The Viscous Display:

A Transient Interface for Collective Play in Public Space

Lily Shirvanee

Submitted to the Program in Media Arts and Sciences,
School of Architecture and Planning, on January 14, 2005
in partial fulfillment of the requirements for the degree of
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Abstract

The Viscous Display is a tangible, mobile, flexible display device that explores the exchange of social information through transient public interfaces. Shaped by principles of so-called 'underground public art', the Viscous Display is conceived as a novel communication medium, where symbolic graphic messages can be shared in public spaces. Similar to stickers that are left in public spaces and pheromones that are left by ants in colonies, the Viscous Display is designed as a mobile artifact that is meant to enable participants to leave traces of activity by picking them up, interacting with them, and placing them in various locations. As a consequence, digital information/artifacts can also be left around public spaces via the Viscous Display for people to stumble upon. This thesis will describe the approach and process of designing, constructing and testing the Viscous Display project. The Viscous Display aims to create landscapes that are charged with the traces and messages of others that have inhabited that same space. This work contributes to a vision for changing spatial metaphors in public space.

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Chapter 1: Introduction

The spatial practice of a society secretes that society's space; it propounds and presupposes it, in a dialectical interaction; it produces it slowly and surely as it masters and appropriates it…the spatial practice of a society is revealed through the deciphering of its space.
-Henri Lefebvre

In *The Production of Space,* Henri Lefebvre describes space as a social phenomenon where history accounts for the "inter-relationships of spaces and their links with social practice"[25]. He argues that the production of space is grounded in inherent conditions, where traces of social existence are forever creating our histories and our perception of space.

Our notions of public space typically stem from ancient civilizations where public space was often defined by grand central plazas, market places, and heroic monuments. As industrial technologies, such as the trains and automobiles of the late 19th Century and the early 20th Century, brought about an ease of motion to everyday lives, the private motorcar not only shifted definitions of what was considered 'public' and 'private', but also shifted notions of public and private space. The open space around the mass of office towers in cities came to serve as pass-through areas, and public space has come to be a place of movement. As notions of 'public' space has been shifting from that of centralized grand spaces to moving thoroughfares, activities within these spaces have changed as well. How are these conceptions of 'public' and 'private' space evolving today, as we use new communication technologies to weave our private social practices within public spaces? What happens to our relationship with the public space around us when we can collectively share information over time with others who are remotely nearby? Can we leave new traces of activity within these spaces? What sort of dialog can this generate in public spaces? Does some sense of empathy between familiar and unfamiliar participants emerge?

Social Culture, 'Street' Technology and Public Space

The Viscous Display proposes to investigate the development of a new medium for expressions/collaborations within public space. The concentration is on the design of systems that create the potential for reciprocal activity and social communication in urban environments. I have chosen to design such systems by creating a novel display that can become a part of a location-based activity where an interactive public display relays symbolic graphic information depending on the interacting person's expressive traces (through touch) and text messages (via Bluetooth). Similar to stickers that are left in public spaces and pheromones that are left by ants in colonies, the Viscous Display is designed as a mobile artifact that is meant to enable participants to leave traces of activity by picking it up, interacting with it, and placing it in various locations. The significance of the Viscous Display's mobility is that it promotes greater personal expression and authorship in the public realm. As a consequence, digital information/artifacts can also be left around public spaces via the Viscous Display for people to stumble upon.

What sort of activity is generated when information can find you on the street? What are the issues of 'public space' and 'privacy' that emerge from this? How might they impact our behaviors in public space and affect our sense of location, identity, and community?

This system is not the first to explore ideas of group interaction with mobile devices. There is a recent history of ad hoc activities forming around mobile communications, and an even longer history of improvised activities forming around public spaces. Within this historical context, this thesis hopes to contribute to the provocative dialogue that is part of a burgeoning area of study of mobile communication in urban environments.

I am especially interested in the collaborative aspects of this experience; in finding how this collaborative experience, where each individual's actions/reactions contributes to the whole, generates activity and connections between people. An example of this is found in underground sticker and graffiti art movements; tracing from the early 1930's hobo signatures on freight trains, numerous schools of graffiti art have emerged to make political and/or territorial statements [15]. The origins of graffiti date back to early civilizations where graffiti has been found on the walls of Pompeii, on ancient Egyptian monuments, and the cave of Lascaux. However, it is the "New York School" graffiti movement of the 1970's, where individual underground artists wrote on subways with their own particular style and grew a subculture of symbolic messages to be seen in the public realm, is of particular relevance to the Viscous Display. Hip-hop graffiti was part of a vibrant street culture in New York City in the 1970s that grew into the downtown Manhattan art scene by the 1980s. Because signs and symbols play a significant role in the hip-hop graffiti culture, information can spread across various social networks and along many countries via symbolic imagery and writing. While the overall aesthetic of the Viscous Display is influenced by modernist abstract art, the social antecedents of graffiti art inform the communication design of the Viscous Display. A further development of Hip-hop graffiti culture with the advent of online social networks, such as Meetup.com, is to 'meet-up' in various urban spaces such as the Dame Street Corridor in Dublin and the Downtown Underground in New York City, to express social visual communication.

This project takes its inspiration from so-called 'underground public art' movements such as graffiti sticker art, and other politically charged public artworks that are fuelled by desires to encode, occupy, and transform shared spaces. With the advent of smaller, more mobile devices, there are an emerging number of location-based systems that begin to examine the relationship between physical locations and devices that can augment spaces. These relationships typically involve either a fixed system that acts upon a moving participant or a moving participant, aided with a mobile device, that acts upon specific locations; for example, a sound in a system can be associated with a particular location and when the participant moves to that location, a sound is triggered, such as in the *Sonic City* project (this is described in further detail in Chapter 2). Because the Viscous Display is designed as an interactive and mobile public display that is not linked to a centralized system and is not part of a fixed system, it allows people to act upon it in various locations and can act upon people with Bluetooth devices in various locations.

Project Description

The Design of the Viscous Display includes the physical object, the communications infrastructure, the input and output interface, as well as a social interaction design with an attention to location and the transformation of space. The display itself is a malleable display with dimensions of 25cm x 25 cm and a thickness of 6 mm.Within its size limitations, it can be physically shaped into various forms that maintain rigidity of form. The current display has a low resolution of 100 pixels (1 pixel per 2cm), created by 100 full-spectrum LEDs that are embedded within a silicone casting . Each pixel (LED) is programmable via embedded microcontrollers.

The device also includes a silicone handle where the PCBs, battery power and sensors are stored. The Viscous Display is a stand-alone mobile device with a current memory storage capacity of 128kb (this may be expanded in the PCB) and, rather than connecting to a centralized host, it is designed to work as a distributed artifact. While Bluetooth has been technologically implemented into the Display design, it was not possible to adequately test communication via Bluetooth in the current iteration of this project because of a current lack of robustness between the Bluetoth module and other Bluetooth devices.

As a physical artifact, the Viscous Display is a dynamic digital two dimensional graphic that can be crumpled and formed to create a third dimension physically. The Display's physical tangibility and malleability enables it to be shaped and formed as a physical and digital object and it also makes it possible to attach the display around other objects. Because of its mobility, and ability to be interacted upon without any dependence on another system, the Viscous Display has the potential to impact physical spaces socially and visually by becoming a public repository and transmitter of symbolic/abstract visual information.

The Viscous Display shares many of the characteristics of other location-based systems in that specific information can be associated with specific locations, yet it also has an adaptive, transient quality, whereby, it can be moved and can recall information specific to changing locations. One example of this might be a person with a mobile phone who can locate a display via Bluetooth and upload graphical information that is contextual to the display's current location. This information is relayed in the form of low-resolution symbolic graphics that can be left by participants who either download graphical messages or who leave simple sensor information that is then associated to graphical information by the display.

Because the Viscous Display is an interactive public display that relays symbolic color information depending upon the participants' actions/reactions, it can create a space for private and public messages and foster social interactions in the public sphere.

Broad Research Questions

While there are larger goals that are discussed throughout this thesis for what the Viscous Display, as a novel medium for interaction, can contribute to the general public and public spaces, this project begins with an inquiry into some of the more immediate issues of interaction. The areas of focus are on how individuals and small groups of people understand and interact with the Viscous Display. The three main social categories are; the individual participant, shared participation between two people, and the overall Viscous Display interface.

With regard to interface issues, a first goal is to look at issues of resolution and visual graphics, how the form supports interactivity with the device, and the ease with which people approach and communicate with the device. How does the resolution and form make a difference here? Are the symbolic representations successful in relaying simple messages? If the Display has some sort of emotive resonance, how simple or complex are people's reactions? A second aim is to explore how simple social interactions are augmented with the display. What nuances occur when two people encounter the display together? How does interaction with the low-resolution, symbolic graphics contribute to social communication? Finally, it is important to understand how directly manipulating a visual display graphic can enrich connections to an experience through an active engagement in a construction that is tied to physical actions. Is there a coupling between an awareness of the consequences of an action (in this case, squeezing and bending the display) with the deformation of a graphic?

Overall Hypotheses

This project began with a broad set of hypotheses for social interaction using mediated communication devices in public space. Many of these are not resolved with the current technical implementation of the project; please see the Experimental Design chapter to find the hypotheses that were tested with this implementation of the Display.

The overall hypotheses for the Viscous Display as a novel display device and as a social medium are:

1. The tangibility and simplicity of the physical design of the display offers an accessible way for people to create social connections and engage in public dialogues.

2. A lower image resolution asserts a novel abstract graphical aesthetic (rather than a typical realistic aesthetic) for a display device and also creates an opportunity for privacy in graphical messaging.

3. The ability to physically transform a display and directly manipulate a digital graphic can lead to nuances in interacton experience and this can create more dynamic engagement with the display and in collaborations with the device.

4. The implementation of social artifacts in public spaces encourages dialogues among strangers and greater social engagement among established groups of people.

Project Contributions

As a social device, the Viscous Display provides a novel public medium that is programmable and mobile. It contributes to social communication as a medium where information can be left and accessed via textual and gestural interactions; where gestural interactions are the expressive control of images derived from physical gestures that are picked up via touch to the handle of the display and textual interaction is accomplished using Bluetooth v-card texting to produce graphical images that are associated with a library of SMS texts.

In addition to the intended social communication characteristics of the Viscous Display, this work also contributes a novel display fabric that is pliable. The malleability of the Viscous Display enables it to be formed and attached to other objects, giving it a viscous, 'sticky' quality. The tangibility of the display is meant to encourage greater activity both in a small social scale of two people interacting with it together and on a larger social scale where people may attach it to various locations. Another outcome of this tangibility is on an individual scale, where it becomes possible to physically create three-dimensional transformations from a dynamic two-dimensional display graphic. In this way, the Viscous Display is notable because it merges a tangible social object with a physically deformable display.

This work contributes to a vision for changing spatial metaphors in public space. It is important in that it presents a novel mode for expression and collective communication. This thesis document includes an analysis of the design of the mobile device and the social interactions and expressive qualities it fosters. Once the design of this system has been described, the display interfaces input and output modalities are analyzed in order to refine their collaborative use and evaluate the successes and failures of the interactions and responses, and evaluate approaches for designing subsequent Viscous Display system. A successful work to emerge from this thesis would be a mobile and malleable display interface that is simplistic and enjoyable for people to use, and has the potential to promote expressive messages and responses in public spaces. The aim of this project is to create the first part of a future linked, modular art piece where several displays contribute to a whole.

Thesis Summary

This thesis is divided into six chapters. The next chapter looks at the background and conceptual ideas that inspired and informed the design of the project – spanning from notions of public and private, to conceptions of space, collective social activity, and several relevant digital technologies and electronic art projects. The third chapter then goes on to present the conceptual design of the Viscous Display project, detailing the function and meaning of the project. The fourth chapter goes further into design issues, focusing on the technological design of this project. The fifth chapter presents the development of two pilot studies, and discusses the issues around the Viscous Display based on observed participant interaction and responses to a questionnaire. Based on the pilot studies and design critiques, ideas for future investigations and iterations of the Viscous Display are also presented in the fifth chapter. The sixth chapter draws conclusions from the process of developing the Viscous Display project.

