Limits of Expression:
On Touch, Emotion, and Communication

by
Deborah Tsogbe

B.Arch
University of Southern California, 2020

Submitted to the Department of Architecture in Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE IN ARCHITECTURE STUDIES
at the
Massachusetts Institute of Technology
JUNE 2023

Authored by: Deborah Tsogbe
Department of Architecture
May 1, 2023

Certified by: Terry W. Knight
Professor of Design and Computation
Thesis Supervisor

Accepted by: Leslie K. Norford
Chair, Department Committee on Graduate Students
Professor of Building Technology

Thesis Supervisor

Terry W. Knight, PhD
William and Emma Rogers Professor
Professor of Design and Computation
Associate Head for Strategy and Equity, Department of Architecture

and readers

Athina Papadopoulou, PhD
Assistant Professor of Architecture, Health, and Design, New York Institute of Technology

Felecia Davis, PhD
Associate Professor of Architecture, PennState

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ABSTRACT

Touch, being the first sense to develop in the womb, is fundamental to human experience. The tactile sense allows us to investigate the world by providing a framework for understanding it through its relationship to our body. Tactile methods are capable of expressing concepts beyond language. The most effective and meaningful of these expressions are often emotionally charged. They often concern the unspeakable sentiment behind many of our social interactions, the interpretation of which lends a certain depth to our relationships, but beyond this, we often employ self-touch gestures unconsciously or consciously. Through these gestures, we communicate with ourselves – to self-soothe, as a nervous habit, a mindless fidget. Touch expressions can be deployed in countless ways, and we have only begun to understand them. In parallel, we have developed countless methods of expressing ourselves through digital means which subtract some sensory experience from communication. Perhaps the perpetual digital togetherness afforded by the networks we find ourselves living in has dulled our sensitivities to the physical realm of human experience and all that it embodies. As we continue to move further away from physical togetherness, we may lose an understanding of this emotional depth, or lose touch with ourselves. The intention of this research is to marry physical and digital means of communication to understand the unspoken ways in which we are attuned to our inner emotional states and the physical behaviors we use to then express and regulate those states. In this research, I craft a garment embedded with computational means, so that we might develop a methodology for observing how the body understands and expresses itself through touch, and in turn how it communicates with other bodies.

Thesis Supervisor: Terry W. Knight
Title: Professor of Design and Computation

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Acknowledgments

I would like to express my gratitude to my thesis committee for helping make this project a reality and to the MIT Architecture community for always inspiring me.

I extend my deepest thanks to my friends for saving me from panic countless times, and to my family for making me who I am.

Figures

INTRODUCTION

The purpose of this thesis is to deploy a computational textile as a tool for examining the role of self-touch in self-regulation. The term 'computational textile(s)' refers to e-textiles (electronic textiles) or smart textiles, and in the scope of this thesis refers to a touch-sensitive garment (e-wear). In regard to self-touch, this thesis refers to conscious or unconscious gestures where individuals make contact with their own bodies. These gestures may be communicative, emotionally expressive, or self-adaptive (self-comforting by emulating contact usually enacted by others). I will explore the capabilities of conductive yarn embedded in a garment to detect touch and further understanding of the relationship between touch and emotion. There is precedent for wearable technology intended to monitor the wearer's emotional or physiological states and to help regulate these, but the garment being discussed in this thesis acts a mediation device for understanding the use of self-touch as a regulatory aid. The fabrication and testing of such a garment requires an understanding of the body and its relationship to dress and touch as well as knowledge about the nature of emotion and how social circumstances influence its communication and regulation.

Both touch and dress extend the boundaries of the body and can be used to express things outside of verbal language. Touch is the first sense to develop in the womb and the sense that roots us in the world. Without touch, we might not be able to stand or speak, let alone feel and experience sensations such as the wind on our face. We employ touch to reinforce our social relationships, to intimidate, to seduce, to deceive, or we withhold it to establish emotional boundaries, to punish, and to isolate. In parallel to these body behaviors, dress behaviors can be used to signal a certain social order. In keeping with Joanne Entwistle's 2000 work on dress as embodied practice, perhaps the body is best understood as the dressed body. Dress is fundamental to one's social presentation and it seems that the body cannot be understood without reference to dress. Through our dress we can communicate culture, social position, and even mood. This communication is in some ways conscious, such as wearing traditional garments or clothes from a subculture such as the goth scene, and in some ways unconscious, in that the dress patterns we develop throughout our lives are consequence of the social position we find ourselves in. An understanding of the body necessarily concerns its dressed-ness and its touch capabilities as tools for self-regulation.

While ultimately the human experience is a social endeavor, being able to reap the rewards of togetherness requires certain standards of expression and emotional awareness. Expression here refers to communication and conversation, which both contribute to perceived togetherness – human proximity in its physical and virtual dimensions. 'Communication' here broadly means the exchange and translation of signals, and 'conversation' refers to an intentional process of "concept sharing" between two or more independent entities (Pask 1980). In our modern, virtual lives, we have countless methods of expressing ourselves through wireless mediums, but perhaps the perpetual digital togetherness afforded by the networks we find ourselves living in has dulled sensitivities to the physical realm of communication and the emotionality that it implies. Nonverbal communication, including touch, can express concepts beyond verbal language. These communications often concern the unspeakable emotion behind many of our social interactions, the interpretation of which lend a certain depth to our relationships. If we continue to move away from the physical aspects of communication, we may lose an understanding of this emotional depth. The intention of this research is to marry physical and digital methods of communication to understand the unspoken ways in which we are attuned to our inner emotional states and the physical behaviors we use to then express and regulate those states.

TOUCH

This section explores touch as a sensory modality, in its physiological, social, and philosophical dimensions.

Biophysical Foundations

Touch, or the tactile sense, is one of the submodalities of the somatic sensory system. The somatosensory system enables proprioception, or the sense of one's own body. Touch, considered scientifically, is the sense through which contact with the body is perceived in the conscious mind (Gardner, 2010). Touch allows us to recognize objects by examining them with our hands, to understand qualities such as temperature, texture, and weight, and to experience pain or pleasure.

Tactility is made possible by sensory organs in the skin called mechanoreceptors (so called because they detect mechanical energy exerted upon the skin). They live just under the epidermis among hair follicles and nerve endings, and there are several different classes of mechanoreceptors in the human body, as illustrated in figure 1. For the glabrous (hairless) on the lips, palms, fingers, and soles of the feet, the Meissner corpuscle and the Merkel cell-neurite complex are the primary receptors (Gardner 2010). As seen in figure 2, they are located closer to the skin than other classes of receptors and, in the fingertips specifically, are arranged precisely in the papillary ridges that make up fingerprint patterns, providing a precise detection grid that can read spatial features like Braille dots. The hairy skin on the other parts of the body relies mainly on hair follicle afferents, field receptors, and Merkel cells, illustrated in figure 3. Both skin types also use Pacinian corpuscles and Ruffini endings which are a little deeper in the subcutaneous tissue (Gardner 2010). Mechanoreceptors can be rapidly adapting (RA), like the Meissner corpuscle, or slowly adapting (SA), like the Merkel cell receptor. RA receptors respond to initial contact and motion but not steady pressure, while SA receptors respond to pressure and compression (Gardner 2010).

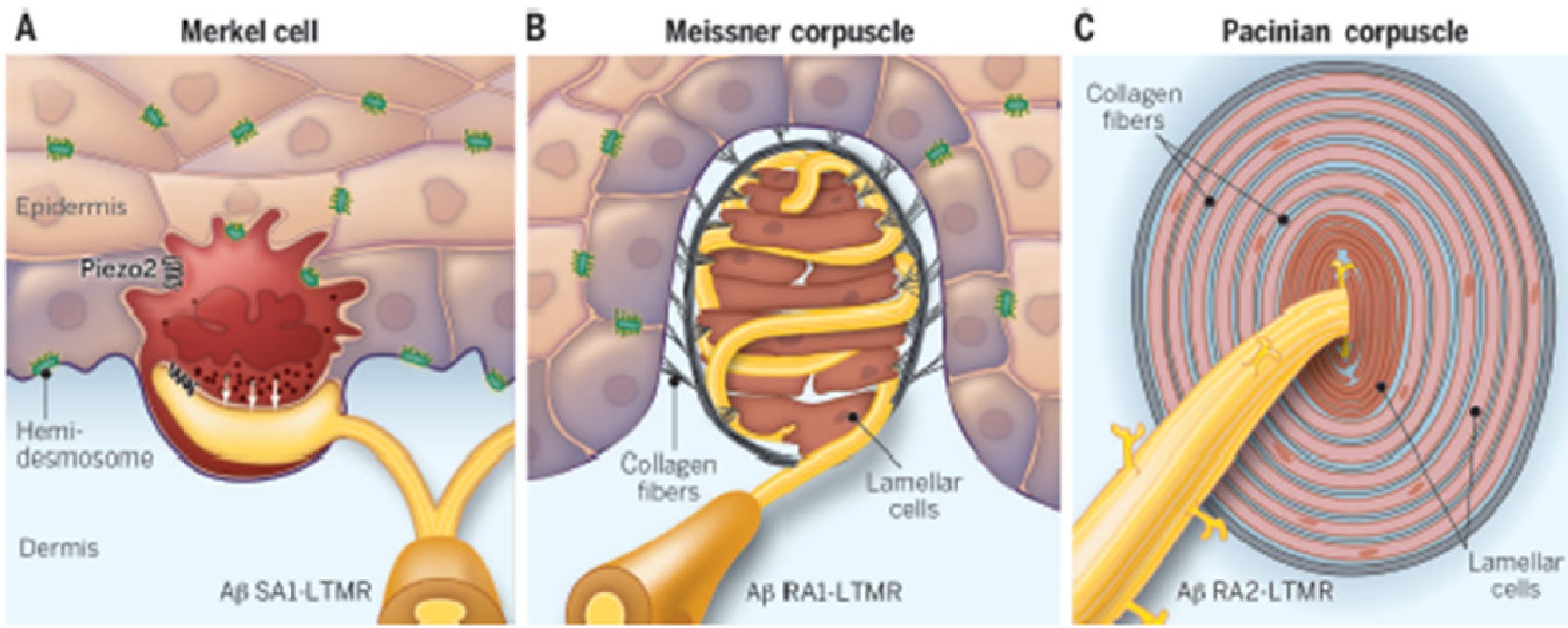
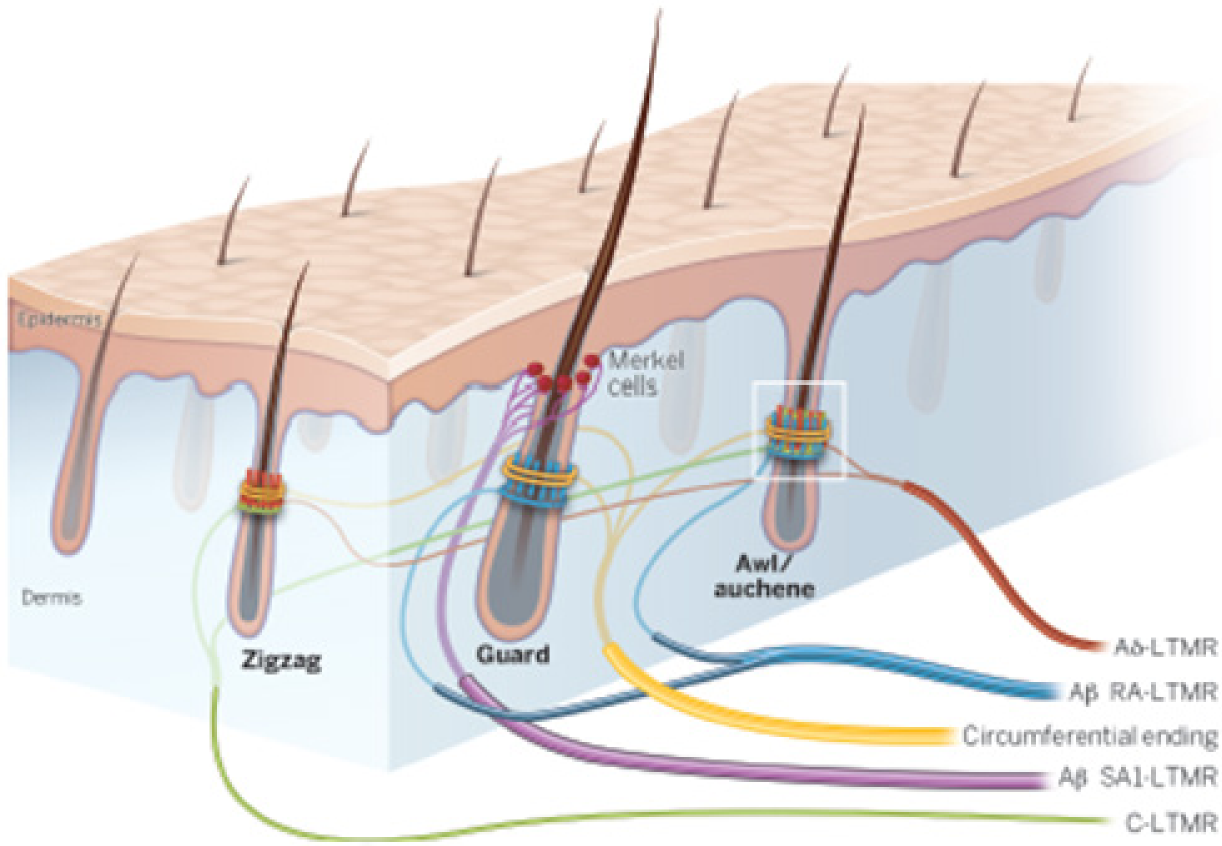


Figure 1: Depictions of each class of mechanoreceptor. From Zimmerman, Amanda, Ling Bai, and D. David Ginty. 2014. "The gentle touch receptors of mammalian skin." Science, November 21: 950-953.



