# The Use of Abstraction and Motion in the Design of Social Interfaces

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## ABSTRACT
In this paper, we explore how dynamic visual cues can be used to create accessible and meaningful social interfaces without raising expectations beyond what is achievable with current technology. Our approach is inspired by research in perceptual causality, which suggests that simple displays in motion can evoke high-level social and emotional content. For our exploration, we iteratively designed and implemented a public social interface using abstraction and motion as design elements. Our interface communicated simple social and emotional content such as displaying happiness when there is high social interaction in the environment. Our qualitative evaluations showed that people frequently and repeatedly interacted with the interface while they tried to make sense of the underlying social content. They also shared their models with others, which led to more social interaction in the environment.

## Author Keywords
Socially aware systems, social interfaces, public installations, interaction design, social cues, design methods

## ACM Classification Keywords
H.1.2 [**Models and Principles**]: User/Machine Systems – *Human factors.* H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *Evaluation/methodology, User-Centered Design.*

## INTRODUCTION
A social interface uses accepted social norms of human-to-human communication to bridge the gap between people and products. An increasing number of applications, ranging from computer interfaces to household appliances, provide users with the opportunity to interact with social interfaces.



**Figure 1. Our abstract social interface installed in a university foyer.**

Research in HCI suggests that even the simplest attributes of a computer interface, such as the language style used in a computer interface (i.e. strong vs. weak), are sufficient to create a "personality" for the interface. These personalities form the basis for interpretations of complex social behavior [23]. Our research builds on this work to understand how minimal cues might evoke a social response.

To explore the idea of how minimal cues can be effectively used in the design of social interfaces, we conducted a design study where we used simple dynamic visual cues in the design of an interactive public display (Figure 1). The use of simple dynamic visual cues was inspired by the literature in perceptual psychology about high-level responses to two-dimensional displays. Studies of dynamic visual displays have shown that even the simplest movements are perceived as having complex properties [10, 18, 29, 31]. Viewers make social attributions, including animacy and intentionality, to relatively simple displays. For example, a small set of motion cues was shown to be sufficient not only to determine whether or not a moving object was animate, but also to determine its intention [3, 7]. These attributions are made by children and adults and over a variety of cultures [15, 28].

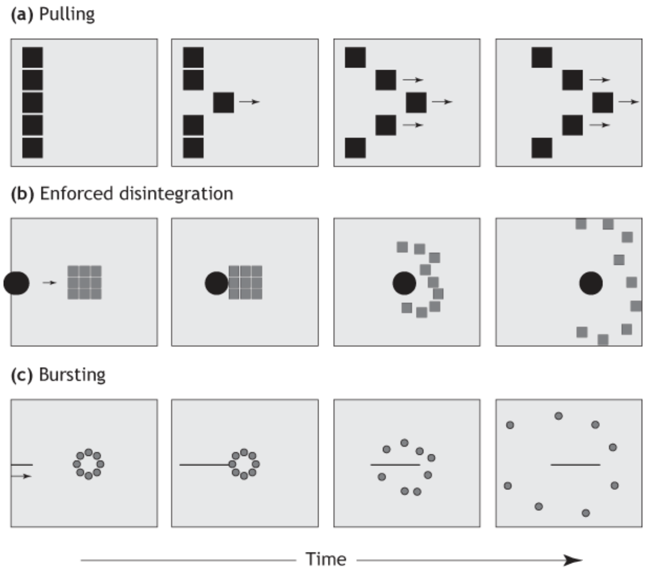


**Figure 2. Displays that relate to functional relations such as pulling, enforced disintegration, and bursting. Adapted from White and Milne [36, 37].**

Figure 2 shows snapshots from these simple animations, where viewers described the perceived motion as pulling, disintegration, and bursting. Even though such responses have long been studied in the perceptual psychology literature, the idea of using this human perceptual attribute as a design element has not yet been extensively explored.

The public display was designed to be aware of passersby and respond to voice and movement in the space by dynamically creating visual and motion patterns. The goal of these responses was to communicate simple social and emotional content, such as displaying happiness when high levels of social interaction were occurring in the environment. Through an iterative design process, we qualitatively evaluated how these patterns communicated such content, and integrated these findings into our design. We implemented our final design and installed the system in a university foyer for six weeks. A qualitative evaluation of the installation showed that people made sense of, and social attributions about, the interface both independently and in groups. In addition, behavior in the installation area changed dramatically as a result of the presence of the installation.

