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Title of Thesis: Developing an Ethical Framework for Affective Computing Applications

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ABSTRACT

Title of Document: Developing an Ethical Framework for Affective Computing Applications.

Lydia Stamato, Master of Science, 2020

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Sensing technologies increasingly common in both private and public spaces present the opportunity for systems aware of and responsive to human emotion (affective computing). The personal and social consequences of affective computing applications in ubiquitous computing environments are not well understood. This thesis seeks to illuminate these potential impacts by analyzing three types of human-computer interaction described in an account of a neighborhood's experience with smart home security cameras, applying the Process-Person-Context-Time model—an ecological systems theory model commonly used in social science and developmental psychology

research—to a design scenario and set of counterfactuals. This approach highlights potential developmental consequences of this technology and the interconnected effects of interaction, informing a preliminary framework for considering the ethical application of affective computing in private and shared spaces. This framework aims to support ethical decision-making regarding affective computing technology by researchers, designers, policy makers, and everyday users and other stakeholders.

DEVELOPING AN ETHICAL FRAMEWORK FOR AFFECTIVE COMPUTING APPLICATIONS.

By

Lydia Stamato.

Thesis submitted to the Faculty of the Graduate School of the University of Maryland, Baltimore County, in partial fulfillment of the requirements for the degree of
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One of the main takeaways from this thesis regards the potentially life altering impact of hidden processes. Thus, it is impossible to thank everyone who has helped me along the way. I am grateful beyond measure for all of the unacknowledged interactions that have contributed to my development and begin by acknowledging those who have walked alongside or guided me on my thesis journey.

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Try as I might, I cannot capture the scope and impact of Bharat Prakash's kind and generous spirit. Some birbs were born to be free ♥

"For within living structures defined by profit, by linear power, by institutional dehumanization, our feelings were not meant to survive. Kept around as unavoidable adjuncts or pleasant pastimes, feelings were expected to kneel to thought as women were expected to kneel to men. But women have survived. As poets. And there are no new pains. We have felt them all already. We have hidden that fact in the same place where we have hidden our power. They surface in our dreams, and it is our dreams that point the way to freedom. Those dreams are made realizable through our poems that give us the strength and courage to see, to feel, to speak, and to dare."

Audre Lorde, *Poetry is Not a Luxury* (1977)

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Chapter 1. Introduction

That the verb "to affect" (sometimes confused with another verb, "to effect") and the noun "affect" share the same spelling is no coincidence: we are affected by affect, by our physiological and emotional responses to countless everyday events that take place in private and public spaces. Consider what you feel when you spot a security camera. And, if you own a home security camera, what you feel when you receive alerts, or review recordings on a companion app. Furthermore, whether or not you own a home security camera, you may notice feelings that arise when you encounter video footage or still images posted online by others. If readers wonder why it matters; they are wondering whether this thesis *affects* them. While the users' emotions have long been acknowledged by user experience designers, emerging computing technologies that aim to *sense* and *respond* to the affects of users and other stakeholders present a novel opportunity for interaction design.

My thesis explores this new territory in human-computer interaction (HCI) and the ethical issues that may arise using ecological systems theory as a compass. Ecological systems theory is well-suited to aid in understanding how affective computing systems and humans (together with other environmental factors) interact and can highlight how variations in system or product design and implementation may result in different and more or less desirable outcomes. A design scenario with detailed counterfactual analysis using ecological systems theory culminates in proposed directions toward an ecological framework for ethical decision-making in the research, design, evaluation, and acceptance of affect-aware computer systems.

Motivation

Langdon Winner's 1980 article "Do Artifacts Have Politics?" (Winner, 1980) is considered one of the most influential texts in the social study of technology (Matthewman, 2011, p. 70). In this article, Winner introduces technologies and applications imbued with the political priorities of their creators. These priorities are invisible to users, especially when accustomed to them. As an example, he points to the 200 or so bridges spanning parkways in Long Island designed and built by the public official Robert Moses in the mid-twentieth century. While one may not be inclined to attach any particular meaning to the low clearance of these bridges, Winner argues that they were built this way intentionally to prevent city busses from passing, limiting access by people reliant on public transportation and thereby of less means—a theory supported by Moses' biographer. While this and the other examples Winner provides are compelling and have been widely perpetuated without criticism, they are not without controversy (Matthewman, 2011).

The present study is partially motivated by Winner's question, which remains a matter of debate. This thesis seeks to explain why technologies are as they are (or could be), but also to illuminate the impact of design[1] choices and the benefits or harms that result (or could result) from them. Thus, this is not a deontological ethics that looks for rules that can be followed to ensure a positive outcome, but rather a pragmatic ethics that is social and iterative (Dewey, 1922).

Current events and challenges

Trends in contextually aware computing involve devices with intimate knowledge of users' lives; collecting, for example, data about biophysical and emotional states, daily routines, relationships, and more. These data improve the user experience and usability of systems and can make possible new kinds of systems. At the same time, technologies designed to enhance usability and convenience collect troves of data from active and passive users alike, challenging privacy norms.

The following case initially drew me to this work by demonstrating the risk of assuming technology is neutral and highlighting the importance of considering sociotechnical systems as complex ecological contexts of use.

At least since the spring of 2017, a campaign to control citizens in the northwestern province of the People's Republic of China known as Xinjiang [translation: "new frontier"] Uyghur Autonomous Region (XUAR)

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[1] By "design" I refer not only to the software, hardware, user interface and interaction design, but also the broader strategy of designing and implementing interconnected ecosystems of products and services facilitated by computing technology.

(unofficially East Turkestan) has been underway. It is estimated that nearly two million Uyghur, Kazakh, and other Muslim ethnic minority Chinese citizens have been detained without charge in internment camps (Lipes, 2019). While foreign journalists and external agencies have had little access to the area, the nature of these camps—euphemized in Chinese as “vocational training centers”—has been described in detail by Uyghurs who have escaped and citizens of neighboring Kazakhstan erroneously imprisoned and since released (Mauk, 2019). Their descriptions are evocative of the worst atrocities in human history.

This campaign has relied on emerging technologies to surveil and control residents of the area. Facial recognition technologies built into public surveillance cameras have been designed specifically to identify people of Uyghur ethnicity (Mozur, 2019). Residents of the region (including ethnic majority Han residents) have been forced to provide biometric data samples including blood (to extract DNA), fingerprints, the face from various angles, and voice recordings (Chang & Fountain, 2019). Other kinds of data are amassed, including location, phone use, communication data, and purchase history (Shih, 2019).

The Chinese Communist Party (CCP) has repeatedly and with the support of the United States pointed both to the Bush era “war on terror” and to the mass surveillance of US citizens empowered by the Patriot Act as justification for increased surveillance of Uyghur citizens (Leibold, 2019; Millward, 2004). A more concrete factor is the CCP’s escalating pursuit of remote economic development initiatives: settlement activities in XUAR for this purpose have disrupted the local agricultural economy, which experts point to as instigation of recent unrest in the region (Byler, 2018).

The reported (and openly disclosed) mass surveillance is at least in part driven by research conducted by scientists from Microsoft Research Asia with the Chinese military university National University of Defense Technology. This collaboration was first reported by *Financial Times* (Murgia & Yang, 2019), but attempts to locate the publications resulting from the research have been unsuccessful. In response to Microsoft President Brad Smith calling for "public regulation and corporate responsibility" in facial recognition technology (Smith, 2018), Stanford University's Center on Democracy, Development and the Rule of Law described Microsoft as, "way ahead of the curve in thinking seriously about the ethical implications of the technology they're developing and the human rights implications of the technology they're developing" (Thurm, 2018). Microsoft defends its collaboration with the National University of Defense Technology, stating that, "the technologies have no closer relation to surveillance than WiFi or [an] … operating system" (Editorial Board, 2019). While illustrative of the tension of between artifacts and politics, I am not alone in finding this response inadequate given the unique affordances of facial recognition technology (Stark, 2019).

There is no evidence that these surveillance strategies include identification of affect, however facial recognition cameras and contact-free physiological data collection have recently been used to control the spread of the novel coronavirus (2019-nCoV), raising concerns about the future of surveillance (Yuan, 2020). As will be discussed, these kinds of data play a critical role in affective computing. Last year, Amazon published a blog post announcing the addition of emotion recognition to their Rekognition service ("Amazon Rekognition improves Face Analysis," 2019) which is currently used by police departments in the United States, the Federal Bureau of Investigation, and was pitched to Immigration and Customs Enforcement by Amazon (Garvie, 2016; Harwell, 2018).

While the events unfolding in XUAR and elsewhere in China provide a dramatic illustration of the need for ecologically aware and ethical research, design and implementation, similar experiences may be found elsewhere (Rodriguez, 2017), and indeed might occur anywhere. These events demonstrate the potentially explosive reaction between social structures and beliefs and technology, wherein technology serves as a catalyst. Well aware of this fact, scholars have long sought to understand and improve the design and integration of emerging technologies.

Need expressed by research community

The need for a framework for thinking about the ethics involved in emerging applications of affective computing has recently been articulated by Rosalind Picard, a pioneer in affective computing research and application. In an interview published in June 2019, she asked:

> The way that some of this technology is being used in places like China, right now … worries me so deeply, that it's causing me to pull back myself on a lot of the things that we could be doing, and try to get the community to think a little bit more about, ok, if we're going to go forward with that, how can we do it in a way that puts in place safeguards that protect people? (Fridman, 2019)

In light of human rights abuses facilitated by emerging technologies, a panel of affective computing experts led by Picard (2019) convened at the recent Affective Computing and Intelligent Interaction conference to discuss the ethical responsibilities of researchers revealed extensive interest and anxiety about the potential misuse of the technologies and even the concepts being developed by the field.

While there is much interest, little is known about how affect-aware systems influence and are influenced by broader social and cultural contexts. This in an important gap in knowledge about affective computing and ethics, because ethics—the study of moral value, or differentiating between right and wrong—is, in my view, socially situated.

The HCI research community has long played a role in defining standards and norms of computing technology use. A classic example is the careful design of collaborative work systems (Greenberg & Marwood, 1994). In the same way, the community guides the co-creation of norms around other existing and emerging technologies involving data analytics, machine learning, and artificial intelligence (ML/AI) that support affective computing systems. In so doing, the research community must consider the effects of its work with respect to the diverse personal, social, political, and cultural contexts of application and use. Designers can support consentful adoption by users and prepare policy makers for unintended effects requiring action (c.f., Lee & Toliver, 2017).

Recent work in the development of an HCI perspective on smart cities and buildings highlights surveillance ethics and data privacy as an urgent gap in the knowledge (Alavi et al., 2019). Early work expressing a vision of an "affect-aware city," a "smart city that is capable of interpreting and harnessing the affective states of its citizens" (Guthier, Abaalkhail, Alharthi, & El Saddik, 2015) highlights the urgency of this need with respect to affect detecting sensors.

<u>Contribution and Organization</u>

The ecological systems theory-based Process-Person-Context Time (PPCT) model was developed by Urie Bronfenbrenner in response to observed limitations of developmental psychology studies conducted in laboratory settings (Bronfenbrenner & Morris, 1998). Bronfenbrenner called for a way of thinking about human development ecologically in real-world settings. Human-computer interaction researchers have faced similar needs in their work, moving from the lab into the field (Rogers, 2011).