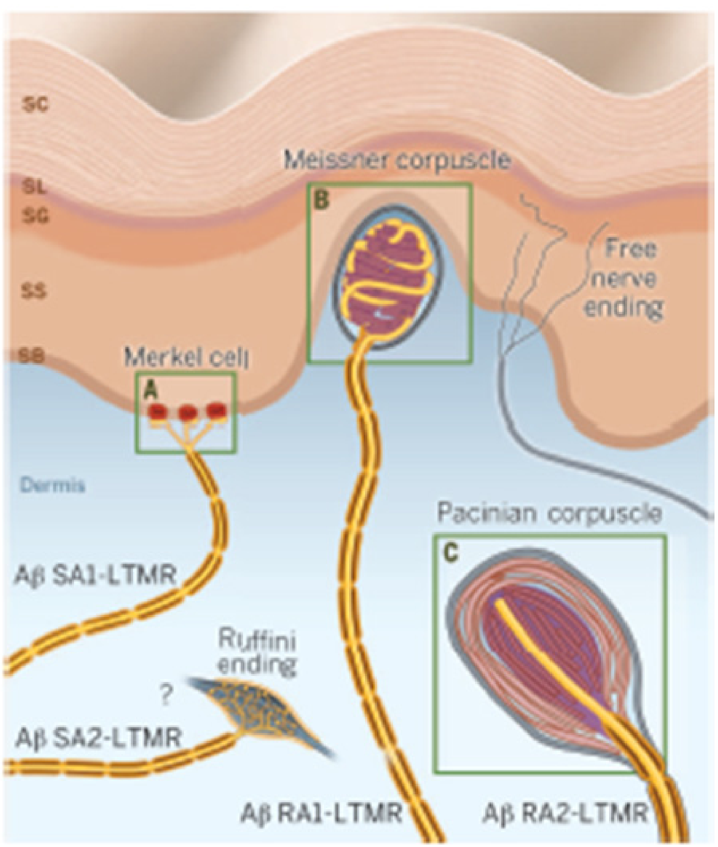


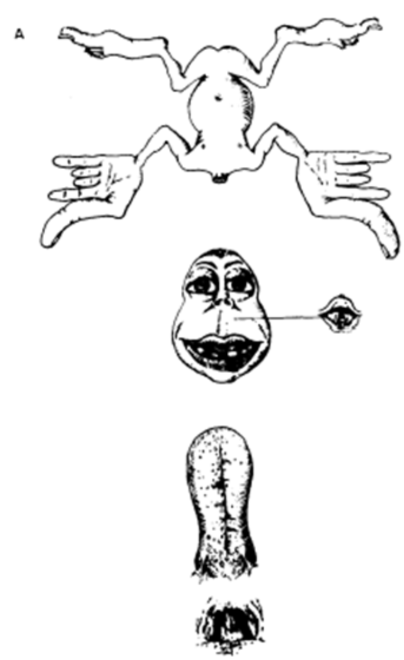
Figure 2 (left): Depictions of mechanoreceptors in glabrous skin. From Zimmerman, Amanda, Ling Bai, and D. David Ginty. 2014. "The gentle touch receptors of mammalian skin." Science, November 21: 950-953.

Figure 3 (above): Depictions of mechanoreceptors in hairy skin. From Zimmerman, Amanda, Ling Bai, and D. David Ginty. 2014. "The gentle touch receptors of mammalian skin." Science, November 21: 950-953.

Each receptor has a receptive field, the primary afferent fiber that transmits touch information to the brain, which can cover a larger region of skin than the receptor physically takes up. While the whole body is covered in receptors of some class, the regions of the body that are most used to touch, the fingertips and lips, have the largest number and density of sense organs with the smallest receptive fields, giving them high resolution in localizing touch. Other regions of the body such as the arms, legs, and torso are less densely populated with receptors and have larger receptive fields, thus lower resolution in spatial detail (Gardner 2010). These mechanoreceptors are connected to the brain via peripheral nerves and nerves dual serving for cutaneous (of the skin) sensory modalities like pain, temperature, and itch.

Sensory processing is organized by topographic and functional axes through a somatotopic map of the body preserved in all somatosensory areas of the brain. An example of such a map is the homunculus, which represents the relative importance of each sense in brain processing. Though mechanoreceptors have their respective functions, all the sensory modalities converge on common neurons (Gardner 2010). In this respect our sense of touch is biophysically tied to the other cutaneous modalities, and this contributes to the complexity of sensory experience. It is difficult to divorce touch from any bodily sensation, and even more so to conceptualize the body without involving touch.

Figure 4: An illustration of the homunculus, from Dykes, Robert W. 1978. “The Anatomy and Physiology of the Somatic Sensory Cortical Regions.” Progress in Neurobiology 33-88.



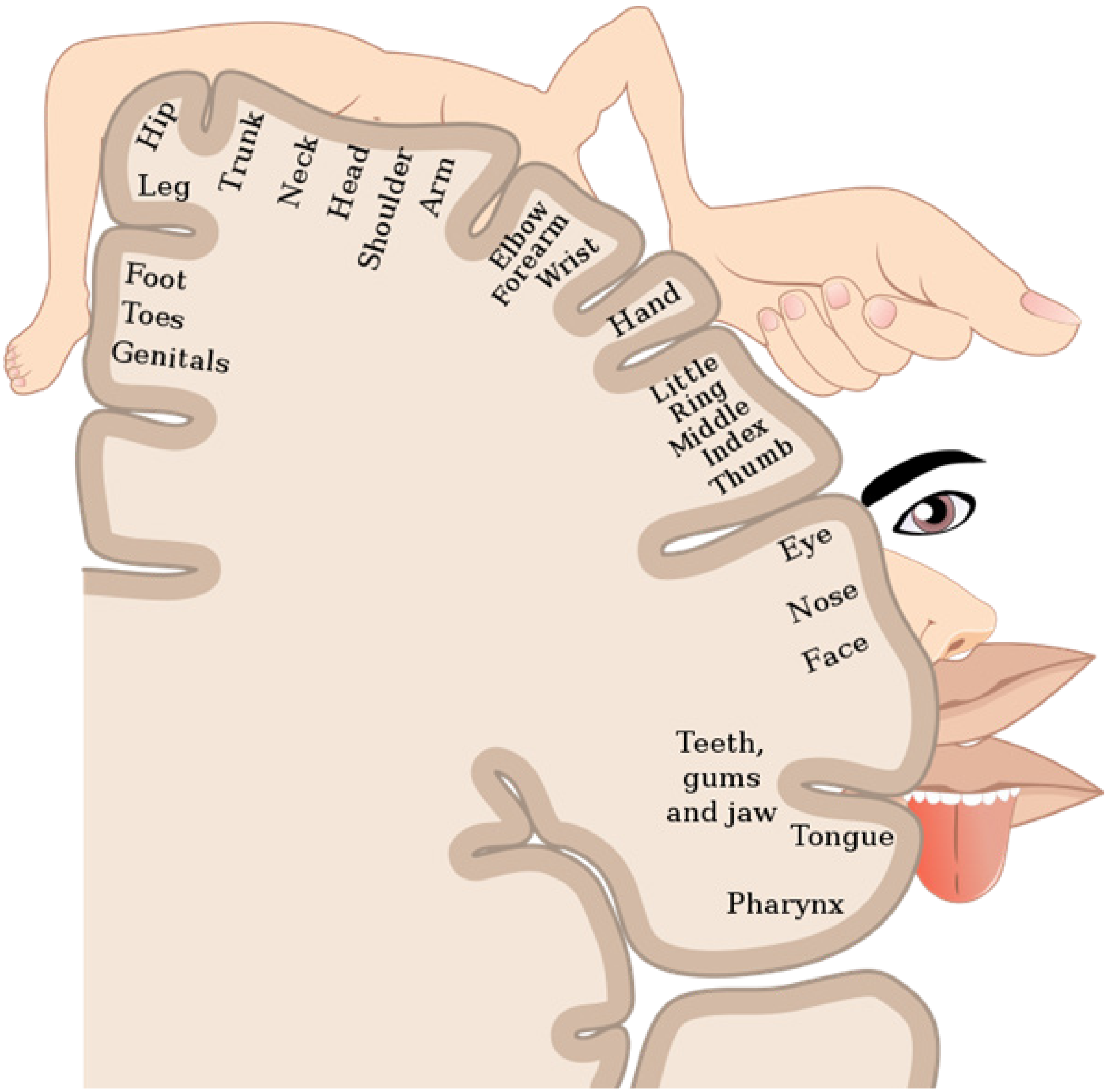


Figure 5: Another example of the human homunculus,

https://commons.wikimedia.org/w/index.php?curid=88916983

The bodily awareness (both proprioception and interoception) and physical experiences afforded to us by touch are fundamental to development. There are many divisions of touch (active vs passive, body directed vs object directed, cutaneous vs haptic), but this thesis is mainly concerned with discriminative vs emotional (affective) touch. Touch that is purely for extracting information is described as discriminative, while affective touch is often social in nature, and might even be regarded as "affiliative" in some respects (Fulkerson 2014).

Discriminative touch is addressed with the mechanoreceptors discussed previously, while affective touch has an additional dimension which was under-investigated for some time. Besides the rapid and slow acting receptors, there is a class of nerve fibers called C-tactile afferents which exist in hairy skin (McGlone, et al. 2007). They respond to low, slow forces and were previously thought to account for tickle sensation until research from Vallbo et al. (1999) advanced thinking to understand their role in emotional, hormonal, and behavioral responses to skin-to-skin contact. The CT-system is predisposed towards communicating with emotional systems in the brain (the insular and orbitofrontal cortex), an interoceptive function. Other systems disposed towards interoception include those related to the perception of pain, itch, temperature, and hunger (McGlone, et al. 2007). CT fibers can be considered as accounting for pleasure, especially that associated with interpersonal touch. In this sense they are responsible for bodily wellbeing, signaling positive biophysical responses when we are close to friends, family, or partners that contribute to confidence and calmness (McGlone, et al. 2007). The presence of this system reveals the social aspect of touch and how the presence or absence of it impacts lifelong socialization and communication.

Affective Touch

Physical contact can often convey things beyond the capabilities of language. Even the briefest of touches can draw out strong emotions, and this is evident in the way we use touch as an added layer of expression underlying other verbal and nonverbal communication. For some time, the interpersonal and emotional aspects of touch were overlooked by cognitive scientists, but research has advanced significantly in the late 20th and 21st century.

As it concerns this thesis, the pivotal studies concerning touch and emotion are those of Hertenstein et al, published in 2006 and 2009. The results of these studies make great strides in proving that emotions can be communicated through touch alone and are the basis for the framework being developed.

In their 2006 paper, “Touch Communicates Distinct Emotions”, the researchers’ aim was to investigate whether individuals could communicate distinct emotions through tactile stimulation and whether they could accurately interpret emotions just by seeing other individuals communicate via touch. Their research was the first to provide evidence for the human ability to express love, gratitude, and sympathy with nonverbal behavior, expanding previous knowledge. They also add to the lexicon of emotion-specific signals by providing descriptions of emotion-specific touch behaviors. The emotions of concern in their studies were: anger, fear, happiness, sadness, disgust, and surprise (all emotions proven to be decoded in the face and voice in different cultures following Ekman, 1993); embarrassment, envy, and pride (classified as self-focused emotions), and love, gratitude, and sympathy (prosocial emotions). Figure 6 is a table of some of their findings, detailing the frequency of types of touch by percentage as well as percentage of emotional decoding accuracy.

Percentage of Most Frequent Types of Touch Used in Study 1 and Percentage of Decoding Accuracy of Most Frequently Chosen Emotion for Studies 1 and 2

Emotion and tactile behavior	Most frequent types of touch in Study 1 (%)	Decoding accuracy (%) Study 1 (United States)	Study 2 (Spain)
	Ekman's emotions		
Anger		Anger, 57**	Anger, 59**
Hitting	23		
Squeezing	20		
Trembling	11		
Fear		Fear, 51**	Fear, 48**
Trembling	50		
Squeezing	27		
Shaking	6		
Happiness		Happiness, 30	Gratitude, 38
Swinging	55		
Shaking	15		
Lifting	7		
Sadness		Sympathy, 35*	Love, 31
Stroking	26		
Squeezing	6		
Lifting	6		
Disgust		Disgust, 63**	Disgust, 83**
Pushing	55		
Lifting	14		
Tapping	5		
Surprise		Surprise, 24	—
Squeezing	24		
Lifting	12		
Shaking	12		
	Self-focused emotions		
Embarrassment		Embarrassment, 18	—
Shaking	14		
Tapping	11		
Pushing	10		
Envy		Envy, 21	—
Pulling	22		
Lifting	12		
Stroking	11		
Pride		Gratitude, 25	—
Shaking	39		
Lifting	16		
Squeezing	15		
	Prosocial emotions		
Love		Love, 51**	Love, 62**
Stroking	40		
Finger interlocking	13		
Rubbing	12		
Gratitude		Gratitude, 55**	Gratitude, 66**
Shaking	67		
Lifting	9		
Squeezing	6		
Sympathy		Sympathy, 57**	Sympathy, 48**
Patting	35		
Stroking	15		
Rubbing	7		

Note. Dashes indicate that the emotion was not used.
* $p < .05$. ** $p < .01$.

Figure 6: Table of types of touch associated with their respective emotions from: Hertenstein, Matthew J., Dacher Keltner, Betsy App, Brittany A. Bulleit, and Ariane R. Jaskolka. 2006. "Touch Communicates Distinct Emotions." Emotion 528-533.

Their findings indicate that anger, fear, and disgust as well as all three pro-social emotions were decoded at above-chance level of accuracy (above 50%). They conducted studies where decoders (receiver) could not see the encoder (actor), interpreting solely from tactile experience, and where the decoder was not receiving touch, merely observing the touch interactions of other individuals. These findings indicate that distinct emotions can be communicated through touch, and not solely the tone and intensity of emotion. They also indicate that touch might convey more positive emotions than other modalities, like facial expression (Hertenstein, Keltner, et al. 2006). Another interpretation of the findings might say that encoders were communicating intention, rather than emotion, which requires further understanding of what exactly emotion is.