In the remainder of this paper, we will describe related research, our iterative design process and methods of evaluation, and present our findings along with implications for the use of abstraction and motion in the design of social interfaces.

## RELATED WORK

Social interfaces use accepted social norms of human-to-human communication to bridge the gap between people and products. Examples of social interfaces include speech interfaces used in automobiles and appliances and interactive on-screen agents used in websites and desktop software. Nass and his colleagues, through their "Computers Are Social Actors" theoretical framework, have systematically studied how people interacted with computer interfaces using human social norms [20-23].

As designers, we are interested in understanding how dynamic visual cues can be used to create accessible and meaningful social interfaces without raising expectations beyond what is achievable with current technology. We suggest that by utilizing abstract, dynamic features, we can simplify the design of these interfaces, while reducing both computational overload and user expectations. For example, an in-car navigation system that used abstraction and dynamic presentation of information proved to be easier and more efficient for an information-seeking task [14].

Researchers have theorized that exposure to unfamiliar artifacts is an affective event that triggers a process of sense-making, through which cognitive processes and emotional responses are triggered to link the familiar to the unfamiliar [26, 35]. When an interface is human-like in appearance and expression, the sense-making process may be bypassed, and the viewer's mental model or conceptual framework for human interactions may create overly high expectations of what the humanlike interface is capable of. With experience, mental models become richer and more complex [9]. For example, an interactive robot used to deliver medications in a hospital or nursing home might be assumed to share such characteristics as the ability to follow hospital rules with hospital staff [34]. Over time, expectations about the robot might become more accurate as staff observe and interact with it. We hope that abstraction will encourage people to interact with the interface, allow users to "fill in" by constructing relevant parts of the experience instead of relying on their existing mental models of social behavior.

A substantial amount of work in Human-Computer Interaction borrows from biological and natural materials for the design of interactive displays that deliver information on the periphery of attention [1, 4, 6, 11, 16]. These ambient displays fill functional, aesthetic, and experiential roles: responding to nearby conversation, a user's email activity, temperature and daylight, or the rate of recycling in a community. An approach similar to ours to reflecting the changes in the social environment was employed in Miro, a public display that sensed and displayed the collective emotions and activity levels in a public space [32]. While our work is a type of ambient display, it differs in that specific responses to viewer input were dynamically chosen from a group of six responses based on sensor signals. The selection of responses included a random factor, creating an unanticipated experience.

Our work contributes not only to the design of social and peripheral interfaces, but also to the design space of interactive art by creating a public installation that has the capacity to provide a dynamic experience while responding to and even changing public behavior. Interactive objects, even before the advent of technology, has a long history of using dynamic visual cues to evoke strong emotional and social responses (e.g. mobiles). Critical art theory has examined the potential for museum exhibits and public displays to create compelling interactive experiences [19]. Many interactive art pieces that make use of technology have a direct connection between the viewer's action and the system's reaction. Body movements are tracked by motion sensors, vision cameras are used to track change in a scene, or sensors may be worn or to create a direct, if not personal, experience [5, 8, 12, 13, 17, 25, 27, 33].

In the next section of this paper, we present a design exploration of a social interface that uses simple, dynamic visual cues to communicate social content and allows the user to socially construct models of the behavior of the interface.

## DESIGN PROCESS

We employed an iterative, user-centered methodology to design, implement, and evaluate a social interface using abstract, dynamic, visual cues.

### Design of the interface

Our design process started with identifying the social and emotional content that the interface would communicate. We examined several taxonomies of human emotions from the literature on emotion and used mood boards (Figure 3) to identify motions that characterized particular emotions [24, 30].