Chapter 2: Background

The inspiration for this thesis follows several levels of inquiry. The furthest out is an interest in public space, to understand how these spaces are changing with new paradigms for personal interaction, and a desire to create new forms of engagement and participation within these spaces. The next aim is to understand what sort of activity is occurring amongst people or social groups who are engaged in these spaces. How do we enable them to contribute more to their environment and, in turn, understand how they are a part of a larger whole? A third, more specific aim, is to find out how to design a tangible, social device that an individual can interact with and have a sense of directly affecting this change – directly manipulating their environment on all of these levels of activity. How is it possible to design something that we can think with while having a sense of autonomy and engagement in our public environments? How can we understand these reciprocal effects along these different granularities, ranging from the immediate personal environment and out to our collective spaces? How can this work promote a further engagement and sense of autonomy in our environment?

To better address these questions, this section looks to theories of collective intelligence, changing conceptions of public space, and examples of art movements, projects, and tangible interfaces that relate to and inform the ideas that ground the development of the Viscous Display.

Collective Intelligence

Groups of humans, connected through networks, are thought to make collective decisions that prove more accurate that the performance of the best individuals in social orders that are hierarchical in nature.
-Bernardo A. Huberman

The coupling of symbolic signals with group activity has precedence in the ethology of collective intelligence through a broad spectrum of species that spans from the behavior of ant organisms to that of humans.

In 1810, in his book about ant behavior, naturalist Pierre Huber argues that the social behavior of ants resembles the social play of other species of animals and that if we could see them as creatures rather than as machines, we might attribute emotional behavior to these organisms [1]. Charles Darwin, in 1870, went on to compare these seemingly abstract organisms with that of man and made significant connections between social behaviors and collective activity. In 1911, William Wheeler further examined insect colonies and defined the ability of the hive to accomplish tasks that no individual ant or bee is intelligent enough to do on its own as "emergent properties" of a "superorganism" [51].

In *Emergence* (2001*),* media and cultural critic Steven Johnson composes an analysis comparing organisms of ants with that of cities that continues where naturalists such as Pierre Huber, Charles Darwin and entomologists such as William Wheeler left off. Johnson describes how an ant organisms' ability for pattern detection allows meta-information to circulate through the colony mind; he argues that while "compared to human languages, ant communication can seem crude, typically possessing only ten or twenty signs, ants don't need an extensive vocabulary and are incapable of syntactical formulations, [instead] they rely heavily on patterns in the semiochemicals they detect" [20]. Johnson compares this interaction between a 'superorganism' of ants with that of strangers in urban public space where "neighborhoods of individuals solve problems without any of those individuals realizing it"[14]. He maintains that the vitality of a neighborhood and the "local interactions of strangers" whose eyes collectively bring about safety in public spaces are equivalent to the minor actions of ants that, as a whole, contribute to the greater good of their colony. Johnson sees the city as a dynamic moving system rather than as a static political theater. He argues:

> The value of the exchange between strangers lies in what it does for the superorganism of the city, not in what it does for the strangers themselves. The sidewalks exist to create the "complex order" of the city.... Sidewalks work because they permit local interactions to create global order. [20]

Over the past decade, the emergence of greater numbers of people using mobile devices in urban cities has created a culture of mobile communities that has begun to resemble some of what technology and cultural critic Kevin Kelly describes as the key characteristics of so-called 'swarm systems' [21]. Some of the characteristics of 'swarm systems' include the absence of imposed centralized control along with autonomy and high connectivity among the smaller groups and individuals [21]. In human social groups, because these 'swarm systems' have the ability to connect in transitory space (while moving), large-scale populations of people begin to exhibit a "collective intelligence", where the actions of one has a greater consequence on the whole. An example of this behavior with new technologies was seen in the Philippines in 2001, where an ad hoc group of people demonstrating against their government, began texting on mobile phones from one phone to another with political jokes that later spread to information about the location of demonstrations. This spontaneous activity ultimately led to the resignation of President Joseph Estrada.

Figure1 Public piazza in Naples

While the Viscous Display does not have a particular political agenda, it aspires to contribute to the social life of the public sphere with improvised dialogues among strangers and social networks of people in public spaces. The decentralized quality of the Display, in enabling people to leave graphic information via direct touch and Bluetooth texting, endeavors to extend nodes where information is exchanged locally. Because of the symbolic, non-explicit character of the graphics displayed, this information can be viewed along various levels of granularity and creates a fairly simplistic mode for people to communicate, participate, and leave traces of their local activities that can also be seen as a broader pattern of activity

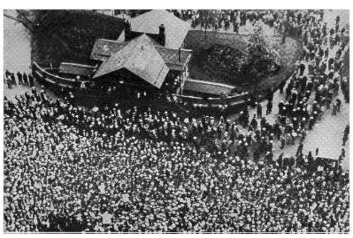


Figure 2 Protest in 1921, Union Square, NY

Conceptions of Public Space

Traditional conceptions of ‘public space’ have often suggested open spaces that are based upon shared social histories and are structured around central nodes, monuments and events. City squares have been conceived as social gathering places where a dissemination of information and political discussion could flourish. This sense of territory has inscribed itself well enough in some squares like, for example, Union Square in New York City [fig.2], to inspire a scene of many protests, rallies, and gatherings in our recent history. But in most cities, on most days, do we attach ourselves to these spaces? Do we think of these places as part of our own space? With the advent of new communication technologies, do we look to these places for information? As our physical environments become increasingly permeated with sensorially provocative forms of technology and as our perception of location and presence within space becomes coupled with ephemeral attachments, can our sense of public spaces have transient meanings?

In Kevin Lynch's seminal work, *The Image of the City*, he studies three different American cities, moving west from Boston, Massachusetts and Jersey City, New Jersey to Los Angeles, California to look at urban identities and to understand how people imagine themselves in their cities. In his explorations, he notes that, " moving elements in a city, and in particular the people and their activities, are as important as the stationary physical parts" [28]. He talks of the city dweller as a part of the spectacle who is "on stage with the other participants" [28]. Lynch also suggests that we perceive our own cities as a sort of fragmentary composite of spaces that we have had long associations and have, therefore, created memories and meanings in those spaces. He finds that "image development" can be strengthened by a dialectical process between the observer and his or her surroundings; as an attachment forms wherever the perceiver reshapes her or his surroundings and becomes a participant. Another important finding in Lynch's study of the three different cities was that, in all of these cities, most city dwellers didn't characterize the city as one center or whole, but rather, as a collection of boundaries, nodes (typically a significant intersection) and paths that ranged from those that were well-known to those that were particular to individuals being interviewed.

In a similar sociological study called *The Street Life Project*, sociologist William Whyte looked at plazas in American cities to understand how people were using their central spaces. Here, he observed that what attracts people most is other people [50]. He found that people prefer to be in the flow of pedestrian traffic and his study concluded that “a good plaza starts at the street corner. If it’s a busy corner, it has a brisk social life of its own. People will not just be waiting there for the light to change”[50].

In *The Death and Life of Great American Cities*, Urban Sociologist Jane Jacobs goes further to describe the city sidewalk as a public performance space where, “the intimacy of sidewalk use” brings about an order that is “composed of movement and change…The ballet of a good city sidewalk never repeats itself from place to place to place, and in any one place is always replete with improvisations” [19]. Jacobs describes the sidewalk as a place where many specialized components “unite in their joint effect upon the sidewalk which is not specialized in the least. That is its strength”[19]

Steven Johnson, in his comparison of ant organisms and the society of city dwellers notes, “The brilliance of *Death and Life* [*of Great American Cities*] was that Jacobs understood…that those interactions enabled cities to create emergent systems [20]. Johnson conceives of ‘public space’ as a place created by the “low-level actions of borderline strangers going about their business in public life” [20].

How do we form our attachments to place and what influences our perception of the subtleties between what we deem to be private and public interactions? Demonstrative communications such as a conversation, an argument, or a hug made in public by two people are examples of observable interactions in shared spaces. What draws others to become engaged or involved in this interaction? Is our interest in these events a form of engagement through

Figure 3 Graffiti on New York subwaycars

Figure 4 Graffiti in the Shibuya District, Japan

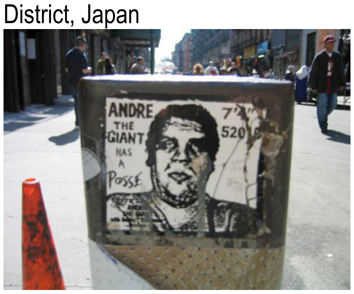


Figure 5 Andre the Giant sticker near Delancy Street, NY

Figure 6 Andre the Giant sticker

curiosity? This project hopes to support the desire to communicate in public and private and the need to play a part in shaping, owning, and occupying shared spaces. By adding to the diversity of activities and the exchange of information in the public domain, the Viscous Display attempts to contribute to textured social spaces within the nodes and pathways that make up our public sphere. Perhaps new social groups facilitated by the Viscous Display can inhabit these public places and generate a greater sense of vitality, activity and attachment to them. With the Viscous Display, the aim is to create an art piece and a tool that can inhabit the urban landscape and explore how this mediating technology can influence behavior, content and interaction in public space.

Social Histories and Public Space

In a city that belongs to no one, people are constantly trying to leave a trace of themselves, a record of their story.
-Richard Sennet

Creating and weaving our own stories in the places we inhabit is an important social practice. If we look to our recent history, we might see stories woven through the freight cars of 1930's America, where passing hobos left trace signatures, relaying a message and conveying a story that we still ponder today. Even more recently, in New York of the 1970's, the "New York School" graffiti art movement where spray-tagging numbers, initials, nicknames, and territorial statements made political assertions that have disseminated through subcultures around the world. Today, in diverse cities such as Barcelona and Tokyo, we see the influence of these earlier movements in the symbols and the style of graffiti that continue to proliferate [fig.3, 4].

In the 1980's, another type of symbol began to spread in the tagging of sticker-graffiti by a burgeoning skate-boarder culture.

Stickers such as *Andre the Giant* [fig.5,6]., have moved from a small subculture of skaters to a larger, global culture. Today, *Andre the Giant* stickers, posters, and clothing can be found everywhere. Finding a sticker with the text "OBEY" in a public space reveals a significant meaning to those subcultures involved and resonates out the general public in the form of curiosity as a universal mark of this movement. In 1999, *Sticker Shock: Artists' Stickers* [45], displayed this 'underground subculture' of sticker art that had previously been posted and read in public urban areas. Shepard Fairey, the artist who created the *Andre the Giant* sticker, continues to create new forms of this sticker, evolving it as he reacts to other people's reaction of the image. The influence of the underground sticker phenomenon that began in Providence, Rhode Island, is revealed in new sticker campaigns that are launched in cities and public spaces around the world.

Figure7 Botfighters game screen shot from mobile phone

Figure 8 Sound Mapping system: The suitcases play music in response to nearby architectural features and the movements of individuals.

The Viscous Display is inspired by the transient and social qualities of 'underground public art' and iconic 'sticker art' that attempt to encode shared spaces and engage a public dialogue.

Mobile Street Culture

One emerging activity of the mobile street culture is to engage in location-based games. Botfighters [fig. 7] is a location-based game that is notorious for being one of the first location-based games using text messaging [5]. Botfighters are opponents who track each other down in urban neighborhoods and streets. Players' mobile phones provide them with information on where other opponents are, and the phone acts as a medium for battles and chats. Mobile positioning is used to determine the distance between players and indicate when another is at close enough to tag or be hit.

