explained also that I hadn’t finished the piece because I didn’t program it to look like an hourglass. So I asked him to help me in that activity.

He found a couple of things bizarre at first: there was only one LED per layer, whereas he would have expected a lot on the top and bottom and just a few or maybe one in the middle. It wasn’t completely symmetrical; one could tell top from bottom. Finally, he had trouble figuring out the level of fidelity that he wanted to model the hourglass sand with the dynamic color pattern.

We continued our conversation talking about the overall effect, what it would look like and behave. He described his idea based on how a real hourglass works: “All the lights at the top will be on and the bottom ones will be off. And then the top ones will go off going downwards. And the lights in the middle will constantly be on until the top ones were

completely off and the bottom ones completely full. And maybe we can have some sensors on it so that it knows when you would flip it over. ... I think it is very interesting”

Act I

Now that he had an idea of what he was trying to make, he expanded his ideas and suggestions for the physical construction: “I have another idea: maybe you can disguise the wires and make the wires part of this. Maybe make a double layer”. I tried to lead him back to his original idea of simulating an hour-glass: “*So when you say that you want to have full LEDs at the bottom what do you mean?*”. He drew the shape of an hour-glass with a lot of LEDs at the top becoming fewer and fewer as he went towards the center (Figure 5.38). He explained: “The basic idea is that we have this shape over here with a bunch of LEDs up here ...”

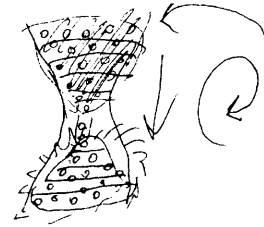


Figure 5.38: “What will you do now that you have one LED instead of a lot?”

I tried to lead him away from thinking about altering the design and said: “*I mean, what if you have just this shape? You mentioned a lot of LEDs; what will you do now that you have one?*” He tried to describe it again in another way: “Here is the idea and let me show you what I mean: these up here (he drew the horizontal lines on the drawing) will be on and slowly these ones go down, we will make them look as if they are going down, and then these will start lighting up. And when all of them light up all the top ones will go off (he shaded the top part in the drawing).” Again, I tried to make the connection with the design of one LED per horizontal line: “*So how can we make one look like as if there are a lot of them? Because as you are drawing this here it seems that maybe you can represent all of them with one. How could you do this?*” He reverted to the construction activity: “If we want one of them to look like a lot of them we can use some Styrofoam because it seemed to disperse light when I used it the previous time and that could make it look bigger”. “*Do you want all the LEDs to look “bigger”?*” “Maybe just the top and bottom ones. And the middle ones can stay the way they are. ...”

Up until then, I had tried to guide Martin into expressing his idea of “bigger” by either using color or the speed of the color change. He chose color. He specifically suggested using the brightness of the colors to represent volume: “Maybe we should make the top one really bright and then the second one less bright and less bright then less and less ... that might work”. “*And what would you say the right color for this is?*” “Well, if it was yellow it would look too much like this (he pointed at the frame), so maybe if we did it ... orange.” He was looking at the pattern of the hourglass where all the LEDs looped through the

same colors and he was trying to determine which color he was going to use. “Blue seems to go very well with it. It gives a nice glow.” *“Are you going to use the same color for all of them?”* “Maybe; we’d have to think about that.” *“Do you think that some colors look bigger and some others not as a big?”* “Maybe, I’m not sure ... It seems like yellow makes it look rather big. But I think blue would go better with it, I don’t know why.” *“Do you think that red fills the whole surface whereas yellow stands out more or the other way around?”* “Let’s see ... I think the other way around. Yellow seems to fill it in ... red actually also fills it in but the yellow stands out more.” At the end we chose blue.

He started by making the color pattern for the top LED and explored the use of the HSB palette. Instead of dragging the mouse across the palette, he did manually by clicking once on the palette. In this way he had better control over the number of colors selected, and he would use the gradation of the palette as a way to make the interpolation from blue to black. Half way through the fading effect that he was trying to implement, he started to experiment with all the parameters he could control with the software: He changed the speed, saw the outcome of dragging a pattern on the timeline component, changed the speed of the whole timeline layer, resized the pattern to be very long and then very short, and changed palettes and colors.

At that point he felt overwhelmed by the activity and lost concentration. I suggested that I could handle the software if he told me what to do¹⁶. He went one more time through what the desired color pattern should be but he changed it slightly from his original description. “I think we should have the colors fading down as they go downward.” He pointed to the first one: “this one should start and then as it fades away this one starts to fade in and continue down. Or maybe when the first starts to fade away this one changes color? And then will continue all the way down.”

Then I asked him: *“When this last one starts to fade away what color should the first one be?”* That was a hard question for him to answer. Our dialog revealed a lot of his thinking about my question:

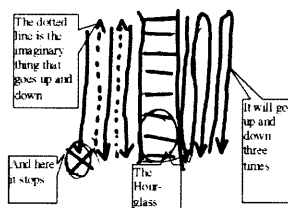


Figure 5.39: “This is a crude drawing that makes no sense whatsoever”.

Martin: “I’m gonna have to think about that. Maybe we should have first one start with red and then as that one fades away, the second one becomes red and the first one becomes orange and then when the third one becomes red the second one becomes orange and the first one becomes green or something else. And that way we can have the rainbow going down” ...

Margarita: “Do you need to draw something to make it clear?”

Martin: “Yes, but this is a very crude drawing; it doesn’t make any sense

whatsoever! (Figure 5.39) So it will come down once (he drew a line with an arrow pointing down) and then it will come down another time (he drew the line that goes up and down). I am going to actually use a dotted line going up and then we go down a second time. And another time and then may be it stops.”

Margarita: “What is the dotted line?”

Martin: “It’s the imaginary thing that goes up and down. And when it goes back up the colors start again at the top.”

Margarita: “You’re not actually saying that you see the colors going back up, just that when it gets to the bottom, it starts over from the beginning.”

Martin: “Yes and then maybe after the third time that it goes down it should stop. Maybe stop at the bottom three.”

Margarita: “But if it is a continuous chain how can we make the top one go off?”

Martin: “Maybe we should program them this way. Or maybe make it so that there’s a lot of black at the end. And we synchronize them so that, as these go black (he pointed at the top ones consecutively) then maybe all of them go black and then all of them start again at the same time.”

Margarita: “And do you want to make all of them go black or do you want to see all the colors down here (I pointed at the bottom three LEDs) and then start over again?”

Martin: “Maybe they should stop here for a few seconds and then start over again. Not really all the colors but just the top three ones.”

Margarita: “Which top three colors?”

Martin: “Or the last three that come out of the top.”

Interlude

From the beginning of this activity Martin found it hard to model and program his original design that closely resembled the sand in an hourglass. When I asked him to describe how he wanted the LED to show, and the effect he was trying to achieve, he referred to the pattern he was experimenting with and said: ‘this is about right’. This is the same answer that he gave me during the CodaChrome workshop, when I asked him about his drawing (Figure 5.28). He again said: “never mind about that, this is what I want” showing me the pattern on his shoulder pad. Now at the beginning at the activity he said: “It is hard; It is going to be hard ... I think the thinking process is going to be the hardest”. Half-way through our session he hadn’t started working on the pattern yet. In his words: “ I still

need to figure something about this.”

Why was Martin so reluctant to start programming the hourglass? What was it that he found very difficult? Why was he changing his design of the overall effect and talked about a uniform motion along the hourglass?

Looking back at the dialog, he attempted to answer a difficult question with a new design, something that would eventually help him answer some of the questions; the idea of a rainbow chain of colors. This uniform motion of the rainbow across the LEDs seemed almost as if it was a comfort zone that he reverted to when the other design was not working. Indeed, the rainbow would color-code all the states of the LEDs and would make the motion of the pattern clear and repetitive. All the colors would “move” at the same speed and time and all LED modules would go through the same sequence of colors. The only thing that would be different was their positioning on the timeline. But his description also revealed that he perceived the color pattern as an entity that can be seen as moving at the macro-level. If the motion at the macro-level was uniform, the details would be easy to master. He had already been through the same exercise during the workshop. The problem arose when the macro-level pattern “moved” in a non-uniform way. This was harder to model and he had to create a new structure to describe and think about it. This “imaginary thing that goes up and down the hour-glass” was not helping him any more.

Although he had to come up with a new way of modeling this more complex and non-uniform behavior, he could still use some of the methods he acquired while designing his shoulder pad: He could keep the same overall duration for all the color patterns. So now instead of keeping the same number of colors (to represent equal duration), he removed the idea of color as the placeholder and replaced it with black. He realized that he also had to count the time “ticks” that he was keeping the LEDs off.

Once he made this realization, he understood that his timebase would be the same for all the LEDs and would expand to include all the time “ticks” that each LED would be off (i.e., he was not counting the time that the bottom LEDs would wait before they would start to light up).

Act II

We went through his original idea again and he began to implement it starting from the top LED that should have been blue right away and then it should be the first one to switch off. Then he said: “The second one is going to do the same thing for longer.” I was observing closely to see what he meant by longer. He made a pattern similar to the first

one but he extended the blue portion of it. The two color patterns are shown in Figure 5.40. The actual length was exactly the same for both of them. This was needed so that all the LEDs would start over again synchronized. Another observation is that he counted the exact number of blue units that he would put into the second pattern. He didn't want to use the resizing feature of the timeline because that would produce two color patterns of the same length through uniform scaling. As a result, the duration of the transition from blue to black would also be scaled and he clearly didn't want that.



Figure 5.40: “The second will be the same as the first one only longer”

Martin was still feeling a bit confused so he described our goal once more: “We start with this one (he pointed to the first) and then the second one does it slightly longer. Then this one (the third) does it slightly longer than the previous one. And then this one ... these two middle ones as soon as the first one starts fading, they light up and when this third one fades away they suddenly fade away too. And then for these three down here, first the last one starts getting brighter and then the second to last starts getting brighter too and then the third one. This third one (third to last) fills up when all the top ones are off.”

The following line of pictures (Figure 5.41) shows the CodaChrome screen with Martin's program in close correspondence to the description above.



Figure 5.41: Martin's hourglass: Successive snapshots of the hourglass.