In this thesis, I demonstrate the application of the PPCT model—commonly used in the study of human health and wellbeing—to a design scenario drawn from a real-life incident and a set of three counterfactuals. This incident involves actors in a neighborhood watched over by "smart" home security cameras (SHSCs), reported and described in a longform article, "The Porch Pirate of Potrero Hill Can't Believe It Came to This," published in *The Atlantic* (Smiley, 2019) and debated on internet forums, private blogs, and far-right media outlets. A counterfactual is a scenario defined by discrete changes made in comparison to a given (factual) scenario in order to reveal an alternate outcome.

This analysis highlights the contextual qualities of affective computing and interaction, which could soon be incorporated into the design of SHSCs. I then suggest directions toward an ecological framework for considering the ethical implications of affective computing in public and private spaces informed by the application of the PPCT model.

Chapter 2 provides background in three areas: affect and affective computing, ecological systems theory, and technology ethics. Chapter 3 introduces in more detail SHSCs, the real-life basis of the design scenario and counterfactuals analyzed, and my analysis plan. Chapter 4 provides a concrete scenario involving interaction with SHSCs for analysis and demonstrates how the PPCT model may be applied to HCI problems using a standard design scenario and three counterfactuals. Chapter 5 presents a preliminary ecological framework to guide thought and discussion about affective computing systems drawn from the analysis presented in Chapter 4. Chapter 6 considers the limitations of this thesis and proposes suggestions for future research.

Chapter 2. Background

Affect and Affective Computing

After years of training in computer vision, a young researcher at the MIT Media Lab was convinced of the importance of emotions in decision-making; Picard pioneered the field of affective computing in 1995 with the publication of a technical report by the same name (Rosalind W Picard, 1995). She recognized the dominance of perceptual computing and cognitive computing and introduced affective computing as a previously overlooked part of a whole, defining it simply as, "computing that relates to, arises from, or influences emotions" (p. 1).

Picard (1995) describes three ways in which a computing system can be affective: recognizing human emotions, expressing synthetic emotions, and experiencing emotions in order to inform decision-making algorithms. She provides as an example a piano-teaching computing system with the ability to sense three basic emotions—distress, interest, and pleasure—and able to tailor the lesson to support students' emotional needs as communicated by biophysical affective signals (Rosalind W Picard, 1995, p. 4). In arguing for affective computing as an important research agenda, Picard (1995) used touchstones in cognitive science that computer scientists would be familiar with, extending the metaphor into the role of the limbic system in emotion and cognition.

Picard drew from both classic and contemporary theories of emotion. Today, the appraisal theory of emotion dominates research in affective computing (Gratch & Marsella, 2015). Appraisal theory posits that emotions are the result of the subjective, cognitive evaluation (appraisal) of events in relation to one's goals (Lazarus, 1991). Picard argued for working with basic emotions such as fear, anger, sadness, joy, disgust, and surprise, among others, as defined by Tomkins (1962a, 1962b), Plutchik (1980), and Ekman (1992). She also recognized an alternative approach analyzing affect by an arousal dimension (calm/excited) and a valence dimension (positive/negative), in particular (Lang, 1995) while Russell's (1980) circumplex model is also well known and commonly used.

Initial work in this field focused on building and training algorithms to recognize biophysical signals such as voice and facial expression (e.g., Castellano, Kessous, & Caridakis, 2008), body posture and gesture (e.g., Kleinsmith, Bianchi-Berthouze, & Steed, 2011), and heart rate and galvanic skin response or electrodermal activity (e.g., Healey, 2015) and categorizing them by the emotion they conveyed. Information related to affective state can be gleaned through other modalities, as well, including sentiment analysis (e.g., Ahmad, 2011), patterns of hardware use (e.g., Hernandez, Paredes, Roseway, & Czerwinski, 2014), and pixel color or photoplethysmography from digital video (e.g., Monkaresi, Calvo, & Yan, 2013). Identifying, categorizing, and responding to categorical emotions is an example of what some researchers describe as a cognitive or "emotion-as-information" approach (Boehner, DePaula, Dourish, & Sengers, 2007). This attitude toward affective computing dominated the first decade of research in the field and remains common.

Picard and Klein (2002) set out to propose a research agenda for affective HCI. At the time their paper was published, affective computing was fairly new to HCI and to user experience designers. Thus, their aim was to illuminate the needs of users engaged with affect detecting systems and what they mean for users and societies. Ultimately, Picard and Klein take an ecological approach, stating in their conclusion:

> The implications that arise from new affective devices and the approach they provide for problem solving are broad in scope, and range from the level of the individual to that of the culture. It is therefore imperative, scientifically as well as ethically, that this impact be explored as fully as possible—before such devices can responsibly and ethically be put into widespread use. At the level of the personal, issues include how humans may use (or abuse) such devices themselves; how such devices might change the nature of human-computer (and human-human) interactions; and how humans will define themselves in a world where such devices are regularly used. On a commercial level, issues include the ethical use of such devices and the incentive corporations may

> have to develop such products—as well as high-quality products in general, when incentive to release fine products is diminished by mounting pressure to release products early. Political issues run the gamut from public consensus on acceptable design and use of such devices, as well as the potential misuse and/or abuse of them, including the use of these devices to help maintain disciplined citizens and consumers. At the level of culture, might the advent of such devices be used to foster positive change on a society-wide basis, or might they be used as another means for manipulation and control, fostering the dismantling of a society that once held dear values of individuality, autonomy, and authenticity? And finally, on the global stage, how might widespread use of such devices help to enfranchise humans around the globe, and how might they be used in the steamrollering effect that Western culture seems to have on other, diverse cultures around the world? (p. 64).

This statement highlights key themes in Bronfenbrenner's PPCT model, including interactions between people and systems or devices, reciprocity, and power. These and other concepts are described in more detail later in this chapter.

Other approaches to affect and affective computing

As affect recognition capabilities improved, Boehner and colleagues (2007) brought insights from anthropology and sociology to bear on

Picard and colleagues' "emotion-as-information" approach. Recognizing the courage of Picard's work as a woman computer scientist bringing emotions into computing (which Picard noted in the introduction to her (1997) book), they describe Picard's work as "rehabilitat[ing] emotion for computing by connecting it to rational cognition, thereby making it recognizably scientific," and identifying "discomfort with the potentially unruly, feminine, and non-rational nature of emotion can be seen in contemporary affective computing" (p. 276).

Experimenting with affective displays in workplaces for several years, they developed a new angle on affective computing that did not see affect as something to be "recognized," plotting a path toward and what they called "affect-as-interaction." This interpretation of affect posits that its meaning is made in interaction with others and in context, rather than constructed inside individuals and transmitted outward (Höök, Ståhl, Sundström, & Laaksolaahti, 2008). Because emotion is interactional, cultural, and dynamic, Boehner et al. write, "Measures of success for such systems therefore do not focus on whether the systems themselves deduce the 'right' emotion but whether the systems encourage awareness of and reflection on emotions in users individually and collectively" (p. 276). One of the most important aspects of affect with respect to the interactional approach is the inability to establish ground truth (Afzal & Robinson, 2015). Relating to the appraisal theory of emotion, emotions are dynamic and subjective. Thus, it is challenging—if at all possible—to identify and measure the affect or emotional experience of an individual, and the interactional approach to affective computing eschews attempts to do so.

Similarly, in contrast with traditional requirements gathering for computing systems, Dourish calls for a paradigm shift from the representational approach to context as something that can be known, defined, represented, coded, and predicted to an interactional approach that interprets context as relational, dynamic, occasional, and arising from activity (Dourish, 2004a). In light of this, it can be argued that affective computing is needed to advance contextual ubiquitous computing. Decisions about whether to use an informational or interactional approach in the design of an affective computing system would impact the meaning and quality of the subsequent interactions, with ethical implications likely.

Emotional design and affective interaction design bring emotion and affect into HCI, as well, but are endeavors with separate goals compared with affective computing. The work of Jordan (2002) and Norman (2004) on emotional responses to and in relation to design has found a home in interaction design. More recently, Fritsch and others have added to this work, drawing on affect theory, which has roots in critical and cultural theory and philosophy (Fritsch, 2018; Fritsch, Loi, & Light, 2019). This work extends the territory of affect from within an individual to among a collective. What this approach to affect could mean for affective computing and affective interaction design remains an open question.

As emerging technology appears to move toward reliance on increasingly numerous and discerning sensors, the distinction between and appropriate application of informational and interactional approaches to design increases its stakes. These systems may come to depend on data regarding affective states of people in the environment, with applications in "smart" homes, buildings, and cities (c.f., Alavi et al., 2019; Guthier et al., 2015). While this is closely related to broader concerns about big data and human interpretation of ML/AI system determinations and the responsibilities of people involved in those systems at various points, the literature reviewed herein finds important considerations and consequences unique to collection and use of data about affect: the approach taken in the design of affective computing systems involves a political decision. As Boehner et al. (2007) write, "Given the fact that we cannot ground our decision on which gives direct access to emotion, we would suggest that decisions about what choice to take should take into account the political, social, and cultural implications of holding a particular view on emotion" (p. 290).

Ecological Systems Theory

An image that to comes to my mind when I hear the word "ecology" is a natural system, such as a rainforest. As an ecosystem, rainforests and other biophysical environments serve as emblematic example of ecologies in that we can identify diverse entities that act in relatively predictable, interdependent ways over time to achieve a goal, such as the continuation of life. It includes all forms of life in the system, including plants, animals, and fungi, as well as non-living entities such as decomposed matter, soil and water, and weather patterns. As a worldview, ecology has influenced many thinkers, including in the environmental and social sustainability movements. It has also influenced thinking in social science and psychology.

Gibson's (1979) and Norman's (2013) work on affordance serves as a familiar example of applied ecological systems theory. While Gibson distinguishes between the inanimate and the animate for the purposes of perception, he writes:

> [I]t is often neglected that the words animal and environment make an inseparable pair. Each term implies the other. No animal could exist without an environment surrounding it. Equally, although not so obvious, an environment implies an animal (or at least an organism) to be surrounded. (p. 8)

Gibson defined affordances as the utility of an environmental artifact by an actor in the environment "directly perceived" via the sensory apparatuses, including, "sight, sound, smell, touch, balance, kinesthetic, acceleration, body position" (Norman, 2013). Norman, on the other hand, believed that this perception was not direct but rather mediated by the mind.

While HCI researchers and practitioners usually think about affordances as utilities (e.g., “A graspable rigid object of moderate size and weight affords throwing” (Gibson, 1979, p. 133), Gibson also considered social affordances arising between people or animals, which he called, “the richest and most elaborate affordances of the environment” (Gibson, 1979, p. 135). Of these social, “mutual” affordances, Gibson writes, “When touched, they touch back, when struck, they strike back; in short, they interact with the observer and with one another.”

