Touch: Communication of Emotion Through Computational Textile Expression

Felecia Davis(✉)

School of Architecture and Landscape Architecture,
Stuckeman Center for Design Computing, Pennsylvania State University,
University Park, PA 16802, USA
fadav@psu.edu

Abstract. Touch of a computational textile on human skin provides a unique opportunity to look at relationships between ambience, emotion and computing. The sense of touch on human skin offers a potential framework to think about ambient computing as the information from skin is multimodal and comes in many forms such as temperature, humidity, sharpness, smoothness, location and movement. Computational materials that shelter, surround and are inside us have become sentient and are able to 'speak' to us. It is common that these things not only speak to us but *also to each other* through what is called the internet of things. This is a physical world web or quite simply a network of physical things. Materials that can connect to this network this author will call computational materials, which are materials that respond to commands and communicate through computer programming, electronics and sensors. A *computational textile* is a textile that responds to commands through computer programming, electronics and sensors. If architects, artists, designers, engineers and scientists and others could begin to understand the nature of what various textile expressions communicated via touch, then it would be possible to more fully understand the role texture of a computational textile plays in communicating emotion through an object. The author of this paper will present and discuss one project, FELT a $5' \times 6'$ wall panel designed to communicate emotion through touch.

Keywords: Computational textiles · e-Textiles · Emotion · Design · Touch
Somaesthetics

1 Introduction: Ambience, Emotion and Computing

The author of this paper presents a project titled FELT, a large $5' \times 6'$ wall panel designed to study emotions communicated through touch (Fig. 1). The results of the study did show that touch does communicate emotions in several ways. These ways are briefly presented in this paper. However, of more interest here is how touch as a multimodal sense can become a framework for thinking about ambient environments. The senses of touch can offer a strong framework for thinking about ways that engage emotions to augment a person's ambient computing experience. Such a framework becomes very useful when thinking about computational materials that can *speak to each other* and to people through a network of physical things. A computational textile is a textile that can

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communicate to people through sensors, electronics and programmed for specific behaviors through microcontrollers. A computational textile may also be a textile that can communicate to people through natural behaviors of that material. Such an example would be using the shrinking and compacting of wool fibers by water when wet to communicate something to people. Communication to people is dependent upon the transformation from one state to another state in a computational textile and the state change sensed or perceived by people. If architects, artists, designers, engineers and scientists and others could begin to understand the nature of what various textile expressions communicated via touch, then it would be possible to more fully understand the role texture of a computational textile plays in communicating emotion through an object.

One might ask why should one care to communicate emotion through an object? A textile which changes its shape could be used on a robot as robot skin for example for people who may live alone and benefit from some communication through touch. A computational textile may be used on a wall, a pillow, curtain, furnishings, toys and many other designed objects to communicate to people and children who do not have access to their emotions. These may be people such as children with autism, or adults with Alzheimer's disease. These textiles may be used to connect with someone not in touch with what they are feeling, unable to communicate what they are feeling or elicit communication from people who otherwise would not have been able to. A textile can be used as a form of non-verbal communication with people through vision and touch.

A good example of showing the difference a textile can make is shown in the studies done by the psychologist Harry Harlow with baby rhesus macaque monkeys at the University of Wisconsin. Harlow performed experiments offering baby rhesus monkeys a choice between a 'wire mother' monkey with a feeder bottle and a 'cloth mother' substitute. He showed that indeed there is something critical in the affordances of flexible, pliable cloth to the survival of baby monkeys and of baby humans [1] (Fig. 2). Even though the 'wire mother' had the food, the baby rhesus monkeys always preferred to be with the 'cloth mother'. Furthermore, Harlow demonstrated that cuddling with, grasping and nesting with the cloth was crucial to social bonding and thus survival of the baby monkey. In addition he showed that this substitute 'cloth mother' had to transform, move, or rock. The cloth had to be active. The ability to connect with place and with others was dependent upon both the affordances of cloth and transformation of or activity of that cloth. The transformation of the cloth changed the environment that in turn changed the baby monkey's relationship to that environment [1]. In Harlow's and his student's work these small changes were understood as necessary to creating flexible, problem solving brains that made it possible for baby monkeys to adapt to a constantly changing environment. This active adaption was necessary for the monkey's survival, and its courage for learning and curiosity. By looking at cuddling, nesting, grasping, Harry Harlow had carefully opened the fundamental topic of emotion or love in his scientific community [2].

Fig. 1. FELT textile panels in daylighting.

Touch is fundamental aspect for survival and its use in communicating with people is basic. The question that this framework addresses is how can one use the qualities of touch as a way to communicate with people?