5.3.3 Martin – Colors and clocks

Martin probably had the most interesting approach to issues of color than the other children participating in the third user study. He used his connection to the colors and the mechanisms of the color palettes for his understanding of the hourglass modeling. He

also gave a very interesting interpretation of how he would color his daily schedule and why.

In Act I, I have already referred to his use of the HSB palette and the explorations he did by using its gradations with or without the dragging feature of CodaChrome. He had the idea of using the brightness of the colors to make the LED seem bigger or smaller. He reverted to the RGB palette “because it’s easier to figure out which color you were using”.

Stemming from the numerical RGB representation of each color on the palette, I explained the basics of the RGB color space to him, starting from the fact that these Red, Green and Blue are the basic colors. His immediate question was: “Why is it green and not yellow? How can green make yellow?” The idea of additive mixing of colors which is different from paints was very new to him and yet he used it right away to make his pattern work. In particular, he saw that the RGB numbers of the colors that he wanted to use were gradually diminishing by a constant amount. This observation helped him to think about the color that gets “subtracted” from the top LEDs and gets “added” to the bottom ones; it formed an equivalent to the amount of sand that drops from the top to the bottom part of the hourglass.

After the conclusion of the hourglass programming activity we began talking about how he would color his time during a normal day. Unfortunately we didn’t have time to proceed to the programming activity of the timepiece, but the way that he colored his day is still very interesting. “My mornings are pretty vague so I’d say they are grayish ... because it’s more obscure”. “Or if I would color it, I would make very sudden changes between the gray and very small splashes of color here and there”. He then describes how his idea of coloring time is context-sensitive: “Some people say that their thoughts have colors, but I would color my thoughts based on the particular things that I was thinking. So if I was thinking of a red and blue car crossing on the street I would think of red, blue and maybe gray for the concrete”. “I would color my day based on what I am thinking instead of what I am doing, so if I run I don’t think as much as if I don’t and therefore running would also be colored gray.” “The peak of the day is when I go to sleep because that is when I think more intensely about my whole day.” Sometimes it might depend on the conditions¹⁷:

Martin: Moving affects how I think

Margarita: So the more you move the less you think?

Martin: Yeah, the more I move, the blurrier my thoughts are.

Margarita: So how would you color it when you move?

Martin: If I was running and I wasn't thinking a lot at the time ... hm probably depending on the weather. It depends on the conditions I am in ... It's hard to describe it. ... If everything else is the same, it depends on the conditions.

5.3.4 Susan – Time Piece

Susan, as I mentioned in 5.2.4.d, had a very practical way of thinking, which manifested itself in a variety of ways. While she was interacting with the software to create her color pattern, she quickly used the software to make exactly what she wanted. Although she didn't elaborate on her actual piece, her original design was very big and elaborate. Her algorithmic thinking was also manifested through the pattern design that she had drawn on paper with a shifting color pattern along consecutive time intervals.

Although the pieces that Susan made during the CodaChrome workshop were not the most impressive ones, the above characteristics of her personality led me to believe that she might be more interested in this new set of design activities in this third user study. The physical design would be constrained and therefore she wouldn't feel obliged to make something that wouldn't match her ambition (as in the previous workshop) but also the programming activity would be more complicated and therefore would engage her longer. Finally, the types of programs that she would have to build for the hourglass and time piece, were algorithmic and would fit more her way of thinking.

Part 1

Susan started with the activity of programming her daily schedule on the abstract clock. She understood the activity at once: So if you had more fun at twelve [o'clock] you would put a color you like up here (pointing at the top LED), and then maybe at 3 you had to do your homework and you didn't enjoy that so much, then you could show the transition from a color you like to a color that you didn't like (pointing at the next clockwise LED on the circle)."

Working directly on the software, she made the pattern on the HSB palette and she explained them to me at the same time: So maybe my favorite color is blue, and maybe I don't like yellow so much. At blue I get to go to soccer practice... because I like to play soccer. Then as time goes by it starts to get worse and then I have to leave, I go home, take a shower, and then do my homework, which I dislike and that is why I put some yellow." The overall idea was that each LED would represent a part of the day with one color and it would fade into the color of the next LED clockwise to show the temporal

transition. The first would change from blue (representing soccer practice that she likes a lot) to green.

I was trying to understand the way she imagined the whole effect so I asked: *“What does the first one do, when this second one is yellow?”* “The first one fades from blue to green and when the second one is yellow it could either turn off or just stay at the end of its thing (meaning the pattern). *“At the end or the beginning?”* “Or the beginning ... yeah. Could it maintain a color and just stay there? I mean go through the colors once and then just go back to one color and stay there?” *“It will have to loop [...] You know what else we can do? We can specify in the color pattern that it should keep the same color until all of them come to this LED again. And then you want them to start over again. ... You wanted to go from blue to green and then stay blue or stay green?”* “Stay blue”.

Then she started making her pattern on the first LED that started from blue and progressively went to green. After she finished this transition she was hesitant. She confirmed that she had to sustain blue, but she was not really sure for how long. I asked her questions to guide her to think of the overall timing of the piece and she replied: “It is six colors on the same LED, times the four LEDs is twenty-four. So I will count twenty-four blue ones”. *“Do these twenty-four ticks include the six ticks that belong to the pattern?”* Then she figured out that she needed to find a way of counting the ticks of the pattern as well to add it to the twenty-four that she has counted so far, or continue with blue until she would get to 24. She again redefined her pattern: “This will go from blue to green and this one will go from green to yellow (pointing to the second LED)”. Unlike Martin, she did not experiment only with one LED. She tried to see their relationship. “This will go from the same blue ... no from green to yellow and red (pointing to the second LED). So as this one (first LED) goes from blue-green ... the high point will be yellow and then will start going to red. Yellow is homework and red is reading because I like reading, especially before bed and dinner. So that one (pointing at the third one) will be night, because I sort of like the night”. The way she was thinking about her pattern (the transition to red) gave her the idea for the next one. She had transitioned to thinking about the overall pattern. She made half the pattern of the third LED—just the transition— and as she dropped it into the layer, she saw the difference in length with the other patterns and redesigned the pattern to sustain the same color for as long as the previous two. She continued: “This one (the third one) will go from red to pink. Pink will be waking up in the morning. I hate that color.”

According to the transition scheme she had used until then, the fourth LED was going to model the part of the day from waking up to soccer practice. But then she had a problem: “It’s sort of weird having it go from sleeping at night to soccer practice” *“Why?”* “The

jump is big, I skipped school! Maybe the pink will also be school.” *“Don’t you like school either?”* “I don’t like some parts. Some things I like, like Math, but what is the point of learning about pronouns in English?” *“Do you think you can make one of the two patterns more complicated?”* “What do you mean?” *“Maybe make the pink one (third) or the blue one (first) to have more states. So the pink actually changes into ...”* “Purple ... for school! [...] That’s good. OK, first red, then I wake up, which is pink, then I go to school which is blue.” She counted the colors and saw that her pattern was not six time ticks long but twelve. “But that would mean we need to make it ... more [colors] on each one [LED]. When they wait for twenty-four [time ticks] it will have to be thirty ... because it’s now five sets of six.” *“But if you put thirty of them, what do you think it is going to happen to your overall thing?”* “If the overall thing takes thirty then this will start (first) when this one (fourth) is still in the middle. So you won’t see the transition. So we need to fix them all”. *“Yes. Or you can make it stay at one color for less”* “This color for less?” “I mean the fill color, the sustain color as you did with the other patterns, where you kept one color for longer.” “So, I can keep this color for longer...no for less” *“Yes. What do you prefer?”* “So now instead of twenty-four it would be ... eighteen?”

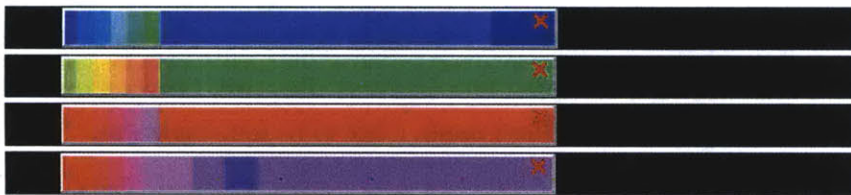


Figure 5.42: Susan’s first program of the time-piece

As Figure 5.42 shows, she made all the transitions at the beginning of the color patterns, which meant that they would start at the same time. Yet, Susan had been describing it as progressing from one to the other because they represented different times of the day. But when she tried it, they started at the same time. I asked her what was happening. “This thing (pointing at the first LED) needs to stop before that (second). Only one goes at a time. So first this (first) would start and go and then this (second) would start. So I need to give it (second) six time ticks before the pattern begins!” After that she realized that she needed an initial delay but did not subtract this delay from the overall delay: “Six green and then the same pattern after that (referring to the second LED).” She still counted the same amount of time-ticks after the transitions as in her previous pattern for a total of 30. She didn’t subtract the six she used in the front. Soon, she realized that she had to subtract six ticks from the end and redid all the color patterns correctly. After an adjustment to the speed she thought that “it follows nicely around.” Figure 5.43 shows her final program.

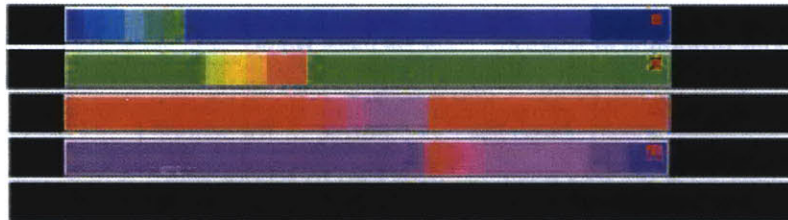


Figure 5.43: Susan's correct program of the abstract clock

Interlude

Like Martin, she started explaining her idea by proposing an alteration on the time-piece: "If you had one more light right there in the middle then you could show better the transition from one to the other". Her alterations were not cosmetic but rather functional. She wanted to have four more LEDs between each pair to show the transition of one pattern to the next much better. Although we did put one more between the first and second LED, she didn't use it after she started programming the patterns (depicted by the extra blank layer in Figure 5.43). Since my intension when I was creating the piece was to limit its expressiveness by putting just four LEDs on the panel, I never thought that the economy of its design matched Susan's needs; it had to be something else.