Urie Bronfenbrenner developed an influential ecological systems theory between 1979 and 2005 in the same academic institution and department as where Gibson developed his ecological approach to visual perception. Bronfenbrenner cites the pioneer of activity theory, Lev Vygotsky, as an early influence, along with Sigmund Freud, Jean Piaget, and others, (Bronfenbrenner, 1979). His model of human development is commonly applied in an effort to understand outcomes in human development by researchers in fields such as child psychology, education, and public health (e.g., Benson & Buehler, 2012; Brooks-Gunn, 1995; Farrant & Zubrick, 2012).

The Process-Person-Context-Time model

Bronfenbrenner created his model of ecological systems to better understand the factors that help and hinder positive human development. He was committed to translating his work into application to improve lives. Interventions were important to Bronfenbrenner, because changes to the ecological system can impact development by modulating the “stability and change in the biopsychological characteristics of human beings over the life course and across generations” (Bronfenbrenner & Morris, 1998, p. 995). In 1965, Bronfenbrenner helped establish the federal program to support low-income children and families known as Head Start.[2]

Called in its most mature form, the Process-Person-Context-Time (PPCT) model, the earliest version of Bronfenbrenner’s model focused on a person’s context, which he described as “a set of nested structures, each inside the next, like a set of Russian dolls” (Bronfenbrenner, 1979, p. 3). It is described as consisting of three nested levels enveloping the individual at the center, as illustrated in Figure 1. The first level is called the microsystem, populated by people, objects, and symbols in close proximity to the individual. An intermediate level, called the mesosystem, represents the processes that unfold among elements of the microsystem. The next level, called the exosystem, consists of more distal

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[2] https://news.cornell.edu/stories/2005/09/head-start-founder-urie-bronfenbrenner-dies-88

people, symbols, and objects, and the outermost level, the macrosystem, contains sociocultural and historical influences. In the PPCT model, roughly analogous levels within a chronosystem describe the impact of time: at microtime, mesotime, and macrotime levels. Bronfenbrenner created his ecological systems theory in order to help researchers better understand human developmental outcomes; thus, the passage of time is an essential factor. The model requires analysis of processes (proximal and distal), characteristics of the individual, contextual factors, and with respect to a variety of notions about time.

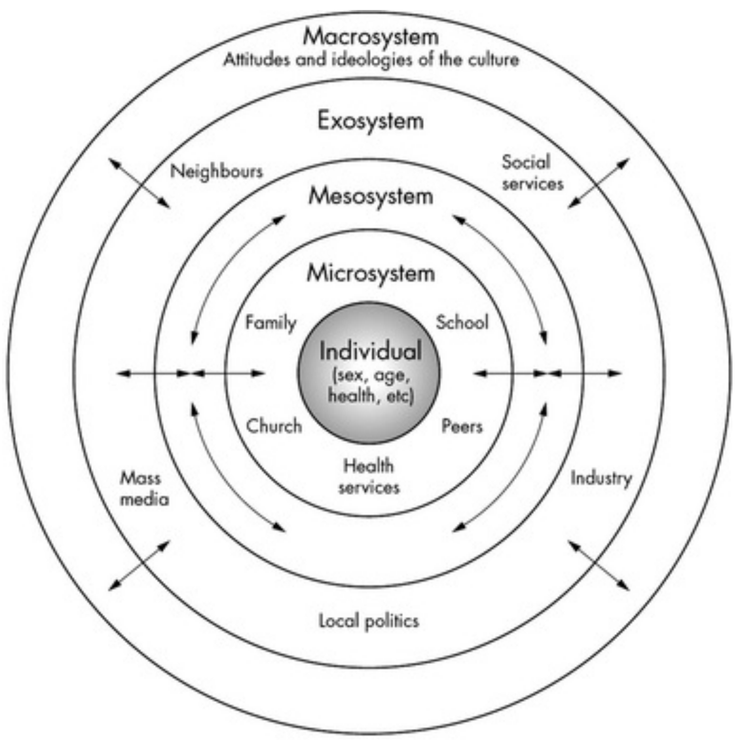

Figure 1. Bronfenbrenner's (1979) ecological systems theory diagram

Process

The concept of proximal processes can be one of the most illuminating in Bronfenbrenner and his collaborators' theory, however, it is often overlooked by researchers applying Bronfenbrenner's model—in part due to early underdevelopment of the concept, which received increasing emphasis in his later work (Griffore & Phenice, 2016). Processes are indicated by arrows in Figure 1.

For or interactions and transactions with and mediated by computers to be considered proximal processes, activities must take place "on a fairly regular basis, over an extended period of time" such that the interaction can grow "increasingly more complex" (Bronfenbrenner & Morris, 1998, p. 996). Bronfenbrenner and Morris write that, "Proximal processes are not limited to interactions with people; they also can involve interaction with objects and symbols. For reciprocal interaction to occur, the objects and symbols in the immediate environment must be of a kind that invites attention, exploration, manipulation, elaboration, and imagination" (Bronfenbrenner & Morris, 1998, p. 997). Design choices might promote or inhibit positive developmental outcomes, or put another way, allow potential to be actualized or remain "nonactualized" (Bronfenbrenner & Ceci, 1994).

Humans are social, and an enormous amount of development occurs in the context of relations with others. For Bronfenbrenner, a relation arises simply, "whenever one person in a setting pays attention to or participates in the activities of another" (Bronfenbrenner, 1979, p. 56). Bronfenbrenner focuses primarily on the dyad, a relation between two people, in part because it is the simplest form of relation and also because, according to Bronfenbrenner, the majority of transactions occur within dyads. Thus, my analysis focuses on relations between dyads. One of the central ideas underlying Bronfenbrenner's theory—and to both ecological and systems theories generally—is that *change (or development) at any part of the system impacts the rest of the system*. This is perhaps most obvious within relations, which require regular "re-calibration" and accommodation in response to changes in either party (Shelton, 2019, p. 31). Drawing on their experience studying affect in relation to computing, Bickmore and Picard investigated the potential for long-term "human-computer relationships," defining a new concept, the *relational agent*, as "computational artifacts designed to establish and maintain long-term social-emotional relationships with their users" (Bickmore & Picard, 2005, p. 294). Affect, together with power and reciprocity, is active in moderating or otherwise determining the course of proximal processes due to its influence on relations, which are connections between the individual and people, objects, and symbols in their environment.

Traditionally, the HCI community is concerned with interaction between a human and a computer or system where the interaction is a reciprocal action and reaction scenario. Bronfenbrenner focuses on one kind of interaction, transaction, which is an interaction that results in the "more or less permanent change in one or both parties" (Shelton, 2019, p. 31). Shelton provides the example of a person going to the store to enquire about a needed item (an action). If the person asks a salesperson about the item and the salesperson says the store does not carry the item, and the person leaves, there has been an interaction. However, if the store carries the item and the person buys it, a transaction has occurred—the person has the item and the store has their money, observable change with potential to impact other individuals and other parts of system. It is because of the power of transactions to create change that they have the most impact on ecological developmental outcomes. In this thesis, I use the term "interaction" to denote relations that induce change as well as those that do not.

<u>Person</u>

According to Bronfenbrenner and Morris (1998), there are three aspects of the developing person: propensity or disposition, resources (ability, experience, knowledge, and skill), and demand (encouragement or discouragement from the social environment). Personal characteristics are believed to be important insofar as they "affect the direction and power of proximal processes through the life course" (Bronfenbrenner & Morris, 1998, p. 995). Due to the influence of reciprocal proximal processes, personal characteristics are both the producer and the product of development (Bronfenbrenner & Morris, 1998).

Context

Contexts include "...the principal settings in which human competence and character are shaped" (Bronfenbrenner & Morris, 1998, p. 995). They can be thought of as a set of concentric circles spheres, as illustrated in Figure 1.

Of the objects and symbols in the microsystem, which the developing person may engage with through solitary activities and proximal processes, Bronfenbrenner was particularly interested in the physical environment, which can have features that shape development for better or for worse. Characteristics thought to improve the conditions for development included "objects and areas that invite manipulation and exploration" whereas instability, lack of clear structure, and unpredictability of events undermine the developmental process" (Bronfenbrenner & Morris, 1998, p. 1014).

The microsystem is typically populated by a person's family, classmates, colleagues, and close friends, while the exosystem may include extended family and family friends, social services, and local representatives, as well as things like mass media. In between, the mesosystem represented interactions between the individual and the people around them, and between other people in their micro- and exo-systems. The macrosystem contains social and cultural forces such as social hierarchies, economic structures, laws, beliefs, and norms. Individuals can and usually do inhabit multiple contexts defined primarily by participation in various cultures or subcultures.

Time

The final aspect pf the PPCT model is time. Development is said to unfold over time at the macrotime level, in which is approximately historical time (time in history); at the exotime level, in the life course and through linked lives (the impact of historical events on people around the developing person); at mesotime levels, which follow the periodicity of regularly occurring events; and finally in microtime, which measures a the duration of a process as it progresses.

I hypothesize that the PPCT model has can support interrogation of affective systems in ubiquitous computing environments. Like all ecological models, it highlights the influence of settings and actors proximal and distal to the individual, recognizing that each individual is an actor in others' lives. This assumption is useful for understanding interactions that occur in ubiquitous computing environments such as we often find ourselves in, including those in private spaces such as the home as well as in public spaces such as cities, schools, or workplaces. The processes and interactions that occur between the individual and other people, objects and symbols (including electronic, digital, and computing technologies) influences the individual and those in their orbit. The model also highlights the impact of the broader cultural, social, economic, and political influences on the wellbeing of individuals.

Bronfenbrenner's ecological systems theory emphasizes the role of affect on human development through its influence on relations. Bronfenbrenner highlights three properties central to understanding their impact on development: affect, power, and reciprocity. Affect plays an essential role in defining and redefining relations between individuals and groups. For example, a negative affect expressed within an individual's microsystem would require the individual to "recalibrate" in response to the perceived meaning of the affect, which repeated over time could lead to a change in developmental outcomes. Bronfenbrenner suggests that emotional tone in relations can influence how much time individuals spend on mutual activities, thereby influencing one another's development (Shelton, 2019). Affect also plays a part in the other two key aspects of relations: power and reciprocity. For example, the balance of power in a relation can moderate how individuals respond to the experience of positive or negative affects, and tending to the emotional needs of others is essential to reciprocity, along with conversational turn-taking, sharing information, considering opinions, and volunteering to help (Shelton, 2019).

A great deal of social interaction today is mediated by computing systems. For example, the Facebook emotion contagion study (Kramer, Guillory, & Hancock, 2014) shows how Bronfenbrenner's ecological systems theory highlights the impact of emotionally-charged expressions shared on the emotions of others, as evidenced by the emotional valence of subsequent posts, emphasizing the powerful effect of emotion on processes unfolding in an ecological system. Humans also experience changes in affect in response to more direct interactions with computing systems. A well-known example lies in the infamous intelligent agent Clippy, whose contradictory and ultimately unhelpful existence is said to have inspired the ire of a generation of Microsoft Office users (Bickmore & Picard, 2005). The impact of emotion on interaction and interaction design has been recognized by user experience professionals for nearly 20 years as a part of their practice (Fakhrhosseini & Jeon, 2017; Norman, 2004).