Fig. 2. The nature of love, a baby rhesus macaque monkey on the cloth mother. Harlow [1]

2 The Qualities of Touch as a Framework

Aristotle in his book *De Anima* Sect. 422b lands upon a quality of touch that is confounding and separates it as a sense from the other senses of vision, hearing, taste, and smell. [3, 4] Each of the other senses has a sensory organ that permits it to receive sensations that can only be perceived by that organ. There is a one to one correspondence linking eyes to vision, ears to hearing, nose to smell and tongue to taste. Yet touch has several perceptible objects [3]. Aristotle locates this confounding sense partially in the flesh and then argues that flesh is the medium of touch not the organ [3, 4]. Aristotle writes "If touch were to emerge from a sensory organ it would be a body part related to us as the air around us would be if it were to be naturally affixed to us" [3].

When discussing touch, James Gibson, a psychologist, argues that there is no separation between the body and the environment. In Gibson's account, therefore, energy flows into bodies from the environment and energy flows out from our bodies into the environment such that it is impossible to understand the body without considering the environment [5]. His coupling the body with environment is similar to two definitions of ambience described as 'circumfused' or 'environing' [6]. The haptic system unlike

any other perceptual system encompasses most of the body and literally puts us in touch with our world; it "lets us grab a hold of things" [5]. The equipment we use to explore, feel, and alter our environment is the same equipment we use to feel and produce emotional experiences [5]. Mark Johnson a philosopher writing about bodies and emotions argues that our bodies are inter-connected to the environment or woven with the environment. Johnson writes, "Emotions are both *in us* and *in the world* at the same time […] they are one of the most pervasive ways we are continually in touch with our environment" [7].

A specific quality of our haptic system is that unlike the visual system, it enables people to explore and alter our environment. Further, this ability means that people can also change what they perceive using their haptic system, which again is not possible with their visual system. Gibson gives a good example of this: "when we reach out to feel the edge of a table, we feel the edge, but simultaneously the table makes a dent in us." He argues that there are poles of experience that place the concepts of subject and object in a continuum. If you wish, you "can focus on the dent made in your hand or you can focus on the edge of the table" [5]. The choice Gibson mentions here outlines the difference between cutaneous perceptions that are felt on the skin or passive touch versus kinesthetic produced by actively touching a thing. The human haptic system uses both passive and active inputs that permit people to select between experiences of subject and object [8, 9].

2.1 Passive Touch

Passive touches are sensations arising from inputs that come from thermos-receptors and mechanoreceptors embedded in the skin [9]. To sense a thing with touch is to detect something, to detect the state of change [5]. In the case of a passive touch the change can be of temperature, or of a location on the skin or, texture or shape and other qualities such as wet or dry. Passive touch tends to make people focus on their own bodies and experiences related to their bodies and makes for an inward reflection in an environment [8, 9].

2.2 Active Touch

Active touch is exploratory not simply receptive and its sensations are input by actively moving limbs, fingers and body parts. Active touch is kinesthetic arising from inputs to mechanoreceptors in tendons, muscles and joints [9]. A person using active touching makes for an outward focus in an environment, and can change that environment with that touch [5].

2.3 Touch as a Medium

Looking to Aristotle, Mark Patterson writes that touch is a mediated experience; it is mediated through our skin. To discuss touch as a mediated experience goes against the grain of sensory studies that emphasize the immediacy of experience [4]. He writes that "the mediated aspect of touch is undeniably present, as Aristotle pointed out, but we do not notice this and it is usually transparent to consciousness. [4] Whenever we deal with

tactile phenomena we are not conscious of the particular referents of certain receptors in particular positions, of course. We touch something which happens to be in a particular position, at a particular temperature, and which has certain textural qualities. It is the totality of the experience that can be characterized and described as 'touch,' despite being the synthesis of a variety of different receptors distributed around the fleshy body, each providing a range of information concerning temperature, pressure, pain, and texture, always already mediated through the organ that contains these receptors, the skin" [4].

2.4 Technology as an Extension to Remediate Touch

The issue that stands out in Patterson's concept is that people do not notice the mediated aspect of touch because it is transparent to consciousness. Patterson argues for remediating touch by making it appear in people's consciousness. He suggests technology helps remediate touch because it can extend touch and make people notice it for example using a pair of touch sensitive gloves or a tactile vibrating suit that can make you feel one environment while existing in another. It is the act of making touch re-mediated or noticed that can perhaps be of help to those who may not be in touch with their feelings, other people's feelings or their environment such as Alzheimer's patients, autistic people or those people so stressed out they are not noticing how they are in an environment.

2.5 Relating Expression, Communication, and Emotion

Designers and artists have always engaged the problem of creating expressions that expand beyond their own experiences into something that can be shared. They have always worked to find ways to place users of their designs in a world that is relational. Expressions can communicate and are methods to connect and live with others, across boundaries. In this section, the author will discuss the relationship between expression, communication and emotion. The author will discuss the ways in which expression in a body, human or animal does or *does not* communicate. If designers, scientists, and others understand that communication through the body is perceived through the expressions formed by the body in its habitat, then it is possible to understand how the body communicates via emotion.