Mood boards are widely used in advertising design to explore images that describe a given theme. Using this technique, we identified dynamic visual cues that could represent a set of three emotions. For instance, randomness consistently appeared in our mood boards on curiosity. Happiness could


**Figure 3. A mood board depicting curiosity.**

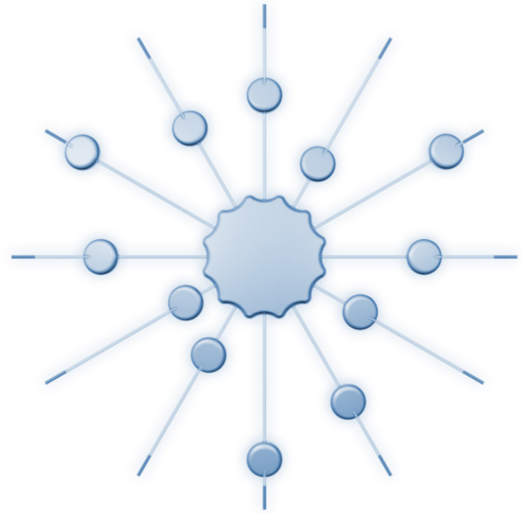

**Figure 4. The final design of the social interface.**

be characterized by attraction and fear by repulsion. We focused on the emotions happiness, curiosity, and fear in our design because they represented distinct features, which we incorporated to the design of motion patterns.

Our form exploration was constrained by the need to build a platform that could express these socially constructed emotions using dynamic visual cues. Furthermore, we believe that forms that are physically possible evoke stronger causal reasoning such as an oscillating circular shape on a blank surface vs. a 3-dimensional disk oscillating at the end of a string. Therefore, our form studies aimed for creating only physically possible forms and motions. Our final design used a two-dimensional display to portray abstract, geometric shapes using patterns of motion to respond to the social activity in the public space. The form included a static circular shape in the center and twelve smaller circular shapes aligned on a radial array around the central shape (Figure 4). The smaller shapes independently moved away or toward the central shape to create patterns of motion.

### Initial evaluation of the design

To assess how the visual cues that we identified using mood boards might communicate particular emotions, we designed a variety of smoothly repeating motion patterns (Figures 5 and 6) and evaluated them with users. For instance, patterns 1, 2, and 10 used 'harmony' as a feature, which represents strong casual relationships between the moving shapes while four of the patterns used randomness as a design element in a variety of ways.

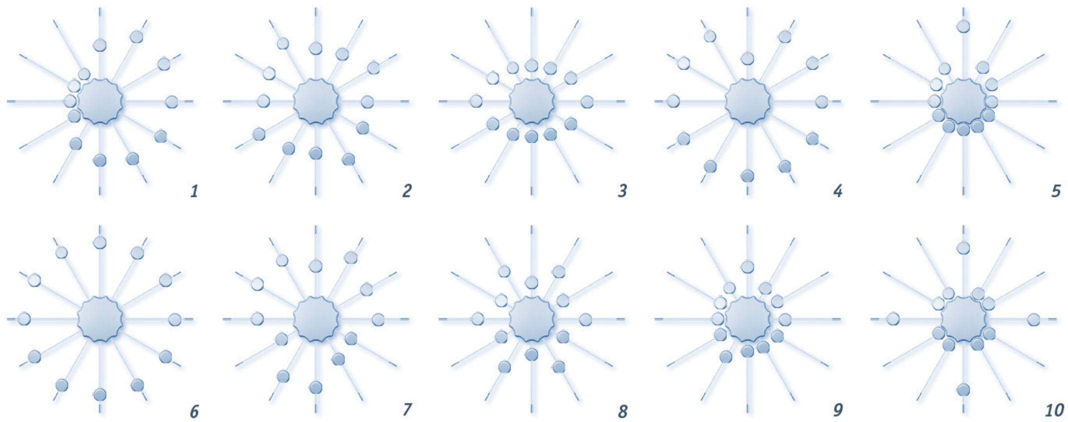


**Figure 5. Snapshots from the motion patterns designed for our interface.**

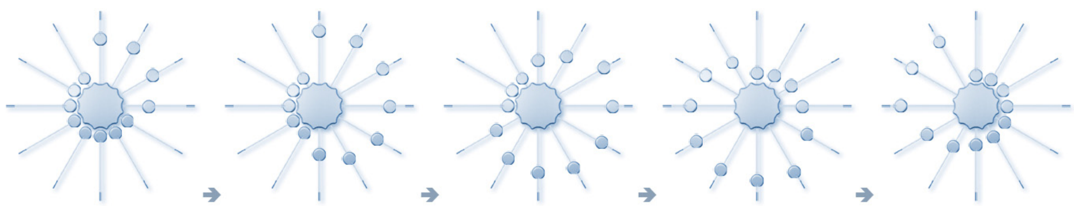

**Figure 6. Snapshots of the interface as it executes motion pattern 1.**

We designed a 10x3 (ten motion patterns and three emotions – happiness, curiosity, fear) web-survey using a within-subjects design. We showed participants ten different motion patterns, and asked them to rate each pattern for the emotion they thought the interface was expressing. We provided rating factors for the three emotions and a blank "other" field so that users could enter free-form descriptions. Ratings were measured using a 5-point Likert-scale for each motion pattern across conditions (emotions). Responses were collected from 53 participants. Participation was voluntary and participants mostly consisted of university students and their family members.