The PPCT model may not explain affective HCI perfectly: it was not created with these kinds of interactions in mind, and part of the work is to determine where computing systems “fit” in the ecological context. One example of this kind of decision is in the analysis of the aforementioned Facebook emotion contagion study. While we might understand the ripple effect of emotion that begins outside our social network, reaching us via our own network as the result of processes unfolding at the meso- and exosystem levels, this may not be an adequate description. In addition, individuals may also interface directly with the content of people outside their network as a result of differing privacy settings and algorithms. Is content posted by people who I do not know but which I view directly part of my microsystem? Or, is this content more similar to Bronfenbrenner's view of mass media, which he places in the exosystem?

Finally, Bronfenbrenner developed his ecological systems theory and related models explicitly in order to effect change for the betterment of human life; it was designed to help researchers identify areas ripe for intervention. I explore this model in order to understand whether it might help researchers, users, and other stakeholders identify areas where policy, research, and design decisions can affect ethical outcomes with respect to the wider system.

Themes in Technology Ethics Discourse

To return to the question of whether artifacts are political, Pfaffenberger extends Winner's analysis and identifies ways in which artifacts can have politics (Pfaffenberger, 1992). However, Pfaffenberger and others reject Winner's claim that technological artifacts are inherently political, instead comparing any potential political force in an artifact to affordances as described by Gibson (1979) followed by Norman (2013)—attributes that may or may not be useful in a given context (Hutchby, 2001; Pfaffenberger, 1992). This position does not prove that artifacts are not political; rather it places greater focus on the agency of users. However, what is not accounted for in this argument is the power or lack of power of users to make use of or to avoid use of these affordances due to restrictions in agency an autonomy.

The Association for Computing Machinery (ACM) Code of Ethics and Professional Conduct acknowledges several types of ethical issues that can arise in computing research and practice, including the capacity for computing artifacts to influence society. In section 3.7, "Recognize and take special care of systems that become integrated into the infrastructure of society," it explains: "Even the simplest computer systems have the potential to impact all aspects of society when integrated with everyday activities such as commerce, travel, government, healthcare, and education" (Association for Computing Machinery, 2018). This section calls for computing professionals to monitor the implementation of their systems, stating that events such as increased adoption can cause a system to evolve from ethical to unethical, and urges professionals to raise awareness of any such observations.

The question of agency invites us to consider contemporary conceptions of ethics such as those defined by medical and human subjects research ethicists under the umbrella of principlism, a type of applied ethics. Analyzing the tenets of principlism for their potential to frame the AI ethics debate, Mittelstadt (2019) found several areas in which it cannot support issues in AI ethics as it does, for example, medical ethics: common aims and fiduciary duties, professional history and norms, methods for translating principles into practice, and legal and professional accountability mechanisms.

Data privacy is a common concern in research and medical ethics as well as for everyday people. Privacy is treated in the ACM Code of Ethics and Professional Conduct in sections 1.6, “Respect privacy” and section 1.7, “Honor confidentiality.” These sections focus on practical aspects of data collection and use, such as refraining from collection of unnecessary data, staking measures to prevent unauthorized access of data, and transparency to support informed consent (Association for Computing Machinery, 2018). The Feminist Data Manifest-NO (Cifor et al., 2019) describes a more radical vision for both research and everyday data privacy in clear and actionable language. A list of 32 refusals and commitments for data privacy, it includes several points that related to the use of affective computing in social environments.

Greene and colleagues analyzed the ethical vision statements claimed by high-profile ML/AI companies and organizations (for example, OpenAI) in order to illuminate different “modes of moral reasoning” (Greene, Hoffmann, & Stark, 2019). For example, they suggest that a facial recognition system that is less accurate in recognizing people of color may be a problem of business ethics, whereas the question of whether we should design systems to identify people of color at all is an altogether different sort of ethical problem.

Greene et al. identified seven themes that describe these ethical vision statements and offer two observations: 1) that these organizations are aware of the public and the academic conversations about ethics in

ML/AI and 2) that they appear to use some of the language used by critical HCI and STS scholars, but fall short of making clear commitments to "social justice or equitable human flourishing" (p. 2129), revealing a tension between moral values and law-oriented business or professional ethics.

Greene et al. also found that each of the institutions examined expressed in an ethical vision in terms a belief in technological determinism, or the idea that there is nothing researchers, designers or developers can do to change course. Highlighting a potential conflict of interest, they write, "There is little sense from [the examined] documents that ML/AI can be limited or constrained (a feature perhaps stemming from the involvement of AI companies)" (p. 2122). Greene et al. identify a sense of "values-driven determinism" in these organizations, which supports the belief that ethical problems can be resolved through application of technical expertise, and that concerns about whether technologies should be developed at all is irrelevant. While most STS scholars reject technological determinism in favor of a nuanced and contextual understanding of the interactions between people and the technologies they use, the HCI community may in some ways more closely aligned with the institutions evaluated by Greene et al. by virtue of a historical connection to computer science and industry. The authors call for a new kind of conversation focused explicitly on social justice and ML/AI.

Working at the intersection of STS and interaction design, Stark proposed that information or data about emotions is different than other kinds of data and should be thought about, designed for, and regulated on its own terms (Stark, 2016). He describes the two approaches to affective computing, the informational (what he calls "organismic") and the interactional approach, and makes this distinction to suggest that the many applications fail to consider the social nature of emotion and so may reduce the real meaning of it. Stark also describes the emotional and visceral relationships people have with both hardware and software, but that the way we design data and metadata has made it difficult for people to identify with their own data. He proposes addressing the challenge of protecting personal data using the tools of affective computing for what he calls "data visceralization" and "visceral privacy."

Stark draws on Nissenbaum's work, which "locates the germ of privacy in the notion of 'contextual integrity,'" that is, "the 'contextually appropriate' flows of information" (quoted in Stark, 2016, p. 17). Stark also draws on Dourish's view of embodied interaction (Dourish, 2004b) to advance his thesis, suggesting that investigating emotional contexts and experiences—influenced by physical states and environments—can aid in understanding privacy.

Emotions of users and other stakeholders can be exploited to aid in raising awareness about the amount, nature, and potential abuse of personal because emotion is an important "value lever" for making design decisions. Value levers, introduced by Shilton (2013), are practices that aid in building consensus around "social values as design criteria," resulting in concrete design decisions.

Keys and colleagues' (2019) work on anti-capitalist values in HCI can contextualize the contributions of STS researchers. Keyes et al. draw attention to a perceived ambivalence within the HCI community whereby other researchers have demonstrated an interest in the societal implications of their work, but few have gone so far as to articulate an explicit "politic" in response to these concerns. The authors call on the HCI community to "re-examine our core values and radically alter the ways we enact these values in our relationships with each other and the world" (p. 4), providing specific examples in three areas: the world/environment, the people we study and collaborate with (e.g., research participants), and HCI researchers and the structures they work in. This would also require justification of funding sources. A framework for thinking about ethical use of emerging technology with attention to the ecological systems of human and other forms of life with technologies could advance an agenda focused on equity by bringing attention to the possible consequences of power in relations, processes, and ultimately developmental outcomes.

Ethics in Affective Computing

While ethical guidelines for intelligent systems can guide the design of intelligent affect-aware systems, affective computing invites unique considerations. Engaging with diverse user stakeholders, Loi (2018) found that people are skeptical about affect-sensing technology, disbelieving its reliability and averse to its potential to be intrusive. Picard and Klein (2002) outlined areas for thinking about the ethics of affective computing, focusing mostly on the need for transparency, that is, ensuring users are aware of systems' affect detection or synthesis capabilities and aware of "…when he or she has control over the sensing, and when he or she chooses to allow this channel of communication because of perceived benefit" (p. 154). Other areas they identify as needing further discussion include the ethical and practical problem of a computer encouraging a user to express strong emotions but being ill-equipped to support them; deception; displacing humans; mood manipulation; and the potential value of negative emotions (avoiding "computational Soma" p. 159).

Reynolds and Picard explore tools for understanding the ethical nuances of affective computing design and implementation by framing design and use as a contract (2004) and by building on value-sensitive design (2005). Value-sensitive design—an ongoing area of inquiry developed over many years—consists of three core aspects: value, technology, and context of use (Friedman, Kahn, & Borning, 2008). In addition, it considers the needs of direct and indirect stokeholds, potential conflicts of between values, and it focuses on application of value-sensitive design as a heuristic tool. While value-sensitive design appears to bear many similarities to ecological systems theory, this connection is not explicit in Friedman and colleagues' descriptions of their thought and experience.

Cowie (2015) describes application-specific ethical concerns about affective computing that fall into two categories: the potential impact on interpersonal relationships and potential military and surveillance applications; for example, stress detection. Regarding surveillance, Cowie states that ethical decision-making necessitates a careful weighing of costs and benefits: while some consider surveillance an infringement on autonomy, others see it as "profoundly moral." Adding that beliefs about ethics and surveillance vary widely by culture, and that research on these differences are in the early stages (p. 343). Cowie (2012) is also concerned with the deception that occurs when a computer pretends to have emotions that it does not, the potential of affective computing to influence human decision-making, and unintended consequences related to oversimplification of human complexity.

Affective computing applications have been conceived of as falling into three categories based on principlism: morally neutral, positive, and negative (Cowie, 2012). To Cowie, most applications are neutral. Negative applications or potential applications include building systems that encourage the darker sides of human nature, the deception of a synthetic display of emotion, and human devaluation of authentic (i.e., human) emotion. Negatives that are not unique to affective computing but may be exacerbated by it include surrogacy (human immersion in virtual worlds) and semi-intelligent information filters. He is especially concerned about affective technologies falling into "manipulative hands":

> [T]he real potential of emotion-oriented technology is so unclear, and partly because of uncertainties surrounding the question of how illegitimate control may be established and resisted. Among other things, if experts cannot be trusted to resist illegitimate control of technologies, it is not clear how much is gained if they refuse to develop them under more benign regimes. The issues deserve a clear-headed debate. (p. 419)

This serious concern invites an ecological understanding of application of affective computing technologies, because these decisions very likely do not merely exist between "experts" that develop the technology and "illegitimate control," but should include the voices of other stakeholders, especially end users and other stakeholders affected by implementation of affective computing applications.

Ethicists Baumann and Döring (2011) focus on potential infringement on autonomy, finding that affective computing systems are especially liable to influence autonomy compared with other types of interaction. One way in which affective computing systems can infringe on autonomy is by inhibiting procedural independence, the capacity for self-reflection and reasoning. This principle can be described negatively (we should not interfere with people's autonomy) and positively (we should support people's capacity for autonomy).

Baumann and Döring (2011) are also concerned with privacy questions related to affective computing. Privacy relates to ethical principles because emotional privacy "…is a fragile state that people deeply care about because they want to protect . . . their *autonomy*" (p. 741, emphasis in original). They present an analogy between human social norms and affective computing ethics: assuming that people have a duty to refrain from passing on information about others' emotions without their consent, and a duty not to use such entrusted information against them, designers of systems that obtain information about emotions have a similar duty. One complication that arises in this thesis is the question to whom data about emotion belongs and how we might think about protecting privacy when data or information is not directly connected to an individual (either in reality or in system design).