If you look up the word expression in the Oxford English Dictionary, you will find two meanings ascribed to it. The second meaning has most relevance for this chapter. This meaning of expression designates it as a "representation" or "manifestation," for example, "the action of expressing or representing (a meaning, thought, state of things) in words or symbols; the utterance (of feelings, intentions, etc.)" [6]. A critical word in this meaning or definition is that of intention. The word intention will be returned to later in this section. When the term "expression" is used in this paper, no ontological claims are made. The word considered here is closer to the term "expressive power" as defined in computer science. "Expressive power" means the "measure of ideas expressible in any particular language" [10]. The language examined in this chapter is shape changing textile textures rather than symbols.

Communication has three primary senses in the Oxford English Dictionary [6]. The first of these senses is related to affinity or having something in common; the second is related to imparting or transmitting something: "The action of communicating something (as heat, feel-ing, motion, etc.), or of giving something to be shared." The last sense is that of having access, access between two people or places, having a shared physical link. Before discussing the methods and results of the experiments with FELT, it is important to understand the relationship between expression, communication, and emotion.

In *The Expression of the Emotions in Man and Animals*, Darwin starts to look at the issue of expression in the bodies of humans and animals [11]. In this follow-up to *The Origin of the Species*, he describes hundreds of human and animal body expressions in minute detail and maps them to different emotions and functions [11]. Yet Darwin made no comment on the causal connection between expression and emotion.

Darwin never investigated whether a person could experience an emotion without a corresponding bodily expression or whether bodily responses were a necessary condition for an emotional experience [11]. Neither did Darwin make a connection between expression and communication.

In Darwin's account, many expressions of emotion such as the hair rising on the back of a person's neck when afraid are leftover responses related to an evolutionary function designed to maximize chances of survival in some prehistoric time. Summarizing from an extensive report on the expressive behavior of two classes of vertebrates, Darwin was trying to understand the function of emotional expression in the context of evolution. Expression in this sense is *about changing the body in relation to the environment.*

According to the psychologist Nico Frijda, the expressions that Darwin discusses are not intentional and have very low communicative value other than in the broadest sense of communication because those expressions are not intentional. In such cases, Darwin describes the fearful communication discussed above as a type of communication that is a by-product of witnessing a message that was not intentionally sent although others received it [12]. The message was inferred by an observer based on the subject's body response in context.

Frijda argues that there are actually two senses of communication. A more restrictive sense refers to behavior produced in order to be perceived by another animal, and "in order to influence the latter's behavior" [12]. This more restrictive sense is understood as true communication. Frijda proposes that to understand emotional expressions is to sense the impact of those expressions on the observer.

Of import in Darwin and Frijda's writings on expression and communication respectively is that these expressions and communication are observed not touched. Yet simply visually witnessing some person or creature's terrified body expressions can call forth feelings of terror and fear in another. Things seen can turn into things felt and we could in some sense be said to be touched. We are acted upon.

The neuroscientist Antonio Damasio would explain this phenomena with what he calls empathetic mirror neurons or what he terms an "as-if-body-loop" experience, in which we can to some extent put ourselves in someone else's shoes [13]. Mirror neurons permit people and animals to simulate body states that happen as a result of certain

stimuli as if they have actually experienced the same stimuli. For example, on hearing a story about a bike accident in which the rider has hurt his knee badly, the listener might actually feel a twinge of pain in his/her knee. Damasio explains that direct stimulation of body-sensing regions of the brain can induce the same signals going to the body as if those pain sensations were coming from the body itself. In such instances, "the brain rapidly creates a set of body maps that does not correspond exactly to the current reality of the body" [13].

For Arnheim, a German perceptual psychologist, the meanings of aesthetic expression can also be understood through the expressions of the body. In dance, a dancer expresses happiness and joy by moving his/her body upward and an audience can recognize this as happiness. Similarly in dance, if a dancer wishes to communicate sadness to an audience, his/her body droops downward [14]. People's ability to make inferences through these intentional clues is described as a process whereby people draw on their understanding of the relation-ship between patterns of bodily sensations and the emotions they produce [14].

This message is the kind of intentional, influential communication that artists and designers often want to achieve with their designs and is of interest in the FELT study.

3 The Study FELT

3.1 The Design of the FELT Panel Texture

FELT is a large (150 cm × 180 cm) modular panel seen in Fig. 1. FELT was an opportunity to explore how changing the scale of a textile could change emotions communicated to people from the textile expression through vision and touch.

The design of the FELT textile was inspired from animal reactions some of which Darwin mentions. Examples of these reactions are seen in the top row of photos in Fig. 3. It was expected that movement of each animal's skin, fur or feathers would communicate or permit a person to infer a different emotion(s) using their vision alone and using vision and touch together.