Looking back at the way that she tackled this task, I saw a continuous interplay between how she understood a transition and a state. At first she thought of the color that represented that portion of the day as the **state** of the LED, namely the blue for the first, the yellow for the second, the red for the third and the combination of pink and purple for the fourth. Then she wanted to add another LED in between all of them to represent the **transitions**. So the hypothetical LED between the first and second would go green to show the moving between the blue and the yellow. But in the end she did not use it because a transition is not an entity of its own. It is part of the state of the LED, which is the entity that she was modeling. Therefore, the state and the transition would blend to produce the patterns created at the end. Each pattern now started with the color of the previous one and finished with the color of the next one with a discontinuity between the fourth and the first.

Susan thought of her patterns as entities that moved along the circle in a timely fashion. First, she defined the color transitions, and then translated them on the global timeline to create the overall effect. She never made any mistakes about what the state and transitions of the resulting color pattern would look like. She even had the algorithm for making the

additional color on the last LED work when she explained that the overall length of the pattern should be thirty instead of twenty-four because now we have five instead of four sets of six colors.

Part 2

After she had made the pattern that she liked, we started talking more about colors and how they can express her daily schedule better. During this session I was trying to look more deeply into the process that she used to establish the pattern. I was trying to understand whether this pattern was a random choice of colors or whether the pattern could convey the same information to her at a later day. In particular, I asked her whether she could distinguish two given days by their representation on the abstract clock. She said: “Tuesdays are better than Mondays and Wednesdays are better than Tuesdays and Thursdays are better than Wednesdays and Fridays are the best.” *“How are they different? How is Monday different from a Tuesday or why is Friday better than Monday?”* “Friday! I would be feeling better about school because we have no homework on Fridays. So this one (pointing at the second LED that represented homework) would be purple or blue ... sort of a medium color for me.” When I asked her about the ranking of her preferred colors she said: “Blue, then green and purple, and then yellow and pink”. *“Are yellow and pink the worst?”* [...] *“Would that purple be brighter on Friday or would it last longer? Or maybe the whole day would have more a purple aspect to it?”* “The whole day would be more purple ... maybe the whole morning would be better... so Fridays would be more blues and purples and Mondays would be more reds and yellows”. *“If you see this (I pointed to the abstract clock), now that you know what it represents, would you be able to tell which day it is just by looking at it?”* “Yes!” *“Do you want to show me what another day would be like?”* “OK, so on Friday I wake up. Still no fun. So it’s yellow. Then the yellow would change to green for school. Green is my second favorite. And because I would have no homework the green would change into teal, which is one of my favorite colors, and for after school ... maybe blue ... for reading a book after school. And then maybe purple for going to bed. I don’t like going to bed that much. Because you just have to “go to bed”. And then I would be asleep and I couldn’t really judge my day when I am asleep, except that I like sleeping”. [...] “Overall you can tell that a weekend day is more interesting. And if it’s Wednesday and I hate Wednesdays, I could just look at the weekend”.

Another connection that I tried to make similar to Martin’s narrative was to understand the connection between the color choices and the types of physical activities. Instead of changing the colors as Martin did, she used the idea of the speed of color change on the pattern. At the end though, they were both addressing the same idea. Martin described it

as “flashes of color” whereas Susan used the term “blinking of colors”. *“How would you change this to show that you were running? Or thinking of something that is more intense?”* “I don’t know about that. Maybe blue and purple ... and then it would be blue-purple, blue-purple, blue-purple ... not because I dislike purple but just because it’s close to blue and to show that it is on and off. Maybe it would go fast and when they would fast it would be the blending of blue and purple. ... Blink almost”.

5.3.5 Susan –Hourglass

In Susan’s case of programming the hourglass, I allowed more freedom in her choice of an overall effect instead of modeling a real hourglass as in Martin’s case. She replied with a similar description of her idea, as Martin did with his rainbow. “Maybe we can have color go upwards... and have maybe a blue... lighter blue, purple to pink, to red to yellow to green, to orange. **Almost like an eruption.**” *“Will it go smoothly?”* “It will go fast” *“And then?”* “Go back down... no wait ... it will go up and then it will just come down to the bottom... the way it is shaped it looks like it’s going up.” *“When it comes down, will it show?”* “No, it will just... flash back at the bottom”.

Once she had the idea about a program for the hourglass she went ahead and started making the color patterns. She also had the experience from the programming of the other time piece so for her this activity was just an iteration on the same algorithm, the shifting pattern in time to show an upward motion. She quickly came up with her pattern, which specified that each LED would keep one color of the rainbow and at each time tick (or every five seconds as she explained) only one of them would be brighter than the others. This consecutive flashing of brighter colors progressed smoothly across the chain of LEDs and would loop back at the beginning as shown in Figure 5.44.

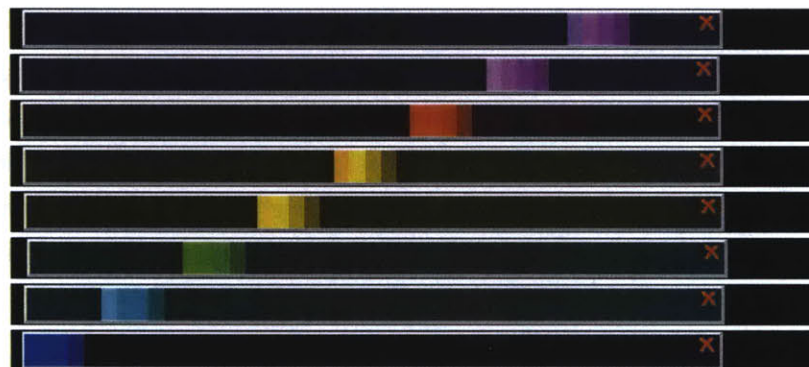


Figure 5.44: Susan’s hourglass pattern

She programmed the piece easily. After the programming activity I proceeded to questions that I did not have the chance to ask Martin due to lack of time.” *“Would you have it in your room as a decoration?”* “Yeah, that’s cool” *“When you are thinking of a color pattern to create on this, what do you have in mind? Do you think of something moving on them? Do you want to make a line that moves? Sort of like a small snake?”* “Something that it is shooting up ... almost like a volcano and lighter on the top... and then it goes back down”. *“Why did you choose this order of colors?”* “They look good together ... they are the colors of the rainbow ... they look good together.” *“You said it looks like a volcano .. If you wanted to make fireworks, how would you make it look like?”* “Blues ... make green to yellow to orange to bright red.” *“Would you change the order of the colors or the speed as well?”* “I would change the speed as well ...”

She continued to talk about new features that she would find interesting in CodaChrome. “... It would be great if this had a dial to change the speed so if you are feeling in a good, maybe fast mood it could go faster up and down, but if you feel like you just not want to do anything and you just want to read a book and not be distracted, then I would change the dial to make it go slower.” That of course was a very close description to the functionality of the sensors, which I explained to her. She first decided on the use of a light sensor to change the speed of the pattern and then she described how it should behave: “If you are feeling tired and you have the lights down, then it can change too. So that way it will change according to your mood as well because when if you are feeling tired you have the lights down, or if you are feeling well you have the lights up. You don’t have to interact with it.” She thinks that its shape and form factor lead to a less interactive mode of engagement with the piece.

We concluded our session with a small exercise about paper representations. I asked her to show me on paper how she would represent the program, so that someone else would be able to reproduce it.

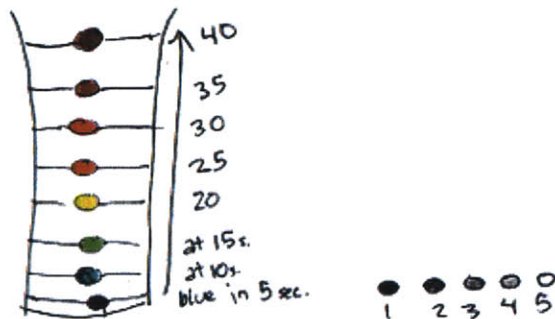


Figure 5.45: Susan’s paper based program of the hourglass

Susan first made the drawing on Figure 5.45 and then she explained: “This is the light pattern. That is the sequence, but you can also draw eight of them and then all the others would be darker and only one would be brighter and you would do that eight times.” A couple of questions later I was trying to get Susan to elaborate on her drawing and description. *“If you had to show the timing on that drawing, how would you show me the sequence or your transitions?”* “I would say that they go on consecutively [...] This is blue in the first five second then this would be green at ten seconds...” *“And then it goes into green for how long?”* “So then, fifteen seconds before it turns on ... and then ...” *“And how would you say how long each one stays on before it goes off?”* “They stay until the next one goes on. But they are sort of dimmer. The brightest would be when they first turn on and then they dim. And then the next one comes on bright and dims.” *“How would you show that?”* “You can show a diagram second by second...” *“On this drawing? Would you draw it?”* “I can’t really shade with a marker, can I use a pencil? Like that, so it’s consecutively getting lighter and this one runs off”. At the end Susan says: “I would use these colors and this pattern for my room because they are subtle and non-obtrusive ... but I would reprogram the pattern to flash and blink like an advertisement to draw your attention to it.”

Susan addressed the issue of the dynamic color pattern as a rainbow moving up and down the hourglass, as Martin had done too. Susan differed from Martin though because she was showing the motion that she talked about with a change in the brightness of the color that was constantly occupying a certain level. She also has a similar only better way of explaining how the synchronicity among the LEDs would work on the abstract clock: “After it goes though once it should stop” ... “Well I guess I can fill in the rest of them with black, or I can keep the same color until all of them have gone through their pattern.” She has a more clear picture earlier on about what the other LEDs should be doing while the “action” of the overall effect is somewhere else.

She was using the sensors in such a way that minimized the interactivity of the hourglass with a person and promoted the connection between the light and the speed of the color patterns. This was depicted by her preference of a light sensor over a distance sensor that could be more easily associated with a tabletop light sculpture than a wearable piece of jewelry.

5.3.6 Fred and Mary – Time Piece and Hourglass

Mary and Fred became part of this third set of user studies because both in their own unique ways were the “impressionist type” as I have already mentioned in section 5.2.5. In the previous workshop, they used the materials they were given and chose their colors to fit with the overall design (and not the opposite). They both remained very close to their

paper designs and used the timing capabilities of the CodaChrome system to enhance the color selections rather than to produce an effect, like motion. I wanted to see how much they depended on the overall design idea and other materials, when they were creating the color patterns and using the system. It would become more interesting in Fred's case, since I decided to bring his mask to determine how much he relied on the construction activity to produce the artifact.