Sneddon and colleagues (2011) created a practical guide to ethical research involving affective computing. They describe the creation of the HUMAINE (now the Association for the Advancement of Affective Computing) ethics committee after identifying a lack in consistency in procedures at ethics committees across the institutions involved in HUMAINE. Regarding systems that recognize emotion, they prioritize two problems: overestimating the accuracy or validity of an affective system and surveillance. About the latter, they write, "it is not clear if the use of machines to monitor people in public places without their knowledge should be regarded as a[n] […] invasion of privacy" (p. 765). They also state this kind of use of affect recognition "begs the question about the uses to which such technology might be put to" and that it is important that information about affect is not "used unreasonably" (p. 765). These concerns add to those raised by Picard and others, motivating exploration into new privacy norms related to affect monitoring in public places as well as what it means to use data about affect reasonably.

Summary

This chapter first introduced background information about affect and affective computing. "Affect" includes a range of experiences, such as emotion, mood, and personality. While models of affect are debated, affect is widely understood to play an important role in behavior and decision-making. Affective computing incorporates data about user affect (or affect represented in user-generated content) into decision-making algorithms that impact the functional and interactional qualities of the system and user interface. Data about affect can be obtained via multiple modalities including through analysis of voice, facial expression, posture, or gesture; biophysical signals such as heart rate or electrodermal activity; as well as through other means including sentiment analysis, patterns of hardware use, and pixel coloration.

There are two primary paradigms for the design of affective computing systems: an “emotion-as-information” approach that aims to empower systems with data about user affect, based on the idea that affect exists within people; and an “affect-as-interaction” approach that aims to empower users with access to data about affect, based on the idea that affect exists not within individuals but in the interactions between people, objects, and symbols in context. A third paradigm based on affect theory and the role of affect in interaction design more broadly is also growing. Data about affect can guide system decisions, tailoring them to suit contexts of use, thereby improving usability and user experience, and perhaps less obvious experiences such behavior change through microtargeting.

The PPCT model, grounded in ecological systems theory and developmental psychology, has the potential to help researchers, designers, policy makers, and users and other stakeholders better understand the interdependent nature of HCI and interaction design, specifically related to affective computing. The PPCT model is composed of four parts: *process*, or the interactions and transactions between actors, objects, and symbols in the system that impact the development of the individual; *person*, or the personal characteristics and biological inheritance of the individual; *context*, or the actors, objects, and symbols that surround the individual at different levels of proximity, described as having four levels and including, for example, close friends and family at the microsystem level; interactions between levels represented at the mesosystem level; laws and services at the exosystem level; and cultural beliefs and social norms at the macrosystem level; and finally *time*, described as impacting the quality of interactions due to frequency, regularity, or duration, as well due to time in the individual's life and historical time.

We can think of a focus on the individual like a magnifying glass that can be moved from person to person in a given system. Interactions lead to changes in the individual's development, as well as changes to the development of other people in the system. Relations between people (and objects and symbols) are mediated by three variables over time: affect, power, and reciprocity—which impact the quality of the relation and the processes it might facilitate.

Perspectives on technology ethics touch on concerns relevant to affective computing in ubiquitous computing private and public spaces. Foremost among these for the present study is politics inhering in technological artifacts, a consideration affecting not only affective computing, but all design. Important insights can be found in principlism, most commonly known through its application in medical and human subjects research ethics. Values such as autonomy, justice, and beneficence have been expounded upon in ethics conversations grounded in principlism, but do not fully encapsulate the impact of affective computing from an ecological perspective. Views on data privacy and on ML/AI applications typically invoke debates about values, with rich contribution from the field of STS with exiting potential application to better understanding the ethics of affective computing.

Each of these bodies of literature—affective computing, ecological systems theory, and technology ethics—touches on the complex personal and social nature of affect in human-human and human-computer interactions. To address the need for a framework for ethical decision-making for affective computing applications, this thesis integrates these areas of inquiry by applying the PPCT model to affective computing interactions.

Chapter 3. Scenario and Counterfactuals: Methods

Smart Home Security Cameras

Technologies built to collect personal data of passive users in public spaces are growing in number and acceptance. Many of these devices are carefully designed to enter seamlessly into a smart home ecology, what Pierce (2019) calls foot-in-the-door devices. Foot-in-the-door devices are "product[s] and services with functional offerings and affordances that work to normalize and integrate a technology, thus laying groundwork for future adoption of features that might have earlier been rejected as unacceptable or unnecessary" (p. 1). Growing interest in SHSCs may be one such example. Ring (owned by Amazon), sells internet-connected video cameras with motion detection and facial recognition software, two-way audio communication (one-way video), and (for the flagship model) a doorbell. An important factor of the Ring product line is tied to the design of the device, reflected in the company's name: it is a doorbell. As industrial designer Raymond Lowey apparently said, if you want to sell something strange, make it seem familiar (quoted in Pierce, 2019, p. 8). The Ring "video doorbell" achieves this, embedding a smart camera into a sleek and modern-looking case only slightly larger than a traditional doorbell, with a calming blue ring of light around the doorbell button, likely familiar to users of Amazon's Echo Dot. In this way, SHSCs designed to blend in, like Ring, breach the previously existing norm informing the public of the presence of video camera surveillance (the transition principle of notice), compromising contextual integrity (Nissenbaum, 2009). In addition, companies market SHSCs as delightful telepresence devices; ads have titles such as, “Man Uses Ring to Brighten His Girlfriend’s Day & Dog Caught Stealing Hat from Garage” and “Mom Gets to Have the First-Day-of-School Picture Moment Through Her Ring Video Doorbell.”[3]

This perspective highlights a potential tension between safety and convenience on one side and privacy concerns on the other. As an example, the Baltimore City Council recently approved an ordinance called the Private Security Camera System Rebate Program (file# 20-0486), expected to be signed by the Mayor, which will incentivize city residents to install SHSCs and to register the devices with the police department. A similar program implemented in Washington, DC three years ago has so far resulted in two arrests in a homicide case (Richman, 2020). There is no plan in the Baltimore ordinance for measuring unintended harmful effects of the program.

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[3] These examples and more can be found on Ring’s YouTube page: https://www.youtube.com/channel/UCSDG3M0e2mGX9_qtHEtzj2Q

Figure 2. A Ring video doorbell installed on a home

The American Civil Liberties Union (ACLU) called for more debate in another case involving police use of surveillance in Baltimore, this time by privately funded aircraft (Rector & Duncan, 2016). The ACLU states that, “the impulse to blanket our public spaces and streets with video surveillance is a bad idea. The growing presence of cameras will create chilling effects that bring subtle but profound changes to the character of our public spaces” (ACLU, n.d.). Four years after the secret, unauthorized tests of the aerial surveillance system, the plan was pushed through with a six-month pilot period by a contentious vote of the Board of Estimates meeting via conference call due to the novel coronavirus pandemic (Opilo, 2020). Thus, there is an urgent need for human-centered computing researchers to better understand the ecology of systems with broad impact and diverse stakeholders, and to communicate effectively with them.

Research suggests support for SHSC systems. A qualitative study on perceptions of a “digital neighborhood watch” (Brush, Jung, Mahajan, & Martinez, 2013) found that most participants in the communities surveyed would be willing to share camera footage as part of a collaborative program, and that more than half of people interviewed indicated willingness to have audio recorded. However, they also found that fewer women were supportive of audio recording compared with men, which aligns with the finding that women are more concerned with privacy in relation to video recording (Friedman, Kahn, Hagman, Severson, & Gill, 2006). Despite popular support for networked SHSC systems, convicted burglars report being undeterred by the presence of home security cameras (Erete, 2013). It is not clear is whether burglars are unaware that communities hold these beliefs about security, or whether there are other reasons for being undeterred, such as lack of faith in the criminal justice system or a simple risk assessment.

Smart home security cameras as exemplified by Ring and other brand products are an appropriate device around which to speculate about future affective computing applications because it is a well-known yet little-studied consumer product that, due to its “foot-in-the-door” position, could be upgraded to include affective detection and interaction capabilities. The social media and companion apps that often come with

SHSCs provide a potential platform for speculating about affective computing applications for mobile devices, as well. While the Ring website does not contain documentation suggesting their system currently includes facial recognition, Amazon's machine learning service Rekognition enables facial recognition,[4] as well as emotion recognition.[5] The SHSC brand Nest Hello (owned by Google) includes facial recognition. Most SHSC systems have motion detection capabilities, triggering an alert on the owner's mobile device that allows them to remotely view and speak through the doorbell.

"The Porch Pirate of Potrero Hill"

The present analysis focuses on a case involving SHSC and related technology use unfolding in Potrero Hill, a rapidly gentrifying neighborhood in San Francisco, California, reported and described in a longform article entitled, "The Porch Pirate of Potrero Hill Can't Believe It Came to This," published in *The Atlantic* (Smiley, 2019). This case provides a suitable unit of analysis in the experience of Ganave [pronunciation: juh-nAY-UH] Fairley, a woman documented stealing packages by her neighbors' SHSCs (hence known as a "porch pirate"). Using the information reported, Ganave's social, cultural, and technological surroundings stand to be analyzed, as well.

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[4] https://aws.amazon.com/rekognition/faqs/?nc=sn&loc=7
[5] https://docs.aws.amazon.com/rekognition/latest/dg/API_Emotion.html

To summarize, using SHSCs, SHSC companion apps, and social network sites (SNS) such as Nextdoor to mediate interactions with Ganave, the neighbors of Potrero Hill eventually succeed in bringing Ganave to court. As she struggles to reintegrate into society after stints in jail and rehab, Ganave becomes homeless. While she no longer steals, she wanders the neighborhood, lost, still a nuisance to her neighbors. This story invites investigation into the role of these technologies in further destabilizing Ganave's precarious situation, and whether achieving the desired outcome (dissuading Ganave from stealing) was worth the severe damage to her life. Most of all, it invites investigation into whether alternatives are possible.

Analytic Approach

Counterfactual construction

This analysis applies Bronfenbrenner's ecological systems theory and specifically the PPCT model using scenario-based design techniques. Scenarios used for this purpose, "…have a plot; they include sequences of *actions* and *events*, things that actors do, things that happen to them, changes in the circumstances of the setting, and so forth" (Carroll, 2000, p. 47, emphasis in original). Scenario-based design has many strengths: it provokes reflection, is "at once concrete and flexible" (p. 54), focuses on use, illuminates constraints, highlights relationships, allows for speculation beyond current technical capabilities, and supports the creation of new theories of use (Carroll, 2000). This approach to scenario analysis is described in the most recent edition of *Interaction Design: Beyond Human-Computer Interaction* (Sharp, Rogers, & Preece, 2019). Creating a design scenario abstracted from the events described in Smiley (2019), I organize the actors and events in accordance with the PPCT model. I then consider the consequences of the PPCT model as an organization tool for ethical evaluation.