In colloquial speech we often use the word 'emotion' to refer to feelings, and common thought towards the expression of emotion is that they are behaviors caused by feelings. It's important to know that emotions are functional (mental) states that cause feelings and behaviors (Fox, et al. 2018). Continuing from that, emotions are triggered by stimuli or sensory input, they are dynamic and relatively short in length, and the signals associated with an emotional state often depend upon culture and context. One line of thinking in affective science is that the purpose of emotions is to prepare the body for action; emotion can be motivating (such as a learned fear that keeps one out of danger); emotion promotes communication and social bonding (in terms of emotion-specific signals being understood in a culture, or the attachment one has to their family, for example) (Fox, et al. 2018). The expression and communication of emotion is necessary for social problem solving and can be done through myriad verbal and nonverbal means. The classifications of emotions as self-focused or pro-social, then, refer to the behaviors that have been observed as outcomes of the corresponding emotional state. Nonverbal emotional expressions, especially body language and gestures, are often communicated with more potency and speed than other stimuli and often take precedence over non-emotional stimuli in information processing (Fox, et al. 2018). This efficiency then makes emotional expression key to communal behavior and bonding, and basic to humanity.

Returning to Hertenstein et al, research on the decoding of touch-specific emotional expression has come far in recent years. After their initial studies, they refined their research. Where earlier studies did not account for the location of touch in relation to emotional expression, their new findings created a rough grammar for where an emotion can be accurately communicated through touch on the body. Their methods involved pairing individuals randomly in both same and opposite sex dyads, with an encoder (person communicating through touch signals) and a decoder (person receiving touch). The decoder was blindfolded while being communicated with and asked to respond to questions directly after each gesture. Researchers coded each tactile display as it happened, observing such types of touch as squeezing, tapping, tickling, hugging, hitting, etc. The locations where touch was encoded were the head, shoulders and arms, and torso, front and back. Researchers limited participants to "appropriate" body areas (Hertenstein, Holmes, et al. 2009).

The results of this study are richer in that they not only account for the location of touch on the body (shown in the figures below), but also for the equipotentiality of touch and emotion. This is to say that, in line with the flexibility of the emotional signaling system in communicating a functional state, tactile displays can signal very different things depending upon contextual interpretation. For example, in the case of the dyads, men and women may use different gestures to communicate the same emotion but overall, the decoding of specific emotions was equal among genders (Hertenstein, Holmes, et al. 2009). The fact that the pairs were strangers signals that tactile expression is innate in some respects to humanity, although it operates differently depending on environment and culture. The research of Hertenstein et al. has made great strides in opening up our understanding of human touch behavior, but questions still to be answered include (of course) the nuances of culture and gender in touch expression, how tactile displays operate in more naturalistic contexts and, for me, how touch expressions individuals enact on themselves stand in relation to touch grammars and how that self-touch manifests in one's emotional states and mood.

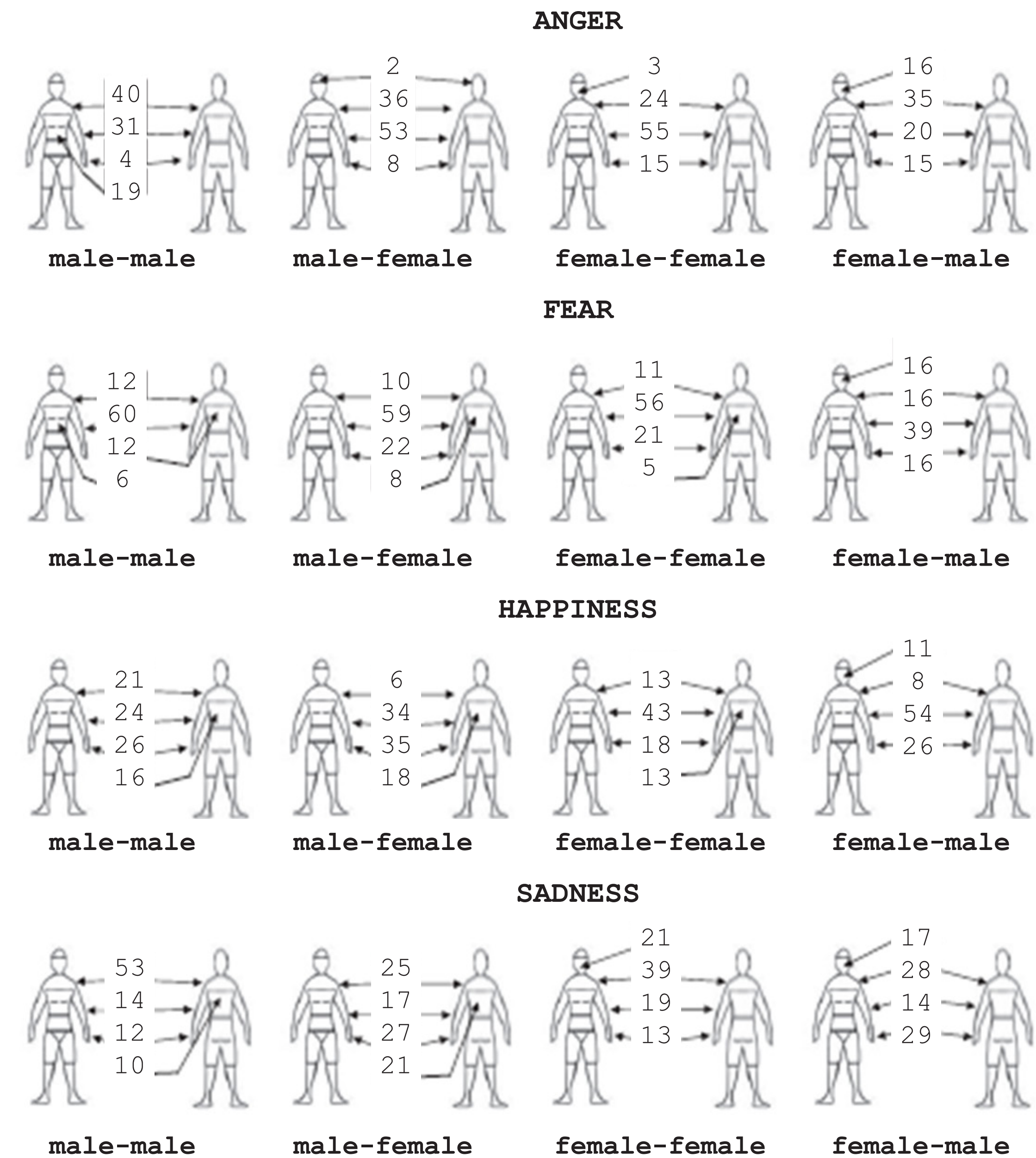


Figure 7: Chart showing the location where and percentage of time decoder's body was contacted by encoder when emotions were accurately decoded. Left figures in the pairs depict front side and right figures depict back side. Starting from left shows: male-male pairs, male-female pairs, female-female pairs, female-male pairs. From Hertenstein, Matthew J. , Rachel Holmes, Margaret McCullough, and Dacher Keltner. 2009. "The Communication of Emotion via Touch." Emotion 566-573.

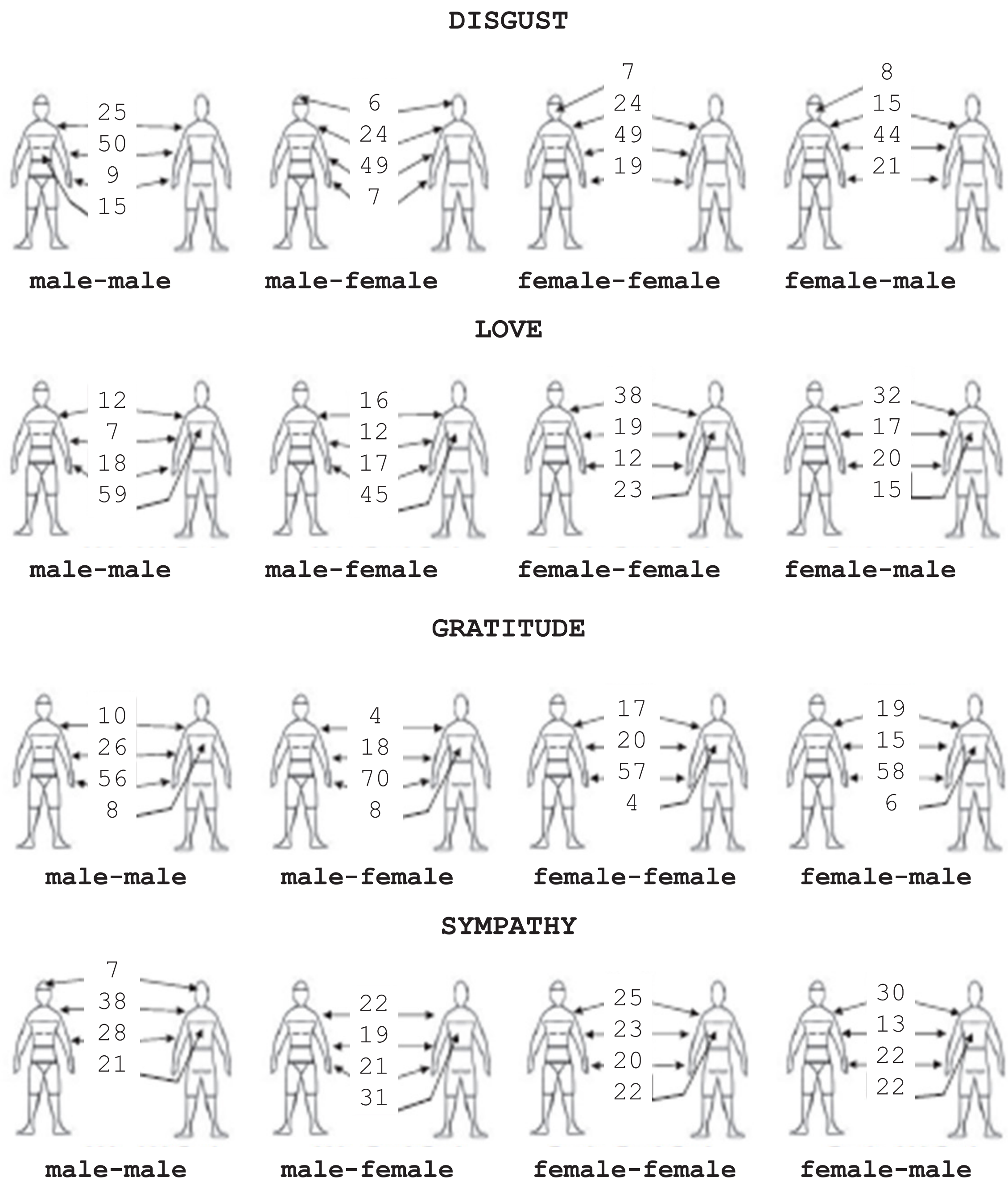


Figure 8: Chart showing the location where and percentage of time decoder's body was contacted by encoder when emotions were accurately decoded. Left figures in the pairs depict front side and right figures depict back side. Starting from left shows: male-male pairs, male-female pairs, female-female pairs, female-male pairs. From Hertenstein, Matthew J. , Rachel Holmes, Margaret McCullough, and Dacher Keltner. 2009. "The Communication of Emotion via Touch." Emotion 566-573.

Self-Touch

As far as touch in general is a relatively unexplored modality in terms of emotional expression, self-touch is an even newer field of study. The phenomenon of self-touch is just as ubiquitous as social touch. While social affective touch is often used to reinforce relationships or communicate emotional concepts, self-touch is suggested to be a method of experiencing one’s own body (Boehme and Olausson 2022).

It is important for individuals to be able to differentiate self-touch from social touch. In a study investigating the attenuation of self-controlled vs external stimuli, findings showed self-controlled tactile stimulation produces less activity in the cerebellum than externally controlled (Boehme and Olausson 2022). Since interpersonal touch often uses more unpredictable and complex patterns of touch, it follows that the brain is more sensitive to interpreting external touch signals. Self-touch, on the other hand, is often passive and predictable – adult humans touch themselves on average 50 times per hour – so its processing inside the somatosensory cortex and cerebellum may rely on a different framework than social touch (Boehme and Olausson 2022). Rather than reinforcing an external relationship, self-touch can be seen as a method of self-regulation.

In the scope of this thesis, self-regulation refers specifically to affect regulation. “Affect”, referring to the tone of feeling an individual is experiencing at any point in time, can vary in terms of hedonic valance, felt energy, and arousal (Baumeister and Vohs 2004). If the feeling tone is strong or consciously recognized, it is referred to as an emotion, while a feeling tone that is in background awareness is a “mood”. Self-regulation then, as I view it, is any automatic or effortful process by which an individual controls affect. Of specific interest in this case is the use of self-touch to modulate feeling states.

Self-regulation is of interest in affective science because of its relation to one's physical and mental health (Baumeister and Vohs 2004). Research shows that disruptions in the ability to regulate the experience of negative affect (its duration or intensity) can be linked to depression and other mood disorders or physiological functioning.

The hope is that the findings of this research can open up new avenues in understanding of self-regulatory processes. Touch, and the loneliness that comes with an absence of it, is a timely topic in a world that seems to be steadily moving further from physical togetherness. The recent isolation of the COVID-19 pandemic has produced a wave of new research into the loss of quality of life associated with an increased longing for touch. Public health measures required social isolation as much as possible which, while necessary for the greater good, had a significant impact on general emotional states. Pre-pandemic, many touch deprivation studies were conducted with children, so little was known about the consequences of longing for touch in healthy adults. A survey administered online to participants (healthy individuals 16-87 from several different countries) during lockdown found that, out of 1,982 people, at least 13% experienced a decline in quality of life (physical, social, environmental, or psychological) due to being in lockdown (Hasenack, et al. 2023). A lower physical quality of life was associated with a higher longing for touch, along with more severe lockdown requirements. 83% of participants in the study reported experiencing a longing for touch (Hasenack, et al. 2023). This was one of the first studies to provide evidence for the relationship between longing for touch and physical, psychological, and social wellbeing. It has previously been shown that touch can reduce stress, anxiety, and feelings of depression (Hasenack, et al. 2023). Touch is largely a social modality, but it is important to examine the capabilities of self-touch so that, in cases where social touch is restricted, we might understand self-touch expression patterns that lend themselves to affect regulation. Social behavior might also be understood from the standpoint of an individual's ability to regulate themselves in order to communicate effectively with others.