### Analysis

Our data analysis used two methods; analysis of variance (ANOVA) and regression (Least Squares Estimation). The first method applied an Omnibus F-Test to see if ratings were effective in any of the conditions for each motion pattern. The second technique performed a linear regression on the variables that were significant across conditions to identify the direction of the main effect. This second technique was conducted for each motion pattern as a within-subjects analysis of variance using participant as a random factor, condition (emotional state) as the independent variable and participant ratings for each condition as the dependent variable. We also performed a mean value comparisons for verification purposes (Figure 7).

The Omnibus F-Test (ANOVA) showed that the dependent variable was significantly effective in 8 of the 10 motion patterns (#1, #2, #5, #6, #7, #8, #9, and #10). As a second step, we ran pairwise contrast tests (Least Squares Regression) within these 8 patterns to compare ratings across conditions. Results of these tests showed that motion patterns #1, #2, and #10 had significantly higher values of happiness, over both curiosity and fear. In pattern #1, happiness was highly effective over both fear and curiosity with above 99% confidence. Ratings for pattern #2 showed happiness to be highly effective over fear with above 99% percent confidence and marginally effective over curiosity with above 90% confidence. In pattern #10, happiness had higher values than fear with above 99% confidence and curiosity with above 95% confidence.

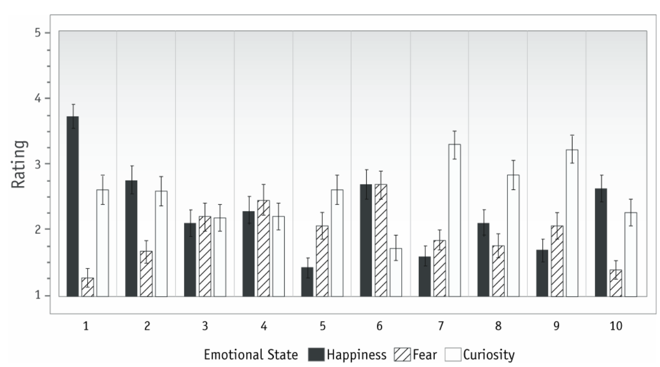


**Figure 7. Plot of the mean value comparisons of the response variable (rating) for each motion pattern across emotional states.**

| Motion Pattern | Omnibus F-test | Pairwise: *happiness vs. fear* | Pairwise: *fear vs. curiosity* | Pairwise: *curiosity vs. happiness* | Effective emotion |
|---|---|---|---|---|---|
| **# 1** | F(2,150) = 45.26<br>**p < 0.0001** | **< 0.0001** | 0.0042 | **< 0.0001** | ***happiness*** |
| **# 2** | F(2,150) = 8.28<br>**p = 0.0004** | **0.0034** | 0.22 | **0.088** | ***happiness*** |
| **# 3** | F(2,147) = .07<br>p = 0.9370 | - | - | - | - |
| **# 4** | F(2,141) = .34<br>p = 0.7102 | - | - | - | - |
| **# 5** | F(2,153) = 8.91<br>**p = 0.0002** | **< 0.0001** | 0.85 | **0.0001** | - |
| **# 6** | F(2,159) = 7.02<br>**p = 0.0012** | 0.16 | **< 0.0001** | **< 0.0001** | - |
| **# 7** | F(2,147) = 27.63<br>**p < 0.0001** | 0.016 | **0.001** | **< 0.0001** | ***curiosity*** |
| **# 8** | F(2,159) = 7.33<br>**p = 0.0009** | 0.96 | **0.044** | **0.040** | ***curiosity*** |
| **# 9** | F(2,150) = 17.48<br>**p < 0.0001** | **0.0034** | **0.031** | **< 0.0001** | ***curiosity*** |
| **# 10** | F(2,147) = 12.04<br>**p < 0.0001** | **0.0005** | 0.32 | **0.012** | ***happiness*** |

**Table 1. Results of the Omnibus F-test and pairwise contrast tests for all pairs of factors across all conditions.**

Patterns #7, #8, and #9 produced significantly higher values of curiosity compared to values of happiness and fear. Pattern #7 showed curiosity as highly effective over both fear and happiness with above 99% confidence. In pattern #8, curiosity was more effective than both fear and happiness with above 95% confidence. Ratings for pattern #9 showed curiosity to have higher values than fear with above 95% confidence and happiness with above 99% confidence. None of the patterns produced significant results for fear. Table 1 includes more detailed results from our statistical analysis.