This approach was chosen after first considering the usability and user experience issues (positive and negative) of the speculatively affective SHSC technology described in "The Porch Pirate of Potrero Hill" (Smiley, 2019) as experienced by actors featured in the article from a usability engineering perspective (Nielsen, 1994). It was evident that these issues could be described as occurring at levels more or less proximal to the individual user under consideration and having effects on other characters in the story. Having used Bronfenbrenner's PPCT model to frame similarly complex sociocultural problems in the past (e.g., Stamato, Johnson, & Cheng, 2018), I saw an opportunity to supplement the existing tools for understanding the complex social and physical contexts of ubiquitous and affective computing. Motivated by the need for an ethical framework, I wanted to find out whether the PPCT model could supplement traditional usability heuristic evaluation tools in this respect, as well.

While this work bears similarities to traditional scenario-based design methodology, it is also in conversation with Winner's (1980) approach to understanding the relationships between technology and society. I am not neutral: I am a person experiencing these emerging technologies in my own life and interpreting their effects through my experience. As Joerges writes, "Artefacts may then, in Winner's sense, have politics: but surely politics have artefacts—well-built parables like Winners" (Joerges, 1999, p. 421). I acknowledge my perspective as a novice HCI scholar concerned with the real and potential intended and unintended effects of technological artifacts on diverse people living in society. Furthermore, I deliberately seek to explore these scenarios from the view of socially marginalized stakeholders in order to challenge dominant epistemologies (Bardzell, 2010), and acknowledge that this analysis is only a beginning. While I aspire to present an unbiased description of actual and potential scenarios for the purpose of more clearly seeing areas in need of greater consideration, the bracketing necessary to create such knowledge is perhaps unrealistic given the surveillance society I find myself in as a resident of Baltimore city. Instead, I aim to acknowledge my biases as I identify them and to use them productively to inform my analysis (Corbin & Strauss, 2014, p. 119).

Counterfactual reasoning has a foundation in everyday human thought, and through formal logic has found applications in a range of fields, from applied ethics and law to computer science (Pearl, 2011). Counterfactual scenarios have many uses, from making decisions to explaining automatic decisions made by algorithms (Wachter, Mittelstadt, & Russell, 2017). Scholars such as Wachter, Mittelstadt, and Russell (2017) suggest using counterfactuals generated by computing systems in this way. For example, a system might generate a human-understandable counterfactual that could provide an acceptable explanation or reveal unacceptable bias, for example:

> You were denied a loan because your annual income was £30,000. If your income had been £45,000, you would have been offered a loan. (p. 5)

One challenge of creating counterfactuals for analysis is knowing when to stop, as many alternate outcomes could be defined. To manage this, a standard practice is defining the smallest counterfactual change possible while still leading to an observable change in the outcome (Lewis, 1973). However, in some cases, greater changes or changes to multiple variables yields a more meaningful scenario (Wachter et al., 2017).

The counterfactual scenarios that follow were generated using human intelligence, operating around three variables:

1. Passive user (passerby) interactions with SHSCs,
2. Active user interactions with SHSC companion apps (for telepresence/communication and reviewing recordings), and

3. Use of SNS (including but not limited to those built into companion apps).

Analysis of each counterfactual is informed by the PPCT model, as described in the following section. While one aim of counterfactual reasoning is to obtain information in support of causal inferences, the PPCT model also acknowledges complexity. I do not claim to identify causality in this thesis, but rather to demonstrate the utility of this model for emerging HCI problems.

Another challenge to counterfactual reasoning and analysis in the present study relates to the socially interdependent nature of affect. Thus, it is unavoidable that there are interactions described in the design scenario and counterfactuals that cannot easily be described. I invite readers to bring their own experience, knowledge, and values, to each.

To begin the analysis, a scenario was created as a distillation of the article "The Porch Pirate of Potrero Hill Can't Believe it Came to This" (Smiley, 2019). The scenario was written with Ganave at the center and with telling details concerning her history and the people, objects, and activities around her. This kind of data is best considered a type of researcher-generated document, rather than a popular culture document, though it is based on a popular culture document (Merriam & Tisdell, 2015).

Analysis plan

In order to best apply Bronfenbrenner's ecological systems theory, I sought examples of incorrect or inappropriate application. These most commonly involve drawing from outdated versions of the model or not considering important aspects of the model (Tudge et al., 2016). This thesis draws on the most mature version of the model developed by Bronfenbrenner (the PPCT model) as an analytical tool, referencing earlier work as appropriate; and considers the influence of each aspect of the model. Bronfenbrenner and colleagues engaged in a process of negotiation with regard to how the PPCT model might best be applied to research in human development, citing the difficulty of working in interdisciplinary space, "between the natural and social sciences" (Bronfenbrenner & Morris, 1998, p. 1000). They agreed that longitudinal studies are the most appropriate design for research engaging the model, because experience suggested that it allowed for the most differentiation. The present study does not employ a quantitative experimental design and so is neither longitudinal nor cross-sectional. Nevertheless, it seeks to consider the impact of time on developmental outcomes and to use Bronfenbrenner's model as intended, as "a structured framework for displaying the emergent research findings in a way that reveals more precisely the pattern of the interdependencies that in fact obtain in the data available" for the purpose of forming more actionable hypotheses, (Bronfenbrenner & Morris, 1998, p. 1000). In this case, in order to form a framework for the consideration of the ethics of affective systems.

The full PPCT model has not yet been invoked in HCI research, however, aspects of Bronfenbrenner's ecological systems theory have been used in research ranging from data privacy in education (Kumar, Chetty, Clegg, & Vitak, 2019), to pediatric asthma management (Jeong & Arriaga, 2009), and mental health management (Murnane, Walker, Tench, Voida, & Snyder, 2018). This body of literature was skimmed in order to understand the scope of work that has incorporated or applied Bronfenbrenner's ideas, but was not thoroughly reviewed until after the scenario and counterfactual analyses, in order to prevent bias. A summary of this literature in relation to the present study is provided in Chapter 6.

The scenario was analyzed with attention to three overarching themes: demonstrations of the PPCT model, description of technology, and description of affect or emotion. These themes and subthemes informed the creation of three counterfactuals:

1. Without technology ("technology" defined as interaction with SHSCs, SHSC companion apps, and SNS)
2. With humans in place of technology, and
3. With technology augmented with affective computing capability.[6]

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[6] For the third counterfactual (with technology augmented with affective computing capability), I present three possible versions of each interaction—however, these are for

Analysis of the actual scenario as well as the counterfactuals with respect for opportunities and responsibilities of technology design and implementation is provided to demonstrate how the PPCT model might be applied to sociotechnical interaction phenomena. While the PPCT model was used as a framework to begin analysis, simultaneous open coding allowed for the generation of additional concepts within the orbit of PPCT, technology, and affect themes.

Drawing on the literature, additional analysis of the scenario and the counterfactual scenarios for areas of ethical salience was conducted. These themes were then mapped to their place in the PPCT model. Findings of this analysis are described in Chapter 4. The themes cannot be said to form a *theory*, as there is not enough data to compare across. Rather, this analysis is intended to demonstrate application of the PPCT model to an emerging ubiquitous and affective computing sociotechnical gap, and to inform discussion about the ethics involved.

Analysis was conducted primarily using NVivo Version 12 (2018) computer-aided qualitative data analysis software.

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illustrative purposes, and the number of possible variations and combinations of affective applications is unlimited.

Chapter 4. Scenario and Counterfactuals: Analysis

The actual scenario is discussed in some detail with respect to how the elements of the story can usefully be explained using the PPCT model as a lens. Then, each of the three counterfactual scenarios are discussed with respect to the potential consequences of the changes made for each variable using the PPCT model as a guide.

Design Scenario

In the original article and in the scenario derived from it, there is no clear solution, no "win" to speak of, for neither Ganave nor the other residents of Potrero Hill. The PPCT model, once applied, can help explain why.

The scenario (Table 1) begins by introducing the protagonist, Ganave Fairly. For the majority of this investigation, Ganave is the person at the center of the analysis; however, one can consider the scenario from the perspective of another resident or any other actor.

Looking at the personal characteristics of propensity, resources, and demand (Bronfenbrenner & Morris, 1998), one can quickly identify areas of influence. With Ganave at the center, it becomes evident that her disposition and propensity to act has been molded by her experience and may impact her tendency to take risks. Her mental and physical resources (ability and acquired knowledge and skill) are strained by the stress of lacking basic necessities and by addiction. Finally, intersecting oppressions impact how Ganave is viewed and treated by others—the “demand” or encouragement or discouragement to believe and act particular ways.

There are several moving parts within the context aspect of the PPCT model. Considering Ganave’s microsystem, a common theme is instability. Ganave has experienced family instability since childhood. As an adult, she also experiences housing instability and income instability. Instability often leads to disruption in healthy or beneficial processes, as part of what defines a process is sufficient time and regularity. The blocks she frequents in search of packages to steal are the equivalent to a workplace for Ganave, taking a place in her microsystem.

Using the PPCT model as a starting point, I describe in turn three interactions with computing devices that represent discrete opportunities for affective interaction: Ganave’s interaction with SHSCs, SHSC owners’ interactions with companion apps, and neighbors’ interactions with SNS and with others via the platforms. Each is drawn from the scenario in Table 1.

Design Scenario

Ganave Fairley is a 38-year-old black, gay woman living in a public housing development in Potrero Hill, a gentrifying neighborhood in San Francisco, California. Ganave's parents lost custody of her when she was a child after they were deemed unfit to raise her due to drug addiction and abuse. Sidelined by an injury, she lost her scholarship, forcing her transfer from a private to a public school. Complications of an early pregnancy lead to dependence on prescription opioids and then to addiction. Accused of stealing from multiple workplaces, it was difficult for her to keep a job. Ganave and her daughter faced constant housing instability. When Amazon's e-commerce and home delivery system took off, Ganave saw an opportunity to earn money by lifting packages from porches and reselling the contents. She had heard that Amazon replaced lost or stolen packages, so she didn't feel that bad about it. When asked about her actions, Ganave stated, "I'm not a bad person, it was just a bad choice … I was in a desperate state" (Smiley, 2019). Things began to change when smart home security cameras (SHSCs) came to Ganave's neighborhood, ramping up in February 2018 when Amazon acquired Ring. Without regular access to news and social network sites (SNS), one could easily mistake the devices for ordinary doorbells. Online, video footage and stills of suspected "porch pirates" flooded neighborhood groups, and cameras were touted by community leaders as a safety measure. Some residents of Potrero Hill felt it was foolhardy to leave things unattended, while others vigorously defended their right to leave their property exposed. For the latter group, buying and installing a Ring, Nest, or other brand of SHSC was an attractive solution. When footage of Ganave and others stealing packages from residents began being posted online, Ganave was unaware. When her neighbors discussed what to do, she didn't have the opportunity to defend herself or to change her behavior in response. She did encounter a neighbor face-to-face, however, when one chased her down in his socks after seeing her on his Ring companion app, recording their confrontation with his mobile phone. As he records, Ganave defends her actions to an imagined outside viewer, potentially in court but even more likely online: "I didn't see her doing nothing, but I'm assuming," she said, imitating the man (Smiley, 2019). Sometimes, residents would yell at Ganave remotely through a speaker on the doorbell: she ignored it. With contextual nuance unsupported by fisheye-distorted, motion-activated SHSC systems, the residents of Potrero Hill are left to imagine local "porch pirates" by relying on the broad strokes of the images caught on tape and reviewed manually ("a black woman in a neon hoodie" (Smiley, 2019). Neighbors then share footage online and give it to police to help identify perpetrators and strengthen court cases. On one occasion, a neighbor harassed Ganave's sister, Kai, who worked in the community, mistaking her for the thief he saw on camera. "He didn't believe me," Kai said, as she described putting her hand up to block the view of a man following and taking photos of her. She added, "I was embarrassed, mostly." (Smiley, 2019). Following trial and conviction for her offenses, Ganave now bounces between prison, rehab, and homelessness in Potrero Hill. She has lost her daughter and found a small black box that sends information about her location to the police fixed around her ankle. Neighbors gossip about her online and shoo her off their property, where she would sometimes linger to sleep or rest. She has nowhere to store the goods she would otherwise steal and resell, and her connections with resale intermediaries have dissolved, anyway. (But at least she no longer steals packages.)