Self-touch is fascinating in that it combines the experience of touching and being touched into one action. In affective science, self-touch is often associated with attention and information processing and has been found to positively correlate with self-evaluation (Kronrod and Ackerman 2019). A study in which participants were instructed to engage in self-touch (such as resting their hand on their leg) while engaging in an information processing task such as watching a video and then asked them to self-report on the effects on their attitudes found that participants experienced a change in self-focused attention. Interestingly, no one seemed particularly conscious of the particular triggers or consequences of self-touch, though all were influenced in some form (Kronrod and Ackerman 2019). It suggests downstream consequences for self-touch behavior on affect.

In situations where social touch is harmful in some way, self-touch can be soothing. Studies show that gestures such as placing a hand on one's heart, face, or belly can improve stress responses (Dreisoerner, et al. 2021). In the way that social touch can express love, gratitude, or other emotions, self-touch can be an expression of self-compassion. Though self-touch can be unconscious, conscious gestures are easier to observe and understand from a research standpoint. A recent study comparing the soothing effects of receiving a hug vs self-touch vs no touch intervention found that both touch interactions showed a decrease in participants' cortisol levels (a reduction in stress) (Dreisoerner, et al. 2021). Further, participants in the study were asked to be especially attentive to each touch interaction, to concentrate on their breathing and the warmth of the hug, or to touch themselves in the way that was most comfortable for them and focus on the warmth and pressure of their hand and their breathing. This is interesting in that bodily awareness was a large part of the evaluation of one's emotional state. The study provides evidence for the regulatory capabilities of conscious self-touch, but it also points to the greater notion that affect is fundamentally body based. Touch, being perhaps the most physical of the sensory modalities, seems especially equipped to communicate the nonverbal emotional expressions of the body.

The Body

In some respects, tactual experience depends on bodily awareness, and in turn tactual perception can enhance the experience of one’s own body. “Bodily awareness” here refers to an awareness of the present state of the body (Fulkerson 2014), sometimes considered proprioception or interoception, and is not necessarily a perceptual experience in itself. One could argue that an experience is perceptual if it involves active engagement with the world and the qualitative awareness of objects and their properties. So, touch, of course, is a perceptual experience. It depends on bodily awareness in that a tactile experience of external objects requires one to have an awareness of their hands (or whichever body part is making contact with the world), in keeping with the duality of touch (Fulkerson 2014). We can experience the external world through touch but by doing so we also experience the present state of our bodies (the temperature of our skin, pressure, the position of a limb). This line of thinking proposes that the conception of the body is virtually inextricable from the touch modality. Visual experience, for example, does not seem to depend on bodily awareness in the same way that tactility does. Generally, perceptual experience requires an implicit knowledge of how sensory input can change relative to how the body is situated in the environment (Fulkerson 2014), but touch seems to go beyond this sensorimotor intelligence. Being aware of situatedness is externally focused, while bodily awareness is inwardly focused. Touch then, can be considered first a personal experience and second a communal experience.

This personal aspect of touch speaks to embodiment and the role of the body in culture. Much in the same way as touch, dress “forms the invisible envelope of the self”, marking the boundary between the self and the world (Entwistle 2000). It is not incorrect to say that human bodies are necessarily dressed bodies, and that the body could be considered a social object in this respect. Dress customs pass social meaning onto the physical body and, since nakedness is generally considered disruptive, dress defines our social dynamics, in part. Dress is regulated such that the degree to which the dressed body can express itself is symbolic of the social context it occupies and mediates the experience of the physical self. This is of interest to this thesis because of the way that dress patterns can be influenced by affective states and how those dress patterns can inform touch expressions communicated by the body.

Methods for understanding touch expressions and their relationship to affective regulation require sensitivity to the centrality of the body to emotion and an understanding of the self. Best practice seems to be an approach to the body through the familiar lens of dress. By using a recognizable medium and object – fashion, specifically, a garment – and imbuing that object with sensory capabilities through computational means, we might be able to capture patterns of affective touch that are related to self-regulation needs.

Investigation

This section focuses on methodology and fabrication of the jacket.

Preliminary Questions

The questions at the center of this investigation:

1. How do we experience touch, in the visceral sense?
2. How do we recognize and interpret our emotional states relative to our body?

As discussed previously, these two topics are necessarily entwined, such that the question can be written as:

1. How does the visceral experience of touch shape how we recognize and interpret emotional states?

It is important to me to investigate these in the interest of true togetherness. The title of this thesis, the limits of expression, follows from Gordon Pask's 1980 paper, "The Limits of Togetherness". His essay focuses on carefully outlining the boundaries between communication (simple signal transfer) and conversation (concept sharing). These boundaries will be explored further in a later section, but at the heart of the paper is Pask's diagnosis that the "information environment" fabricated by the co-evolution of computation and communication alters our perceptions of togetherness (signal distance, in his words). The false togetherness made available to us by constant communication, where the value is accuracy, disallows for meaningful conversation, where autonomous systems can come to an agreement through information transfer. Conversation allows us to be truly seen and understood. Since communication ≠ conversation, a machine is not required to agree or disagree with you, only display information. Digital togetherness, in a sense, is isolating; virtual realities often remove us from embodied experiences. These embodied experiences are of most concern to me.

To better understand the connection between touch and emotion, I attempted to reframe the findings of Hertenstein et al. This meant creating an emotional matrix (seen in figure 9) using the 8 emotions observed in the studies and classifying them using parameters that were more familiar to me.

In my readings I have often found affect categorized in a binary: pro-social vs self-focused, high vs low arousal/valence. This method of classification, for me, implies a positive vs negative dichotomy which seems to place certain emotions at strict odds to one another, where in my understanding emotions are spectrum based, and it’s not impossible to feel a mix at any one time. The emotional matrix makes it easier to conceptualize the relationship between different emotional states and how the signals for these might be interchangeable. The emotions illustrated herein will be part of future studies conducted with the garment.

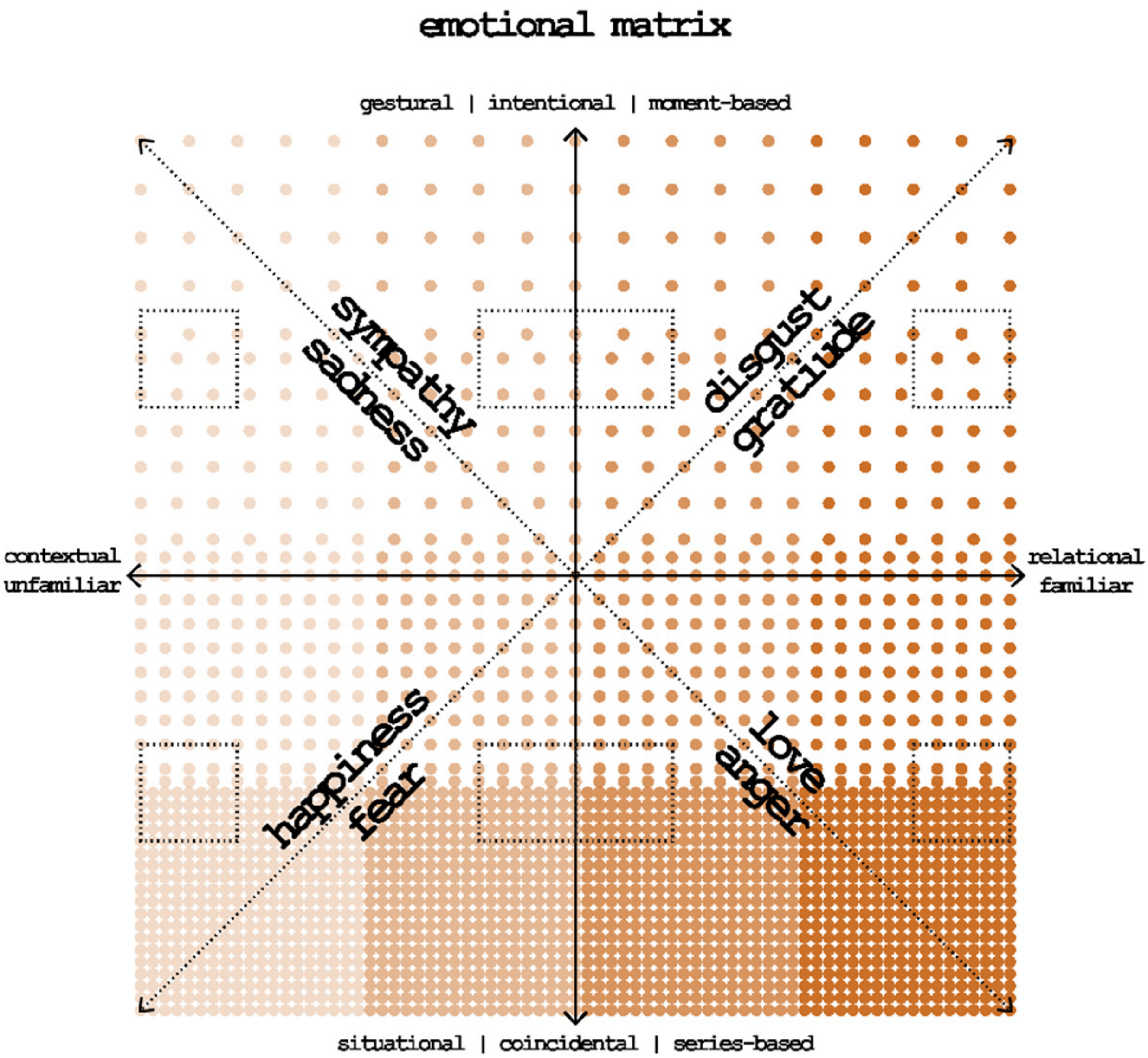


Figure 9: Emotional matrix drawn by the author.

It was also important to me to re-display the findings from Hertenstein et al comprehensively, to understand the sort of sensory heat map of the body that they managed to create. I took the average of all their readings and, using those emotions and locations with a higher than 20% decoding accuracy (shown in the table in figure 10), compiled the results into the body map seen in figure 11.

	love	anger	gratituded	isgust	happiness	fear	sympathy	sadness
head front	0.00%	21.00%	0.00%	5.25%2	.75%	4.00%	1.75%	9.50%
shoulders front	24.50%	33.75%	12.50%	22.00%	12.00%1	2.25%	28.75%	36.25%
elbows front	13.75%	39.75%	19.75%	48.00%	38.75%5	3.50%	20.75%	16.00%
hands front	16.75%	10.50%	60.25%	14.00%	26.25%1	4.75%	15.75%	20.25%
chest	0.00%	4.75%	0.00%	3.75%0	.00%	1.50%	0.00%	0.00%
head back	0.00%	21.00%	0.00%	1.50%0	.00%	0.00%	1.75%	0.00%
shoulders back	24.50%	33.75%	12.50%	22.00%	12.00%1	2.25%	28.75%	36.25%
elbows back	13.75%	39.75%	19.75%	48.00%	38.75%5	3.50%	20.75%	16.00%
hands back	16.75%	10.50%	60.25%	14.00%	26.25%1	4.75%	15.75%	0.00%
back	35.50%	0.00%	6.50%	0.00%	11.75%	6.25%	24.00%	7.75%

Figure 10: Average decoding accuracy for emotional touch expressions recorded during studies by Hertenstein et al (2009). Accuracies above 20% are highlighted orange. Image generated by author with data from:

Hertenstein, Matthew J. , Rachel Holmes, Margaret McCullough, and Dacher Keltner. 2009. “The Communication of Emotion via Touch.” Emotion 566-573.

Figure 11: A front and back view of the human upper body. Emotions with decoding accuracy higher than 20% are mapped onto their corresponding body parts. Image generated by the author using data from: Hertenstein, Matthew J. , Rachel Holmes, Margaret McCullough, and Dacher Keltner. 2009. "The Communication of Emotion via Touch." Emotion 566-573.

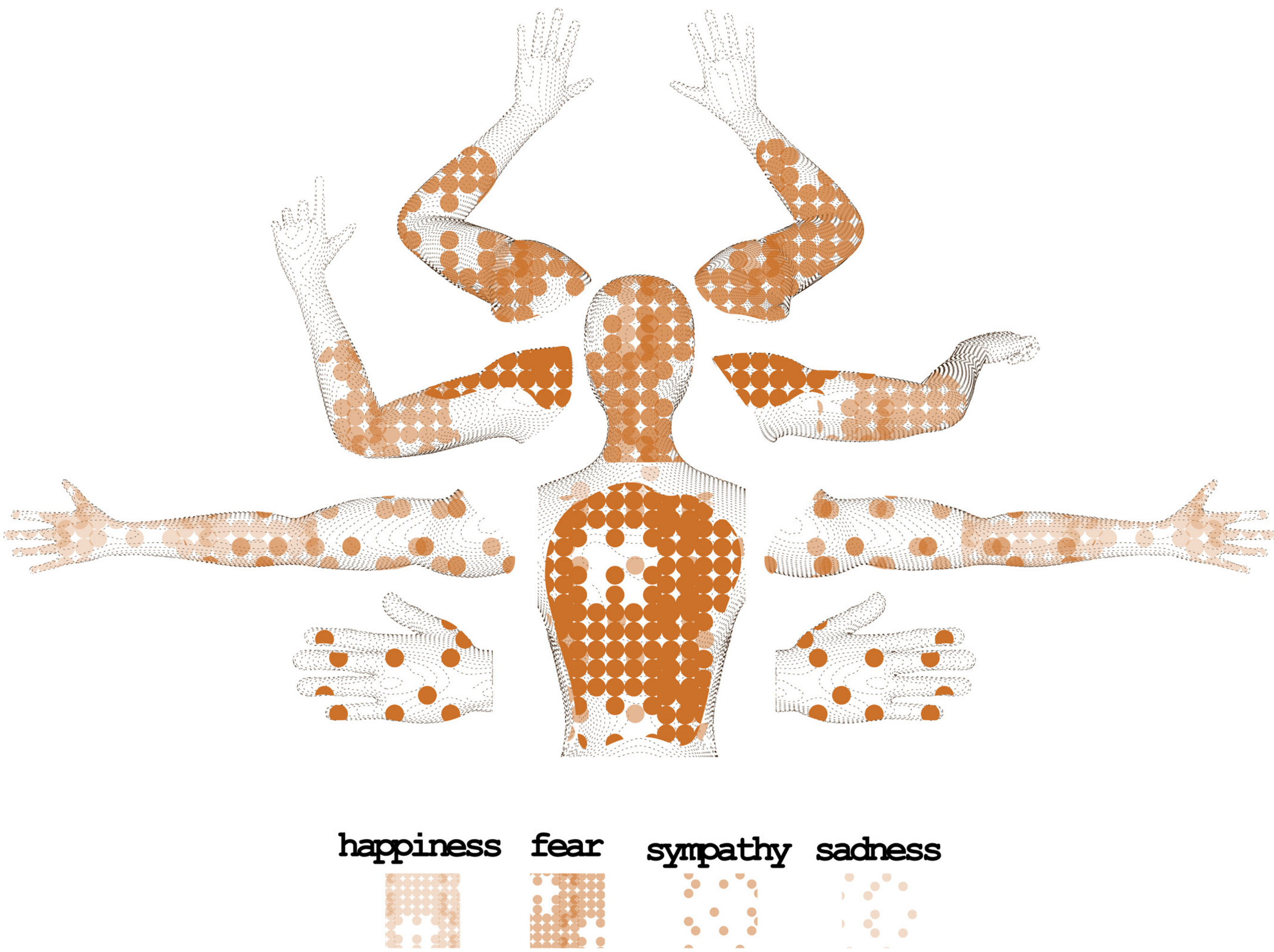


Figure 11 (cont).