In addition to these quantitative results, we obtained qualitative results from participants' free-form entries (Table 2). Combining the quantitative data with a qualitative analysis of these responses reveals a correlation between the style of the motion pattern and the emotions participants associated with these patterns.

In motion patterns where happiness was the effective factor (motion patterns # 1, #2, and #10), the dominant motion cue is a type of harmonic movement. Even participants who rated these patterns as "other" described the emotions represented by this kind of motion with the words "surprise, hula hooping, enthusiasm, exuberance, square dance, excitement, rhythm, joy, excited." These terms largely describe the rhythmic and motivating quality of harmonic motion. Participants also associated harmonic movements with "nervousness, agitation, tentativeness, anxiety" emphasizing not necessarily the "happy" but the fast and repetitive nature of these motion patterns.

In motion patterns where curiosity was the significant factor (motion patterns #7, #8, and #9), the dominant motion was random, individual, and self-directed behavior. Participants who rated these motions as "other" described the emotions represented by this kind of motion with the words "confusion, uneasiness, sickness, trepidation, spontaneity, optimism, creativeness, ambiguous, uncertainty, playfulness, hesitance, restlessness." These terms largely describe the randomness and unpredictability in these motion patterns.

With any subjective interpretations, there is high variability in the descriptions of dynamic visual information given by individuals. Bassili [2] argued that high variability in the perception of motion cues might be a result of observers perceiving different aspects of motion as more or less salient. For example, a harmonic motion might be described as rhythmic by some and repetitive by others.

One interesting result of our qualitative analysis is that some of the entries consisted of descriptions of social constructions of situations and emotions, such as "joining community, rejection, crowd gathering, happy to see you, good morning." This finding is supportive of some of the background research that we mentioned earlier [10, 18, 31]. Other descriptions were anthropomorphic, zoomorphic, or descriptive of natural phenomena, using words and expressions such as "eye opening and closing, good morning, water droplets, thinking, confidence, hand signals, shifting atomic structure, hula hooping, tick tock time, it's breathing." These entries appear to support the research showing that people attribute personality traits to simple moving geometric figures [10].

| Motion pattern | Participant entries |
|---|---|
| **# 1** | **Surprise**, danger, **hula hooping**, **enthusiasm**, **exuberance**, patience, *boredom* |
| **# 2** | *Nervous*, *frenetic*, *impatience*, **square dance**, **agitation**, *nervousness*, *tentativeness*, **excitement**, equilibrium, **agitation**, *anxiety*, *distracted*, *nervous*, **rhythm**, *anxiety* |
| **# 3** | Gravity, content at rest, contentment, tension, anger, excitement, eye opening and closing, pensiveness, look like they are…, contentedness, calm, good morning, patience, surprise, peacefulness, bored, excitement, at rest, contentment, calming, its breathing |
| **# 4** | Rejection, surprising, playfulness, anger, excitement, intrigue, water droplets, thoughtfulness, surprise, thinking, surprise, surprise, surprise, not an emotion |
| **# 5** | Boredom, rejection, ease, desire, concern, apathy, lethargy, braveness, pulling sheets across, melancholy, sleepiness, happy to see you, frustration, recklessness, broken, confusion, aroused |
| **# 6** | Anticipation, order, catchers mitt…, confidence, joining community, extreme excitement or…, withdrawal, playful, enthusiasm, surprise, anger or excitement |
| **# 7** | **Uneasiness**, **confusion**, confusion, **sickness**, confusion, **trepidation**, boredom, hand signals, **spontaneity**, confusion, hesitating, sadness, confused, some normal function |
| **# 8** | Nothing, calm, focus, stability, courage, decision pending, shifting atomic structure, **optimism**, **creativeness**, **ambiguous**, snoring, **uncertainty**, at rest, indecisiveness, **thoughtfulness** |
| **# 9** | **Playfulness**, **playful**, anxiety, boredom, relaxation, impatience, anxiety, **hesitance**, crowd gathering, **shyness**, **confusion** or thinking, excitement, **restlessness**, nervous, ignorance, anxiety |
| **# 10** | *Frustration*, confusion, *nervousness*, anticipation, **excited**, tick tock time, **excitement**, *anger*, wonder, **joy**, *regularity*, *warning*, *boredom*, **rhythm**, *chaotic*, anticipation |