While the interface is merely a mobile phone with text messaging capabilities, the spatial context of the urban street and being 'tracked down' in such a territory adds significantly to the emotional aspects of the game. One player describes his experience here:

"When you get a reaction from another player, the rush is…tremendous, [and] I know that that person gets the same sort of rush that I get." [5]


Figure 9 Seven Mile Boots

Other projects that involve an urban landscape include projects such as *Sound Mapping*, *Seven Mile Boots*, *Urban Tapestries* and *Sonic City*. These projects produce narratives of improvised communication along the landscape, where an exchange of interactions among mobile participants creates an overall narrative. *Sound Mapping*, developed by Mott et al in 1998, uses geographical location with DGPS (a combination of radio and GPS) to create an interactive urban environment where participants can generate sounds using mobile sound-sources/transmitters along predefined paths and produces a collaborative composition that is broadcast to the listening public [fig. 8]. Similarly, Beloff et al's *Seven Mile Boots*, developed in 2004, incorporates a wearable boot device for the participant to merge her/his geographical space with virtual space by mapping physical locational information to internet links [fig. 9]. Proboscis' *Urban Tapestries Project* engages the virtual realm by allowing users to annotate their own virtual city and proposes to enable wireless access to 'threads' that link locational information with social threads. Participants are given mobile phones that have been adapted to constantly keep track of their locations and enable them to leave notes at specific locations for other people to read [38]. *Sonic City*, a project by the PLAY Research Studio, "enables people to create music by walking through a city" [37]. *Sonic City* translates the participant's sensor information such as IR detection


Figure 10 Sonic City

for proximity, metal detector, light intensity sensor, microphone, and accelerometer to sense the local interactions and pace of the user and decipher it into MIDI signals that are mapped onto a sound [fig. 10].

As with the Viscous Display, these projects also seek to embed digital information into shared spaces, however, these projects use centralized databases of information as opposed to distributed, independent systems. Where distributed tangible interface components are present, these components act as a 'digital pointer' metaphor where objects point to a centralized digital data rather than storing the data within that object itself. While centralization has some advantages in simplifying the implementation of these schemes, it is important to note that there are significant social and artistic ramifications in the distribution of information in networked systems. The interaction issues resulting from this initial research with the Viscous Display will hopefully further develop design elements for future distributed location-based systems and will continue to invigorate public space with meaningful digital artifacts.

Narratives/Stories in Time and Space

Narrative space indicate[s] that the productive experience of complexity doesn't just happen in a city but needs to be organized as an unfolding experience, much as the complexities of a novel are unfolded.
-Richard Sennet

Several significant antecedents to these locational activities exist in works by Glorianna Davenport's Interactive Cinema and Story Networks Groups. Works such as *The Wheel of Life*, *PlusShorts*, *M-Views* and *Texting Glances*, create authoring tools that use visual metaphors to generate a narrative activity in spaces. Instead of competing with opponents as in the Botfighters and other hunting games or simply pointing to a centralized database such as the communication narratives of *Sound Mapping*, etc…, these projects create a 'storied' narrative where a " participant audience" is provided a scenario and invited to actively "follow, make choices, and interact with the consequences" [9]. In *The Wheel of Life* (1995), 'explorers' and 'guides' navigated an environment that responded to their actions, where "the explorers task was to decipher the rules and narratives governing each area, while the guide sought to help the explorer by using the computer to manipulate the images, lights, and sounds in the area"[9]. Together the participants collaboratively created and shared a narrative story dependent on locations within a physical space. *PlusShorts* (2001), is a networked software application that allows "a distributed group of users to contribute to and collaborate upon the creation of shared movie sequences…[and] presents individual movie sequences as elements within an evolving cinematic storyspace, where participants can explore, collaborate and share ideas" [22]. Similarly, *M-Views* (2002) enables participants to create, edit and share videographed stories along a physical path [8]. *Texting Glances* (2003) builds upon these previous projects by combining a storied and communication narrative approach that enables the participant to use her/his mobile hand-held to author and collect visual and textual stories onto a fixed screen in a public space [49].

While the Viscous Display is informed by and carry's some of the traits of its antecedents, in that it: 1). Attempts to enable authorship in public space, and links social information within a locational space. Yet the Viscous Display also contains several nuances in that it proposes to create a reactive environment with collective activities. Because the Viscous Display is meant to be left in public space, it enables people to leave digital traces in the public landscape that may, in turn, locate other participants via Bluetooth sensing as they pass by. Viscous Display aims to create landscapes that are charged with the traces and stories of others that have inhabited the same space.

Other Existing Work and Influences

Figure 11 Krzysztof Wodiczko and his Alien Staff

Art installations that attempt to engage a social dialogue, such as those by Krzysztof Wodiczko, are also a significant influence to this work. Wodiczko's work is based around urban narratives and autonomy, where he proposes a design practice that confronts historical space with what he terms the "memory of the nameless" [52]. Wodiczko focuses on creating a space for the "nameless" where a city may engage in a consciousness and democracy through the sharing and understanding of people's experiences that might otherwise remain unknown. An ongoing theme that is woven through Wodiczko's work is the concept of maintaining democracy through "autonomous identities." In one example, he proposes an "interruption of the victors [of history] by the nameless…through the design and implementation of a new psycho-cultural artifice, …which on the one hand will encourage the stranger to open up and on the other hand will encourage the nonstranger and other strangers to bring themselves closer to the stranger's experience and presence"[45] One of these artifices for social engagement was Wodiczko's *Alien Staff* [fig. 11], which was both a symbolic form (resembling a Shepard's rod) and a storytelling device. The small display is meant to provoke observers to become engaged with their curiosity in moving closer to the screen, and closer to the presence of the 'immigrant'-alien.

This project aims to learn from Wodiczko's creation of beautiful artifacts that infuse spaces with the potential for greater engagements, greater confrontations and that lend a sense of autonomy for people over their environment. It is this approach that inspires the concepts that give meaning to the Viscous Display.

Tangible Interfaces


Figure 12 Electronic paper being unrolled

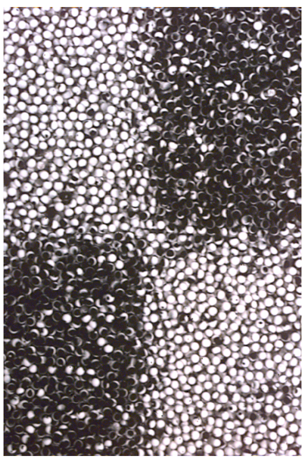


Figure 13 Electronic Ink

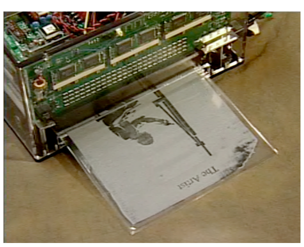


Figure 14 Electronic paper being printed (using electronic ink)

The Viscous Display project draws upon related work in the areas of tangible interfaces, electronic fabrics/materials, and mobile applications. Initial inspiration for the physical form of the Viscous Display was derived from electronic materials such as *Electronic Ink*; a material that combines microcapsules of black and white electronic particles suspended in fluid within a plastic film/circuitry encasement. Using positive (white) and negative (black) electronic fields, the particles create a material that is made up of black and white pixels and display information using an external display driver [fig. 12, 13, 14]. Other projects concerning the relationship of subtle information and physical representations are seen in Hiroshi Ishii's Tangible Media group where projects like *Ambient Fixtures* [fig. 15] display temporal information in the physical environment. Using tangible objects (fixtures) as the interface between digital information and ambient space, subtle representations of information are conveyed through physical changes in the environment (light, sound, movement). Similarly, *Electric Plaid*, which was being developed at the same time as the Viscous Display, displays representations of time and motion in a fabric that changes color over time and can be combined with textile sensors that implement touch interaction to operate as a light switch controlling environmental lights [fig. 17].

While the Viscous Display has a connection with these projects, there are some significant differences in what it proposes to do. In terms of display technologies, the Viscous Display is a full-spectrum, programmable pixelation and, while it may be constructed at a higher resolution, it capitalizes on the limitations of resolution to convey an aesthetic where subtle social information may be communicated. With regard to the subtle information of ambient objects and fabrics, the Viscous Display differs in that it conveys information that can be directly and actively engaged and produced/programmed by the user. It is with this merging of the active, direct engagement of the participant along with the passive, indirect engagement of the general observer that the Viscous Display aims to contribute to a greater sense of autonomy and connection to participants as well as to the general public.

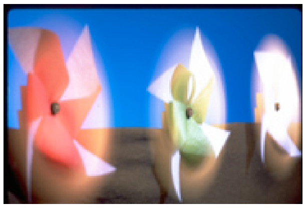


Figure 15 Pinwheels as an ambient fixture


Figure 16 Water lamp

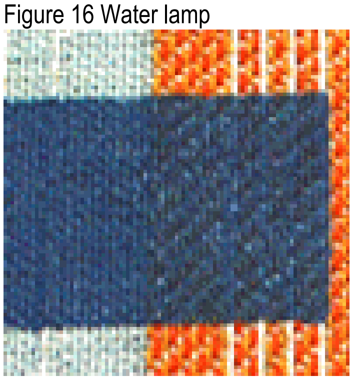


Figure 17 Detail of Electronic Plaid

Chapter 3: Conceptual Design and Inspiration

This chapter looks at the conceptual design of the Viscous Display beginning with a brief description of the concepts that motivated the design. Next, it reviews the existing work that has influenced the conceptual design of the Display. This follows with a description of the initial sketches and the process that led to the current display. This section concludes with a summary of the social interaction concepts and future software applications.

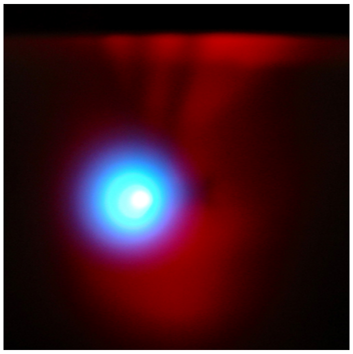


Figure 18 Viscous Display with graphical representation

Design Motivation

The Viscous Display is meant to create a sense of autonomy, engagement, and responsiveness among communities where individuals can conceptually shape and occupy shared public spaces.

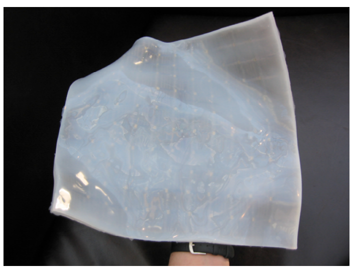


Figure 19 Viscous Display

The initial motivation was to facilitate the spread of private, perhaps intimate messages within a public arena, to encourage greater use of public spaces and to create spaces where social histories can be left behind, traced and meaningfully visualized. Another aim within this idea of spreading and visualizing social histories was to have a hierarchy towards privacy; on one level various groups can only access their own symbolic messages, on another level traces of these interactions are publicly seen and an overall trace of social interactions can be seen and sensed by all passersby who engage with the display. The aim was to also create a novel urban fabric/material/display that is mobile and transient so that it can be mounted in any public path or space and that can create a sort of social interaction 'viscosity' within these spaces.

Figure 19 Viscous Display

In order to achieve this goal of designing a display fabric for social communication, this project began with an exploration into the characteristics what this object would need to include. The most significant characteristics were touchability/tangibility, malleability/flexibility, resolution, sensing, portability, and mobility. Most of these elements were defined by their relationships to each other; for example, the desire for something that could be acted upon in a social situation, led to a focus on touch and tangibility and a physical deformation. The desire to be able to physically deform a graphical object, and enable it to be something that is mobile and portable led to a limitation in display resolution. Yet many of these design constraints led to more interesting solutions, such as the abstract imagery of the graphical messages that can relay subtle and meaningful information without detailed graphics.

Initial Design Sketches

The initial sketches leading to the first prototype were based on a concept of graphic stickers that are left around along paths and public spaces.

The aim was to construct a physical device that embodied this 'sticker' concept, enabling people to leave private messages behind in their public spaces, yet also enabling an interaction that can be sought in a digital/dynamic device. This digital flexibility is important because, when people can effect or change the graphical information being displayed, there may be a greater sense of autonomy among participants within these spaces. Additionally, as a part of this notion of changeability and public control of their environment, it was important that this 'sticker' device could be left around and moveable, like pieces of sticky paper – therefore, transience and mobility were important considerations in the overall design. Mobility is also central to the idea of 'traces', where similar to stigmergy, the system by which ants leave chemical imprints, people are able to move and drop their own messages/information in places and create a visual representation of social activity within public space.