Texture 3, circled in a dashed rectangle in Fig. 3 is the base texture for the FELT panel. This texture showed high variance i.e. people reacted strongly to it either very positively or very negatively and for this primary reason it was selected as the texture for the FELT panel.

Four key steps were followed in order to make FELT. The first was making the fabric, the second was designing the framework to hold the textile, the third was connecting the electric motors to the frame and textile, and the last was mounting the frames with textiles onto a rack, which allowed it to be used as a screen or a divider in space (Fig. 4).

The textile texture for FELT consisted of two sheets of white laser cut felt that were sewn together to create a 22″ × 35″ (56 cm × 89 cm) panel, thereby replicating Texture 3 at a larger scale. The felt used was a wool and polyester blend. The final size of the sheets of felt was determined by the maximum that could be cut on the laser cutting bed.

For this project, two methods of actuation were considered, Nitinol and servo motors. Nitinol was preferred because it does not make any noise when activated. However, the author did not use Nitinol two reasons: Nitinol becomes too hot to touch such that wires

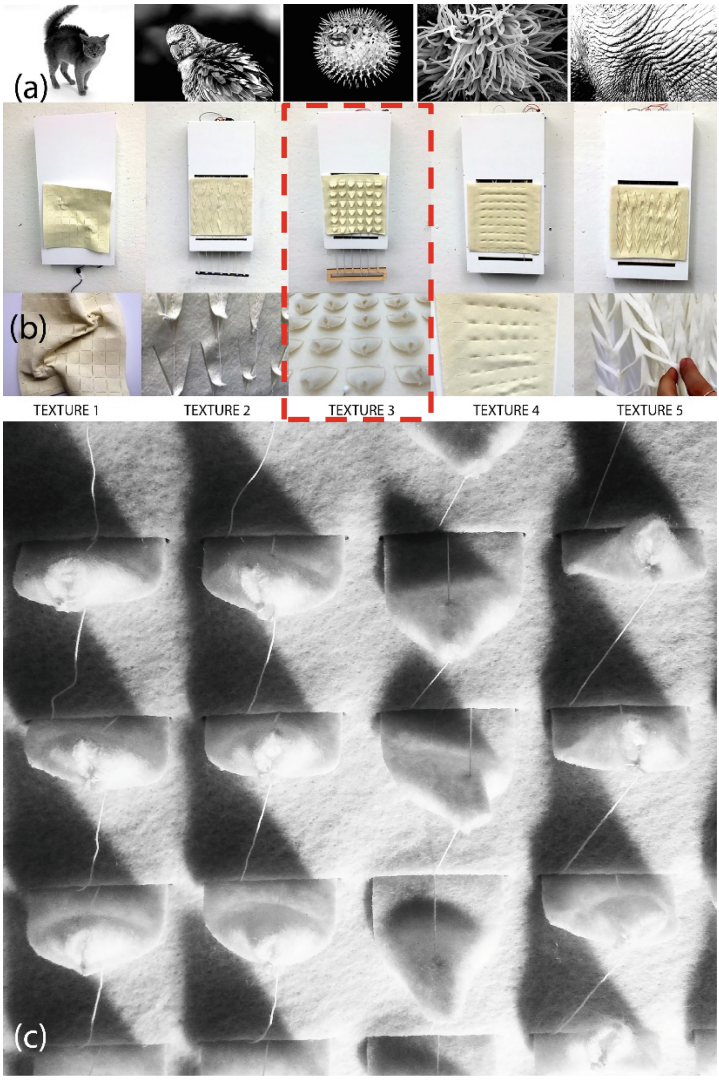

Fig. 3. (a) Animal reaction models used to design textile and textile motions (top); (b) Felt textile textures on motorized boxes (middle); and a detailed view of the felt textile textures (c) Close up of Texture 3 used for FELT panel. The texture for FELT used monofilament of nylon to lift 'petals'.

made from it must be covered. In addition, Nitinol requires a lot of power. Further by using servo motors, a simpler power system running with lower current could be used.

Figure 4a shows an exploded axonometric drawing showing the various layers of the FELT panels in the Plexiglas box. Figure 4b shows an axonometric of one of the Plexiglas boxes mounted on the supporting rack.