Fred and the Time Piece

With Fred and Mary I tried a different approach during the introduction of the activity. In the case of Fred and the abstract clock, I provided very little information about the ways that he could represent his daily schedule. I wanted to observe his inclination on his mappings of his daily activities onto a color pattern. The intentional lack of guidance produced confusion at first about the nature of the activity, although he was able to describe his day and attribute colors to it: "I would start out by ... maybe pink in the morning cause, I am just waking up and it's a light color and I am a little bit light and don't really feel down to earth. [...] But when I get to school probably light blue because it's when I learn and blue is a good color. And well, then when I get home, I do homework and that is something that I really don't like so I would pick something like gray. And then after that I would play outside and that would be really fun, so I would put that as ... red, green and blue mixed because I like those colors, they are my favorite colors. So I would mix them together because I like playing outside. After that, I would go home and watch TV ... that's pretty relaxing. It would be like an orange or something. But then when I get home ... food ... so a yellow or brown. And then ... for sleeping I would put dark blue because it's nighttime it's kind of dark and that's about it."

When he was thinking about the representation on the time piece, he was puzzled. While he was describing his morning he explained it as pink and darker pink but then he had to figure out how to map the colors on the LEDs. Should pink go on the first LED and darker pink on the second? He says: "... we can use pink and dark pink in here, I don't really see why not, but ... it would be good to do pink and then dark pink over there (pointing at one LED) and then the rest of the day ... (pointing at the other LEDs). And then go around in a circle. But if you cramped all of them in here, where these are going to go?". After a number of different alternatives that he thought about he chose the one shown on the following Figure 5.46.

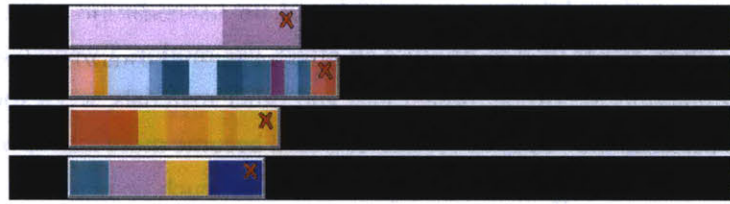


Figure 5.46: Fred's program of his day.

The Rest of the Day was a combination of different things that did not blend with each other because they are discrete activities, like watching TV or eating dinner that always happen every evening, in contrast to other events that are alternating among different days. For example, he mentioned that he might skip lunch if he continued playing after school, so that one day would not include lunch within the After School color pattern. The evening activities had a more clear definition that concluded with dark blue which was the night. : ...

After he programmed the time piece according to his description, he said: "I cannot tell which is which"! This was an understandable reaction since his color patterns were not even of the same duration and did not have the visual cues incorporated to show the right order. Ever since the beginning of his programming activity, his explanation of his daily schedule mapping onto the abstract clock did not include the idea of synchronization among multiple threads of color patterns. Naturally, to him his whole day was one single sequence and conceptually might map better onto a single LED.

Now that he had programmed all four LEDs, he found the result confusing. Would he return to the software to incorporate the necessary visual cues into the color patterns? In fact, he did not choose to change the color patterns at all; rather he decided to make small paper captions for the four LEDs.

His last statement, "I cannot tell which is which", did not only show the lack of temporal relationships among the color patterns, but it also showed a lack of identification of how his day was like. The overall effect of the time piece looked more like a random change of color, rather than a narration of a day. Susan on the contrary would be able to tell the difference between two days using her color patterns. Fred used CodaChrome to create color patterns that were aggregates of his daily schedule. As he made the color choices, he was already taking under consideration the potential differences among the various days of the week, so the pattern at the end was a small collection of all the possibilities during his day. This aggregation was expressed by the similar colors used per color pattern, i.e.,

pink for Morning and yellowish colors for After School, and it was confirmed by Fred himself when he labeled the abstract clock as his “Average” day.

Mary and the Hourglass

Mary worked with the hourglass for a short period of time and she tried to model a color change over time that we see in nature, i.e. a sunset. We tried to think of other things –not just natural phenomena– that change over a short or long period of time. Mary thought for a while and then said: “Like fireworks? [...] like a television set? [...] It doesn’t show a particular color change but the colors on the TV screen change with the different pictures ... like when you put food coloring into something and you mix it and it changes from a light color and then gets darker...”

Her description of the color pattern that represented the sunset was: “I think it should start from blue, like the sky during the day and it would go from purplish to orangish – kind of a hazy light of the sun going down– which is kind of a yellow and orange. Then the clouds get pink and purple and then it will go to black”. She used the HSB palette to make the fuzzy transitions between colors and wanted to arrange it on the hourglass with the blue-purple on the top, purple to lighter purple second, lighter purple to pinkish third, pinkish to orangish fourth and then dark blue, dark purple, and black.

Although during our conversation, Mary decided on using the color patterns in order, she implemented it as if they all start at the same time. (Figure 5.47) Also, her color patterns were not of the same length, and consequently not of the same duration. Therefore, they would loop at random points in time. Yet, she was not concerned with it. At the end, when I asked her what she would change if she had more time, she replied that she would change the color on one of the LEDs because it seems greener than what she wanted.

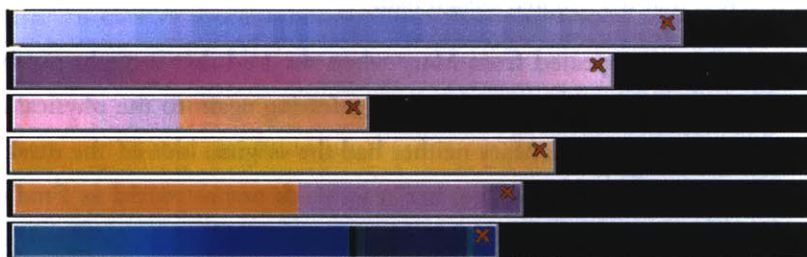


Figure 5.47: Mary's sunset pattern

Fred and the Mask

I have already mentioned the fact children were showing unequal interest in the

construction of the piece over the programming of it. This follow-up session with Fred gave me the opportunity to observe the importance of the physical construction and to verify that the children indeed think of both the color patterns and the physical activity at the same time when they are coming up with their design.

Fred was engaged in making his mask during the CodaChrome workshop (5.2.4.b) and it turned out to be a very successful piece. So I brought the mask to him and asked him to change his mask's expression by changing the color patterns and not the actual artifact.

Mary was already in the room with us, while I was explaining this to Fred, and she said: "How can you change the expression now that the clay is hardened and in place?" Fred says: "I don't know if I can make him happy ... because ... he is scary..."

I asked if he could make it look sad and Mary suggests right away to him: "Yeah, you can make it sad. You can use all dark colors and blues". Derek first tried to make it sad. Then he changed his mind and tried to change his lips to green in case he could make it look envious as he had mentioned during the CodaChrome workshop. At the end he said that the mask was made to look scary and the best he could do was to make it look gloomy.

Conclusions

Fred was very consistent in his design approach both during the CodaChrome workshop and in the follow up session where he reprogrammed his piece. The physical construction of his mask played an important role in the design and making of the artifact and the color patterns have an important and complementary role to it. He wanted he mask to look scary all along and its physical construction was an integral part of it. Both the color patterns and the physical aspect of the mask contributed to the scary expression. Since making it look happy would not work, he settled for making it look gloomy but without the dramatic affect that the original design had.

The same reaction gets repeated from Mary when she said that it might not be easy to change because the clay was already hardened, referring again to the physical aspect of changing the mask's expression. Mary neither had the original idea of the mask, nor was part of its construction and, therefore, her reaction is not as partial as Fred's reaction might be.

They both focused on the aggregate or average effect of seeing the colors changing, rather than timing it carefully. This is apparent from their selection of colors. In Fred's case the colors he chooses are just a merging of all the possible activities that he might do at one particular time of the day, therefore, they might be different between them, or one of them might last longer than the others. In other words the color selection is rather

fuzzy. In Mary's case the color selection was also fuzzy, but in a more controlled way, since she was using the HSB palette to make gradual transitions from one color to another.

Both Mary and Fred did not use any of the software features to make their color patterns equal in duration and they didn't think about its appearance, when each color pattern would start over again. On the other hand, they both changed the speed of the pattern. In retrospect, as I think about my session with them, they do not seem interested in accurately or correctly conveying information as Susan and Martin did. By watching both of them it occurred to me that they were both trying to create an effect or leave an impression.

6.1 Uniform modeling of motion in time using rainbow colors

One of my original goals during the development of CodaChrome was to see what children would make with the system and how they would choose to express themselves with it. I wanted to see in particular, how they would use this new capability of building temporal animations of color patterns and what things they would want to represent with it. Would they make fireworks? A static image? An abstract behavior? A complex moving pattern? A funny and playful toy?

The most prominent temporal structure that I have seen until today is the imitation of various types of motion created from a rhythmic change of colors on the LEDs. Usually this motion involves the interchange of the rainbow colors on the LEDs that are usually arranged in a line or circle. Even the LEDs that are incorporated into complex structures and seem arbitrarily arranged, were originally made and programmed on a straight line.

The motion patterns usually contain the uniform shifting or rotating of a color sequence across all connected LEDs. Once the children understand the idea of shifting or rotating, the motion effect depends solely on their accuracy in shifting all the LEDs for the same number of time units. The key to synchronization among color patterns is the understanding of the common timing frame that each color pattern needs to have. In other words, every color pattern in a sequence of LEDs needs to have the same duration as all the others. If this common frame or duration is achieved, then it is very easy for the children to change the speed of the overall effect by changing the speed of all the individual color patterns uniformly.

The rainbow colors are usually chosen not only because they are so distinct, but also because they provide a kind of color-code to help children think about the state of each LED at different times. There were cases where different colors were used, but they were still discrete and much different from each other, to distinguish between the various states.

Both Martin and Susan created such color patterns with the ideas of motion across the LEDs. Two such examples were made by Martin; one is the pattern for his shoulder pad during the CodaChrome workshop and the other is the color pattern that he described verbally during the third user study, but did not implement at the end. Susan used this approach for both patterns during the third user study.