**Table 2. Free-form entries describing the state of interface.**

### Implementation of the interface

A public space, the entrance to our university department, was the context for our installation. Both occasional visitors and regular inhabitants passed through this space. The space served as a waiting area for visitors, a small social area for office workers, a place for ad-hoc meetings, and a route to the coffee machine, cafeteria, and bathrooms for people whose offices were located in the that wing of the building.

The motion patterns that we evaluated were used to create responses to the changes in the social environment. We defined two internal emotional states for the social interface: happiness and curiosity. These states corresponded to two states of the social environment, inferred by sensing environmental activity levels and determining state via comparison to a set of thresholds: highly social and inconsistent. The interface simply responded with a set of happy expressions when the activity levels showed high social activity and curious expressions when the activity patterns were inconsistent. It did not respond when social activity was low. We used a stereo microphone to detect the sound levels and a camera to detect the motion level in the environment. Motion capture was done using a simple optical flow algorithm. More movement meant higher levels of motion.

Data from both sensors were calculated as a running average. Running averages were mostly used to show trends and flatten our fluctuations in data over a period of time. Figure 8 shows the trends for motion and sound levels in a usual weekday. Our time period was a 2-minute window. This average was compared to the pre-selected thresholds to determine the emotion to be expressed. Depending on the emotion, the interface randomly selected one of the six motion patterns that represented this emotion to express for five seconds.

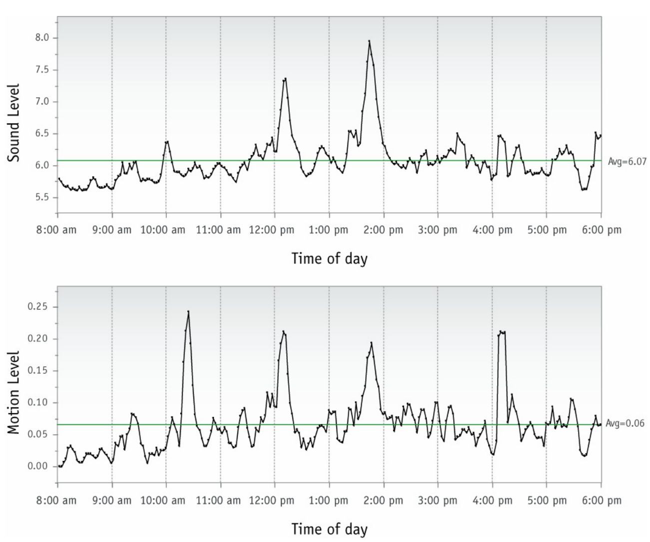


**Figure 8. Patterns of sound and motion levels for April 10th, 2005 shown as running average in a 2-minute window.**

The graphical portion of our interface was built as a realistic, context-free three-dimensional rendering, using Rhinoceros 3D and 3D Studio Max software packages. Dynamic motion was programmed using Actionscript in the Flash environment. Java was used to process and interpret the sensor data to infer the state of the social environment.

Installation of the system included (1) a ceiling-mounted projector that projected the visual content on the wall in the hallway; (2) a stereo microphone and a camera for sensory input; and (3) a networked laptop computer for data collection and state determination. Because the interface was installed in a university office space, a timer started the projector at 8:00 a.m. and shut it down at 6:00 p.m. on weekdays, although the data collection and computation ran continuously. The projection was approximately 3 feet in diameter. Its lowest point was 5 feet above the floor – slightly higher than average eye-level. Next to our installation, we provided a description of the project including disclaimers regarding recording personal information. The project description included a few sentences of high-level information about the motivation for the project and the technology used. We also included a simplified explanation of the two emotions expressed by the interface and how these emotions were triggered.

We went through several phases of prototyping for our implementation. We first installed the interface in our lab to test the technology. The next prototype was installed in the university foyer. We also made minor improvements as we received feedback from users.