Among these social visualizations, there is a static sensibility as well as an active one. For a more static interaction, participants are meant to leave behind symbolic messages that can be retrieved by others who are aware of this device and choose to seek out these messages. Other participants will be able to see that several symbolic messages were left behind, but they will be limited in their understanding of these messages; only those that are aware will be able to understand their own group's messages with a greater depth of meaning.

In order to accomplish this sense of private messages versus something that can be discovered by the public, there may be a convention relating to certain overall colors that are known to be associated with a general meaning (by anyone engaging with the Display in various capacities). For example, orange colors could have an overall happy tone, while green colors might be more cautious, etc…

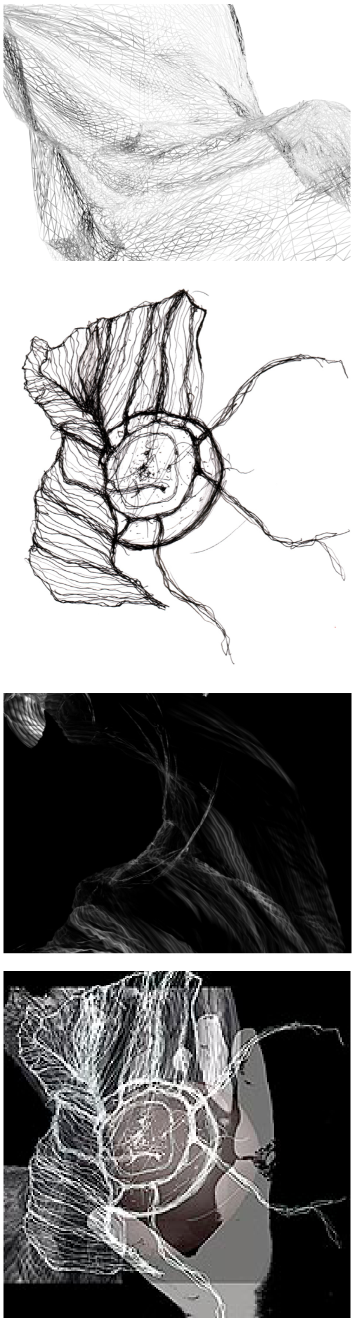


Figure 20 Initial design sketches: Drawings and CAD models

Tangible Display

The Viscous Display is also meant to contribute to public space with the physicality of a digital artifact, an object that can act as a dynamic digital instrument engaging the people who socially interact with it. In this way, the tangibility of the device is a crucial aspect of the design.

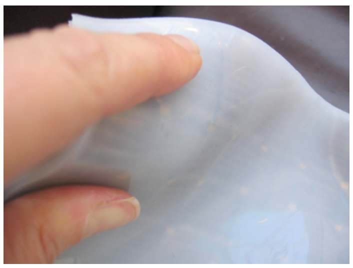


Figure 21 Detail of malleable display

In exploring various design considerations for tangibility, it was important that the physical form of the display fit into an average hand size and have a fairly light weight so that participants can easily handle and move the display. After several iterations, a display size of 25cm x 25cm was found to be easiest for most people to handle. It was also important that the design of the handle could support the physical handling of the display and that it could also store the electrical components that drive the display. First, it seemed like the shape of a small ball would be a good form for squeezing and sensing. Then, after several iterations, a grip-like handle, was found to be the better for handling and also storing electronics.

The material for the display was also an important element in the design consideration because it was necessary for it to be flexible and comfortable to touch as well as durable for many people to handle it over a period of time. In the research into materials, silicone, typically used for prosthetic devices, was found to possess a great deal of flexibility. As a casting compound, silicone can be formed with several grades of rigidity, from very hard to soft and sticky. A rubbery, medium-hard grade that is soft to the touch, without being too sticky, and that was viscous in texture was chosen for the display material.

The Viscous Display offers a unique tangibility where participants are able to physically handle and have a tactile experience with two-dimensional graphics. With the Viscous Display participants can pull visual representations around their hands and the malleable, ‘sticky’ quality of the display can enable participants to attach it to many objects in the environment. The Viscous Display’s merging of tangible object and a malleable display, can be seen as a fully merged projection, where the low-resolution image is able to be directly and physically manipulated.

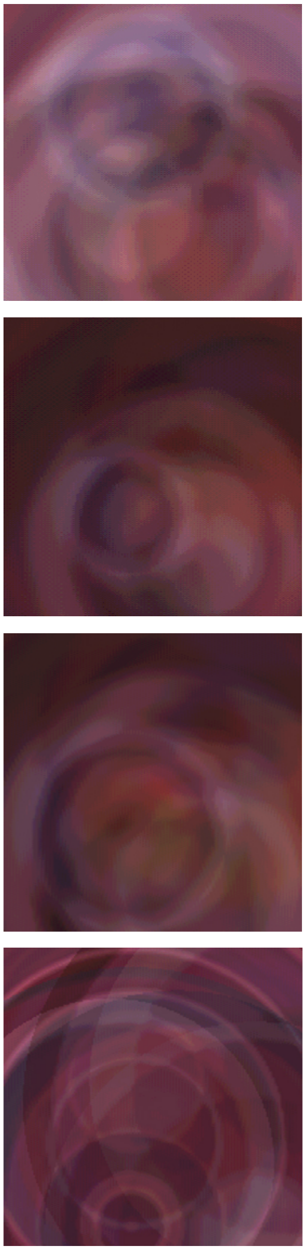


Figure 22 A series of abstract graphics that can be downloaded to the viscous display via a v-card text associated with a graphic (or series of graphics).

Abstract Graphics

For greater computational speed, efficiency, and a lower cost, the Display is designed with a low resolution of 100 LEDs. The resulting pixelation is suitable for symbolic messages and abstract imagery that has a similar aesthetic to that of abstract 'modernist' art [fig. 22]

Social Traces

While trying to design a medium for social interaction based on this idea of stickers, traces, and collective activity, various communication models were explored and it was found that more than one mode of interaction would be needed to enable the social activity that the project was aiming to promote. For the exchange of information with the Display, two modes that are conceptually different from each other were chosen. One of the ways of leaving information is via expressive traces, where nuanced interaction gestures are captured in the way people handle the device (grip) and the other is textual, where Bluetooth v-card 'texting' brings about a graphical representation rather than actual text. For different reasons, both of these modes were found to be important in enabling more people to become engaged in the device. The expressive input enables information that is more momentary and less planned to be left as 'mood' traces of people that have engaged with the Viscous Display in that space. While texting to the display enables people to leave behind more specific, albeit symbolic (not textual), messages to their own groups.

The expressive information is meant to relay information about the place to a general public; it is a way for people to leave general ‘mood’ states in a place. Participants are able to leave these traces by handling the grip of the display and stabilizing a viscous, morphing graphic that appears on the display by maintaining a constant pressure at any number of pressure ranges (anywhere from soft to hard pressure). Each level of pressure is associated with a different graphical symbol that relays a different sort of mood; conceptually this has similarities to information revealed by a handshake.

Whereas the expressive graphics are a result of stabilizing a morphing graphic that is already embedded in the display, texting to the display enables people to leave behind specific graphics that they have created (within the limits of the system). They are able to leave these messages to the general public and to their own groups. Additionally, as a part of the exchange of information, certain conventions relating to colors and shapes of the graphics may need to be agreed upon by those that are using the device. For example, graphics that are more orange in color, etc…could represent a general meaning of happiness for all to understand as well as a specific message that is associated with that particular graphic. These conventions are similar to ascii icons, where people understand a colon and a right parenthesis as a smile because there is a general consensus.

Graphic Visualization

The graphic representations that are part of the current Viscous Display system, and are related to texting and expressive inputs, reveal a wide-ranging hierarchy of social use/interactions. The hierarchy of information left is threefold; the first, more personal level, displays private information for individuals seeking to leave and retrieve messages onto the display; the second, more public

level, displays private symbolic information for all to see, but only those who are aware of the meaning can deduce the message, while others have an indication of some sort of activity. The third, and most abstracted level, is a visualization of these devices in public space and is meant for those who can analyze the data from these graphic visualizations to deduce a meaningful information about the patterns of activity around the Viscous Display spaces.
The visualization aspect of the Viscous Display is significant because the data received via Bluetooth enables us to find the approximate locations of these devices and, in turn, retrieve data

from the interactions that take place using the Display in order to understand meaningful patterns of activity using these devices in various locations. Also, because the Viscous Display can be seen by anyone walking through these areas, the visualization can be experienced spatially along a path. While the data experienced in the public environment will most likely contain less accuracy than the quantified data, there is an overall perception that could be valuable for a more generalized understanding of the environment and this could provide another way to learn about data patterns in a spatial environment.

Future Applications

Another significant aspect of data visualization from the Viscous Display is that the software algorithms would automate the process of finding patterns. In order to accomplish the data mining required for discovering patterns from these visualizations, there would need to be an understanding of simple visualizations from complex abstract patterns. Because visual data mining is such a large area of research with many emerging applications, this thesis would not attempt to explore this area, but rather, the idea of recording data from the interactions with the Display could be a part of a greater study in the future.

Chapter 4: Technical Implementation

This chapter describes the display in more technical detail, beginning with a brief technical description. This follows with a review of the technical design of the display prototypes and the design decisions that have shaped the current prototype. The technical description has been separated into several parts; the Viscous Display is made up of a woven fabric, a silicone encasement, a silicone grip, an input and output interface (sensors, Bluetooth, graphics), and storage and retrieval hardware (communication board, graphics board). This chapter concludes with descriptions of the design constraints and the opportunities that they presented, as well as some future design goals for the Viscous Display.

Overall Physical Design

The Viscous Display is a mobile input and output display device that is embedded with simple intelligence and sensors. The physical design of the display itself is made up of a cast, square silicone material that is embedded with a mesh of woven LEDs. A rubbery silicone grip is attached to the display via connecting/implanted wires and is embedded with sensors and hardware (FSRs, microcontroller, Bluetooth). Expressive information can be sampled from a participant's touch onto the attached silicone grip, it is then read by the microcontroller, and it is mapped onto the display. As the user touches the device's silicone grip, the Viscous Display's dynamically responsive, fabric-like interface unfolds visually represented messages. The shape and silicone quality of the grip is conducive to pressure and expressive input. The integrated characteristic of these embedded sensors permits the robust transmission of expressive information.

Display Prototypes

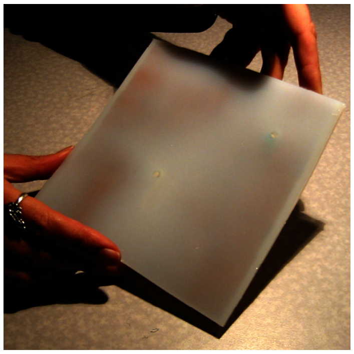


Figure 23 The first prototype of the Viscous Display

The first prototype consists of a separate mesh and LEDs that are held in place once they have been embedded in a silicone encasement. The first display prototype also has fewer LEDs and is not mobile.

Because mobility, transience, and communication capabilities are very significant social manifestations of the viscous display concept, Bluetooth was integrated and power mobility was mad possible by using a rechargeable Lithium-ion battery. Additionally the sensor/PCB casing in this model, is in the shape of a ball that is sensitive to pressure. This ball is attached via wires, but because these connecting wires are exposed, there is a greater chance of breakage over a long period of use. To solve this problem, the ball has been integrated into the display in the form of a tangible grip that could fit the shape of an average hand. This new form, due to its inherent characteristics, may also encourage more exactness in the gripping of the sensors. Because this grip is attached via a hardware connector, the wires are left inside the grip and are much less likely to be damaged over time.

Figure 24 The second prototype of the Viscous Display

Figure 25 The third prototype of the Viscous Display

The second prototype is a woven mesh of 100 surface mount, full-spectrum LEDs that are woven in place in an 11”x11” grid pattern. The weaving process involves the design of a tightly woven non-conductive metal mesh with lines of LED’s interlaced into the weave and special wire that is woven into the warp and also attached to the LEDs (anode and cathode connections). This second version is mobile; it includes a Bluetooth module and uses a rechargeable Lithium battery to power the Display system. The choice of 100 (10x10) LEDs, is due to both a limitation in power and a desired aesthetic.