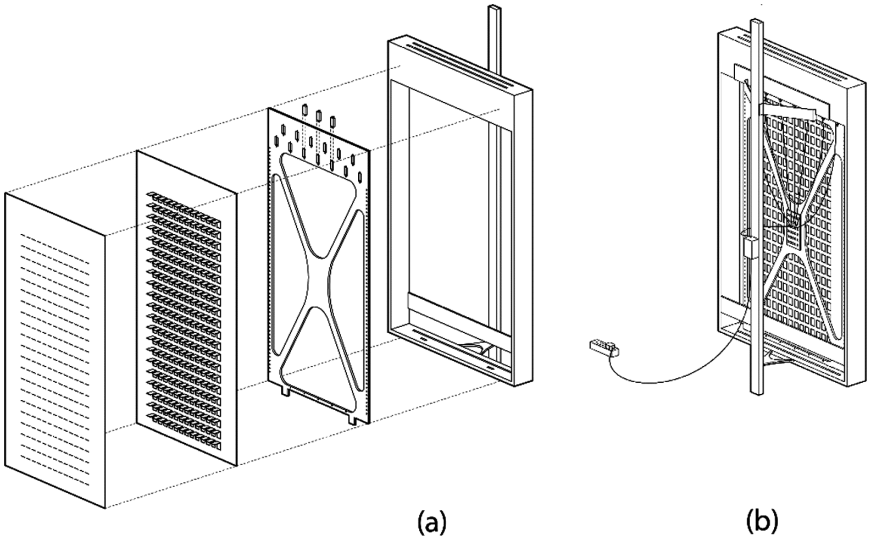

Fig. 4. (a) Exploded axonometric of FELT Plexiglas frame, aluminum frame and textile sheets 1 and 2 of the felt textile panel. (b) Axonometric showing one Plexiglas box mounted on the supporting rack.

3.2 The FELT Study

The purpose of the FELT Study was to obtain feedback from participants regarding emotions communicated to them from the wall panel or large screen through *vision* alone in a still state and in a moving state [15]. The study was also designed to obtain feedback about emotions communicated to participants from the wall panel in a still state and in a moving state using both vision and touch together. As something that participants were asked to touch it engaged active touch. In addition, the purpose of this study was to understand if received from a large scale texture. The FELT panel is designed to have people focus their thoughts outward to the environment and engages primarily active touch rather than passive touch. Although, as Gibson mentions the state of focus outward and focus inward are polar opposites, they are nevertheless in continuity and can be selected as a matter of attention.

The FELT Study took place at the Pennsylvania State University, Stuckeman Center for Design Computing at the School of Architecture and Landscape Architecture in August 2016. There were 17 participants, 13 of whom were women and 4 were men. The age range was 20–65 with the men's average age at 36 and women's average age at 35. Each session took half an hour to complete four rounds of questions. The participants interacted with the FELT panel one on one with me in the room.

An outline of the study format is as follows:

1. FELT Panel is Still
   a. Looking (**ROUND 1**)
   b. Looking and Touching (**ROUND 2**)

2. FELT Panel is Moving
   a. Looking (**ROUND 3**)
   b. Looking and Touching (**ROUND 4**)

Hypotheses for the Study
Table 1 below describes the hypotheses used for each round of the FELT Study.

Table 1. Hypotheses used for the FELT study.

Hypothesis number	Hypothesis description
Scale & context hypothesis	It was expected that participant responses would change if the textile was designed as a large architectural panel or space divider rather than small textile sample
Hypothesis 1 Round 1	It was expected that using vision alone, people would consistently associate specific emotional states with specific characteristics of the textures of textiles in a state of stillness. Crisp, curvilinear shapes associated with positive, excited, and happy feelings; smooth curvilinear shapes associated with positive and calm feelings; triangulated shapes associated with negative and angry feelings; smooth triangulated shapes and superimposed systems or a poorly defined combination associated with negative, depressed, and calm feelings
Hypothesis 2 Round 2	It was expected that when people use vision and the haptic senses together the emotional associations would change. It was expected that when people could see and touch a still texture, a negative emotional association using vision alone would change when using both vision and the haptic senses to a positive emotional association
Hypothesis 3 Round 3	It was expected that when the textures were in a state of motion that this characteristic would raise or lower the participants' rating of what was communicated on a Circumplex grid based on what was associated with that texture motion
Hypothesis 4 Round 4	It was expected that the act of touching the moving textures would again change the ratings and what the textiles communicated

3.3 Study Methods

There were four rounds in the study, each of which comprised four questions. The participants had the opportunity to see the FELT wall panel by standing or sitting in front of it. The participants were asked to free associate for the first question.

1. For the free association the author proposed three kinds of questions to encourage the participants to respond. For example, "What are some words that describe some of the emotions that you could attribute to this textile?" "What are some adjectives that you could use to describe the mood of this textile?" The author told the participants that the free association should focus on what the textile communicated to them in terms of emotional attributes. The participants were also told that it was fine to talk about things that the textile reminded them of and to talk about any particular

associations or memories that they attached to the textile. Their responses to this question were recorded in my notes.