## EVALUATION

We installed the social interface for approximately six weeks, running it from Monday through Friday only. The level of activity in the environment was continuously recorded to see the overall patterns of social activity throughout the day. The interface was used by hundreds of first-time users (mostly anonymous visitors) and about 25 long-term users (mostly administrative staff and faculty), whose offices are in the wing of the building near where the interface was installed. First-time users interacted with the system for a few minutes and the interaction was usually not repeated. Long-term users interacted with the interface throughout the 6-week period of the study with frequencies that varied from a few times a day to every few days. The interaction also varied in the levels of involvement from a passing glance at the interface to spending time in front of the interface: looking at it, talking, clapping, and yelling.

Our evaluation of the interface focused only on long-term users because we were interested in understanding how social interaction between the interface and its users took place over time. We conducted structured interviews with eight users, who had interacted with the interface for six weeks. Participants were asked questions regarding:

- The form of their interaction with the interface (i.e. frequency, individual vs. as a group)
- The way that other people interacted with the interface
- The purpose of the interface
- The appearance and behavioral characteristics of the interface
- Their associations about the interface
- The contribution of the interface to their affective state
- If and how their perception of the interface changed over time
- If and how the interface changed other people's social behavior

We also encouraged participants to comment on anything they observed or experienced that was interesting to them.

## RESULTS

Two main findings emerged from the qualitative evaluations of the installation. First, the installation changed the behavior of the inhabitants of the space, by fostering more social interaction. Second, people made sense of the interface both individually and in groups, collaboratively constructing a social meaning for the interface.

### Increase in social interaction

The installation changed the behavior of the inhabitants of the space by fostering more social interaction. Most interviewees reported that the presence of the installation significantly changed their social behavior and the frequency of face-to-face encounters in front of the interface. I4 (Interviewee 4) repeatedly saw groups talking about the interface to figure out its purpose. I6 described the social situation as inviting when others were interacting with the interface. I5 saw a direct connection between the presence of the interface and more frequent gatherings in the hallway. I7 would join in hallway conversations about the interface. I8 observed others having conversations about the interface:

I4: "…people observing, talking about it, try to figure out its purpose."

I6: "…showing it [the information] in an abstract way, it creates this engaging factor for group interaction."

I8: "It gives people something to talk about…"

### Individual and group sensemaking and social meaning

People interacted with the social interface individually and in groups to make sense of its purpose and underlying technology. This process began with discovering a causal relationship between people's actions and the system's response. For example, I5 originally thought that the interface was decorative, but realized in time that it was responding to human behavior, and that different patterns were displayed at different times. Others identified different responses based on differences in their actions.

I5: "…initially I thought it was decorative… [Now] I am aware that there are patterns that move, that don't move, or ones that are symmetrical or asymmetrical…"

I1: "I notice is when people come in and out; the balls extend in and out. Some balls, they go out, some don't. I sometimes see more people doing different things there. That probably causes different patterns."

I3: "There was a difference when I had a cart with me the other day as opposed to just walking by. It was moving more."

People interacted with the interface in a variety of ways: moving their bodies, making noises such as coughing, clapping, and stepping on the floor, and most commonly, talking to the interface. I7 saw others talking to the interface, but described herself to be too shy to talk to it. I2 said different words to the interface to see how it responded to particular words. I5 explored different responses by changing intonations and whistling. I2 also reported a colleague repeatedly talking to the interface:

I1: "Yes, I've seen someone talk to it. She approached to it and said "Sexy Hair," a number of times…I don't know why she does that…I'd like to know why…"

The majority of interviewees described the interface as engaging, and described its positive effect on their mood. I3 described the interface to be "amusing" and "entertaining." I6 said "…it moves to asymmetry in an engaging way."

I2 described the interface as a "happy" interface, emphasizing its calming effect. The interface made I4 more "alert" when she passed by it. I5 said the interface made her feel welcomed and happy. She mentioned that there was something positive about the interface even though she couldn't describe what it was. She associated it with a smiley face:

I5: "It's like a smiley face. You can't look at a smiley face and feel grumpy about it. It sort of shapes your mood in a positive way."

I2: "I think it's a happy robot. I don't find it annoying. It's kind of calming to me."

I4: "It makes me more alert when I walk in that area."