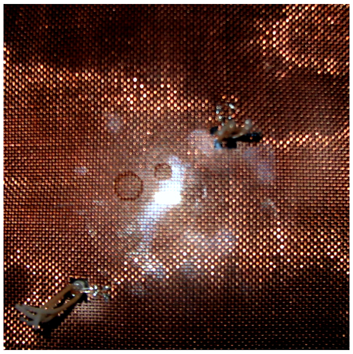


Figure 26 Detail of mesh for first prototype

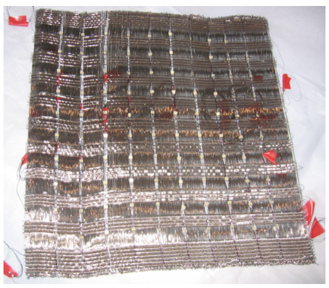


Figure 27 Woven LED mesh for second and third prototype

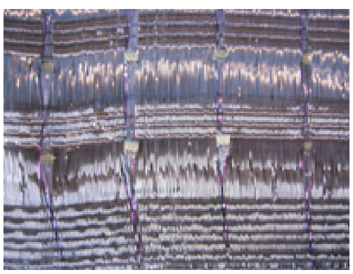


Figure 28 Detail of LED weave

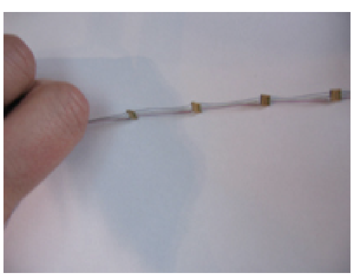


Figure 29 Single string of LEDs

The Display is meant to relay simplistic symbolic information and 100 pixels is the lowest resolution that still conveys information. A large font, for example, is still legible at 100 pixels. Also, these iconic images create a unique abstracted character with an aesthetic that is representative of abstract art from the 'modern' art movement.

The second prototype was found to be a bit too large in size for a comfortable physical interaction. The display is meant to be very malleable and handled with one or two hands, so the third prototype was constructed an inch smaller in both width and length. The second prototype continues to include a grip that is the expressive interface to the Display and is embedded with the PCBs, the power, and the sensors.

The dimensions of the third prototype are slightly smaller and thinner; the length and width are now 25cm and the display has a thickness of approximately 6cm. The slightly smaller dimensions are closer to the size of an average hand, and is more manageable for one hand to grip the handle while the other hand is free to manipulate the display into different shapes. The overall texture of the display is firm, but squeezable and pliable, while maintaining the shapes that are physically manipulated and formed, and the thinner display holds forms with greater rigidity. Altogether these final changes for this prototype have made the display lighter and easier to manipulate.

Woven LEDs

The LEDs are woven into a mesh using traditional weaving techniques using a loom. A traditional weave has a warp (vertical elements) and a weave (horizontal elements). The warp of the Viscous Display fabric is made of insulated metal wire and strings of LEDs [fig. 29] are woven between the warp in two centimeter segments. Insulated metal wire is also woven along the weave, between the strings of LEDs to create an array of LEDs along a two centimeter grid [fig. 28].

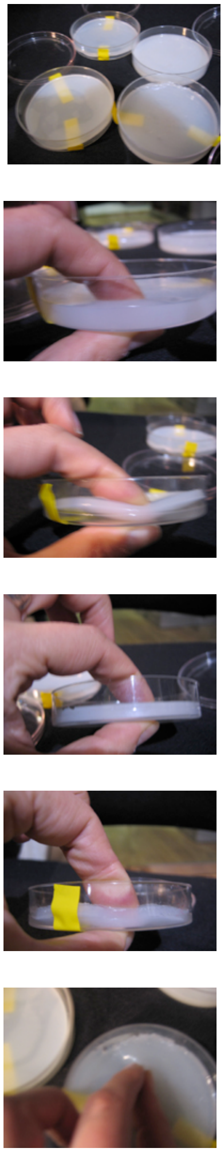


Figure 30 materials study for first prototype

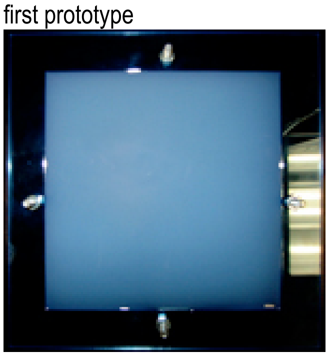


Figure 31 Viscous Display being cast in a mold

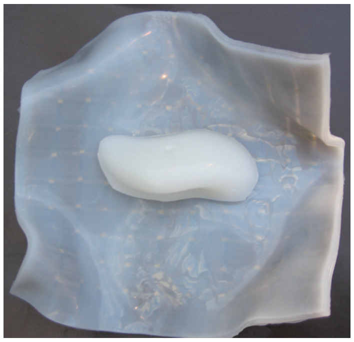
Silicone Encasement

The Silicone encasement consists of a cast Silicone that is poured into a mold over the woven display fabric [fig. 31]. There are several significant purposes for this silicone encasement; firstly, it provides protection for the woven wire mesh and LEDs; secondly, it creates a diffusion of light that spreads the light from the LEDs over a larger area; thirdly, it creates a viscous texture than lends to the malleability and flexibility of the display.

The type and hardness of the silicone can vary from a softer to a harder silicone, depending on the use. For the purposes of this project , it was important that the display material have a more resilient surface for public use, therefore, the surface that was implemented is easily formed, is somewhat soft, yet remains rubbery to the touch. Future Displays could be a bit stickier or stiffer depending on the proposed use.

Silicone Grip

A grip attached to the viscous display replaced the original ball from the first prototype, because it represents more clearly that it is meant to be handled and gripped. The form of the grip is similar to that of a climbing hold and is ergonomically suited for the grip of several hand sizes. Additionally, the grip is a good place to encase the intelligence hardware of the system. The PCBs, FSRs/sensors, and power components are encased within the grip. Silicone was chosen for the handle as well as the display for several of its attributes. Firstly, silicone is comprised of carbon and is a very conductive material; therefore it can facilitate in the transmission of sensors/electrical information such as pressure or touch sensing.



Secondly, it is flexible which is also helpful in a place that is meant to encourage gripping with the hand. Thirdly, it integrates well with the display itself, since they are both encased in similar types of silicone.

Figure 32 Silcone handle

Interface (input and output)

Sensors

Force Sensing Resistors (FSRs) utilize the electrical property of resistance to measure pressure that is applied to the sensor. A FSR is made up of a resistive material that is applied to a film and a set of contacts that are applied to another, attached film. The resistive material creates a path of electricity between the two sets of films. When pressure is applied to the overall sensor, a connection is made between the two contacts and this electrical conduction can be read in a digital format.

The range forces along the FSR follow a linear function of force ($F \alpha C$, $F \alpha 1/R$) [fig. 34]. There are two regions of transition within the FSR, the first region occurs at approximately 10g of force, and within this region there is greater sensitivity to resistance. Above the 10g region, the force is proportional to 1/r until it reaches a saturation point of pressure that can be sensed.

The advantage of using an FSR sensor for the Viscous Display is that it can measure pressure along the grip of the display, which is a comfortable way to handle the display as well as to measure information along the display. Additionally, since the graphics can also change based on this expressive information, there is a direct mapping that can be perceived between pressure and the resulting morphing graphics that are seen by the participant.

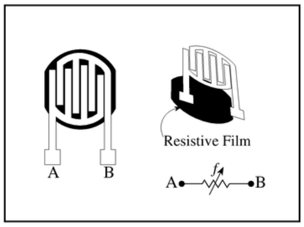


Figure 33 FSR

Future Sensors

In a future implementation, acceleration sensing to the Display will also be included. The physical principle behind an accelerometer is that of a spring- displacement system. Conceptually, accelerometers are based on Hooke's law, where a spring exhibits a restoring force that is proportional to the amount that it has been stretched or compressed [fig. 35]. This brings about a sensing of motion in two axes. The accelerometer that is currently embedded on the communications board is a two-dimensional, dual axis, accelerometer that can measure the x-y orientation of the Display.

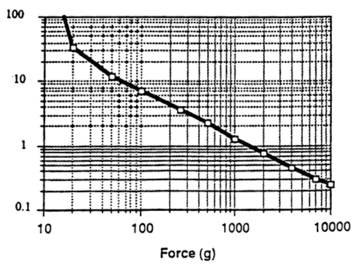


Figure 34 Resistance as a linear function of force. Resistance within the FSR sensor becomes less sensitive beyond approximately 10g of Force

An accelerometer has already been integrated on the Communication PCB, but the data software and analysis will be implemented in a future application. The addition of an accelerometer would enable the Display to not only have the large area of locational awareness that currently is part of this display (via Bluetooth), but a 'self-awareness' for the two dimensional axes of the display itself could also exist. This 'self-awareness', because of the sensing of motion in two axes and the dimensional information it reveals about the system, would also make it possible to connect many displays along a modular network.

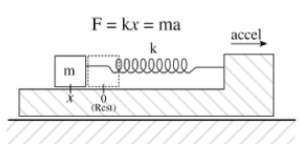


Figure 36 The mass-spring system of the ADXL1311 accelerometer (Analog Devices).

Graphics Display Output

Graphics experiments were necessary to guide the resolution of LEDs that were to be embedded in the device. The goal was to find the minimum number of LEDs that could still relay symbolic information. It was necessary to create low-resolution graphics that were simplistic enough for a low-resolution display, yet dynamic enough to relay relevant information. In conducting many experiments with various types of graphical information, it was found that the minimum number of LEDs for the size of the Viscous Display was 100 LEDs. This resolution of graphical information is interesting in that it has an abstract character that, due to its abstraction, becomes very memorable as a symbolic element. The illumination of LEDs occurs along a two-dimensional array, analogous to a television or screen, where the LEDs are scanned along a diagonal line at a rate of 400µseconds.

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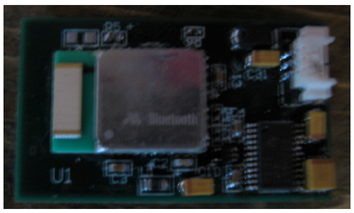
Figure .37 Example of Graphical representation

Storage and Retrieval Hardware

The input of expressive and locational information is stored to the communications and graphics boards.

The communications board [fig. 38] is embedded with a Bluetooth module (Miitsumi C20), an active microcontroller (ADUC7020), a dual-axis accelerometer (ADXL1311), and is stacked with the graphics board. The Bluetooth module has a 30 meter range and acts to communicate between any Bluetooth enabled device and the Viscous Display. The active microcontroller is active in that it is always checking for activity and it communicates any activity that occurs over Bluetooth to the graphics board. This enables the graphics board (and the subsequent display) to remain turned off when there is a period of non-activity, thereby saving battery power for longer periods. The accelerometer is embedded for future use in determining the two-dimensional x-y orientation of the Display.

The graphics board is embedded with a microcontroller (ADUC7026) that acts as a passive display driver and also stores graphics that are associated with the v-card texts communicated over Bluetooth. The current board has a storage capacity of 128kb, which was sufficient for the current system, but this can be extended on the PCB via external memory chips.



Bluetooth was chosen instead of Infra Red, which currently is more robust than Bluetooth, because it was important to have the greater range that is enabled by Bluetooth. Bluetooth enables devices to communicate wirelessly using radio-waves to transmit messages over short-ranges (approximately 30 meters or less). Because it utilizes radiowaves, it has alower power consumption than something embedded with 802.11x wireless LAN. Bluetooth also does not compete with wireless LAN, which could also be problematic in terms of interference. It is mainly meant to replace wires and cables that are usually required for communication between devices.

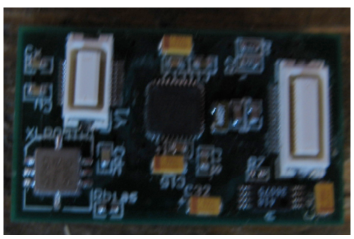


Figure 38 Double-sided Bluetooth communication board

While Bluetooth is still in it's early stage, it is being adopted in greater numbers of devices and is replacing IR emitters for communication between devices (just as the laptop that I am currently using no longer has an IR port, but relies solely on Bluetooth for intra-device communication). As Bluetooth becomes more robust, it will enable greater activity to larger numbers of people. The experimental studies that follow do not test interactions with v-card texting to the display due to a lack of robustness between the Bluetooth module and other Bluetooth devices and a necessity for more development in the hardware.