Table 1. Design scenario for analysis, derived from (Smiley, 2019)

Interaction 1. Smart home security cameras

In a given week, Ganave has repeated interactions with SHSCs used as telepresence devices (Figure 2). While Ganave often slips away unnoticed, sometimes she is caught by the owner of the package and SHSC system. This happens when the device detects her motion on the porch, sending an alert to the owner. The owner can then open the companion app to view and speak through the wall- or door-mounted device. When this happens, the owners usually yell at Ganave to return the package, and Ganave ignores them. Here, Ganave interacts both with the SHSC device and with the distributed neighbor. Thus, these interactions with actors in Ganave's microsystem are part of the activity of stealing packages in which Ganave is engaged. Ganave interacts with SHSCs regularly. Though the encounters are brief, they occur frequently. Thus, these interactions may be said to meet the criteria for being a proximal process, impacting the worldview of Ganave and SHSC owners watching her.

Interaction 2. Smart home security camera companion apps

Many residents of Potrero Hill own a SHSC, which comes with a companion app installed on users' mobile devices. The companion app (Ring's is called "Neighbors") includes information about the time, location, and nature of reported incidents. These incidents can be filtered and displayed on a map (Figure 3). Depending on users' settings, video footage or stills are included in the post about the incident. For the present analysis, sharing and commenting through companion apps is considered a type of social media or SNS. I limit my analysis to the apps' other functionalities.

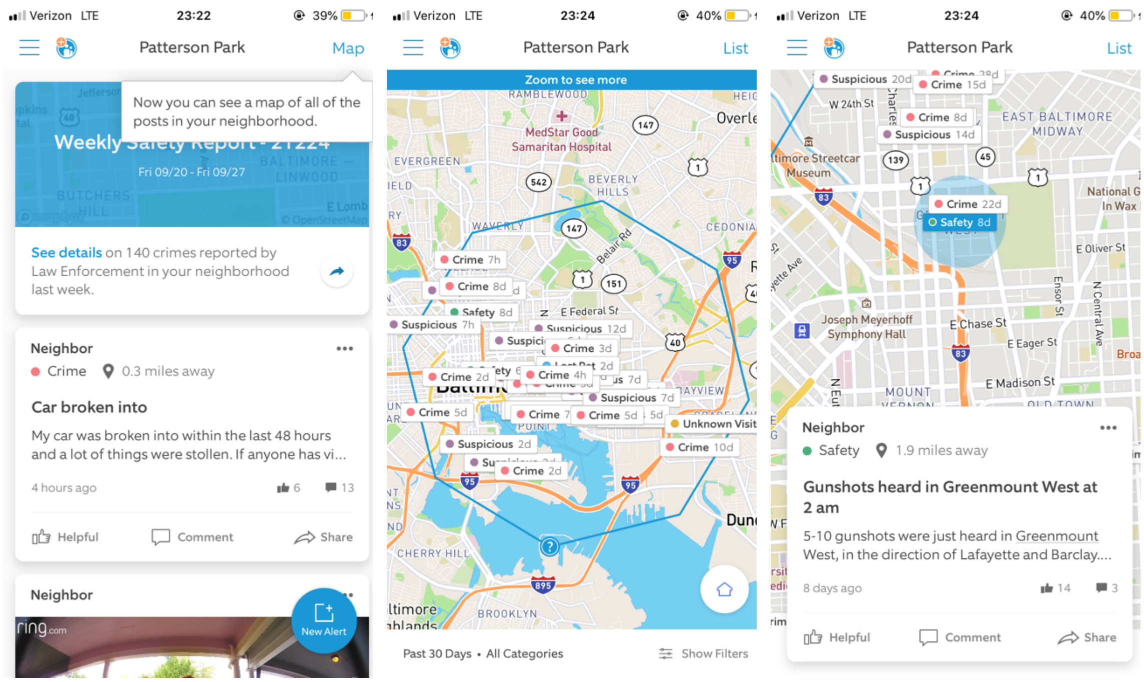

Figure 3. Ring Neighbors app community activity interface

The SHSC companion app plays an essential role in the SHSC experience by alerting users to activity, allowing users to check on their property remotely at any time, and allowing users to review past recordings (Figure 4). These interactions, if repeated regularly and with sufficient time spent on them, become proximal processes that influence the individual and their worldview.

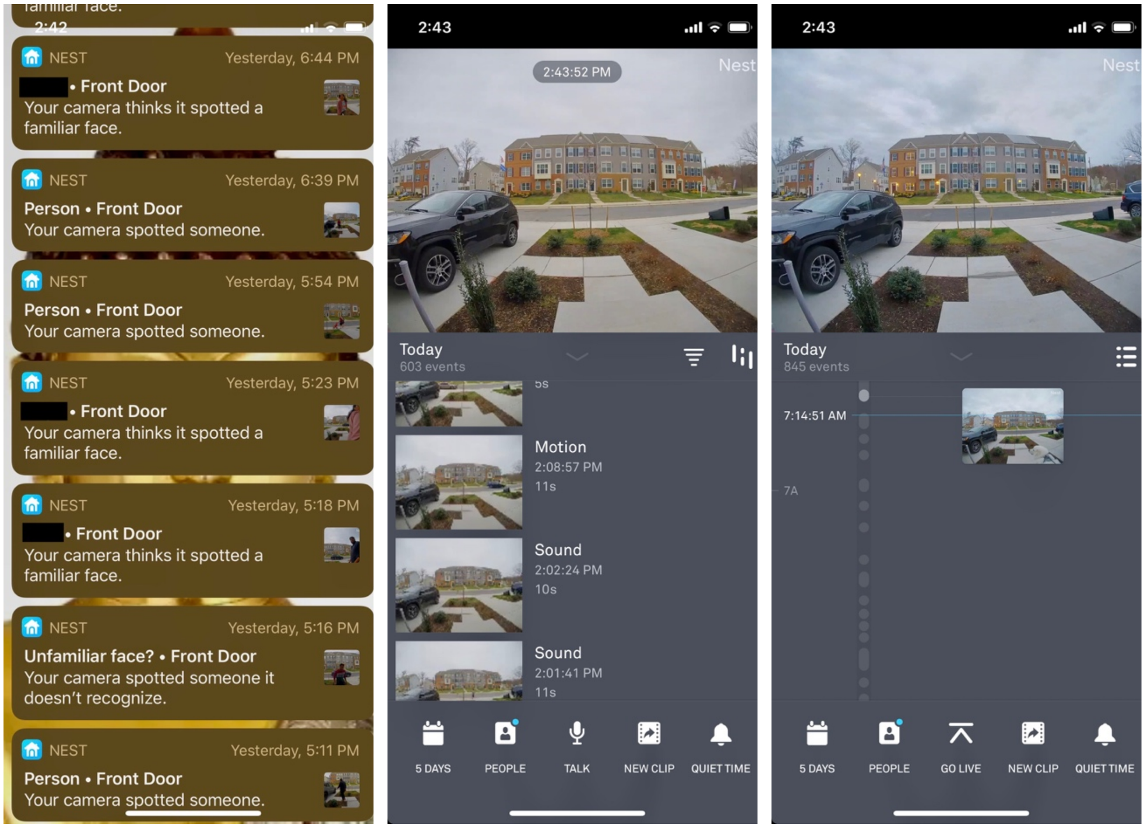

Figure 4. Nest camera companion app notifications and user interface

As an example, I consider how routine use of the SHSC companion app might have influenced the man who misidentified Ganave's sister Kai as Ganave herself (see Table 1). I imagine he receives a notification on his phone while he is at work indicating motion in the range of his SHSC. A full analysis of this situation might include the effects of notification settings and badges. With apps designed to encourage users to spend time on them, it is likely that this interaction was designed to be can be described as a proximal process.

Next, I consider what context the streaming video is shown in and whether the user has any idea what to expect—sometimes an alert is triggered by wind or rain, other times by a person, and twice (we can imagine) it was a person taking off with the Amazon package that had just been delivered; both times, "a black woman in a neon hoodie." (Smiley, 2019). As one study of SNS and discussion about crime found that 90% of crime-related photos shared were of black males (Erete, 2015), I imagine this user is conditioned to perpetuate stereotypes about what criminals look like. I imagine that the first time the package theft happened, the SHSC owner was in a meeting and could not do anything, but the second time he used the communication function to yell at the woman to put the package back, threatening to call the police if she did not comply.[7] Either way, he cannot get a good look at her, and she was out of view with his packages within seconds. The interface told him only the date and time.

On the days he does not receive any suspicious alerts, I imagine that he reviews the recorded footage in the evening. Sometimes, a person looking like that woman who stole his packages walks by, and he feels his heart rate increase as he wonders what will happen next, if he missed an alert or the motion sensor failed to capture something. According to Bronfenbrenner's ecological systems theory, because using the companion app is a routine activity and proximal process, it has a transformative effect on the individual, in this case, the Potrero Hill resident who thought he saw the woman who twice stole his packages.

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[7] Examples of similar interactions can be found on Ring's YouTube page: https://www.youtube.com/channel/UCSDG3M0e2mGX9_qtHEtzj2Q

When he finally saw her in action, walking down the street, he raced out of his house, berating her and snapping photos with his phone (Smiley, 2019).

While less is known about the personal characteristics of this resident of Potrero Hill compared with Ganave, his characteristics are impacted by his interactions with his SHSC companion app. As with Ganave, he experiences these interactions in time—both in his life course and on a much larger scale. He is also affected by mesotime, that is, the linkages of the time situations of others in his microsystem, such as Ganave.

Interaction 3. Social network sites

Each of these contextual factors is influenced by Ganave's personal characteristics, and the interactions between the individual and people, objects, and symbols in their immediate environment (and between those things and other things in the environment)—the mesosystem. An example from the design scenario (Table 1) of an interaction occurring at this level is: "When footage of Ganave and others stealing packages from residents began being posted online, Ganave was unaware." Here, two mesosystem interactions are at play: between each individual neighbor and their social network site interface, and then between neighbors via the sites.