I5: "Makes me feel welcomed, happy…something positive about it. She turns on…it's nice to be responded to…"

Over time, the individual meanings were shared, and a collaborative social meaning was constructed by the hallway inhabitants. The system was named "Mathilda" by those with offices in the corridor. Subsequently, many referred to the interface using the female gendered name. Others missed the presence of the installation on the days it was not running:

I2: "I've grown to like it even more. A couple of times, I missed it when it wasn't there."

## DISCUSSION

In this paper, we explored the use of simple, abstract attributes and motion in the design of social interfaces. Our approach is inspired by research in perceptual causality, which suggests that simple motion displays can evoke high-level social and emotional content. For our exploration, we iteratively designed and implemented a social interface in a public space. This study will hopefully lead to further studies and help establish methodology for the design of social interfaces. The qualitative and context-dependent nature of this study precludes generalization for other contexts, in particular those built for short-term use such as an airport transit lounge. However, we would like to speculate on the implications for design indicated by our results.

#### Design implications

Users of our social interface reported more ongoing social interaction in the foyer during the installation of the interface. Their reports reflected both first-hand experiences and their observations of others. The presence of the interface changed both the nature of the interactions in the hallway and the frequency of face-to-face encounters in front of the interface. We surmise that this was a result of the social nature of the sense-making process. When people's mental models of a phenomenon are incomplete, they seek information about how others make sense of the phenomenon in order to enrich their own mental models. This result reaffirms the social nature of the sense-making process. This quality of the sense-making process can be utilized by designers to facilitate social interaction through interactive products and systems.

Our qualitative evaluations showed that people interacted with our interface both individually and in groups in order to make sense of the purpose and technology within the system. This process mostly began with discovering how people's actions related to the responses that they received from the interface. Although most long-term users admitted to interacting less with the interface over time, all users voluntarily continued to interact with the interface until the end of the 6-week study. Most users reported that their perceptions of the interface were shaped over time, as they continued exploring the capabilities and the underlying purpose of the interface. These results highlight the key role that sense-making plays in how people build relationships with products. Therefore, designers of socially interactive systems should consider the sense-making process as a part of a user's experience, as well as a facilitator for shared social experiences among groups of people.

Users also made social attributions to the interface, by giving it a female-gendered name. These findings suggest that interfaces like our abstract social interface can evoke social responses even when they do not employ explicit social cues. This finding is in keeping with previous research by Nass and his associates, and extends their findings to interfaces beyond desktop computers. Abstraction, along with motion, can be used by designers to create social interfaces that evoke social responses when using explicit social references is inappropriate.

Even though most users referred to the interface using the word "art," the results of our evaluation imply that the interface was perceived as a social character as well. We argue that this effect is due to the systematic use of abstract elements to evoke social responses as well as the long-term use.

#### Limitations

Our study has some limitations due to its exploratory and qualitative nature. One factor that might have influenced our results is the novelty of our interface in the context of use. Further exploration is required to understand long-term effects of the interface — whether it will remain interesting to the residents of the hallway over a period of months or years.

We did not have a base condition that would allow a systematic comparison. Therefore, we cannot determine whether the presence of our interface or merely the presence of an interactive artifact caused the social interaction in the foyer.

We provided users with a project description, which might have affected their sense-making processes. A couple of interviewees described their perceptions to be different before and after they read the description, while some did not read it or ignored the description. Our evaluation could have controlled for this effect.

Another limitation to our design is that our inference algorithm – evaluating a running average using a threshold function – was relatively simple and represented only short-term changes in the social environment. A more sophisticated machine learning algorithm might be more effective in representing both short and long-term changes, and might create an interface with greater appeal over time.

Finally, the kind and complexity of the social information represented by the interface may significantly change people's experiences with the interface. For instance, social activity information about a remote environment might cause people to explore more or less, and build different mental models of the interface.

#### Future Work

This study is an early exploration of a novel approach to designing social interfaces. The contribution is the use of abstract, dynamic visual cues in designing social interfaces that can communicate high-level social and emotional content. Our results have provided initial findings and early guidelines about the validity of this approach. Further exploration is needed in order to draw out more detailed principles and guidelines for design practice. We will continue to explore how other dimensions of abstraction might be used to successfully design social interfaces.

Our design was focused on an animation style that could be implemented in physical hardware. We would like to implement a physical version of the interface and explore how physical embodiment affects perceptions of and interactions with the interface.

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