Future Design Directions

For future prototypes, it would be interesting to increase the resolution to 400 LEDs (20 x 20 pixels), to see the different types of information and activities this might facilitate. This would increase the system requirements exponentially and it would entail designing a graphics board that maintains a small enough size so that it can be embedded within the grip, while controlling a greater number of LEDs. It will also require a much larger power consumption, which may limit its mobility, but would be reasonable for a display that is locationally fixed, yet still flexible, tactile and malleable. As battery power and microcontrollers become more powerful and smaller in size, this resolution could be created with the same mobility that is a part of the current version of the Viscous Display.

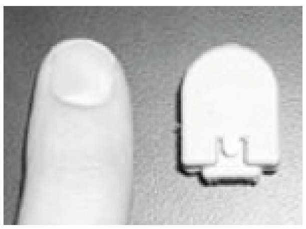


Figure 39 Image of the V1120 vibrotactile transducer

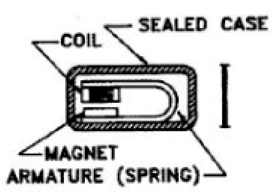


Figure 40 Schematic of the internal mechanism of the vibrotactile transducer.

For a sense of greater responsiveness from the display, in addition to the graphical output, tactile output could be located within the handle via vibrotactile transducers. One of the reasons for this would be to enable a sense of touch to the graphics that are being displayed. The vibrotactile transducer [fig. 39, 40] conveys a tactile stimulus to the skin, by responding to an electrical input, which in this case would come from the hand gripping the Display handle. Vibrotactile transducers, such as the V1220, have a frequency response that vibrates along a narrow contact area and at a level that is at skin's greatest sensitivity. While, finding an appropriate mapping between graphical information and haptic vibrations will be a difficult endeavor, it will also be a significant addition to the overall tangibility and tactility of the display. A good example of a tight coupling that is possible between a gestural input and a vibrotactile display is the *Mesh Maze* project, being conducted by Sile O'Modhrain's Palpable Machines Group. The *Mesh Maze* project is a hand-held hardware platform that couples physical sensing with haptic feedback; the combination of accelerometers and vibrotactile transducers for sensing and affecting provides a rewarding haptic interaction while utilizing relatively low-cost sensors[34].

Also, as mentioned earlier in this chapter, the already integrated accelerometer could be implemented to create a sensing of motion in two axes by the display, which would make it possible to create a tiled connection of many displays.

Chapter 5: Experimental Design

In this chapter, the broader context of potential social interactions with the Viscous Display are first described by outlining the social purpose, the intended audience, and example scenarios. Next, the issues that are explored in these studies are described, and the hypotheses related to the current prototype are presented. This follows with a review of the results of the initial pilot study and a brief discussion about how they led to further prototyping of the display. Finally, the experimental design considerations for the second pilot study are summarized and the results are evaluated addressing specific interface issues and the interactions that took place with the Viscous Display.

Social Activity

As a social device, the goal in constructing this device is to share private information in the context of a public space and, in doing so, create an interesting experience for people participating in the activity as well as for observers who are not informed about the content but who can observe the displays at a distance as they move through their public spaces. The overall assertion for this project is that a mobile, interactive, tangible communication medium that relays symbolic graphic messages can help in promoting greater personal expression and authorship in the public realm. More specifically, it is proposed that a graphical message that is simplistic and very explicitly defined, but is legible and meaningful on different scales, to different groups of people, can become an engaging source for social activity. The scales of legibility range from private individuals, with explicit interpretations of what is being displayed, to a larger public sphere, where there are looser interpretations of what is being displayed. These varying scales of legibility, because they enable a range in the levels of privacy of messages in public spaces, are thought to be significant in promoting communication in public spaces and greater social activity.

An example of a similar situation that this activity might resemble is a demonstrative communication such as a conversation, an argument, or a hug made in public by two people. The two people can understand the meaning of this communication on a particular, personal level while the observing public understands this interaction at a looser granularity. What draws us to become engaged or involved in these interactions? Are we engaged through some form of curiosity? How do these demonstrations, both on an active and a passive-observational level, create a greater sense of attachment to that space?

Intended Audience

While it is important to identify intended users of the Viscous Display system within a general context, it is difficult to define the full range of people that will adopt the Viscous Display. One of the goals of conceiving and scripting the scenarios was to define some key subcultural groups that are likely to adopt this system. There are many social networks that may adopt this form of communication such as the online communities of freindster.com, orkut.com, and meet-up.com to name a few. A more specific example of an intended audience is the hip-hop graffiti subculture—due to the aesthetic, political, and social contexts of hip-hop culture. The social antecedents of graffiti art inform the output design of the Viscous Display, which displays low-resolution symbolic information related to expressive input. While the overall aesthetic of the Viscous Display is influenced by modernist abstract art, because the Display creates a possibility for visual social communication similar to that of graffiti street culture, it is the assertion that computationally savvy people within the hip-hop graffiti culture are an example of people who are likely to adopt this digital form of social ‘street’ communication. For the purposes of the research, design, prototyping, and evaluations, the pilot studies were conducted with a variety of people ranging from people with basic everyday experiences with computers to computer scientists, engineers and designers.

Example Scenarios

The following example scenarios were helpful in determining the small interaction tasks for the pilot studies and are presented as a way of seeing the social potential for the Viscous Display. The pilot studies do not cover the breadth of these scenarios, but rather, they include a sampling of basic interactions that can help further designs of robust prototypes for larger-scale studies.

In one example scenario, a pedestrian might notice a Viscous Display attached to a public bench. This person knows about the Viscous Display because her friends mentioned playing with one of them. She walks over to the Viscous Display, touches and slightly squeezes the handle. Colors on the low-resolution display begin to change. Because her pressure was soft and she was unsteady as she was pressing the handle, the colors become more blue and yellow and they shift rapidly in a diagonal pattern. Her expressive/color trace affects several nearby Viscous Displays; their colors become slightly more green and more vibrant as a result of this greater change in one Viscous Display.

Another person is walking in the area and his phone sounds because he has enabled searching via Bluetooth and he is within twenty meters of a Viscous Display. He downloads the Viscous Display’s graphic information and, in case it has been moved and doesn’t have a correct locational awareness, this also uploads locational information to the Display. The color and pattern information give a simplistic indication of the mood of people who have been walking through this area, how they have interacted with the Display (shapes of patterns), and how recently the interactions occurred (through intensity of color). He notices that the colors and patterns are quickly changing from green to red and purple. This means that several people are interacting with the display and have very different sensor information (e.g.: green/fast diagonals = hard pressure and purple/circles= slow shaking). He decides not to touch the Viscous Display's handle. Now that the Display has an awareness of its location it can relay its locational information in addition to its color information for anyone who is searching for the Viscous Display.

In another example scenario, a member of a 'truffles community' sees a viscous display along his path to school and he wants to leave information for his friends about a restaurant nearby. He has several graphics stored in his mobile phone that have special meaning to other members of his social group. One of the graphic symbols announces that there is a restaurant serving truffles nearby; he sends a v-card text via Bluetooth to the display and the graphic is downloaded. The graphic can be retrieved by his friends when are in the area and they send their v-card information to the display or if they squeeze the handle and scroll through the various graphics that have been stored on the Display. Other members of the same community understand the meaning of this graphic because they have previously shared this information with each other. Another person, who is familiar with this community but not an active member, may understand that this graphic refers to information about this community while not understanding the details of the message.

Hypothesis

The hypotheses for this implementation of the project are:

1. The lower resolution graphics can be successful in conveying symbolic messages.

This is measured in the anecdotal responses from users in the questionnaire after having interacted with abstract graphical representations displayed throughout the study.

2. Retrieving graphics by physically acting upon the display can create a sense of discovery among the participants as they uncover hidden messages/graphics.

This is measured in a game of retrieving graphics that have been stored to the display from expressive interactions with the grip.

3. The ability to physically manipulate and play with a dynamic two-dimensional graphic produces a novel interaction where dynamic graphics can be extended into a third, physical dimension.

This is measured in a game where participants directly manipulate the display into a three dimensional object using two dimensional graphics that are represented on the display.

4. This combination of directly Interacting with dynamic graphics while physically manipulating the display object can also lead to greater engagement and cooperative play when used collaboratively.

This effect is measured in a collaborative game that involves the cooperation of two participants.

The evaluation is based on two studies that investigate the component parts of the display and how the design of the flexible display, with its limitations in resolution, can be optimized for interactions spanning from an individual to a collaborative scale. The questionnaires that follow the participant interactions focus on how engaged people were with the display and each other while playing with the display and how easily they interacted with it.

The initial evaluation of the Viscous Display was in a pilot study that was designed to identify very general issues associated with the physical design and the interaction graphics. This initial investigation helped to modify the design of the display and to further define the hypothesis.

Initial Pilot Study

For the first study, the success or failure of the first Viscous Display prototype is evaluated by focusing on the qualities of the physical design and the interaction design. A goal in this initial evaluation process was to gain a general understanding of the patterns of use and play within particular contexts to further inform the design of the Viscous Display.

The pilot study included two participants working together and one display that was attached to a laptop and an urban park bench. It is important to note that both participants were informed of the study before they interacted with the display and did not happen upon it in passing.

Initially, at the beginning of the observation, the participants approached the bench. For this study, the Viscous Display system consisted of one display and one sensor ball containing two FSRs and a battery. The system was connected via serial port to a laptop. The laptop was stored under an outdoor urban bench, and the flexible display and 'sensor ball' were attached to the bench. The first participant interacted with the display by first detaching it from the bench and then attempting to manipulate it. As soon as she grabbed the 'sensor ball', the display lit up and began to rapidly change color. The second participant then became engaged in the interaction with the Viscous Display by also grabbing the sensor ball and trying to move it in the same direction as the shifting graphic.

The Display began to rapidly shift through several low resolution colors until a steady set of heart pulses was captured, and then the Display shifted between reds, blues and purples to finally become more stable on a red display with a blue circular pattern.

The participants were initially told to feel free to manipulate and touch anything within the Viscous Display system. During the interaction with the Viscous Display, the participants' first reactions to the display were that of surprise and curiosity. Once the display became active and lit up, they began playing with both the 'sensor ball' and the flexible display. Although the participants took turns holding the 'sensor ball' during the interaction, the first participant seemed to be more engaged than the second participant with squeezing the ball. The Second participant spent more time loosely manipulating the display itself. When the second participant did interact with the 'sensor ball', he seemed to be a little confused with the relationship between the ball and the display. Afterwards, the two participants were asked about their experience with the Viscous Display with a brief questionnaire.

The questionnaire posed questions about the interaction with the display and the 'sensor ball'. While all of the responses to the flexible display were positive, most of the issues of difficulty were thought to be related to the 'sensor ball'. The participants remarked that they "enjoyed the physical interaction with the display" and that "manipulating the display was very satisfying". In his comments about the 'sensor ball', the second participant remarked that "the ball response wasn't immediately obvious and it took a while to realize that the overall pressure was linked to the graphics". The first participant also commented on the sensor ball, stating that it was "too hard" to the touch.

In the initial implementation with these two participants, I found that the physical and computational design (using adaptive algorithms) enabled some exploration and storage of information in the Viscous Display, but there were user interface issues that needed to be addressed.

The first issue involved a gap in the timing between the sensor data and the time it took the first participant to have a sense of control over the device. It was necessary to design a system that would tie an estimation of sensor data to the rate at which the device learns, the system could then adapt to the repeated sensor information that are part of the background interaction (unstable pressure), but would respond with little adaptation to the interaction designed to recall what was previously there (stable pressure).