Related Works

The garment at the center of this thesis is not the first affective computational garment, but it offers a chance to understand the emotional dimensions of touch in a more naturalistic manner than previous touch studies. The tradition of computational textiles is a relatively new practice but certainly not uninvestigated. This particular e-wear device borrows principles from works such as the affective sleeve from Athina Papadopoulou, FELT by Felecia Davis, movement-based interactive textiles from Mengqi Jiang et al., and memory rich clothing from Joanna Berzowska (Berzowska 2005), (Davis, Softbuilt Computational Textiles and Augmenting Space Through Emotion 2017), (Papadopoulou, Affective Matter: A Haptic Material Modality for Emotion Regulation and Communication 2022).

A reminder that computational textiles are textiles that are embedded in some way with digital capabilities through the use of micro-controllers and sensors. The fabrication of such a textile requires one to understand the role that fabric texture, form and behavior play in the human-computer interactions that play out. The FELT project, a 5’x6’ textile wall panel, studies how emotion-specific touch expressions play out across such a material. The texture and movement of the wall panel was inspired by reactions in animal skin, feathers, or fur, thinking that the movement of the textile might invoke the same reaction when seeing and touching it. The panel was made up of pieces of felt mounted in a Plexiglas and aluminum frame with attached motors. In this study the computational textile was used in some ways as a lightning rod; participants were asked to describe the way the textile made them feel or emotions that they might attribute to it just by seeing it, then asked to touch it and describe the affective experience of that touch. The expectation was that the textile could communicate emotion to participants in some way, either through visual or textural means, and the FELT study did confirm that motion or shape change in the panel did increase excitement ratings of the wall (Davis, Touch: Communication of Emotion Through Computational Textile Expression 2018). In the portion of the study concerning touch, participants’ responses changed in parallel to changes in the textile and the information it was relaying through sight and touch. This is promising in that participants were not inherently put off by a touch interaction with this novel genre of object and that it was successfully able to communicate emotionally.

While FELT demonstrates that computational textiles are compatible with emotion, other work focuses on how e-textiles can act on the body. The interaction of computational textiles and human skin is a unique opportunity to understand how emotional bodies respond to computing paradigms. For this reason, movement-based textiles, memory-encoding clothing, and the affective sleeve are compelling instances of wearable technologies. The Memory Rich Clothing developed by XS Labs focuses on reactive garments that display their physical memory. The Intimate Memory skirt, for example, has a strong use of the soft circuit as an aesthetic element on a wearable material; the soft switches on the skirt are sewn with metallic silk organza and connected to a circuit, but they also serve as embroidered decorations (Berzowska 2005). This may enhance the experience of touching it, in the way one absentmindedly plays with a fun texture or element on their garment. In this case the Intimate Memory skirt displays the length and pressure of its last touch memory.

The movement-based textiles and affective sleeve projects address emotional regulation in its wearers. In the first case, researchers developed a full sleeve t-shirt that detects elbow and shoulder movement, arm opening and closing, and neck movement, and responds with audio, visual, or vibrotactile feedback to motivate wearers to perform those movements. The encoded movements are purported to impact emotional states by enhancing positive emotions (Jiang, Nanjappan, et al. 2021). The long sleeve shirt was embedded with two types of fabric sensors developed to detect those motions, made from conductive knitted fabric, along with LED lights, small motors, and a Bluetooth module to play audio feedback. User evaluation found that the audio and vibratory feedback from the garment was effective for wearers, and that completing the upper body movements saw improvements in positive emotions (Jiang, Nanjappan, et al. 2021).

Similarly, the affective sleeve is a wearable device engaging motion in some fashion to promote user well-being. Unlike the movement-based shirt, the sleeve produces haptic action (squeezing/pressure change accompanied by warmth) as a form of therapeutic intervention to aid in emotion regulation. During user evaluations, wearers were exposed to a stressor before the sleeve performed some haptic action (none, slow, or fast). The study demonstrated a positive correlation between the pace of the haptic action and a change in physiological signals, indicating that the sleeve may have an impact on breathing regulation – a slower pace meant slower breathing and suggests that it could promote calmness (Papadopoulou, Knight, et al. 2019). These results are promising for the use of haptic interventions for emotion regulation.

There are many rich examples of computational textiles, wearable and not, that address emotion and touch. The garment being developed in this thesis is less an intervention and more a touch mediation device. In fabricating and testing it, the researcher hopes to offer a framework for understanding how individuals communicate with themselves, and the sorts of emotions they may express through touch interactions with their (dressed) bodies.

The Garment

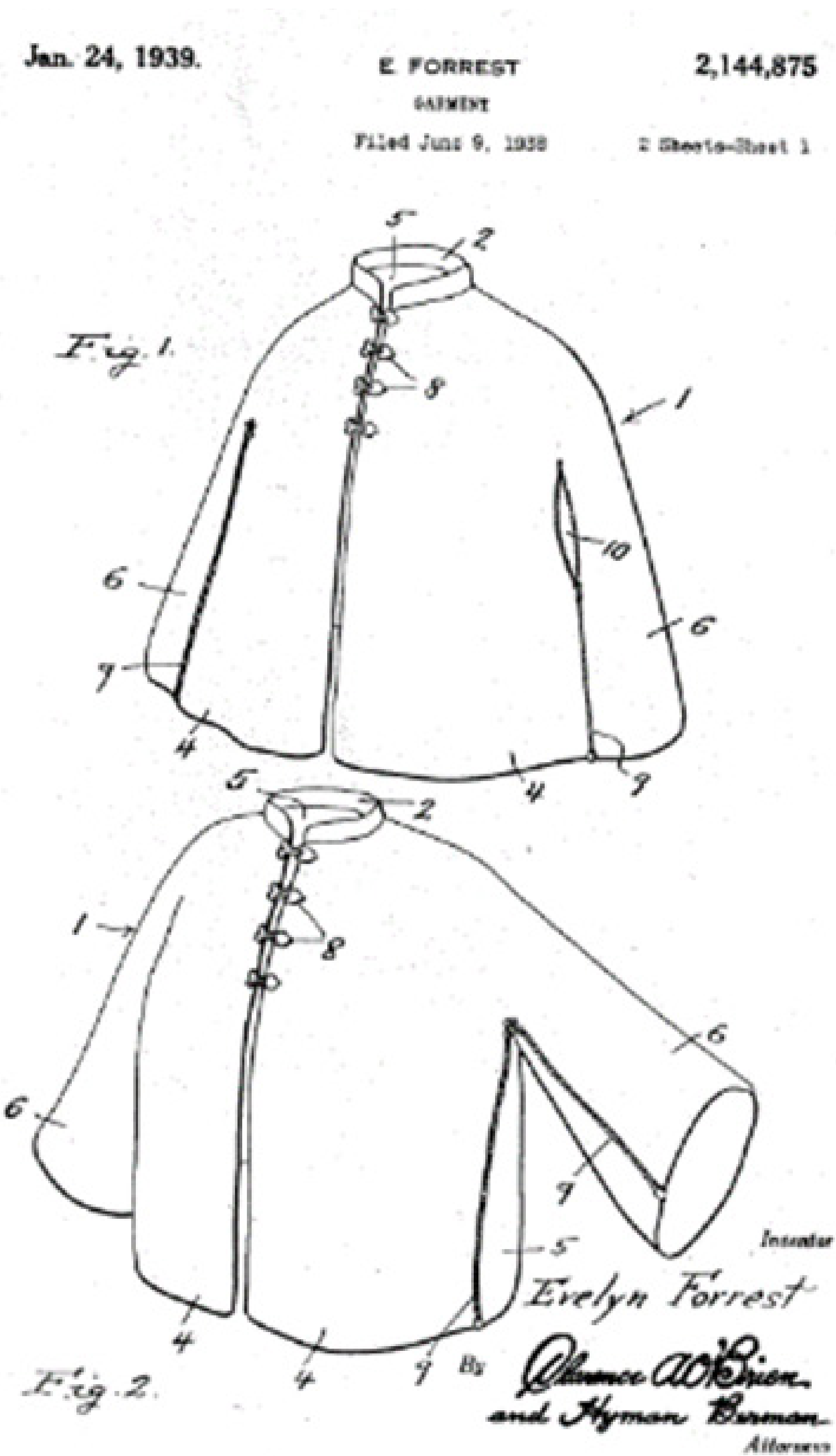
In making this garment, I wanted to be able to study touch behaviors as unobtrusively as possible. Studies I've mentioned previously have observed touch in clinical settings, where natural behaviors may be altered in some way just because they are being observed. The garment lends a certain flexibility to the nature of interactions that it engenders that I have not really found in previous studies. If deployed correctly, it could be possible to log touch interactions as they happen in natural social settings and evaluate their affective qualities accordingly.

The form of the garment was inspired in part by Evelyn Forrest's 1939 patent for a convertible garment (figure 12), but its final cut also calls to mind the looseness and dramatic sleeve of the African boubou (or dashiki, in Western language), which appears in countless cultures across the continent. Like the example in figure 13, textile traditions in West Africa (the region from which both I and the garment pictured hail) have strong graphic qualities and often incorporate fun, imaginative silhouettes. Textiles are also used, traditionally, to communicate messages about social status, culture, and family. The rich textile traditions I have grown up with necessarily inform the way in which I view dress and in turn, the body, and its senses.

Figure 12: An image of Evelyn Forrest's convertible jacket patent:

Forrest, Evelyn. GARMENT. U.S. Patent 144,875A Filed June 9, 1938.

Inside the image: Figure 1 is a perspective view of an embodiment of the invention, showing the garment as a cape. Figure 2 is a perspective view illustrating the garment as a coat. Figure 3 is a top plan view of the article, showing the garment spread out flat. Figure 4 is a view in side elevation of the invention.



Jan. 24, 1939. E. FORREST 2,144,875

GARMENT

Filed June 9, 1938 2 Sheets-Sheet 2

Fig. 3.

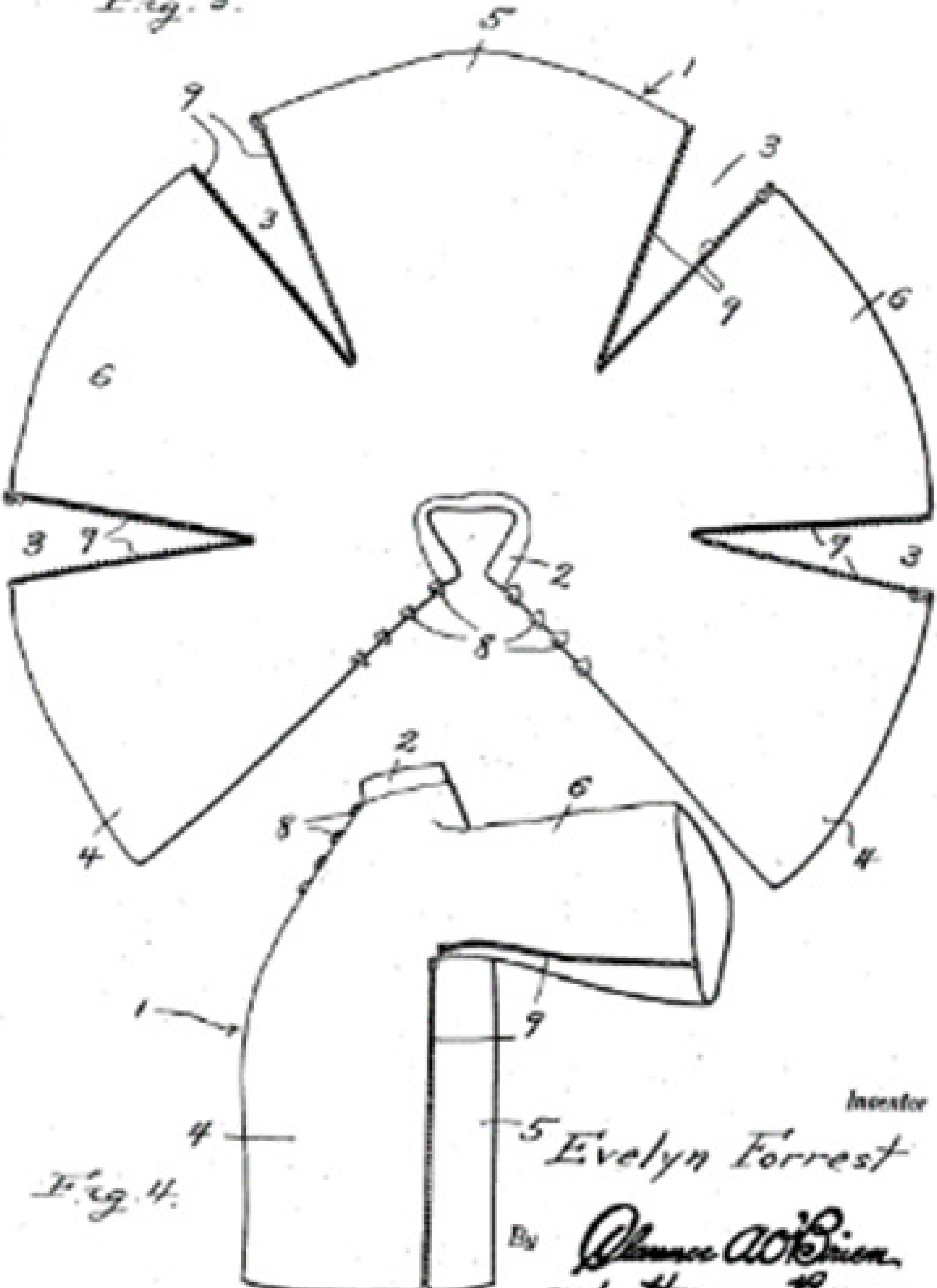


Fig. 4.