The mental model described by the children when they are describing this uniform motion is that of one entity –a single chain of colors- that moves across the LEDs. Martin describes it as “the imaginary thing that goes up and down”. Susan says: “...and then it will go back down... no wait ... it will go up and then it will just come down to the bottom...” without showing.

The change from a uniform model to a more arbitrary one is difficult and takes a lot of time and effort. Martin had a lot of trouble modeling it during the hourglass activity, where he had to break the metaphor of a uniform motion and think of the behavior of the sand in a real hourglass. For the whole session he was trying to understand the new metaphors whereas Susan in the same amount of time had programmed both the time pieces.

6.2 Media Dependence

Existing research (Ackermann, 1990) informs us of the media dependence in the way children understand and describe various concepts and relationships. Another one of my original goals was to examine how children express ideas about temporal effects and relationships through a computational medium like CodaChrome. I wanted to see the differences in expression from other types of media, e.g., paper and colored markers, and what their preferences were.

In my user studies I tried to look for such differences in the way children used colors and paper on one hand, and CodaChrome on the other. The comparison between the two began after Martin made a drawing during the CodaChrome workshop, which illustrated discrepancies between his verbal explanations and his paper representation. In fact, his drawing almost conveyed the opposite information of what he wanted to say. On the other hand, his color pattern made with CodaChrome was much closer to what he had

described. Alice had similar problems when she drew the color separators vertically aligned to show that they were synchronized, whereas nothing else was correctly placed.

Most of the confusion and misrepresentation of their ideas is due to the coexistence of spatial and temporal information. For example, Martin tries to express the colors in order of appearance, and at the same time he shows where the next step of the “action” is going to happen, i.e., the next LED to be added to the pattern. If Martin had separated the color sequence from the topology of his LEDs, then the drawing would probably reflect his correct idea. This is what Susan did with her drawing of the color patterns and turned out successfully. She separated the spatial and temporal aspect of her program. She made one drawing with the colors on the arranged LEDs and another that showed the change of brightness that each color pattern goes through. Her idea of the upward motion created by the change in brightness rather than the change of colors on all the LEDs helped her to arrive to this representation.

Two reasons can account for the more accurate expression through the CodaChrome software than on paper. First, the representation of the LEDs on the CodaChrome software is common for all LEDs, which makes them equivalent. This representational fact minimizes the need to emphasize the spatial relationship or topology of the LEDs and the spatial motion of the pattern. In other words, the macro-effect of the color pattern becomes more distant than the synchronization among the micro-effects needed to create it.

The second and more important reason for the children’s preference in CodaChrome is its “computational reaction” to their programs. The interaction between the user who specifies a color pattern and the way that CodaChrome shows it on the software and on the LED is the key point of a better coordination.

Looking back at the children’s original contact with CodaChrome, I watched them experiment a lot with its various features before starting a specific design. They would define a color sequence and then simulate it, or they would drag it onto the LED to see how it would look, and sometimes they would download it to the Tower to test it on the actual LED. When they returned to the software, they would usually try a totally different experiment until they felt comfortable enough with its understanding and moved on to create all the color patterns.

Consequently, a relationship appears to exist between the children’s quick explorations and the system. The computation involved in this interactive process allows the children to engage in a dialog with their medium until they reach a comfortable level of understanding. This relationship is not possible with paper, since it promotes a unilateral

approach to thinking about such representational issues.

6.3 Difficulties in representing time as a spatial dimension

The different ways that we represent time on calendars and organizers shows how we usually structure and think about our daily or monthly activities. If we take the example of an average organizer, or PDA, our day is split up in equal time slots half- or one-hour long starting from six or seven o'clock until eight or nine in the evening. Some calendars include the night hours shaded; others don't include them at all. Calendars usually shrink the weekend into the same time slot. But if a child wanted to represent his whole day and not just the working hours what would be an appropriate representation for that?

I asked the children to map their day onto just a few LEDs because I wanted to see how they could "shrink" their day. I wanted to see how they would use the LEDs' ambiguous spatial arrangement (all of them are at ninety degrees angle with each other) to show progression of time and activity. I saw the questions and the difficulties that children had when I asked them to go through such a programming activity.

They had two difficulties during this activity: One was how to break up the day in four periods and where the boundaries were. The other difficulty was the synchronization between the flow of time on the time piece and the spatial relationship of the color patterns. The major difficulty of the two was the second, the spatial dimension of the color pattern.

Susan for example is thinking about her daily schedule in terms of her activity at the four milestones of the time piece, noon, three, six, and nine in the afternoon. After she has created her color patterns she is surprised to see that she has to jump from going to bed (nine in the evening) to soccer practice (noon). In other words, she sees her day as a collection of milestones that define her activities. Her idea of a daily schedule is very close to that on a PDA. But when she maps her whole day, all twenty-four hours onto it, suddenly the time piece represents a three-hour slot and a fifteen-hour slot in equal distance to each other.

6.4 Doing more things makes the day longer

We are informed by research about the children's subjective understanding of time, which depends, either on spatial metaphors like the height of people (Piaget, 1946), or on the sequence and strength of our memories (Friedman, 1990). Similar data appear in my user studies, when the children are programming the time piece with their daily schedule. They show how a color pattern representing school or a soccer game can last longer than the

“rest of the day” or the “night, waking up and school” respectively.

Fred in particular was choosing the colors for school and at the same time he was naming the various activities. The more he did during a time period, the more colors were on his pattern and consequently the longer the duration of what he named “School” was. “Morning” on the other hand was just two colors showing how he is in a funny state while he is waking up and other than that, nothing particular happens. For Fred, the more things he does, the longer his day becomes.

6.5 Colorspace and Choice of Color Palettes

The use of color by the children was multifaceted and depended a lot on the task at hand. The choice of which color palette to use seems to be uniform across the three user studies and depended on the type of color pattern that was going to be created. **When accurate timing was needed for the synchronization among color patterns, the discrete palette –with the color swatches– was always used.** The reason for that is the uniform duration of each color selection when made on the discrete color palette. For example, Martin (5.3.2) at first used the continuous palette to create the hourglass pattern. But in a short period of time, he changed his mind for two reasons: one, he wanted to know exactly which was his previous selection, so that he wouldn’t make a mistake and choose a different kind of blue that wouldn’t look the same. Second, he wanted to have fine control over the timing of the LEDs. Susan (5.3.4) also started using the continuous palette, but switched to the discrete one, because she needed to count the number of colors as if she was counting the number of time-ticks on each color pattern. This counting of hers became the main method for the overall color pattern synchronization. Going back to the Electro-Jewels workshop, the hat was also programmed with the discrete color palette due to synchronization issues.

On the other hand, **when the focus was on the color transitions and the overall timing of the color patterns was not as important, the choice of palette was usually the continuous palette.** Mary (5.3.6) used this palette when she wanted to have fine control over the color transitions of her sunset, and at the same time she didn’t want to focus on timing issues. Joan (5.2.4.c) wanted her necklace to fade through all the colors of her necklace and the color transitions were more important than the timing of her single LED. She also used the continuous palette.

In general, **subtle changes in the user interface make a lot of difference.** All the children were helped in the last user study, by the coloring of the color pattern when dropped onto the timeline. Even in the case when a couple of the children ignored it at

first, it turned into a valuable –usually debugging– tool after the first try of the pattern onto the LEDs.

The children set a great **example of their ability to abstract concrete day-to-day activities into clean representations like the color-coded patterns of CodaChrome.** Usually the colors they chose were not basic hues but different tones of the basic colors. That restricted their choices in the RGB and the HSB palette because of the dominance of red, green, and blue. But the intermediate tones in these palettes occupy only a small portion and, therefore, restricted their choices. The Munsell color palette would have probably helped them choose colors closer to the tones they wanted, but unfortunately was not ready on time for the third user study. However, based on the conversations with the children, if they had the support of the color palette, they would have used the Munsell color palette more than the other two. Alternatively, a continuous version of the same palette would also support better the activities of the children that used the HSB palette in these user studies.

6.6 Some Personal Thoughts

As I was watching the children become acquainted with all the new tools and materials that I was showing them, I had the following question: Are today's children born computer-savvy? By watching them over the last months, it would sure seem so. And it is not because they are ten-years old. I remember a 2-year old once tried to open the case of my PDA the same way that she saw her father open his laptop. I was surprised at the time, but now I think I understand better what is happening.

An increasing number of children in our days –especially in parts of the developed world– are growing up with gadgets and technological tools of all sorts around them. Children do not seem puzzled when they encounter a new object, as if they have known it all along. Their readiness to discover “what it does” is given, and one surprising observation is the little amount of time they require to familiarize themselves with it, as if they are just remembering what they already knew. Why? Could it be, as in the case of the little girl and the PDA, that they are just adjusting their understanding of a bigger and abstract class of objects to the particular behavior and function of this new object? And if so, how much of the special capabilities of each object are revealed in this process? Is it possible that children are faced with new kinds of misconceptions that are not related to the way things work in the “real world” but to the potential that each of the objects around them has?

I have already mentioned at the end of Chapter 2 the tension that I felt when trying to place my research in the described research framework. One of the tensions was the

difference in the nature of Piaget's experimental objects (everyday objects, like the bottle) and the newly introduced CodaChrome system in mine. Although the objects are not the same, it can be said that they are in the familiarity realm of today's children. CodaChrome in particular deals with algorithmic possibilities and explorations of the children as well as with color that is already one of the most familiar tool/material that children use today.

The pervasive nature of such technological tools and materials is expanding and is reaching new levels constantly in our time. Up until now, there are a few examples of the use of computation and technology in areas where traditionally it was not customary, like in fashion. Some prototypes have been developed by researchers and artists in recent years. Lights and computation for fashion has been explored by Elise Co in her project Halo (Co, 2000). Events, like "The Beauty and the Bits"¹⁸ have been organized with the collaboration of fashion designers and the Wearable Computing¹⁹ group at MIT Media Lab.

The penetration of very small tricolor LEDs to everyday devices is also increasing at a rapid rate. An online article by Nikkei Electronics Asia (April, 2003) titled: "Digital Devices Being Jazzed Up With Lights"²⁰ describes the wide range of electronic devices and appliances with "an ingenious use of light effects". Examples of such devices are wrist watches and mobile phones.