The second issue was of participants being unsure if they had succeeded in actually embedding information into the device. During the interaction, the first participant said that she couldn't control the colors as much as she would have liked to. While the graphical resolution became more uniform as the sensor data became more stable, one of the participants was not aware of this interaction. This issue is addressed in the designs that follow by using a learning algorithm that provides feedback as to how well stabilized the sensor information is. Specifically, the graphical information displayed will indicate whether or not the input process has been successful; if the graphical information is smooth and uniform (although, possibly moving at various rates), then a user can know that the input process has been successful; however, if this display consists of a number of different colors that flash incoherently, then

the user can tell that their input to the device must continue. This input should typically take less than one minute.

The final issue that the participants faced was in the physical interaction with the ‘sensor ball’, the second participant didn’t easily recognize that it was meant to be grabbed and held onto. Instead of manipulating both the display and the sensor ball, he focused on the flexible display, and did not input information via the ‘sensor ball’. Also, the separate form of the ball and the display did not create an easily perceptible relationship. The key findings from the first pilot study were:

1. Participant’s were able to explore and stabilize the graphics
2. Because of the simplicity of the graphics, any gap between the input of data (squeezing) and the resulting changes in the display (graphics) makes it seem as if the mapping between the two are not related.
3. Participants were compelled to play with the malleability of the display, but found the ‘sensor ball’ to be less engaging.
4. The relationship between the input (ball) and the output (graphics) modalities were not obvious enough.

Second Pilot Study

Based upon observations from the first pilot study, it was important to make some changes to the graphical algorithms as well as to the physical design of the display system. The subsequent implementations of the Viscous Display include a handle/grip with sensors rather than the ‘sensor ball’ for easier handling and for a more obvious interaction form. This handle is also a better form for the embedding of the PCBs, power, and sensors. For the second set of studies, the Viscous Display system consisted of two sets if flexible displays and handles, where each handle was embedded with two FSRs and connected to a communication and graphics PCB and a 4.5volt battery. This system was self-contained and mobile, with information embedded in the microcontrollers instead of being connected to a laptop or to a desktop computer.

Five main questions going into this second pilot study were:

1. Would users understand the coupling of pressure with graphical representations?
2. Would they have difficulty manipulating the display in three dimensions when guided with two-dimensional graphics?
3. How long will it take people to stabilize a graphic? And how long to retrieve someone else's?
4. Do people find that the graphics relay some sort of information?
5. In a collaborative setting, will people be able to effectively cooperate to bring about a result?

For this study an individual, a multiple-participant, and a shared scenario were conducted and the results between the three scenarios were compared. The first game/study consisted of six individuals, each participating separately and completing two tasks; the first game task was to stabilize a graphic on the display and the second task was to physically manipulate the display to create a three-dimensional object from the two-dimensional graphical information contained on the display. The second game/study was similar to the first study, in that it involved the same game tasks, but instead of six individual participants, there were three sets of pairs of participants each with their own display. The third game/study entailed a communication task between six sets of paired participants In this shared scenario, the goal for each pair of participants was that each person had to stabilize their own graphic/message and then each participant had to retrieve each other's graphic using a shared display system.

The same six participants were included for the individual and then the subsequent shared scenario, and another six participants were paired for the multiple and shared scenarios; twelve participants in total, with six individual participants, three sets of two participants paired with multiple displays, and then six sets of paired participants for the shared interaction with a single display. All of the participants engaged in the shared display scenario after their initial single or multiple scenarios, where they had their own display. Since this second pilot study had a more defined task than the initial pilot study, it is important to define the interactions that took place within the three scenarios:

Individual participant interaction (six participants)
The single participant scenario addressed the following questions:

How comfortable is it for an individual participant to interact with the squeezable handle and the display? What is the complexity of this interaction? How can it be simplified?

The Individual study is focused on the interaction with certain aspects of device itself. Because there is only one participant, he or she will control all the parameters, such as:

— The handle: this is embedded with FSRs that maps to the graphical representations that are preloaded, but that change depending on the variable pressure that is exerted onto the grip.

— The display: this flexible and pliable, and can therefore be manipulated into many shapes that remain intact.

— The graphics: these are manipulated according to the grip of the person(s) holding the display.

— The placement of the display: the display system is moveable within a certain distance, and can be attached to different areas nearby.

The interaction can be described as follows: A single participant arrives at a Viscous Display that is wrapped on the arm of a chair. The display screen is blank, without any graphics or color. The participant is then asked to touch the display and manipulate it in whatever way she or he chooses, and is given information about the game tasks for the pilot study. The participants are also told that the experiments will finish when they finish the game tasks and when the feel that they have fully explored the device.

Multiple participant interaction (three sets of two participants)
The multiple participant scenario addressed the following questions:

How does an individual's observation of another person's interactions with a device affect his or her understanding of the device and subsequent interactions with that device? How can the device be constructed to facilitate easily observable interactions by several participants?

In the multiple-participant interaction, both people had their own Viscous Display system. The parameters that each person controlled were the same as in the individual participant interactions. This study focused on how two people might influence each other's understanding of the device, while remaining completely in control of their own device.

Shared Interaction (six sets of two participants)
The shared scenario addressed the following questions:
Can the users establish communication to each other by manipulating different aspects of an object? How do the users relate to each other by manipulating the same object?

In the shared interaction, two participants interacted with one display. Because all participants at this stage had experienced some type of interaction with the Viscous Display, the instructions were very general. They were asked to follow the given game instructions and to work together with the same display. The participants were also asked to observe and interpret how their partner manipulated the display. The aim of this part of the study was to understand how participants are able to decipher the retrieval of each other's graphic/message after having observed each other stabilize and save their graphic to the display system.

Procedures

At the beginning of the study, each participant was given general information about the Viscous Display device. They were then asked to read and sign a disclaimer stating that they were informed about the device. Next, they were taken to the chair where the Viscous Display was located. Each participant was then told that they could interact with the display and were given an oral set of instructions for the game tasks. A period of 10 minutes was allocated for each experiment, but the participants could choose to finish whenever they felt that they had fully explored the display.

After the experiment, each subject completed a questionnaire and was briefly interviewed using the set of predefined interview questions.

Game Tasks

Because the Viscous Display is meant to be a social-communication device, it would necessitate large numbers of people over a public landscape to test the display's success as a communication tool. Therefore, for this stage of the design process, a series of games were created that could be tested with one to two people and could give an understanding of the robustness mapping between a participant's action, the graphics on the display, and the participants' perception of the information being conveyed by the display.

Game One: Individual and multi-person interaction with the grip

At the beginning of the interaction, the participants are instructed to graph the handle and to manipulate the display while holding the handle. When the participant grabs the handle the Viscous Display will reveal a simple graphic (either an abstract circular graphic, or a more linear graphic of varying colors). The graphic will slowly change, morphing with the varying range of pressure exerted onto the handle. The goal of this game is to control the shifting graphic to one that is steady. As the participant keeps a steadier grip on the handle, the graphic will remain steadier. Once the Viscous Display system displays a particular graphic for 5 seconds, the resulting graphic is permanently associated with that range of pressure and it will flash (rather than morph) onto the display whenever the handle is pressed at that range.

The second goal for the participant is to recall the same graphic. To recall the graphic, the participant first resets the display by gripping the handle quickly. Next, the participant attempts to exert the same grip as she or he did earlier to recall the previous graphic. The graphic that has been set will flash unless a participant presses at that same range for a duration of at least 5 seconds.

The multi-person, multi-display interaction scenario is the same as the individual scenario, except that two people explore their separate displays at the same time and location.

The game for the individual and the multiple participants is finished when they are able to leave and then retrieve their graphic/message.

Game Two: Individual and multi-person Interaction with the display and simple geometries

In this second game, in order to better understand the participants' comfort and engagement in manipulating the flexible display, the participants are asked to isolate a graphic on the display and to create a three-dimensional object by physically bending the display around the two-dimensional graphic. The graphic that appears on the display is a two-dimesnional outline of a square and four diagonal edges. A typical manipulation of this two dimensional graphic would be to bend the four edges upwards and create a three dimensional pyramid.

The game is finished when they feel that they have successfully completed the task of bending the display within the constraints they are given.

Game Three: Shared interaction with one display

The shared game follows the other games, therefore, all participants have had some practice with the display and the grip when they begin this game. In this final game, one display is shared between two people who attempt to control/insert a graphic to the display with their individual levels of pressure. Once they have done this, they each attempt to recall the other's graphic by guessing at the pressure exerted and then keeping it for 5 seconds.

This game is over when they both have been able to leave a graphic/message and retrieve each other's graphic/message.

Evaluation Questionnaire

For this study, there is an emphasis on a questionnaire-based evaluation that combines the participants' descriptions of the interactions with numerical ratings of the degrees of interaction. The method of evaluation uses qualitative data derived from interviews rather than a statistical, quantitative method.

The interviews are meant to support the overall impressions resulting from the questionnaires. The written questionnaire consists of 16 questions; 11 questions for the individual and multiple participant interactions, and five additional questions about shared experiences that are geared towards the multiple participant interactions, and one question for further comments.

Results of Second Pilot Study

The method for assessing the results of this study was with the measurement of the time it took for participants to complete a task (or perceived completion), and with their responses to a questionnaire.

Most people tended to become engaged with the display fairly immediately – within one to two minutes at most. This engagement seemed to facilitate a better ability to grasp the characteristics of the display, such as its malleability and the mapping between the dynamic graphics and the pressure of the handle (although they were given this information in the oral instructions of the games). Some of the participants took longer than others to understand this mapping, about three to five minutes, and expressed surprise once they realized it.

Games

For the first game of individual graphic stabilization and retrieval, all of the participants were able to stabilize a graphic. Participants were timed and it took all of the participants at least two attempts, approximately two minutes, and it took three of the participants four to five attempts, approximately five minutes, before they could confidently stabilize the dynamic graphics. The participants that were paired together, each with their own display, generally learned to retrieve their graphics more quickly than those who worked individually; all of the paired users were able to retrieve a previous graphic in two to three attempts (approximately four minutes), and it took individual participants between three to five attempts (approximately 6 minutes). During the first game, the participants mostly made comments about the illumination of the display rather than about the game itself.

The second game of forming simple three-dimensional geometrical shapes from the two-dimensional graphics also seemed effective. All of the participants had become more confident with the display and they easily formed the shapes. All of the participants were immediately absorbed in this game, and many continued to make other shapes once they had successfully completed the game. In terms of individual and multiple-participants, there wasn't any noticeable difference in the level of engagement or the length of time in completing the task. Perhaps the reason for this was that the graphics were very simple and the game could be understood more readily.

By the third game, all of the participants were somewhat experienced and comfortable with the display; by this point, they realized that they didn't have to treat it as a precious object and could manipulate it at will. Several of the participants played competitively with each other and all of the participants communicated with each other verbally and seemed to enjoy the interaction. Most people were able to stabilize a graphic within one to two attempts. It took between two to five attempts for participants to retrieve each other's graphic, but the increased time was mostly due to play. There was much more liveliness in the participants when they played together than when they interacted with their individual display. Some nuances were discovered during these interactions, possibly because of the greater ease that people had with each other and with the device. One of the ideas was that bend sensors in the display piece could be another way to directly manipulate the graphics. Another suggestion for augmenting the display was to add a microphone as a sensor for controlling the graphics.

Questionnaire Results

The first question asked about experience with some typical digital media that people might integrate into their daily lives. All of the participants responded that they had some familiarity with computers. Three of the twelve participants only used computers for work and the remaining nine also used computers outside of work. Four of the participants had some experience in playing computer games, eight used their mobile phones for sms texting, and four were experienced as hardware developers. The questionnaire (Appendix B) involved scores from the participants ranging from a possible one to five (five being the most positive), as well as anecdotal comments for each question. The anecdotal comments are reviewed in the following Discussion section.

The participant response to the first question of overall satisfaction ranged from 4 to 5, averaging at 4.75 (on a scale of 1 to 5). In terms of overall engagement, five participants gave a score of 5, five scored their level of engagement at 4, and two participants were in the middle with a three score, brining the average to 4.25. In response to the shared interaction question about establishing communication with another participant, all of the participants gave a score of 5, indicating that they communicated all the time with each other over the shared device.