Inventor

Evelyn Forrest

By Clarence A. O'Brien and Hyman Berman

Attorneys

Figure 13: A Cameroonian man in traditional wear, from:

Arts Plastiques. "Le Tour Du Monde En Costume Ethnique," October 28, 2019. https://perezartsplastiques.com/2019/10/28/le-tour-du-monde-en-costume-ethnique/.

Figure 14 (above) & Figure 15 (left): Photos of the garment. Both by the author.

The garment (figures 14 & 15) is made with black cotton quilt backing fabric embroidered with 60g stainless steel conductive yarn (28 Ohms/ft resistance), measuring 23 inches in the bodice and 33 inches in the sleeves. There are 2 layers of fabric; conductive yarn is embedded in the top layer so that it can be touched from the exterior and protected by a second layer from the back to account for any signal noise from contact made when simply wearing the garment. The yarn is stitched in rows, grouped five at a time on the front of the torso, cuffs, sleeves, and shoulders of the garment. There are 38 possible inputs (mapped in figure 16), but in prototyping, hardware limitations meant only 32 were hooked up to a circuit. The embroidered steel rows, when connected to power, give off constant voltage readings. When touched by human skin, the readings drop, electronically indicating touch action. This is capacitive touch, which is how touch is computationally defined and measured.

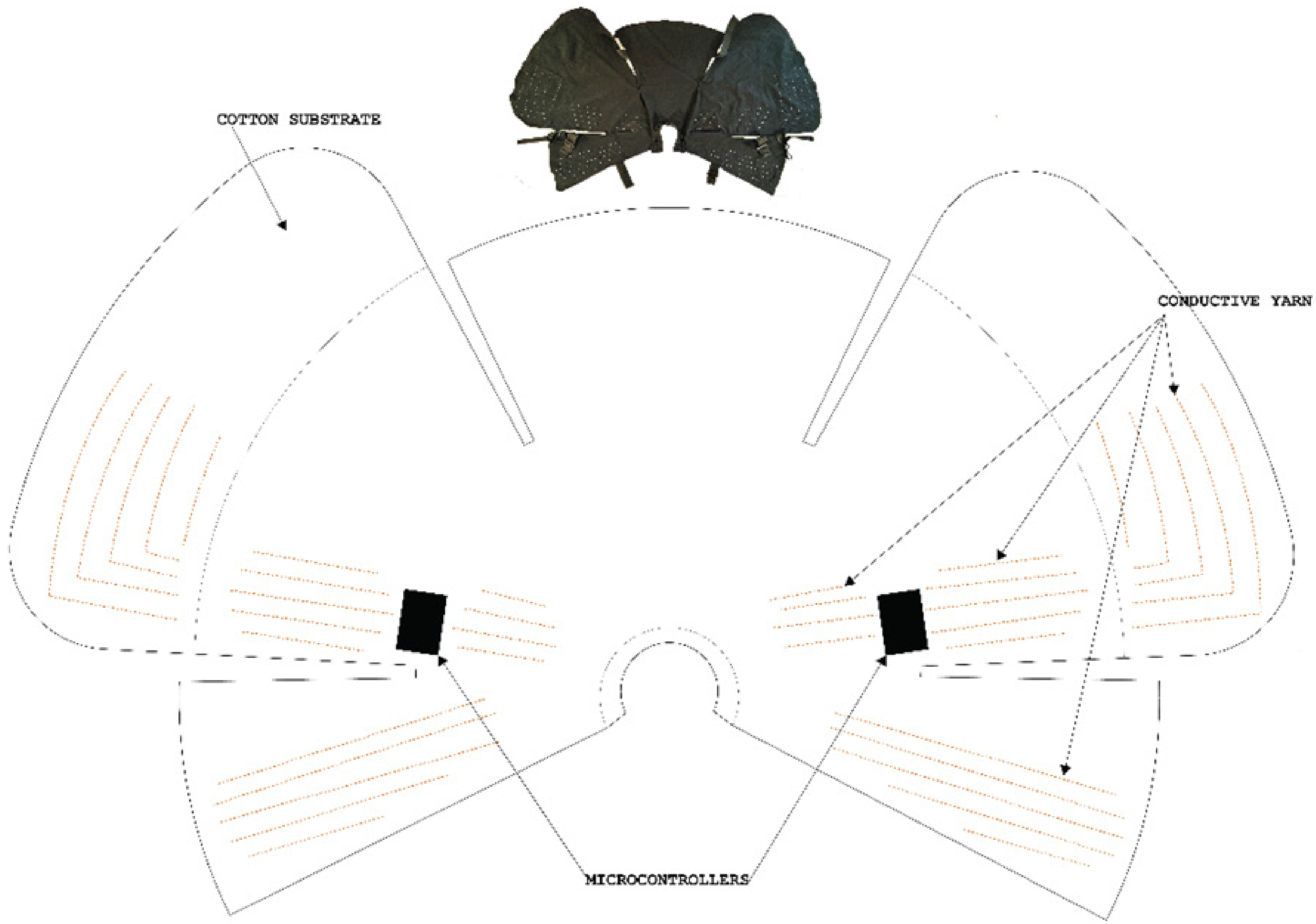


Figure 16: Schematic of the jacket, showing conductive yarn and micro-controller placement. Image by the author.

Hardware used for circuits:

- 1 AT MEGA 2560 Board (left side – 16 analog inputs for sensor rows)
- 1 Elegoo 2560 Board (right side – 16 analog inputs for sensor rows)
- 2 Adafruit data-logging shields (previously 2 microSD modules)
- 2 9-volt lithium batteries
- 32 alligator leads

The back ends of each sensory array were passed through the fabric to the interior, covered with a felt square for some insulation/resistance, and clipped by an alligator lead that was then connected to the micro-controller. Each section of connections was covered with more cotton fabric for protection (both for the wearer and the hardware). You can see this configuration in figure 17.

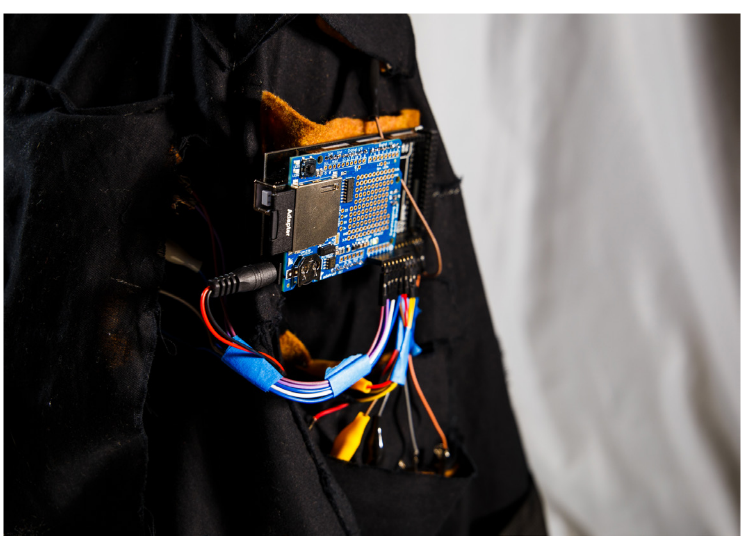


Figure 17: Photo of the right shoulder of the garment, showing the Elegoo 2560 board, its attached data-logging shield and analog connections. Photo by the author.

The code that the garment runs on is as follows:

```
/*
Pressure Sensing & Logging Matrix Code
parses through a pressure sensor matri grid by switching individual
rows/columns to be HIGH, LOW, or INPUT (high impedance) to detect
location and pressure. Logs each sensor value to .csv file by
microseconds and indicates 'touch' when sensor value < threshold
modified from code found at:
>> https://www.kobakant.at/DIY/?p=7443
and dataLogger example from SdFat library by Bill Greimen
*/

#include <SPI.h>
#include <SdFat.h>

#define numRows 16
#define numCols 1
#define sensorPoints numRows*numCols

int rows[] = {A15, A14, A13, A12, A11, A10, A9, A8, A7, A6, A5, A4, A3, A2, A1, A0};
//A0, A1, A2, A3, A4, A5, A6, A7, A8, A9, A10, A11, A12, A13, A14, A15
int cols[] = {1};
int incomingValues[sensorPoints] = {};


unsigned long then = 0;
unsigned long now = 0;
unsigned long between = 0;

const uint8_t chipSelect = SS;

// Interval between data records in milliseconds.
// The interval must be greater than the maximum SD write latency plus the
// time to acquire and write data to the SD to avoid overrun errors.
const uint32_t SAMPLE_INTERVAL_MS = 100;

// Log file base name.  Must be six characters or less.
#define FILE_BASE_NAME "Left"

SdFat sd; // file system object
SdFile file; //log file

uint32_t logTime; // time in micros for next data record.
const uint8_t ANALOG_COUNT = numRows;

//------------------------------------------------------------------------------
// Write data header.
void writeHeader() {
  file.print(F("micros"));
  for (uint8_t i = 0; i < ANALOG_COUNT; i++) {
    file.print(F(",adc"));
    file.print(i, DEC);
  }
  file.println();
}
```

```
//------------------------------------------------------------------------------
// Log a data record.
void logData() {


  uint16_t data[ANALOG_COUNT];

  // for (int i = 0; i < numRows; i++) {
  //     pinMode(rows[i], INPUT_PULLUP);
  //   }

  // for (int i = 0; i < numCols; i++) {
  //   pinMode(cols[i], INPUT);
  // }

  // Read all channels to avoid SD write latency between readings.
  for (uint8_t i = 0; i < ANALOG_COUNT; i++) {
    data[i] = analogRead(i);
  }

  // // Write data to file.  Start with log time in micros.
  file.print(logTime);

  // Write ADC data to CSV record.
  for (uint8_t i = 0; i < ANALOG_COUNT; i++) {
    file.write(',');
    file.print(data[i]);
    if (incomingValues[i] < 1021){
    file.print(" touch ");
    }
  }
  file.println();
  }

//==============================================================================
// Error messages stored in flash.
#define error(msg) sd.errorHalt(F(msg))
//==============================================================================

void setup() {

  const uint8_t BASE_NAME_SIZE = sizeof(FILE_BASE_NAME) - 1;
  char left[13] = FILE_BASE_NAME "00.csv";

  // set all rows and columns to INPUT (high impedance):
  for (int i = 0; i < numRows; i++) {
    pinMode(rows[i], INPUT_PULLUP);
    //calls current row; INPUT_PULLUP configures the pin as an input
    //and enables internal pull-up resistor.
    //When no external device connected, pin is at level of microcontroller
    //(reads HIGH by default, unless external device pulls LOW)
  }

  for (int i = 0; i < numCols; i++) {
    pinMode(cols[i], INPUT); //column pin as input
  }
  Serial.begin(9600);

  if (!sd.begin(chipSelect, SPI_FULL_SPEED)){
    sd.initErrorHalt();
```

```
  }

  // Find an unused file name.
  if (BASE_NAME_SIZE > 6) {
    error("FILE_BASE_NAME too long");
  }
  while (sd.exists(left)) {
    if (left[BASE_NAME_SIZE + 1] != '9') {
      left[BASE_NAME_SIZE + 1]++;
    } else if (left[BASE_NAME_SIZE] != '9') {
      left[BASE_NAME_SIZE + 1] = '0';
      left[BASE_NAME_SIZE]++;
    } else {
      error("Can't create file name");
    }
  }
  if (!file.open(left, O_WRONLY | O_CREAT | O_EXCL)) {
    error("file.open");
  }

  // Read any Serial data.
  do {
    delay(10);
  } while (Serial.available() && Serial.read() >= 0);

  Serial.print(F("Logging to: "));
  Serial.println(left);
  Serial.println(F("Type any character to stop"));

  // Write data header.
  writeHeader();

  // Start on a multiple of the sample interval.
  logTime = micros()/(1000UL*SAMPLE_INTERVAL_MS) + 1;
  logTime *= 1000UL*SAMPLE_INTERVAL_MS;

}

//------------------------------------------------------------------------------

void loop() {
  for (int colCount = 0; colCount < numCols; colCount++) {
    pinMode(cols[colCount], OUTPUT);
    digitalWrite(cols[colCount], LOW);

  for (int rowCount = 0; rowCount < numRows; rowCount++) {
    incomingValues[colCount * numRows + rowCount] = analogRead(rows[rowCount]);
  }// end rowCount

  pinMode(cols[colCount], INPUT); // set back to INPUT!
  // end colCount

  for (int i = 0; i < sensorPoints; i++) {
      if (incomingValues[i] < 1021){ //touch
        now = millis();
        between = now -then;
        Serial.print(i);
        Serial.print(" touched; last touch: ");
        Serial.print(between);
        Serial.print("\t");
```

```
    Serial.print("\t");
    Serial.println();
    }
   }
   then = now;
   delay(10);
 }


 // Time for next record.
 logTime += 1000UL*SAMPLE_INTERVAL_MS;

 // Wait for log time.
 int32_t diff;
 do {
   diff = micros() - logTime;
 } while (diff < 0);

 // Check for data rate too high.
 if (diff > 10) {
   error("Missed data record");
 }

 logData();

 // Force data to SD and update the directory entry to avoid data loss.
 if (!file.sync() || file.getWriteError()) {
   error("write error");
 }

 if (Serial.available()) {
   // Close file and stop.
   file.close();
   Serial.println(F("Done"));
   while (true) {}
 }
}

//------------------------------------------------------------------------------

//   for (int i = 0; i < sensorPoints; i++) {
//     Serial.print(incomingValues[i]);
//     if (i < sensorPoints - 1) Serial.print("\t");
//     }
//     Serial.println();
//     delay(10);
//   }
// }
```