This widely spread use of tricolor LEDs has an impact on their further development and their availability. In other words, the time when such tools are readily available to wider audiences including children, has come. These "everyday" objects have great potential that needs to be revealed; potential for experimentation and personal expression through these computationally enhanced as well as aesthetically pleasing objects.

As related technology evolves constantly, ongoing research is required to shed light on the required degrees of freedom and control incorporated in these new devices in order to help people express their personal style and, therefore, transform their use into a creative and meaningful experience.

The story of the current work as it has unfolded over the previous chapters, shows the progression of the study in multiple dimensions: technological, methodological, in the activity design, and even in my personal attitude and skills as a researcher and interviewer. During this time, new ideas have been generated, some of which have been incorporated in the study and some others not. The reasons have sometimes been very practical or logistical, and sometimes very fundamental. In this chapter, I wish to state such ideas to reveal another aspect of this work that is not shown in the previous chapters. But most importantly, I describe the changes and further development that stem from my study up to date, and that –given time– would be my starting point of a future version of CodaChrome.

User Studies

My user studies although linked with each other, had unique character and distinct structure. They ranged from large workshops with a lot of participants and facilitators, to one-to-one sessions with children. Ever since the Electro-Jewels workshop we have been meaning to return and repeat such a workshop maybe just for the jewelry designers at first and then for both professionals and novices. I have been referring to Electro-Jewels as a preliminary study for the purposes of CodaChrome, since it was indeed in a prototype state. But its overall structure and dynamics of the people seemed very rich and diverse, and therefore, a more in depth study of the participants' interactions and cooperation is required. A lot of related data exist in the numerous video tapes from the workshop that haven't been properly analyzed in this document, because they are not directly related to CodaChrome and its research questions about temporal issues.

As a first step in future studies with the CodaChrome system, I would extend my third user study. Specifically, I would continue the individual sessions with the children of the CodaChrome workshop, because of the great wealth of information that they provided me with. Each child with its own personality –even in the small subset that I was dealing with– gave me a new perspective of how they related to issues of time, and how they approached new materials and tools like CodaChrome in their design explorations. These sessions would enable me to understand better the inclinations and difficulties of people when dealing with issues of time. Such data would help to extend the number of participants in workshops like the CodaChrome one, similar to Electro-Jewels.

Last but not least, the age group –apart from the Electro-Jewels workshop– has been restricted to the age group of nine to twelve years old. Among other reasons, this age group was chosen because of the body of previous work that this study could build upon. One of the most important reasons for this selection is the connection of children of this age to their personal artifacts and their critical attitude to how they usually choose to wear them. Such reasons do not inhibit the organization of a new cycle of user studies with different age groups, including adults, since temporal concepts are ever-present in various forms and representations of our daily activities, throughout our lives.

Platform and Hardware Considerations

At the beginning of the development of the CodaChrome system, the plans included at least the experimentation if not the porting of the system to a handheld computer, as a means of establishing what was the most resonant medium or platform for the programming activity. Over the course of its development CodaChrome got established as a desktop application, and questions like the nature of the gesture of the hands when programming, were transformed into ideas about the use of a Tablet PC as the platform.

I was privileged during my study to use the Tower system at a stage where it was stable and reliable, due to the efforts of Chris Lyon and Tim Gorton, who also helped me use the firmware to its memory and timing limits. But the Tower system, although a great rapid prototyping system, was a little big relative to the size of the pieces created with it. That was probably one of the reasons –as well as the wired connections– why the creation of big pieces was favored over smaller ones, like the hat made in the Electro-Jewels workshop. By Tower system, I am referring to the particular components of it used in CodaChrome, i.e., the foundation, sensor layer, memory layer, tricolor LEDs and even the wires that connected them.

In a future version of the CodaChrome system, I would envision new Tower parts to be designed targeting jewelry design as the main application: although they would function

similarly to the existing ones, they would be packaged in a different way to better match the form factor of jewelry. For example, the Foundation and tower layers could be collapsed into one piece in the size of the tricolor module. And the tricolor module could become even smaller and communicate wirelessly to the foundation. Relative to the form factor of jewelry, even the wires and wire connectors could be made out of different materials to provide a more pleasing end result. The properties of the different jewelry-making materials could be used as conductors and insulators themselves. These proposed future directions become even more challenging in their design when they are combined with sensor functionality. In that case, the packaging of the electronics and their placement on the body become more important. For example, to monitor body temperature, a sensor need to be close to the body, probably detached from the actual piece of jewelry, and that may require a common protocol for their wireless communication, e.g., Bluetooth.

The representation of the physical topology of the LEDs on the software was not implemented partly because of the lack of such information passed from the tricolor modules to the Tower Foundation. Specifically, the Tower listens to a bus where all the tricolor LEDs are connected. Practically, this means that all the four connectors of the LEDs are equivalent and no connections are distinguished from others. Therefore the tower has no way of knowing the topology of the connected LEDs. A change in the hardware/firmware of the Tower system could produce more information about the spatial formation that could in turn be passed on to the programming environment.

Sensor Interactivity

The original implementation of the CodaChrome firmware included the functionality of varying the playback speed of the patterns according to sensor input. It turned out, after all the user studies performed with the CodaChrome system that it was more common for people to specify changes in the colors of a pattern based on sensor input, than to change the speed. In other words, people more frequently asked for a change in colors, to match their mood for example, rather than a change in the speed of the pattern. In the next version of the CodaChrome firmware, the colors could change in a number of ways: 1. Switch to a whole different array of colors 2. Alter color coordinates like change the hue, or value, or chroma. 3. Other ways could include a change into colder or warmer colors.

Color Palettes

In its current state, CodaChrome contains essentially one representation for programming the LEDs. The development of more tools and representations of the visual programming are definitely in order. Especially in the development of the color palettes, CodaChrome

needs to incorporate a lot more of the research results of color science. CodaChrome, apart from the predefined color palettes that exist so far, could also contain tools to enable users across various ages to choose colors and create their own palette. These tools would incorporate rules and principles of color science for a more pleasing aesthetic result.

Most of the studies were performed with the RGB and HSB palette. In the current version of the software a Munsell palette was also in place, but wasn't used in the user studies. Future versions of CodaChrome should probably contain the new Munsell palette, the RGB palette with a more trivial role than its current one, and no version of the HSB palette, which proved valuable only when timing issues were not as important. It also proved difficult for children to understand and in the one case that it was used the emphasis was to make a slow and gradual transitions from one color to the next, as happens to the clouds during sunset.

Finally, I would make stronger connections between the palettes and the sensors by allowing experimentations relating to the changing of the color coordinates through sensor input. So the sensors instead of changing the speed of the color pattern, would affect variables like the value or chroma seen in the Munsell palette.

Programming Environment

As already mentioned in Chapter 6, the representation of the physical topology of interconnected LEDs on the programming environment could be the starting point for further study. Therefore, the environment should include one or more representations of the topology in order to produce data for a comparative study with the results of the paper-based version. Either the firmware/hardware could be changed or an extension of the software could turn it into a different exploration. One idea about how this second alternative could work, is to incorporate into the environment a canvas-like component that would just represent the connected LEDs in a random, sketch-like topology. The user after checking the IDs of the LEDs in the physical topology could rearrange the virtual ones to match the physical configuration.

Finally, one of my personally favorite ideas about how to extend CodaChrome in meaningful ways is the addition of simple programming primitives to the existing visual programming. This capabilities would reveal a whole new characteristic of the color patterns: their appearance as an identifiable entity that could be separated in the physical realm and move from one LED to the next. Such functionality would enable children to see the color pattern closer to their inclination: like a separate entity with a behavior and the capability of “jumping” or moving across the LEDs (Kramer, 1998).

Endnotes

- ¹ iMovie Web Site, <<http://www.apple.com/imovie/>> accessed on May 15, 2003.
- ² This idea of the physical spot has another instantiation on the “Physical Pixel” (Heaton, 2000).
- ³ A lot of resources can be found on the WWW regarding Piaget’s work as well as his colleagues and in general supporters of his theory. More information can be found at the web site dedicated to Piaget’s research: <http://www.piaget.org>.
- ⁴ The web site of the Epistemology and Learning group at the MIT Media Lab can be found at: <http://el.media.mit.edu>.
- ⁵ Reference to the variety of projects and workshops can be found at the three web sites of the groups that comprise the Epistemology and Learning group at: <http://el.media.mit.edu>.
- ⁶ Grassroots Invention group web site: <http://gig.media.mit.edu>
- ⁷ Ark’s web site: <http://www.ark.ie>
- ⁸ More information about LogoBlocks and the Cricket can be found on the Cricket web site: <http://cricket.media.mit.edu>.
- ⁹ Electronic jewelry as the workshop theme grew out of conversation between Eric Fraad and Carol Strohecker.
- ¹⁰ The Everyday Learning web site is: <http://www.medialabeurope.com/el/index.htm>
- ¹¹ This was caused by last minute cancellations.
- ¹² Chris Lyon –despite the short amount of time at his disposal– designed and fabricated the tricolor LED modules that formed the core of the CodaChrome hardware and the basis of this thesis.
- ¹³ The firmware for CodaChrome would not have been as robust and reliable as it was since the first user study without the help of Tim Gorton.
- ¹⁴ The Java tools and APIs used for the development of the CodaChrome software are: JDK 1.4.1 and Java Communications API (COMM 2.0) and the Java IDE JBuilder.
- ¹⁵ “Electro-Jewels” took place during the summer of 2002 in Dublin, Ireland. It was organized by The Ark, a cultural center for children, the Everyday Learning group from Media Lab Europe and the Grassroots Invention Group from the MIT Media Lab.
- ¹⁶ I ask him whether he would like to focus on the flow or the colors. “I think we should start with the flow because colors are different. The right colors depend on what your idea of the right colors is”.
- ¹⁷ The omitted dialog can be found in the Appendix.
- ¹⁸ Fashion show “The Beauty and the Bits” web site: <<http://www.media.mit.edu/wearables/lizzy/out-in-the-world/>> accessed on May 15, 2003.
- ¹⁹ The Wearable Computing and Human Design web sites respectively are: <<http://www.media.mit.edu/wearables/index.html>> & <<http://hd.media.mit.edu/>> accessed on May 15, 2003.