There were several questions regarding user interactions:
In response to the question of a sense of control over the graphics (question 3), the responses ranged from 3 to 5, averaging at 4.25. All, but one of the participants scored 5 in response to the question of control influencing their interaction, bringing the average to 4.83. When asked if the resolution was sufficient to understand the visual image, all the results ranged from 4 to 5, averaging at 4.67.

For the questions regarding the physical aspects of the Display, both the handle and the display itself:
The responses to the comfort of the handle averaged around the middle of the scale, averaging to a 3 score. When asked if the handle encouraged touch or interaction, the responses were again in the middle, with one score of 2, two scores at 5, and the remaining 9 participants scored this at 3, bringing the average to 3.25. Participants responded with high scores to the question of ease in manipulating the display, ranging from 4 to 5, and averaging at 4.75. In response to the question of how enjoyable it was to manipulate the display, most participants gave a positive score of 5, and this score averaged at 4.92.

Discussion

The results from this third prototype and second pilot study led to some important findings regarding the interaction and design issues. The second pilot study resolved many of the questions that resulted from the first experimental study and the insights are also useful for future prototyping. Users were able to store and retrieve messages and they all seemed intrigued by the flexibility and the illumination of the display.

In terms of the visual interface, one of the unexpected findings was that all of the participants were compelled by abstract graphics of the display and some described the visual graphics to be “hypnotic”, “beautiful”, “relaxing”, “soothing” and “exciting”. Some additional comments included statements such as:

“It is totally cool as it is – but I would add more to the interface, like sensors on the display itself”,

“it is beautiful – the illuminated graphics are mesmerizing”,
“the display made me feel happy, maybe it was the moving graphics” and
“I liked that it was an abstract image”.

It was expected that, since the graphics are not typical and people have different design preferences, a portion of the participants might not enjoy the overall aesthetic. The common criticism was that it would have been even nicer to see and play with the display in a dark space, since it was located in a sunny area.

Another important finding was that participants preferred to manipulate the device into defined lines and around the structure of the chair and their own arms – they did not attempt to crumple the display. Participants seemed to enjoy forming various shapes with the display and many remarked that they liked the texture and lightweight quality of the display. All of the participants were able to form explicit geometries when guided by the graphics in the second game. They wrote comments such as:
“Being able to manipulate the display with my hands, and the nice feel of the silicone were very satisfying”,
“The texture feels solid and malleable, not at all flimsy”, and
“The texture and size of the display made it fun to mess around with”.

As in the first prototype, the interaction issues were not in the display piece, but in the handle. While the observed responses to the handle interface were much more positive than to the ‘sensor ball’ of the first study, they also indicate that there is need for greater improvement. Some participants remarked that they found the grip to be comfortable and “nicely textured”, several participants had some difficulty with the handle. One of the participants in the individual user study broke the silicone handle apart from one of the displays, and it had to be replaced with another display in the middle of the first game-experiment. Because the interaction with the handle wasn't immediately responsive, some of the participants conflated this slight delay with a lack of control over the device. Some of the participants commented on this issue with statements such as:

" I wanted to feel like I was immediately controlling the display",

"it might be nice if the handle was squishier- softer", and

"the difficulty in controlling the graphics made it frustrating at first, but once I could understand how to control it, I enjoyed the game."

The handle and the display in this prototype have a different density with the same overall texture. An improvement for the next prototype would be to cast the handle with a slightly softer silicone compound, while continuing to maintain a seamless appearance. The next prototype will also require a more pliable handle that has a sturdier connection with the display, so that the person handling it can feel that it is as robust to touch and grip as the display itself.

In terms of communication and shared interaction, participants seemed to learn from each other and many had more ease with certain aspects of the display system that they did not have when they interacted individually. One example of this was in the multiple-participant games (with two displays), when one of the participants seemed to be very careful in manipulating her display, but once she noticed how far another participant was bending the display, she began to play with hers more freely. When asked about the difference between using separate displays and sharing displays, most remarked that they learned from each other's actions in both types of games, but that when playing together they cared more about stabilizing and retrieving the graphics. They spoke of the enjoyment in playing with someone else and communicating with graphics. In response to the question about whether the display graphics could be a way to communicate symbols/simple graphics as messages, most participants liked the idea of leaving secret messages and responded with comments such as:

" Yes, it is lovely, I liked that they were images instead of text"

and

" I enjoyed the search for my friend's graphic – it felt like I was discovering something hidden in the display"

Participants described the experience of sharing the display with comments such as:

" When two of us control[led] the display, we could try more things than when we were using it alone", and

"It would be fun to have this as a toy on a coffee table to play as a game with each other– sort of like a rubik's cube"

Overall this second study was a success. The constrained interactions – in being specific games, revealed much more information than the first pilot study. Some of the key findings were:

1. Participants were most immediately adept at physically manipulating the display and became most absorbed during that part of the interaction.

2. They liked manipulating the display along defined lines rather than crumpling the object.

3. In the game interactions, the participants were more animated when there were two people playing and seemed to enjoy it as a social performance.

4. Participants enjoyed manipulating the device.

5. While the latency issues from the first study were resolved (between the touch and the graphics), there were still issues with the handle interface that made it less robust and enjoyable than the rest of the device.

From these findings, several areas need to be explored further:

1. More attention needs to be paid to the material and sensors of the handle so that it is as robust as an interface as the rest of the device.

2. If it were to be used in more of a gaming sense, perhaps more complex games/interactions need to be devised for individual play.

3. Because people were most engaged with the physicality of the device, it would be interesting to explore more applications that could involve manipulating the display physically.

Future Design

As a result of what was learned from these studies and from the design process, the future steps that would be interesting to explore for further development of the Viscous Display are:

1. Adding more robust sensing in the handle, such as Galvanic Sensor Resistance (GSR), where the signal is relative to the square area of contact.

2. Adding a tactile output located within the handle via a vibrotactile transducer. This would be to make possible a sense of touch to the graphics that are being displayed.

3. Experimenting with various textures of silicone for the handle, in order to find more comfortable surfaces.

4. Adding acceleration sensing to the display by fully implementing the existing accelerometers for a sensing of motion in two axes. This 'self-awareness' for the two dimensional axes of the display itself could also make it possible to connect many displays along a modular network.

5. Sensing of other displays along a distributed network, where many transient displays can act upon each other depending on locational, Bluetooth v-card, and sensing information.

6. Sensing of other displays along a modular network, where many people can affect/program parts of a larger, tiled display fabric.

7. Constructing mobile and non-mobile displays at a higher resolution to see the maximum resolution possible within the limits of mobility as well as within the limits of the materials.

8. Testing 6-10 distributed devices in an urban setting such as the Dame Street Corridor and Meeting House Square in Dublin.

9. Testing 6-10 modular devices in an urban node space such as Meeting House Square in Dublin.

The future plan for this project is to continue the prototyping and follow this work with a forthcoming qualitative analysis that documents 30 user interactions with video recordings (for later review). A larger-scale study will help us to understand how people interact with the Viscous Display system in a semi-public space, to determine how successfully multiple systems act together, and to identify what sorts of activities emerge. Two scenarios will be generated to cover a wider range of situations; one scenario will be located in the context of a semi-public ‘pathway’ and another in a urban ‘node’. These scenarios will serve as a ‘walkthrough’ of the system, where the various emergent interactions between the participant and the system and with other people will become more defined.

Chapter 6: Conclusion

This thesis presented a new display interface and concepts behind a novel social artifact for public engagement. It is an initial investigation into a novel tangible interface that endeavors to contribute to the broader social concepts that inspired its design. It was developed to support the idea that social objects can transform public space by bringing about greater physical and social engagements and memory attachments. The approach for developing the Viscous Display project was to begin with an emphasis on the tactility of the object in order to facilitate the steps needed to further its design as social communication artifact. While the larger issues of social communication in a public setting will take more time to resolve, the results of the two pilot studies that were conducted supported the hypothesis that the physicality of the Viscous Display, in enabling direct manipulations of both digital graphics and physical shape, can lead to more play and dynamic social activities between people using it.

A constant thread throughout this thesis and project is the concept of ‘viscosity’, where physical deformations of an object can also lead to social deformations of a space. Here, the idea of viscosity, is not only expressed in the tactile, physical texture of the artifact, but it is also a dynamic character that is not readily visible or tangible, where socially dynamic activities are proposed from physically dynamic objects. This work proposes to create a thickness in space – linkages between people using external artifacts through which strangers and non-strangers alike might communicate with each other as though they had some common understanding or desire. The ideas of social and physical viscosity discussed throughout this thesis are inspired by previous works in the interactive design of narrative space, ‘underground public art’ movements, tactile digital technologies, and finally by the collective intelligence of ants by which ants leave their chemical signatures around their spatial nodes and pathways. A hopeful outcome from this project is the further development and proliferation of digital social artifacts in the public landscape, where people may also leave traces of themselves and communicate their desires and histories in the common places that they inhabit.

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Appendix A: **Oral instructions**

The Viscous Display is a device that may be handled and manipulated. The system consists of a handle containing sensors that may be grabbed and squeezed and a flexible display that may be physically manipulated. Please feel free to explore and play with the display and handle in any way that you like. You will play three games with the display; for the first two games, you will have your own display, and for the last game you will share a display with someone else. Once you have completed all of the games I will ask you to fill out a questionnaire about the Viscous Display system.

Game One (leaving and retrieving a graphic; six individuals and three sets of pairs, each with their own display):

For the first game, there are two goals. The first goal is to stabilize a moving graphic using the handle with the display. Once you have stabilized a graphic and the graphic on the display becomes dynamic again, the second goal is to retrieve the graphic that you stabilized earlier. Please tell me when you feel that you have finished the game.

Game Two (two-dimensional to three-dimensional geometric exercise; six individuals and three sets of pairs, each with their own display):

For the second game your goal is to physically manipulate the display and arrange the graphic that appears on the display to create a three-dimensional physical object using the display. Please tell me when you feel that you have finished the game.

Game Three (leaving and retrieving a graphic with a shared display; six sets of pairs, each pair shares one display):

For the third game, you will share the Viscous Display with your partner. There are two goals in this game; the first goal is for each person to stabilize a moving graphic that will then be stored in the device. The second goal is to retrieve each other's graphic/message. The overall goal is to work together throughout the game. Please tell me when you both feel that you have finished the game.

Appendix B: **Written Questionnaire**

Questions 1 to 11 are for the individual participation, and the remaining questions are geared toward the shared interactions.

1. What is your current experience with digital devices (circle all that apply):

a. I use computers in my work.
b. I use computers for recreation – outside of work.
c. I play computer games.
d. I text with my mobile phone.
e. I am a hardware or software developer

2. How satisfying was your interaction with the Viscous Display?

not satisfying 1 2 3 4 5 very satisfying

specific comments:

3. To what extent did you feel that you were in control of the graphics in the display?

not at all 1 2 3 4 5 all of the time

specific comments:

4. Did this influence your interaction with the display?

not at all 1 2 3 4 5 all of the time

specific comments:

5. Was the resolution of the display sufficient to understand the visual image?

not at all 1 2 3 4 5 all of the time

specific comments:

6. To what extent did you feel engaged in the interaction with the display?

not at all 1 2 3 4 5 very engaged

specific comments:

7. Did the display's handle feel comfortable to grip?

not at all 1 2 3 4 5 very comfortable

specific comments:

8. Did the display's handle encourage touch or interaction?

not encouraging 1 2 3 4 5 very comfortable

specific comments:

9. How easy was it to manipulate the display itself?

not easy 1 2 3 4 5 very easy

specific comments:

10. How enjoyable was it to manipulate the display itself?

not enjoyable 1 2 3 4 5 very enjoyable

specific comments:

11. How would you describe your experience of interacting with the Viscous Display?

Shared Interaction:

12. To what extent of at all did you establish communication with the other participant?

not at all 1 2 3 4 5 all of the time

specific comments:

13. If you did establish communication, how would you describe it?

14. How meaningful do you think it is to communicate with this device? Did leaving and retrieving messages using the Viscous Display make sense?

15. Did the graphical images seem sufficient as a way of conveying a simple message/idea? Would you use something like this to relay a secret message to a friend? Would you leave it for them to find in a public place?

16. Any further comments (write on back of paper if necessary)?