After this first question, the participants answered the next 3 questions presented on stapled 8.5 ×11″ (A4) sheets of paper. These are as follows:

2. What does the texture communicate to you?
   (Negative Mood) 1 2 3 4 5 (Positive Mood)
   The participants were asked to circle a number between 1 and 5.
3. (Relaxed) 1 2 3 4 5 (Stimulated)
   The participants were asked to circle a number between 1 and 5.
   Lastly, the participants were given a sheet of faces that projected emotions and asked to pick a face in order to answer question 4.
4. Face: What mood would you associate with this texture? Happy, Cross, Scared, Sad, OK, Horrible, Worried, Excited.

Then, they circled the words that they thought described one of the faces on the sheet. Figure 5 shows the sheet of face/emotion choices presented to participants. The participants could circle as many of faces/words as they wished and were told they could add emotion words and faces as needed.

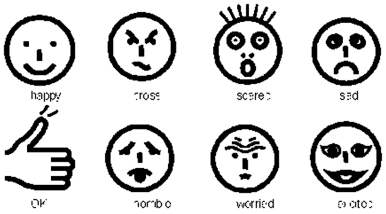

Fig. 5. Face word graphics, The Maketon Charity [16].

3.4 What Emotions Are Communicated by FELT?

In this section the author will discuss the responses to the four questions. The author has used the letter P for participant and identified the different participants by number.

Free Association Question Results. During the free association question there emerged several themes that connected the comments. The author has listed these themes or categories below. While these are categories the author saw as emergent these are surely not the only ones, and indeed many of the comments that could be put into one category would be just as valid in a second category. Here is a list of the most prevalent categories that emerged in all four rounds:

1. Analogy and Memory. This category shows participants connecting to the FELT texture by using their memories of previous experiences and noting similarities to other things.
2. Vitality and Lack of Vitality. Participants described how lively or living the texture was or how lifeless and dead it was in behavior.

3. Aggression or Harm. Participants described their fear of the texture, that it could hurt them or that they could harm the texture.
4. Comparison. Participants compared their experiences with FELT to the previous round.
5. Feels to Skin. Participants described what their skin felt.
6. Color. Participants mentioned or discussed color.
7. Noise. Participants mentioned noise. (In rounds 3 and 4 only).

The Circumplex Model of Affect Results. The most useful analytical tool was James Russell's two dimensional circumplex model of affect. James Russell is a psychologist and professor of psychology at Boston University, who designed a two dimensional model of emotional affect in which people are asked to place words along an x axis where positive is happy on the far right of the axis. Negative is sad on the far left of the x-axis. On the y-axis the highest point is excited or pumped. The lowest point on the y-axis is calm [17]. Figure 6a shows words Russell mapped to a circumplex grid as an example. Note the position of words that express emotion on the grid. Happy excited words like 'astonished' and 'delighted' are in the upper right quadrant. Calm and sad words like 'depressed' and 'gloomy' are in the lower left quadrant. To create the circumplex plot for this study the author took the numbers circled in questions two and three on the survey that provided x coordinates and y coordinates respectively for each participant. The author then averaged the x coordinates, and the y coordinates for each round to make the circumplex plots in Fig. 6b.

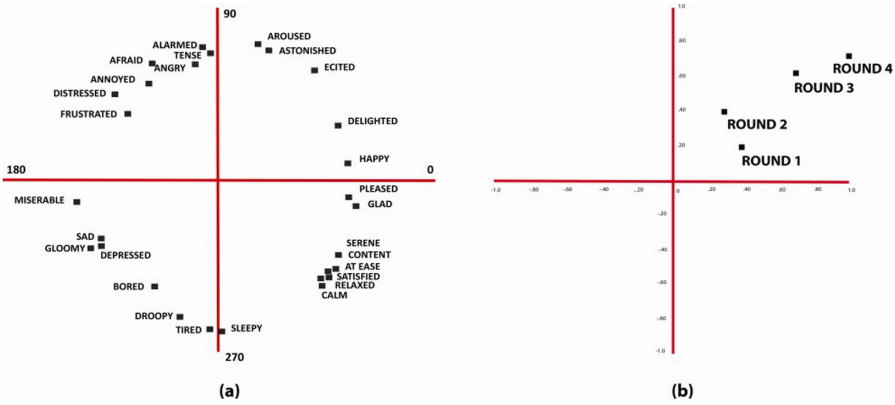

Fig. 6. (a) Circumplex model of emotional affect for words, redrawn from Russell's circumplex [17] (b) Circumplex model of affect for the FELT panel with the averages for all four rounds plotted.

The circumplex model of affect in Fig. 6b show results that are consistent with the free association analysis. Participants were very excited in Round 1. However, when they touched the panels in Round 2 they were disappointed because the soft and pliable visual appearance of the textile panels was not as soft and as pliable to their touch. Participants were further excited when the texture in the panels started to move or show

motility in Round 3. However, in Round 4 when participants were permitted to touch the panels in full motion, most but not all participants reported a happy excited state as the emotion communicated back from the textile.