²⁰ Tomioka, Tsunenori (Deputy Editor, Nikkei Digital Engineering) “Digital Devices Being Jazzed Up With Lights”, <<http://neasia.nikkeibp.com/wcs/leaf?CID=onair/asabt/fw/240542>>, accessed on May 15, 2003.

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Appendix: Detailed Conversations of Third Case Study

Martin-Margarita on coloring his time

Margarita: “But you do that each morning, how can it be obscure?”

Martin: “Pretty much. I used to wake up at the same time every morning; now that the time has changed I wake up at a different time”

Margarita: “How what you describe your afternoons?”

Martin: “I would say they’re more of a rainbowish thing. Every morning I wake up and I’ll take a shower for the first half hour. I would say that my shower is also grayish as well.”

Margarita: “Why gray? Shower is not obscure”

Martin: “It’s not obscure, but ...”

Margarita: “Would you say it’s blue because of the water?”

Martin: “Well maybe the shower is more beige. Maybe because my thoughts are blended at that point. I don’t think so much and I just stare, and I am thinking: What should I think about? I should think about something ... before I get bored and fall asleep in the shower”

Margarita: “If you do think of something while you are in the shower, how would you color that?”

Martin: “Usually, I would color my morning thoughts as rainbowish too, sort of having flashes of color”

Margarita: “How is the morning rainbow different from the afternoon one?”

Martin: “Well, the rainbow in the morning starts darker and gets brighter really fast, it’s a very fast rainbow”

Margarita: “Does it have brighter colors?”

Martin: “Yeah you can say that. In the afternoon the colors ... it’s more distinguishable as a rainbow but the colors are less bright, they are darker”

Margarita: “How fast would they change?”

Martin: “In the morning probably really fast, because I would be thinking of what I would be doing during the day and I am excited because I will be able to do this and that. But in the afternoon, I am already tired, I start thinking: I wish I would be able to do this. And then I start thinking of other things”

Margarita: “What would you say is the peak of the day?”

Martin: “The peak would probably be sometime ... The peak of the thoughts is right before I sleep, right before I go to bed, before I fall asleep. Yeah, because I think the most at that point. Yes, I am most awake at the moment”

Margarita: “What do you think about?”

Martin: “Everything that comes to my mind at the moment. Because I don’t have too

much to do in bed”

Margarita: “So would you color everything according to your thoughts?”

Martin: “Yes...”

Margarita: “But you wouldn’t color the activity so much”

Martin: “Yes the activity is what really defines the thought, it influences it, but the color is really my thoughts”

Margarita: “So what would happen if you were running?”

Martin: “If I was running my thoughts would be more vague, more grayish”

Margarita: “How would you color your schedule? Would it show activity, or would it be blurry? Would you color it according to how much you move or how much you think?”

Martin: “Moving affects how I think”

Margarita: “The more you move the less you think?”

Martin: “Yeah, the more I move, the blurrier my thoughts are”

Margarita: “So what color would you use for when you move?”

Martin: “If I was running and I wasn’t thinking a lot at the time ... hm probably depending on the weather. It depends on the conditions I am in ... It’s hard to describe it.”

Susan talking about colors.

Margarita: “[...] So, why don’t you like yellow?”

Susan: “Well it is not as interesting as the other colors. Apart from the deeper yellows that are more gold or orange that I like, the really greenish yellow I don’t”

Margarita: “What about that middle yellow, the canary yellow?”

Susan: “That is not interesting. I think it is very plain”

Margarita: “Do you think it’s very bright?”

Susan: “Bright and not as subtle ...”

Margarita: “Does it have a texture?”

Susan: “It’s hard ... it’s overly polished almost, it’s weird I just don’t like it “

Margarita: “Do you have the same feeling for another color?”

Susan: “I like dark blue a lot, and I like the grayish blue and I like lavender, the light purple”

Susan talking about her daily schedule

Margarita: “(While talking about the abstract clock) Do you think you would like having such a thing to show you how your days were?”

Susan: “Yeah...”

Margarita: “Do you remember that you are able to save each day into a different file and see them again when you like? Do you think you would spot any differences?”

Susan: “Tuesdays are better than Mondays and Wednesdays are better than Tuesdays and Thursdays are better than Wednesdays and Fridays are the best”

Margarita: "How are they different? How is Monday different than Tuesday or Friday better than Monday?"

Susan: "Friday I would be feeling better about school because we have no homework on Fridays. So this one (pointing at the LED that represents school and homework) would be purple or blue ... sort of a medium color for me. It's not the greatest ... it would turn into a blue."

Margarita: "So blue is the best? How do you rank green?"

Susan: "Blue then green and purple and then yellow and pink."

Margarita: "... yellow and pink are the worst?"

Susan: "Yes"

Margarita: "Why pink?"

Susan: "For one it has been stereotyped as a girly girl color and I don't like that. And it's not that interesting. I like the light pink but that nasty dark thing"

Margarita: "The Barbie pink?"

Susan: "Yes, that pink. Maybe it's simply the fact that Barbie's name is attached to it."

Margarita: "[...] Would that purple (pointing at the LED that represents night and school) be brighter on Friday or would it last longer? Maybe since it's Friday the whole day could have a purple shade?"

Susan: "The whole day would be more purple ... maybe the whole morning would be better... so Friday would be more blues and purples and Mondays would be more reds and yellows."

Margarita: "If you see this pattern here, since you know what it represents, would you be able to tell which day it is just by looking at it?"

Susan: "Yes"

Margarita: "Do you want to show me how another day would look?"

Susan: "OK, so on Friday I wake up. Still no fun. So it's yellow. Then the yellow would change to green for school. Green is my second favorite. And because I would have no homework the green would change into teal, which is one of my favorite colors, and for after school ... maybe blue ... for reading a book after school. And then maybe purple for going to bed. I don't like going to bed that much. Because you just have to "go to bed". And then I would be asleep and I couldn't really judge my day when I was asleep, except that I like sleeping"

Margarita: "[...] How about the weekend?"

Susan: "Weekend... I get to sleep late so waking up would be blue ... which one? Saturday or Sunday? ... Saturday because Sunday you have to go to bed early. And then more Saturdays I have a soccer game which I like ... so more blue. I suppose that if I lost the soccer game the rest of the day would be less blue but still fun. But assuming I won. Then lunch ... [...]"

Margarita: "You have a lot of red here, what is it for?"

Susan: "That is medium..."

Margarita: "Neutral?"

Susan: “Yes”

Margarita: “How about gray?”

Susan: “It’s not much of a color but if I had to categorize it, it would say that darker gray is nice and then that gray... (pointing at a middle gray shade)

Susan: “[...] Overall you can tell that a weekend day is more interesting. And if it’s Wednesday and I hate Wednesdays, I could just look at the weekend.”

Margarita: “How would you change this to show that you were running? Or thinking about something intensely?”

Susan: “I don’t know about that. Maybe blue and purple ... and then it would be blue-purple, blue-purple, blue-purple ... not because I dislike purple, but just because it’s close to blue, and to show that it is on and off. Maybe they would fast and it would look like the blending of blue and purple. ... Blink almost”

Margarita: “Let’s say that you have two hypothetical separate objects here, one next to the other. One changes colors slowly and the other changes faster. How would you map your schedule onto these two objects? They are not shaped after a circle”

Susan: “If the one goes faster, I would represent with that the more interesting parts of the day, the upbeat, the fun part... the highlights. The other that goes slower I would feel more bored and I would say, what am I doing here, I don’t want to be here”

Margarita: “Would you choose different colors for the slower one?”

Susan: “Yes definitely!”

Margarita: “The faster one would be more green purple, blue, green blue purple because it would be the highlights and then the other would go slower and would be like yellow, orange, ...”

Margarita: “...and a little bit of red?”

Susan: “Yes that too.... It’s neutral”

Margarita: “[...] Would you turn any of them off at any point?”

Susan: “What do you mean?”

Margarita: “Not showing any color at all”

Susan: “Probably ... “

Margarita: “What would that say?”

Susan: “Probably means watching TV?”

Margarita: “No color at all?”

Susan: “Maybe red?”

Margarita: “Of no consequence to your day?”

Susan: “Probably of negative consequence”

Margarita: “Even if you see a show you like?”

Susan: “Maybe a red, purplish red ...”

Margarita: “Would that mean ‘Mildly pleasant?’”

Susan: “Yes...”

Margarita: “One last question ... you programmed them in a circular pattern and then you just slowed them down so that ...”

Susan: “You could see it more ... because when it was going faster you miss the transaction. This one (pointing at the second LED), you saw it go back to green (after doing the yellow pattern) and by this time this one (the third LED) had already started doing its thing and it was confusing.

Susan talking about the hourglass

Susan: “ ... interesting dynamic effects ...”

Margarita: “One idea is to representing time, like the sand that falls through an hourglass with the same pace and measures time. But it’s not just an hourglass. You can use it to create a rhythm that you like. What would you do? We can make an hourglass or we can make a rhythm without any connection to the hourglass”

Susan: “Maybe can have color go upwards... and have maybe a blue... lighter blue, purple to pink, to red to yellow to green, to orange. Almost like a eruption”

Margarita: “Will it go smoothly?”

Susan: “It will go fast”

Margarita: “And then?”

Margarita: “Go back down... no wait ... it will go up and then it will just come down to the bottom... the way it is shaped it looks like it’s going up”

Margarita: “When it comes down, will it show?”

Susan: “No, it will just... flash back at the bottom”

Margarita: “[...] Would you have it in your room as a decoration?”

Susan: “Yeah, that’s cool”

Margarita: “When you are thinking of a color pattern, what do you have in mind? Do you think of something moving on the LEDs? Do you want to make a line that moves? Sort of like a small snake?”

Susan: “Something that it is shooting up ... almost like a volcano and lighter on the top... and then it goes back down”

Margarita: “Why did you choose this order of colors?”

Susan: “They look good together ... they are the colors of the rainbow ..they look good together”

Margarita: “You said it looks like a volcano .. If you wanted to make fireworks, how would you change it?”

Susan: “Blues ... make green to yellow to orange to bright red ...”

Margarita: “Would you change the order of the colors or the speed as well?”