This code is a combination of the pressure sensor matrix Arduino code found on kobakant.at and a data logging code that is part of the SdFat Arduino library created by Bill Greiman. It initializes each sensor input as a row or column (here there is only 1 column but the code has possibility for more) and pulls analog readings from each input, logged as seen in figure 18. The microcontroller sweeps for readings every 10 milliseconds. The maximum voltage reading is 1024 (an analog pull converted to digital units), but on average (on battery power) readings pull 1023-1021, and the touch threshold reading is 1020, from sample runs. The code will print “touch” for each detected instance of touch, saving data to csv files with timestamps in microseconds. When plugged into the computer or supplied with more than a 9-volt portable battery, readings from the sensors are more sensitive, pulling lower average ranges from 1020-1016, with 1015 as a touch threshold.

micros	adc0	adc1	adc2	adc3	adc4	adc5	adc6
400000	1021	1021	1021	1021	1021	1021	1022
500000	1021	1021	1021	1020	1022	1022	1022
600000	1021	1021	1021	1021	1022	1021	1022
700000	1020	1021 touch	1022	1023	1022	1021	1022
800000	1022	1022	1021	1021	1021	1021	1022
900000	1022	1021	1022	1021	1021	1022	1021
1000000	1021	1020	1022	1022	1021	1021	1021
1100000	1021	1020	1021	1021	1022	1021	1021
1200000	1020	1021	1021	1022	1022	1021	1021
1300000	1020	1022	1021	1021	1020	1021	1021
1400000	1021	1021	1020	1022	1022	1022	1021
1500000	1021	1021	1023	1021	1021	1022	1021
1600000	1021	1022	1020	1021	1021	1021	1021
1700000	1021	1022	1021	1022	1021	1021	1021
1800000	1022	1021	1021	1020	1022	1022	1021 touch
1900000	1021	1021	1022	1021	1023	1021	1021
2000000	1021	1022	1021	1020	1021	1022	1022
2100000	1020 touch	1021	1021	1022	1021	1022	1021
2200000	1021	1022	1021	1023	1021	1021	1021
2300000	1021	1021	1021	1023	1021	1021	1021
2400000	1022	1021	1022	1021	1022	1022	1021
2500000	1021	1021	1021	1021	1022	1021	1021
2600000	1022 touch	1021 touch	1021	1021	1023	1020	1021
2700000	1021 touch	1022	1020	1020	1022	1021	1021
2800000	1020	1020	1022	1022	1021	1021	1021
2900000	1022 touch	1021	1021	1021	1021	1021	1021
3000000	1021 touch	1021	1021	1021	1022	1021	1022
3100000	1021	1021	1022	1021	1021	1021	1021
3200000	1021 touch	1021	1022	1021	1021	1021	1021
3300000	1021	1021	1021	1021	1021	1021	1021
3400000	1021	1021	1021	1022	1021	1022	1021
3500000	1021	1021	1021	1020	1022	1021	1022

Figure 18: Sample readings from the left-hand micro-controller.

adc9	adc10	adc11	adc12	adc13	adc14	adc15
1022	1022	1022	1022	1022 touch	1022	1022
1021	1022	1022	1022	1022	1022	1022
1022	1022	1022 touch	1022	1022	1022	1022
1021	1022	1022	1022	1022	1022 touch	1022
1021	1022	1022 touch	1021	1022	1021	1022
1021	1021	1021	1021	1022	1022	1022 touch
1022	1021	1022	1021 touch	1021	1022	1022
1022	1021	1022	1021	1022 touch	1022	1022
1022	1021	1021	1022	1022	1022	1022
1021	1021	1021	1021	1022 touch	1022	1022
1022	1022	1022	1022	1022 touch	1022	1022
1022	1022	1022	1022	1022	1022	1022
1022	1021	1022	1021 touch	1022	1022	1022
1022	1021	1022	1022	1022	1022	1022
1022	1022 touch	1022	1022	1022	1022	1022
1022	1022	1022	1022	1022	1022	1022
1022	1022	1022 touch	1022	1022	1022	1022
1022	1021	1021	1022	1021	1022	1021
1021	1022	1021	1022	1021	1022	1022
1021	1021	1021	1022	1021 touch	1022	1022
1021	1022	1022	1022	1022 touch	1022	1022
1021	1021	1022	1022	1022	1022	1022
1022	1021	1022	1022	1022	1022 touch	1021
1022	1021	1022	1022	1022	1022	1022
1022	1022	1022 touch	1022	1022	1022	1022 touch
1022	1022	1021	1022	1022 touch	1022	1022
1022	1021	1022	1021	1022	1022	1022
1022	1022	1022	1022	1022 touch	1022	1022
1022	1021	1022 touch	1021	1022	1022	1021
1022	1022	1022	1022	1022	1022	1022
1022	1022 touch	1021	1022 touch	1021	1022 touch	1022
1022	1022	1022 touch	1022	1022	1022	1022

Figure 18 (cont.): Sample readings from the left-hand micro-controller. Image by the author.

The Proposed Study

Description: This study is a series of conversations that revolves around introducing subjects to a touch-sensitive garment that they will be asked to try on and interact with. The subject will have a conversation with the investigator while wearing the garment. The subject will be told that the garment records its wearer's physiological signs (such as heartbeat) rather than that it records touch explicitly. This is done to remove the aspect of self-consciousness about one's habits and allows the conversation to flow more freely. The conversation between the investigator and the subject will be about the subject's work or research and daily life. The goal is to understand how individuals use self-touch as a mood-regulation tool, so questions will be designed to elicit a heightened response. After the initial conversation subjects will be debriefed and asked to answer questions about their mood throughout the conversation. The conversation will be recorded for ease of analysis later in correlating touch instances and mood.

Domain:

1. **Duration:** 1 hour
2. **Setting:** MIT Room 3-329. A seminar room available for reservation through Atlas. There will be a camera on a tripod set up at the front of the room. The garment will be on a dress form on a table near the camera and there will be a full-length mirror resting on the wall behind, reflective side towards the wall. The camera is positioned so that, when subjects are seated, only their torsos and hands are in view. The investigator will be seated across from the subject but not in view of the camera.
3. **Participants:**
    a. The investigator [Deborah Tsogbe]
    b. The subject(s) [4 adults within the School of Architecture and Planning at MIT]
    c. The garment

4. Background + Definitions:

a. Research has found that individuals use self-touch more when engaged in "communicative tasks involving difficult encoding of information" (Kronrod & Ackerman, 2019). The conversation in this study will serve as a task that exacerbates the need for self-regulation and provide insight into how participants use self-touch for mood-regulation, if at all. The entire interaction will be videotaped and, as the conversation progresses, the garment will log touch data that the investigator will later analyze and visualize.

b. Moods can be understood as a general feeling state that colors behavior and day-to-day events and are a functional tool for monitoring our internal state (where emotions are externally focused, monitoring the environment) (Desmet, 2015). When our internal calm is disrupted (such as when engaging in difficult communicative tasks) we may subconsciously engage in more self-touch, which increases self-focused attention and in turn increases attitude extremity (such as having a higher self-opinion) (Konrod & Ackerman, 2019). This study will build on previous studies to provide greater accuracy on the type of self-touch engaged in for self-regulation and whether that is correlated with mood-states.

c. Let's define self-touch as "a conscious or unconscious gesture involving an individual contacting their own body" such as touching one's hair or chin with a finger (Oxford Reference, 2023). Self-touch can be emotionally expressive, or for concentration, nervous mannerisms (like biting one's lip), or self-adaptive behaviors such as hugging oneself. Self-touch is often more inhibited in public settings versus in private settings (Oxford Reference, 2023).

    i. In this study, self-touch will be quantified as instances of tapping, resting, rubbing, or squeezing recorded by the garment while being worn by a subject; it cannot distinguish type but it records a pressure reading at each occurrence that falls beneath a certain threshold. Any action by the wearer towards the garment will be encoded into an appropriate matrix of data points, defined by time and location.

d. Let's define a conversation as a "progression of exchange among participants", where participants are "learning systems" - that is, they change internally because of their experiences (Dubberly and Pangaro, What is Conversation? How can we design for effective conversation? 2009). Two of the participants, the researcher, and the subject, are humans, and so we know that they are capable of effective conversation. The garment is a sensing technology that can distinguish meaningful signals from noise, assign meaning to them, and act on those signals by logging them to a database, and so it is able to engage in conversation, in the technical sense.

   i. The basic steps to effective conversation (from Dubberly & Pangaro, 2009):

      1. An entity (being an organizationally closed system) opens a channel for communication.
      2. The other participant(s) commits to engage (usually by paying attention)
      3. The participant(s) construct meaning from the concepts that are shared in the conversation (such as leisure activities or feelings)
      4. The participant(s) evolve in some way (perhaps change their opinion or learn something new)
      5. The participant(s) converge on an agreement about the concept being discussed.
      6. The participant(s) act or transact on what has been agreed upon (perhaps a plan for lunch, perhaps establishing a relationship)

5. Goal:

a. To understand if and how individuals use self-touch as a mood-regulation tool. This will be achieved by quantifying instances of self-touch detected by the garment during a conversation with a subject. Variables include:

i. The location of touch (upper and lower arms, hands, torso, neck area)

ii. The pressure reading at the moment a touch action occurred (recorded as a value between 0-1024 V; an average reading for 'light touch' is usually below 1020).

iii. The duration of touch (each instance is timestamped)

iv. At which point(s) in the conversation the action is done (what the person was saying/talking about and/or feeling at the moment a touch action was recorded)

v. Whether instances of self-touch correspond to a change in mood in the participant.

Equipment:

1. One touch-sensitive garment equipped to recognize touch. Fabricated by Deborah Tsogbe (the investigator).

The main body of the garment is made of cotton which has been embroidered with conductive threads (spun aluminum) which are connected to two 2560 micro-controllers. The garment is constantly monitoring the voltage output of the threads; a spike or dip in voltage signifies an instance of touch. In a significant instance (lower than a given threshold of voltage readings) the garment will log the voltage output at that moment in an appropriate matrix for the type and location of touch.

1. One digital camera with video-recording capabilities + tripod
    a. For recording interviews

The Conversation:

1. The investigator will meet the subject outside of the room and walk them in (so that no one gets lost trying to find the location). The garment will be on a dress-form set up along the south wall of the room next to a table which will hold the camera and PC.

2. The investigator will introduce themselves, explain the project briefly, and ask the subject if they are ok with signing a consent form. The investigator might say something like:

    a. This is a smart garment that records its wearer's physiological signs, like temperature and heartbeat. We'll be having a conversation while you're wearing it so I can see if you are able to get comfortable in it, and the conversation will serve as a sort of baseline task to gauge whether the garment is working properly in monitoring your physiology. The data collected by the garment will be de-identified, so your data will be assigned a random number identifier for analysis. The video recording may be shown during my final presentation, with your face cropped out, but if that makes you uncomfortable it isn't necessary.

3. If the subject decides to proceed, they will sign the consent form, the investigator will turn on the camera, and the conversation can begin.

4. The subject will put on the garment; the investigator will give them some time to adjust to their liking. Before the investigator begins asking questions, the subject can ask their own questions. The investigator will answer to the best of their abilities without revealing the true goals of the study or biasing the results.

5. The investigator will ask these questions throughout the course of the conversation, starting with (i) but not necessarily going in order down the list, instead letting the subject's responses guide the direction.

    i. Do you come to campus every day?

    ii. Can you tell me about your work or research?

    iii. Do you think you've taken on a good amount of work this semester? Are you able to balance things well?

i. Do you think that the things you're working on now have a lot of impact on your future?

ii. Can you describe your best-case scenario in terms of where you'll be in five years?

iii. Can you describe your worst-case scenario in terms of where you'll be in five years?

iv. Do you think that the things you're working on now are fulfilling? What aspect of your work or research brings you the most satisfaction?

v. Do you compare yourself to your peers in your work? How so?

vi. What do you like most about being at MIT?

6. When all above questions have been asked, or the initial conversation has lasted 15 minutes (whichever comes first), the investigator will wrap up talking and let the subject know that the main portion of the study is over. The subject can take off the garment now if they choose.

7. The investigator will tell the subject the true goals of the conversation and ask if they wish to proceed with the rest of the study. If they decline, then their data will be omitted from the study. The investigator will say something like:

    a. Thank you for talking with me today, I hope the conversation wasn't stressful for you. The garment you were wearing today was not recording your physiological signs but rather touch. The intended nature of the study was to observe whether, if engaged in a potentially stressful communication task like a probing conversation, you would use self-touch more to relax or comfort yourself. By self-touch I mean any gestures you make towards yourself like touching your hair, rubbing your arm, crossing your arms, etc. Do you have any questions about that?

8. If the subject proceeds, the investigator will ask these questions to gain insight into their mood state during the interview:
   i. Are you aware of any self-touch behavior in general, anxious or not?
   ii. How would you describe your mood throughout the interview?
   iii. Did any part of the conversation bring up any stress or anxiety? (Which part?)
   iv. Did you notice anything about what you were doing with your hands? Do you think it affected you in any way?
   v. Do you have any comments about how it felt wearing the garment?
   vi. Do you have any opinions about the design of the garment?

9. Once all questions are answered or 15 minutes have passed, whichever comes first, the investigator will ask the subject if they wish to see themselves in the mirror, as they have not yet seen themselves. This is just to see if the subject might make any comments about the garment purely as a clothing item, and how it makes them feel to wear it. If so, the investigator will set up the mirror (still in view of the camera) for the subject to look in. The subject can ask more questions or make more comments during this time. After the subject is done (or if more than 10 minutes have passed) the investigator will end the study.
10. The investigator will thank the subject for their time, ask them to take the garment off if still wearing it, turn off the camera, and escort them out of the room. The space will either be reset for the next conversation or packed up.

Endpoints + Outcomes:

1. Instances of self-touch (by the participant) will occur in relation to changes in mood.

2. The investigator will produce a map of touch interactions with the garment for each conversation. This map will show locations of self-touch instances recorded by the garment. The locations will be connected to types of touch because of the sensor patch deployed in the instance. By visualizing location and type of touch, perhaps the data can be correlated with instances of stress/mood-shift in the individual.