In terms of standard deviation, the highest negative/positive or x-axis data deviation was in Round 2, when participants could touch the textile texture. For the calm/excited or y-axis the highest deviation was in Round 3 when participants could see the textile panels moving but not touch the panels.

Face Word Results

The face word graphic analysis for all four rounds for FELT is above in Fig. 7. All graphs are at the same scale and are based on word counts from the responses given to question 4. As you can see in Fig. 11 when looking at all the graphs together across all four rounds, "O.K.", "excited" and "happy" are words that stand out consistently. "O.K." starts off as the primary reading in Rounds 1 and 2, but "excited" and "happy" emerge almost equal in count to "O.K." in Round 2, and take over as equal counts in Round 3 with "excited" being the highest counted word in Round 4. This response is understandable as it is the first time the textile motors were turned on. "Excited" in Round 4 never becomes as strong as the "O.K." in Round 1. In addition to "O.K." fading from Round 1 to 4, the emergence of "worried" and "curiosity" and "curious" exist at the beginning in Round 1 and 2 but gradually fade in Round 3 and almost entirely gone in Round 4. This was to be expected as participants became more familiar with the textile panel. In Round 2, "cross" appears as a second level of counts after "O.K." "happy" and "excited". This is the only instance of the word "cross" rising to this secondary level in the four rounds. One speculation on the appearance of the word "cross" is that people were surprised by how rough the points and monofilament plastic strings felt when touched compared to the soft appearance. Fourteen out of seventeen participants indicated surprise, annoyance or some negativity in their free association responses in Round 2.

Fig. 7. Word face word graph for the FELT panel in Rounds 1–4. Word graph generated using Feinberg's Wordle [18] (2015).

In addition to the observations mentioned in the above paragraph there are fewer words generated in Round 4, 14 words compared with Round 1 that has 17 different words. The density of words trails off as you look from left to right in Fig. 7. This decreasing density seen in the word graph is the result of fewer counts for the smaller words in Round 3, and a coalescing of counts for fewer words. Thus the scale of all the words in Rounds 1 and 2 are closer together than the scale of the words appearing in Round 4 for example. In Round 1 and 2 the word graph is made up of a blend of large,

medium and small scale words. In Round 4 there are primarily large-scale words juxtaposed with tiny scale words with no intermediate scaled words.

Ways of Touching FELT. People touched the FELT panel in a multiplicity of ways in Round 2 and Round 4. Below are some salient comments that accompanied the types of touching from these two rounds.

Round 2

[Pinches gingerly] "Touching this, it is resistant to being touched. Does not feel responsive, the texture is annoyed as if it is saying 'I'm just going to go back to what I am doing'; I'm less invited to touch" [P1].

[Brushing flat of hand against and pulling threads after] "Oh my gosh, it is a lot more stiff that I thought it would be to touch. There is fishing line I can pull it up and down. [I] feel exceptions though; the boarders of the finish stitching reminds me of a kids project and I like that the most. Visually it is not surprising. My eyes are not working as much. The fishing line is now felt. I am surprised by the stiffness. I am more curious and have more questions now" [P3].

[Brushing up and down] "It is soft if I move my hand from top to bottom. Bottom up, it is not as soft. It can be soft but may not be depending on position, could be if my hand was moving down, but not if moving up it; the texture toggles; happy with the soft position; cross with the negative and sharp position" [P6].

[Gingerly moving hand, touching points] "If I put my hand like this, they touch different areas. If I move my hands up to down it feels smooth and relaxing. However, bottom to top it feels like scales of a fish and it rough. It is like touching the surface of a live creature, but it is not responding, but it is also soothing. It is like petting a kitten. I am satisfied with petting it, but not satisfied with no responses. It is still sad because it is not responding; it is dead" [P10].

[Leaning whole arm[s] against the panels, stretching out against panels, brushing with hands and pinching] "I think at first it is a kind of soft material, but now there is something that bothers me in between these it is kind of uncomfortable; when I touch I feel some roughness but it is not good for sitting and laying down, I cannot wear it because it is itchy; it is more negative; why? I cannot touch it so much, I cannot communicate with the tips in a comfortable way or a good way; touch reaffirmed how I felt about it, uncomfortable; it is not relaxed as there are small strings in between the ties at the end; I saw angles first but my feeling was overridden by the strings" [P14].

Round 4

[Touching gingerly, and brushing] "I am drawn to parts working as a team, as a system makes it seem more complex, it does not feel like I am supposed to touch it. It is not granting permission to touch it, when I do touch it I feel like I am interrupting it. It is tickling me and it is not relating to what I'm doing" [P1].