Susan: “I would change the speed as well. It would be great if this had a dial to change the speed so if you are feeling good, sort of in a fast mood maybe it could go faster up and down, but if you feel like you just not want to do anything and you just want to read a book and not be distracted, then I would change the dial to make it go slower”

Margarita: “Do you want to do that with a light sensor?”

Susan: “Is that how it works?”

Margarita: “Yes, the more light it gets, the faster it goes. The less light it gets, the slower it goes. And it can also do the opposite”

Susan: “Cool”

Margarita: “You don’t have to change the patterns, we will just program it to change according to the sensor value. We have light and distance sensor. Which one do you prefer?”

Susan: “Light would be better, it would apply to it more. If you are feeling tired and you have the lights down, then it can change too. So that way it will change according to your mood as well, because if you are feeling tired you have the lights down, or if you are feeling well you have the lights up. You don’t have to interact with it”

Margarita: “[...] How would you draw it on paper and then give it to a friend of yours, so that they can program theirs with the same pattern?”

Susan: “This is the light pattern (referring to the drawing on Figure 5.45) That is the sequence, but you can also draw eight of them and then all the others would be darker and only one would be brighter and you would do that eight times”

Margarita: “If you had to do it on one drawing? How would you show me the sequence or your transitions?”

Susan: “I would say that they go on consecutively”

Margarita: “If I haven’t seen your sequence ... and you show me the colors... I might think that you are describing to me is that it moves up ... that the colors are moving”

Susan: “This is blue in the first five seconds then this would be green at ten seconds”

Margarita: “When you say at ten sec what do you mean?”

Susan: “Counting ten sec and then go on”

Margarita: “And then it goes into green for how long?”

Susan: “So then, fifteen seconds before it turns on ... ”

Margarita: “And how long does each one stay on until it goes off?”

Susan: “They stay until the next one goes on. But they are sort of dimmer. Their brightest would be when they first turn on and then they dim. And then the next one comes on bright and dims”

Margarita: “How would you show that?”

Susan: “[...] I can’t really shade with a marker, can I use a pencil? Like that, so it’s consecutively getting lighter and this one runs off”

Margarita: “So to make the pattern I would take your shaded circles and then ...”

Susan: “... you would apply to every color...”

Margarita: “[...] So number one is full blue? And then I apply less and less blue until five?”

Susan: “Yes”

[...]

Susan: “I would use these colors and this pattern for my room because they are subtle

and non-obtrusive ... but I would reprogram the pattern to flash and blink like an advertisement that want to draw your attention to it”

Fred and Mary

Margarita: “If you had to fit your whole day in ten minutes, how would do it?”

Fred: “OK. First I would say my alarm when off, and then I woke up. And then I got dressed, then waited for the bus to come, then I got on the bus, went to school. Inside school I did whatever like ... I went to all my classes ... I paid attention, or at least I tried to and basically did all my school activities. And then I would get out of school and it was 2:10, 2:15 and then I would wait for my dad to come pick me up. And when he picked me up, so home, sit down relax for a few minutes and probably start my homework. And in an average day I might either go outside and hang out with my friends, or play a game of football or baseball or something, but not really in the winter cause it’s really cold but around these times I might. And then after that I will probably tired so I will go eat lunch or probably by that time I would probably skip lunch and wait until dinner at six o’clock. Then I would go home watch TV or do something else. Like drawing or playing with video games or something else and then around that time I would get bored... most of the time I would usually get bored. Usually at that time I have nothing to do. But sometimes I do have stuff to do and then I go to sleep at a random time”

Margarita: “So if you had to choose different colors for what you just described to me, what would you choose?”

Fred: “ I will choose school as kind of a ... light blue or something... Because that’s when I usually learn and I don’t know and blue is a kind of nice color and learning is kind of nice so ... I don’t know. I am just guessing. [...] So, for the whole day I have to pick one color?”

Margarita: “No”

Fred: “Oh, I can pick a lot? I would start out by ... maybe pink in the morning cause, I am just waking up and it’s a light color and I am a little bit light and don’t really feel down to earth. And when I go get dressed maybe a little darker colors like red or lighter red and when I get on the school bus I would ... I don’t know ... I am skipping that. But when I get to school probably light blue because it’s when I learn and blue is a good color. And well, then when I get home, I do homework and that is something that I really don’t like so I would pick something like gray. And then after that I would play outside and that would be really fun, so I would put that as ... Can you put more than one color for one activity?”

Margarita: “Yes”

Fred: “OK, so then I would put red, green and blue mixed because I like those colors, they are my favorite colors and so I would mix them together cause I like playing outside, so I would put them together. After that, I would go home and watch TV ... that’s pretty relaxing. It would be like an orange or something [...] But then when I get home ... food ... so a yellow or brown or something. And then ... for sleeping I would put dark blue because it’s nighttime it’s kind of dark and that’s about it”

Margarita: “School is blue and sleeping is also blue?”

Fred: “School is blue but sleeping is dark blue ...”

Margarita: “The difference is not in the color? Is it in the darkness?”

Fred: "Yes"

Margarita: "Why? Because it's night?"

Fred: "Because in school I am pretty wake and in school we learn stuff. Yeah. It's light blue in school"

Margarita: "Is it because it's bright? Because of the sun?"

Fred: "Yeah, in the day it's really bright and in the night it's gloomy ..."

Margarita: "OK, so now you have explained all these activities during the day and you have attached colors to them as well. If I told you to put all these activities on these four color LEDs, how would you do it?"

Fred: "I would probably divide this in the sections of the day. Morning, day, evening, night... I should put the colors in order in that section. So let's say in the morning I wake up, get dressed ... all those have different colors so I would put that in order. And then I would have it... let's say this one first (Pointing at the first one)"

Margarita: "What should that do ... what should the morning LED do while you are at school? Or what should the morning LED do while you are doing your homework?"

Fred: "I am thinking that they should be off, but maybe not ... Maybe they should be off"

Margarita: "Do you remember how we made the colors move and change during the workshop? If I told you that morning takes up all these four LEDs in the circle, what would you do with the other parts of the day?"

Fred: "But after these were taken? Well, then.... Are there any more LEDs?"

Margarita: "No"

Fred: "[...] Actually... But I can use these again ... Then I would program them for morning and then I would leave some black and then I would do the day and leave it and so all four would be morning and then day etc."

Margarita: "If all four of them show morning, would all four of them show the same pattern?"

Fred: "Yeah"

Margarita: "But they wouldn't show: (pointing at different LEDs) waking up, shower, going to school, school?"

Fred: "Well, you can do it either like that, or all the same. [...] Well, to use pink and dark pink in here (pointing at one LED), I don't really see why not, but ... it would be good to do pink and then dark pink over there (pointing at the next LED) and then the rest of the day and then the rest of the day (pointing at the other two LEDs). And then go around in a circle. But if you crammed them all in here, then where these are going to go?"

Margarita: "We'll find a place for them... But if you put all of them in here, you won't be able to see all of them at once"

Fred: "Yeah, well ... I guess you should do it in separate LEDs. Cause then when all these are done, waking up, getting up, and eating breakfast, so on. Then morning is done OK? And then it starts with a different color ... school and the rest of the day ..."

Margarita: "Do you want to think about it a bit more or do you want to use the software?"

Fred: “I want to think about it a little bit more. I want to decide what I am going to do ... I have a lot of options. I can do either morning, afternoon, school and then the rest of the day or I can do waking up, getting dressed ... I don’t know which to pick ... they both sound good”

Margarita: “If wanted to say something about your day, would you like to take one look at it and see what your day was like, or would you like to look at four cycles to figure it out? Or do you want to go through two more cycles to figure it out?”

Fred: “I think I prefer cycles ... What are the parts of the day? Morning ... afternoon, evening or something ...”

Margarita: “That is what is commonly accepted, but you can split it differently. You can say that if morning is very important to your day, or if waking up is very important to you, you can choose to represent it separately. Another way to split it is to say that today, waking up was so bad that I really have to tell how it happened ... or ... school was so good that I really have to tell about it”

Fred: “[...] I still don’t know how to split this up”

Margarita: “... OK, so we have said so far: waking up, getting dressed, eating breakfast, waiting for the bus (pointing to the different colors on the pattern)... ...and then get on the bus ... Can you take it from there?”

Fred: “[...] Wait! I know that in school it’s still morning until 12!”

Margarita: “Yes, but you can separate it differently if you want to”

Fred: “I can? OK!”

Margarita: “(once he sees it running) Do you like it?”

Fred: “One thing that is confusing, there are no labels ... can I label each one?”

Mary and the hourglass

Mary: “Things like the sunset ... Like the clouds that change color and get orange and purple? Does it have to be in nature? Like fireworks? [...]... kind of like a television set?”

Margarita: “How can it look like a television set?”

Mary: “Not a particular color change but the colors on the TV screen change with the different pictures ... like when you put food coloring into something and you mix it and it changes from kind of a light color and gets darker... [...] A sunset: I think it should start from blue, like the sky during the day and it would go from purplish to orangish and kind of a hazy light of the sun going down which is kind of a yellow and orange and then the clouds get pink and purple and then it would go to black”

Margarita: “Which colors go on each LED?”

Mary: “(Points at the LEDs starting from the top) Blue to pale purple color to pink and orange ... darker purple and then black”

Margarita: “If you could use more than one color per LED, how would you do it?”

Mary: “[...] The top one will go kind of blue – purple, blue purple, then the next one will go kind of a purple and then fade into a lighter purple more pinkish, then kind of a pinkish and kind of an orangish ...”

Margarita: “Will they flash their colors at the same time, or in order?”

Mary: “In order ...[...] I think I will work on this one (HSB palette)”

Mary, Fred, and Margarita talking about the mask

Mary: “How can you change the expression of the mask if the clay is hardened and in place?”

Margarita: “What’s the other expression that this will take?”

Fred: “I don’t know if I can make him happy because he is scary...”

Margarita: “How about sad?”

Mary: “Yeah, you can make it all dark colors and blues”

Fred: “... I could try sad ...”

Margarita: “I remember at the workshop where you said that you would could choose green for the lips if you wanted to make him look envious”

Fred: “I remember envious ... green on the lips ... I might ... I will make him look envious [...] I liked it when it was scary ...”