Conclusion

Findings & Next Steps

I was able to successfully deploy the garment for some preliminary testing and control evaluation.

This trial period has helped me to understand the behavior of the garment when in motion on a body, how wearers interact with it in return, functionality improvements, and a renewed approach to the methodology.

One of the initial obstacles was the physical configuration of the hardware. When the garment is worn, the micro-controllers sit against the edges of the chest and, since there are several wires extending outward from the boards, they might feel unnatural or uncomfortable when worn for an extended period. This also relates to a fundamental hardware issue where, if any part of the circuit connected to the microSD or battery is disrupted, data logging ceases immediately. This was observed when I had two individuals wear the garment casually while the left half was connected to a micro-controller. The first individual wore the garment for a total of 30 minutes: 20 minutes worn while walking around MIT campus, with no defined task, 5 minutes sitting down with no task, and another 5 minutes sitting with no task. In the initial wear, the microSD module was jostled, and data logging was disrupted. The subsequent tries were intervals of 1 minute each while I rewired the circuit and did some troubleshooting. The last 5 minute wear produced successful logs, even with normal movements while sitting (crossing the arms, for example). The last 5.94 minute interval produced no 'touch' logged, so I decided to increase the threshold from 1020 to 1021, as there were no recordings of a '1020' reading within the log, of which you can see the first 3,300,000 microseconds (4 seconds) in figure 19 (page 66).

The second individual wore the garment for one period of 5 minutes, sitting down with no defined task. With a higher threshold of 1021, the garment did successfully log touch as it happened, but a disruption in the module caused a read error, stopping the log at 11700000 microseconds (11.7 seconds).

Neither individual reported any discomfort in wearing the garment for a period of time, but future testing will require intervals up to 60 minutes long for more nuanced evaluation. As this first round was purely to assess garment function and wearability, the demographics of the individual testers are not pertinent.

After these two short use evaluations, I updated the physical hardware of the garment to include Adafruit datalogging shields for the microSD cards rather than using the smaller, more finicky individual modules. This is the configuration shown in figure 17 on page 46. Datalogging shields are more physically secured to the micro-controller and may allow a wider range of motion from the wearer.

In the subsequent round of user evaluation, the garment was given to 3 different individuals to wear while they went about their regular activities on MIT campus for a period up to one hour, with an average logging time of 51.97 minutes. All individuals were graduate students within the Department of Architecture, 2 male-identifying individuals (32 and 25, both Caucasian) and one female-identifying individual of Middle-Eastern descent, age 27.

The female participant logged an average (for both sides of the body) of 63.23 instances of touch per minute with a total of 5,273 accumulated touch detections over a 51.7 minute period, a majority being on the torso region. A portion of the readings from the left side of the garment are shown in figure 20 (page 68).

In contrast, the 32 year old male logged an average of 11.39 touch detections per minute with a total 1459 accumulated detections over a 64.12 minute period and no trend in location, and the 25 year old male logged an average of only 0.44 touch detections per minute with total 35 accumulated detections over a 40.50 minute period and no major trend in location.

The third round of user evaluation was a trial run of the conversation series intended to be the central component of the study. I engaged in conversation with 6 individuals who study and work in the Department of Architecture at MIT. As the study unfolds, time has necessarily become a concern because of the nature of human behavior and emotion. The questions proposed previously changed after the first test, coming to focus more on topics of routine, work, and the relationship that one's physical situatedness has to feeling fulfilled and comfortable in one's own body.

While there is quantitative data to assess, the qualitative data seems more pressing to consider. Where in the beginning my intentions going in was to speak about work ambitions and daily routines with the intention to uncover some anxieties or insecurities, but ended up focusing more on how people physically inhabit their bodies and the way they conceptualize of and organize their behaviors based on that physicality. In the end the conversations prompted some consideration of the importance of a practiced awareness of one's body to a stable self-concept. This self-concept then relates to how people interact physically with themselves.

The data gathered so far does not indicate any strong correlation between self-touch and emotional-state, not because there is none, but because the nature of the studies conducted thus far don't really lend themselves to a straightforward analysis of affective touch. The data rather points towards the need for a long-term, focused behavioral assessment in which the researcher encourages a relationship between the garment and the wearer and has capability to regularly assess the mood and behavior of the subject. The nature of this subject matter requires a holistic evaluation of participants in order to properly understand the role of touch in any given life experience.

icros	adc0	adc1	adc2	adc3	adc4	adc5	adc6
400000	1021	1021	1021	1021	1021	1021	1021
500000	1021	1021	1021	1021	1021	1021	1021
600000	1021	1021	1021	1021	1021	1021	1021
700000	1021	1021	1021	1021	1021	1021	1021
800000	1021	1021	1021	1021	1021	1021	1021
900000	1021	1021	1021	1021	1021	1021	1021
1000000	1021	1021	1021	1021	1021	1021	1021
1100000	1021	1021	1021	1021	1021	1021	1021
1200000	1021	1021	1021	1021	1021	1021	1021
1300000	1021	1021	1021	1021	1021	1021	1021
1400000	1021	1021	1021	1021	1021	1021	1021
1500000	1021	1021	1021	1021	1021	1021	1021
1600000	1021	1021	1021	1021	1021	1021	1021
1700000	1021	1021	1021	1021	1021	1021	1021
1800000	1021	1021	1021	1021	1021	1021	1021
1900000	1021	1021	1021	1021	1021	1021	1021
2000000	1021	1021	1021	1021	1021	1021	1021
2100000	1021	1021	1021	1021	1021	1021	1021
2200000	1021	1021	1021	1021	1021	1021	1021
2300000	1021	1021	1021	1021	1021	1021	1021
2400000	1021	1021	1021	1021	1021	1021	1021
2500000	1021	1021	1021	1021	1021	1021	1021
2600000	1021	1021	1021	1021	1021	1021	1021
2700000	1021	1021	1021	1021	1021	1021	1021
2800000	1021	1021	1021	1021	1021	1021	1021
2900000	1021	1021	1021	1021	1021	1021	1021
3000000	1021	1021	1021	1021	1021	1021	1021
3100000	1021	1021	1021	1021	1021	1021	1021
3200000	1021	1021	1021	1021	1021	1021	1021
3300000	1021	1021	1021	1021	1021	1021	1021

Figure 19: Data logged from the left side of the garment, showing all 16 inputs (torso, shoulder, elbow area, and wrist). Image by the author.

adc8	adc9	adc10	adc11	adc12	adc13	adc14	adc15
1021	1021	1021	1022	1022	1021	1022	1022
1021	1022	1022	1022	1022	1022	1022	1022
1021	1021	1022	1022	1022	1022	1022	1022
1021	1021	1021	1022	1022	1022	1022	1022
1021	1021	1021	1022	1022	1022	1022	1022
1021	1021	1021	1022	1022	1022	1022	1022
1021	1021	1021	1022	1022	1022	1022	1022
1021	1021	1021	1022	1022	1022	1022	1022
1021	1021	1022	1021	1022	1022	1022	1022
1021	1021	1021	1022	1022	1022	1022	1022
1021	1021	1021	1021	1022	1022	1022	1022
1021	1021	1022	1022	1022	1022	1022	1022
1021	1021	1021	1022	1022	1022	1022	1022
1021	1021	1022	1022	1022	1022	1022	1022
1021	1021	1021	1022	1022	1022	1022	1022
1021	1021	1021	1022	1022	1022	1022	1022
1021	1021	1022	1021	1022	1022	1022	1022
1021	1021	1022	1021	1022	1022	1022	1022
1021	1021	1021	1022	1022	1022	1022	1022
1021	1021	1021	1022	1022	1022	1022	1022
1021	1021	1021	1022	1022	1022	1022	1022
1021	1021	1022	1022	1022	1022	1022	1022
1021	1021	1021	1022	1022	1022	1022	1022
1021	1021	1022	1021	1022	1022	1022	1022
1021	1021	1021	1022	1022	1022	1022	1022
1021	1021	1022	1022	1022	1022	1022	1022
1021	1021	1022	1022	1022	1022	1022	1022
1021	1021	1021	1022	1022	1022	1022	1022
1021	1021	1021	1022	1022	1022	1022	1022
1021	1021	1021	1022	1022	1022	1022	1022

Figure 19 (cont.)

micros	adc0	adc1	adc2	adc3	adc4	adc5	ad
2220150000	1021	1021	1021	1021	1021	1021	
2220300000	1021	1021	1021	1021	1021	1021	
2220450000	1021	1021	1021	1021	1021	1021	
2220600000	1021	1021	1021	1021	1021	1021	
2220750000	1021	1021	1021	1021	1021	1021	
2220900000	1021	1021	1021	1021	1021	1021	
2221050000	1021	1021	1021	1021	1021	1021	
2221200000	1021	1021	1021	1021	1021	1021	
2221350000	1021	1021	1021	1021	1021	1021	
2221500000	1021	1021	1021	1021	1021	1021	
2221650000	1021	1021	1021	1021	1021	1021	
2221800000	1021	1021	1021	1021	1021	1021	
2221950000	1021	1021	1021	1021	1021	1021	
2222100000	1021	1021	1021	1021	1021	1021	
2222250000	1021	1021	1021	1021	1021	1021	
2222400000	1021	1021	1021	1021	1021	1021	
2222550000	1021	1021	1021	1021	1021	1021	1
2222700000	1021	1021	1021	1021	1021	1021	
2222850000	1021	1021	1021	1021	1021	1021	
2223000000	1021	1021	1021	1021	1021	1021	
2223150000	1021	1021	1021	1021	1021	1021	
2223300000	1021	1021	1021	1021	1021	1021	
2223450000	1021	1021	1021	1021	1021	1021	
2223600000	1021	1021	1021	1021	1021	1021	
2223750000	1021	1021	1021	1021	1021	1021	
2223900000	1021	1021	1021	1021	1021	1021	
2224050000	1021	1021	1021	1021	1021	1021	
2224200000	1021	1021	1021	1021	1021	1021	
2224350000	1021	1021	1021	1021	1021	1021	
2224500000	1021	1021	1021	1021	1021	1021	
2224650000	1021	1021	1021	1021	1021	1021	
2224800000	1021	1021	1021	1021	1021	1021	

Figure 20: Readings from the left side of the garment while wearing it with no defined task. Shows readings from 37.005 minutes to 37.09 minutes. Image by the author.

adc6	adc7	adc8	adc9	adc10	adc11	adc12
1021	1021	1021	1021	1020	1022	1021
1021	1021	1021	1021	1021	1022	1022
1021	1021 touch	1020	1022	1021	1022	1021
1021	1021 touch	1021	1021	1022	1022	1022
1021	1021	1021	1021	1022	1022	1022
1021	1021	1022	1022	1021	1022	1022
1021	1021	1021	1021	1022	1022	1022
1021	1021	1020	1022	1022	1022	1022
1021	1021	1021	1022	1022	1022	1022
1021	1021	1021	1021	1022	1022	1022
1021	1021	1020	1021	1022	1022	1022
1021	1021	1022	1021	1022	1022	1022
1021	1021	1020	1021	1022	1022	1022
1021	1021	1022	1022	1022	1022	1022
1021	1022	1022	1022	1022	1022	1022
1021	1021	1021	1022	1022	1022	1022
1021 touch	1021	1022	1022	1022	1022	1022
1021	1021	1020	1022	1022	1022	1021
1021	1021	1021	1020	1021	1022	1022
1021	1021	1021	1022	1022	1022	1022
1021	1021	1021	1022	1021	1022	1022
1021	1021	1021	1022	1022	1022	1022
1021	1021	1020	1021	1022	1022	1022
1021	1021	1022	1022	1022	1022	1022
1021	1021	1021	1023	1022	1022	1022
1021	1021 touch	1021	1022	1022	1022	1022
1021	1021	1022	1022	1022	1022	1022
1021	1021	1021	1020	1020	1022	1022
1021	1021 touch	1022	1022	1021	1022	1022
1021	1022	1020	1022	1022	1022	1022
1021	1022	1022	1023	1022	1021	1021
1021	1021	1020	1022	1021	1022	1022

Figure 20 (continued)

Contributions & Reflections

Ultimately, the garment and framework developed herein represent a turning point in research on the tactile sense. Previously, methodologies have relied on clinical environments to evaluate touch expressions or on narrative accounts of touch experiences. The garment offers the possibility to conduct research at a more intimate, naturalistic scale that might reveal more intricacies in touch behaviors than studies where, for example, participants have the ways in which or reasons why touch is enacted dictated to them. The latter methods may yield less generalizable data, giving us insight into only one magnified aspect of touch. By leaving it up to the garment to register and log touch, it frees the consciousness of the wearer and the investigator to focus on the affective dimensions of the interactions at hand.

Some factors to consider in further development: the fact that people's behavior in unfamiliar or new circumstances may be inherently inhibited (in that participating in a study alone may be an unfamiliar circumstance), and what kind of touch behavior is encouraged or discouraged by the textile itself (are people more likely to touch cotton or organic fibers versus synthetic, or vice versa?). Even such a thing as the garment not being in someone's taste may alter the interactions they have with themselves while wearing it.

I think the most important next step beyond these factors is to consider time much more seriously and as a major influence in [touch] behavior. A possibility might be to fabricate a range of touch-sensitive objects with which people might fill their daily lives and develop a routine or relationship with, and the data from these would be much richer for drawing conclusions.

I look forward to being able to explore my questions in greater depth. Even with limited functionality in these early stages, the capabilities embedded in the garment have implications for the way we conceptualize touch as an embodied experience. Further iteration on this framework may yield a variety of objects traditionally ubiquitous to human living - garments or wearable items being the most familiar of these. The human experience is peculiar to me in the way it is tethered to concepts of dress and physicality. In using computational means to examine the tactile dimensions of this experience, I am necessarily probing at the concepts we have established about ourselves as individuals and in relation to our communities and how our physical selves influence our emotional selves.

Figure 21: Photo of a hand resting on the garment. Photo by Myles Sampson.

Figure 22: Close-up photo of the garment’s left sleeve. Photo by the author.

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