[Touching gingerly] "Pulsating makes me think of a heartbeat and breathing; more of a softness to it now; stiff thread is there but it is not as bothersome; inhalation = softness counters roughness of the threads; up and down is reminding me of something; stimulated positive and curious; wondering what was the person thinking who made this and wonder what they wanted?" [P4].

"Alien; foreign in a weird way. Movement gives it life in itself, but when I touch it, it stops; I'm not interacting with it; feel like I can interact with it in a different way than anticipated; O.K. I'm not sure how to interact with it; wanted to feel its tips vs. in between because wanted feel cause and effect; I'm still not comprehending what it is doing; like do we live in the same world?-yes when I felt it pulling between the nubs; vision gives a different expectation than the haptic; haptic changed it trying to connect the change with my touch" [P5].

[Touching using back of hand] + [palm up of hand] There is lots of distraction from vision; If it was my piece I would have cut fishing line; I would have cut it because it is distracting and disturbing because I cannot feel motion under my hand. [Strokes downward] This forces you to become more subtle, the motor speed makes me move my hand more slowly [sense of randomness increases] Round 2 it is uncomfortable, here it is a playful randomness …" [P8].

[Very carefully rubbing palm of hands over all panels, gingerly pinching] "It is weird! It is kind of like touching a living thing but I know it is not; still it is subtle, If I hang out it feels like it is breathing; It is more negative to me [cool never experienced this before] 'it is not supposed to do that'; this is opposite of my initial reaction; I did not know what to expect; the movement seems regular makes me thing of breathing or life like function; on the one hand it is cool on the other hand I associate it with a creepy, crawly thing" [P16].

Discussion of the Hypothesis Results. Hypothesis 1 is based on a belief that all humans are in some way hardwired or can understand certain shapes and textures in a very basic way through emotion. The results with FELT did not prove this true. FELT designed as a triangulated shape did not plot as negative and excited, or as angry. On the contrary it plotted as positive with modest excitement or happy in the circumplex model of affect, and the face word graph. In addition this was supported in the free association question where there were responses that related to body parts like nipples and udders, skins of animals, but no expressions of things that indicated anger or scariness.

Hypothesis 2 is based on the belief that once a person touches something that thing becomes known and thus is rated more positive. In addition, this hypothesis is based on the belief that if something was rated negatively using only vision that a negative visual rating could be overturned and rated positively using touch. This was partly true. Once FELT was touched, it did change its rating however, the change was not always positive. In fact in Round 2 where the positive rating on the circumplex model for the FELT was less. According to the free association question this can be explained by the roughness perceived in the edges of the felt and the monofilament thread used.

Hypothesis 3 was proven true. Indeed, positive/negative and stimulated/calm responses were raised or lowered when the textile changed shape or moved. The FELT study did affirm that when something in an environment changes, human reaction will typically, not always, change as well. The FELT Study did affirm that motion or shape change did increase the excitement rating of the FELT as shown in the experiments done by Akshita et al. [19].

Hypothesis 4 is true. This hypothesis is relevant for studies where participants interacted with live textile textures that could be touched and textiles, which could move.

Yes, the ratings for positive/negative and stimulated/calm changed in every instance in the FELT Study.

The face word graphs supported the information from the Circumplex Model of Affect.

The responses of people to the textile changed over the time of interaction, reflecting the changing information from their sense of sight and sense of touch exchanged with the textile texture. Because the FELT study textile panel was large in size, people used a lot of bodily exploration and thinking through the body came into play.

In closing, there are a few points of generalizable knowledge that we learned from the FELT Study as a stand-alone study:

1. Whether vision alone or both vision and touch are used, emotions communicated to people change during the process of exchange.
2. Emotions communicated through vision from a specific textile differ from those communicated using vision and touch.
3. The process of exchange when using touch with vision is influenced by touch. The change of the type of touch on the texture changes the texture and changes the communication of emotion.
4. Introducing motion or motility to a textile expression increases the stimulation and excitement of the emotion communicated by that textile.
5. Analogy and memory are the primary methods that people use to determine the emotion communicated by a textile.
6. The scale of the textile changed the emotion(s) communicated by the textile.

The primary focus of this study was what emotions can be communicated to people by computational textile expressions through vision and touch, although this study does not prove that any specific live expression is related to any specific emotion. Much of the communication that we take from expression is context-based and is perhaps inference rather than direct communication. There is much more work to be done, however, if designers, engineers and others are to fully understand the relationship between aesthetic expression and communication. In the end, this study shows that emotion communicated by computational objects is woven between that object or space and an individual body.

4 Contributions

The author proposes three aspects of touch as a framework for future research with computational materials. These aspects are passive touch, active touch and re-mediated touch. As Gibson has pointed out, active and passive touch can be understood to offer continuity between two poles of subjective and objective experiences that can be used in the design of computational materials and objects. The shift in attention between these poles of experiences can be used to develop touch as an ambient way of computing and communication.

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