With Ganave at the center, SNS are best considered an aspect of the exosystem along with mass media; local policy and law;

representatives of other social institutions; and extended family, distant friends, and other less infrequent contacts. Because Ganave does not use SNS (or, at least not to keep current on property crime concerns in her neighborhood), I can more confidently place it in the exosystem. Other people may experience SNS in their microsystem, especially if they engage in prolonged activity with it at regular intervals, at which point the interaction becomes a proximal process, impacting development.

One of the challenges Ganave faced when SHSCs arrived in Potrero Hill was identifying them and understanding their functionality. As described above, these devices are intentionally designed to blend in to the residential porch context as a doorbell, thereby improving social acceptability (Pierce, 2019). Residents of Potrero Hill who were not themselves early adopters of SHSCs may have learned about them online through SNS where images and video footage are commonly posted and where someone in a target audience might be served advertisements for them.

The SNS described in Smiley's (2019) article include Nextdoor and Facebook. In other locations across the US, the SNS mobile app Citizen (formerly Vigilante) is common. Some SHSC companion apps also feature social aspects, where users can share their recordings and comment on others' posts (see Figure 3). A community organizer who lives in the same public housing compound as Ganave and who uses SNS to stay informed about and communicate with other residents of Potrero Hill described

Nextdoor in 2014 as “upper-middle-class Facebook,” remarking that users seemed to blame the public housing residents for everything; Smiley writes, “ ‘They stepped on a banana peel,’ she said, ‘and would be like, ‘The projects put it there!’” This observation supports reported ambivalence about social media use for neighborhood crime prevention among African Americans, people from high-crime neighborhoods, and people with low levels of trust in the police (Israni, Erete, & Smith, 2017).

Next, I turn to two counterfactuals designed to elucidate the affective nature of the three interaction types (Table 2).

Interaction	Actual scenario	Counterfactual 1. Without technology	Counterfactual 2. Humans in place of technology
1. Smart home security camera (SHSC)	Sometimes, residents would yell at Ganave remotely through a speaker on the doorbell, but she ignores it.	Residents called local officials, filed police reports, put signs up to mark their private property. Many had packages delivered to more secure locations; others had lockers installed on their property.	When passersby moved to take a package, they sometimes met people sitting on porches. Once, Ganave was questioned by a jovial elderly woman. She continued off with the package. Another time, she was caught by an angry young man who raised his voice at her, lifting his fist in the air. It reminded her of something. Since then, she hasn't stolen any packages.
2. SHSC companion app	With contextual nuance unsupported by SHSC systems, residents imagine local "porch pirates" by relying on the broad strokes of the images caught on tape and reviewed manually. On one occasion, a neighbor harassed Ganave's sister, mistaking her for the thief he saw on camera.	Residents grew suspicious of people passing through who appeared poor. They complained to each other and to local officials, occasionally leading to additional police patrol. However, no one felt certain who to blame for the package thefts, and there were no direct confrontations.	Ganave's sister, Kai, walks through the neighborhood but has no idea about her sisters' stealing. The neighbors on their porches smile and wave.
3. Social network site (SNS)	When video footage of Ganave stealing began being posted on SNS, Ganave was unaware. When neighbors discussed what to do, she didn't have the opportunity to explain herself, or to change her behavior, because she wasn't online.	Residents communicated about package thefts using private email and text groups. They used these to ask others to look out for and pick up their deliveries.	Residents expressed their frustration with package theft at a community meeting. This alerted residents who were not previously aware to the problem. In response, some decided to have packages delivered elsewhere, while others formed a neighborhood watch committee.

Table 2. Counterfactual 1: Without technology, and Counterfactual 2: Humans in place of technology

Counterfactual 1. Without Technology

I next describe ways in which Ganave's story might unfold if technology as defined herein were non-existent or replaced by low-tech alternatives. The goal of the analysis is twofold: first to illuminate the role technologies play in Ganave's ecology in order to better understand how they impact outcomes and second to identify any affective characteristics of the presence or absence of the identified technologies. The needs met by the three target interactions are investigated in their absence, framed by the PPCT model.

Interaction 1. Smart home security cameras

Without the presence of SHSCs, Ganave's process of stealing could be limited to her and the packages and the intermediary she sells the contents to. The absence of the camera systems could facilitate her activities, allowing her to get away unnoticed and without close scrutiny after the fact. In this counterfactual, fast and free or low-cost home delivery is still assumed. Therefore, residents wishing to take advantage of this convenience but without the option of installing a SHSC may resort to other delivery methods, as alluded to in the design scenario (Table 1): some may have their packages delivered elsewhere, or they may, for example, install a locker (similar to a locked mailbox) on their property. These alternative delivery methods could result in fewer packages available for Ganave to steal, and thereby reducing the time she spends on the activity and the potency of the proximal process as a means of development. Should this process become less developmentally salient, it stands to reason that Ganave might seek alternative sources of income.

Interaction 2. Smart home security camera companion apps

With no SHSCs there would be no companion apps for residents to use to monitor their property from a distance or to review recordings from the day. Among other things, the interaction described in Smiley between the residents and Ganave's sister Kai would likely be very different.

In the absence of these apps, residents might rely on other existing structures to perform the same task. For example, they might instead call on the police to increase patrol in their neighborhood. Thus, instead of engaging in a proximal process with a companion app, residents might reach out to exosystem structures such as local representatives and law enforcement agencies. In most cases these interactions would not meet the time criteria to become proximal processes and would not impact the developmental course of the residents. However, the potential increase in patrol in the neighborhood could shift the elements of the neighborhood microsystem and the opportunities for different proximal processes between law enforcement actors and residents (including package thieves like Ganave).

It is therefore possible to consider that a confrontation such as arose between a Potrero Hill resident with a SHSC companion app and

Ganave's sister Kai may be less likely to occur, as the resident would not have been pouring over video footage of "suspicious" passersby. However, there may be unanticipated effects of increased patrol in the neighborhood.

Interaction 3. Social network sites

In the design scenario, SNS existed in Ganave's exosystem, that is, outside her day-to-day life. However, SNS still impacted her through her neighbors' use. This developmental impact is the result of processes occurring in Ganave's mesosystem.

In this counterfactual, I imagine the residents communicating using other computer-mediated communication tools such as email and text message groups. While these allow for sociality and information sharing, they differ from SNS of today in that they are driven by direct manipulation rather than an agent or algorithm. While not applied to SNS specifically, early HCI researchers saw this kind of interaction as more predictable and controllable (Shneiderman & Maes, 1997). In part due to direct manipulation, these technologies are not as vulnerable to influence by the corporations that manage them, a possibility elegantly demonstrated by the Facebook emotion contagion study (Kramer et al., 2014). This ability can be harnessed to increase ad revenue (Chalermsook, Sarma, Lall, & Nanongkai, 2015), and to influence user decision-making in limitless other ways (Susser, 2019).

Regarding advertising, Smiley notes that Nextdoor, “has capitalized on its neighborhood-watch vibe” by promoting ads for home-security companies including Ring, ADT, and SimpliSafe (Smiley, 2019). While I generally locate SNS and apps like Nextdoor in the PPCT model’s exosystem, the company’s business model is clearly influenced by other systemic factors, including multifaceted drivers of capital accumulation and consumerism at the macrosystem level, and venture capital (Nextdoor is a private company recently valued at $2.1 billion by investors) and related structures at the exosystem level. By applying Bronfenbrenner’s ecological systems theory, we can reasonably hypothesize that these higher-level factors influence the residents of Potrero Hill (for example) who use Nextdoor, and further, Ganave, who interacts regularly with Nextdoor users.

While some email and text message platforms may serve advertisements to users, direct manipulation protects users from invisible influence (Susser, 2019). Consequently, residents of Potrero Hill might use these tools to coordinate assistance looking out for and picking up packages. Whether or not these attempts to protect deliveries are successful, conversations about package thefts are less likely to be sensationalized and “piled on” to as may occur when posts are visible to second degree SNS users. While Ganave might be unaware that her neighbors are discussing their package theft problem, their discussion is less likely to impact her directly due to the above described nature of these computer-mediated communication tools compared with SNS. However, she may find fewer packages out for the taking.

Counterfactual 2. Humans in Place of Technology

Next, I consider a counterfactual where key technology interactions are replaced by interactions between humans (Table 2). The purpose of this exercise is to illuminate the characteristics unique to affective technologies insofar as they influence developmental trajectories. I focus again on three interactions from the scenario in Table 1 amenable to integration of affective computing technology, imagining the story with humans in place of SHSCs, SHSC companion apps, and SNS. Other aspects of the system remain unchanged, such as free expedited shipping and the practice of replacing lost or stolen packages.

A PPCT-informed analysis of the design scenario revealed transformative developmental effects of human-computer interactions. I now seek to describe how human-human interactions have the same or different transformative effects, and how these might impact other aspects of the ecological system. In what they termed "the media equation," Reeves and Nass (1996) found that people follow the same social rules when interacting with media and computer systems that they use when interacting with other humans. For example, by not revealing performance criticism directly to the computer they worked with, while being more forthright when asked by a different computer. Based on this theory alone, we can infer that interactions with humans will be very similar as to interactions with technology, and that both have the potential to transform.

Interaction 1. Smart home security cameras

When Ganave interacts with SHSCs in the design scenario, she sometimes has the option of engaging with the owner via telepresence. While SHSC owners may turn to this functionality in an attempt to interrupt package theft, Ganave is able to ignore these telepresence calls, making off with their package as the owner yells at her through a speaker. Replacing SHSCs with people in this counterfactual yields significant changes to the environment, as people are easier to perceive than most SHSCs due to their size and dynamism. While Ganave is described as having high tolerance for risk (Smiley, 2019), I cannot predict how she might behave in this counterfactual. While she may attempt to continue stealing under the watchful eyes of neighbors fixed to their porches, she may also modulate her behavior in response to her appraisal of human presence and her affective reaction.

Speculative versions of this counterfactual install people with different characteristics on porches, each appraised differently by Ganave (and vice versa). For example, I first imagine Ganave approaching a package, but then questioned by an elderly woman in a rocking chair. The woman might pipe up in a jovial manner, “Oh, hello!” And then, “Oh, excuse me, miss! Miss?” Again, given the description of Ganave’s behavior (Smiley, 2019), I imagine her scowling at the inconvenience and continuing off with the package.

I then imagine Ganave being called out for stealing packages by other kinds of people. For example, an angry young man raising his voice at her, lifting his fist in the air and approaching her while shouting in a deep voice, “Hey! What do you think you’re doing?” While O cannot reliably predict any one person’s response in this exercise, it is reasonable to imagine that such an encounter could remind Ganave of a past experience, triggering an emotional reaction. In such an interaction, Ganave—even with her temperament and need of money—might drop the package and run (a behavioral adaptation to fear). She may even refrain from stealing packages for a time, at least from that area.

Since I imagine that an interaction with a jovial elderly woman could yield a different outcome compared with an interaction with an angry young man over the same period of time, it becomes apparent that time is not the only factor determining the impact of an interaction and whether an interaction has developmental consequences. Affect, power, and reciprocity are important parts of the PPCT model as characteristics of relations between microsystem actors engaging in proximal processes leading to development. Furthermore, Ganave’s personal life experiences insofar as they have shaped her view of the world and inform her affective response to events and the environment must be taken into consideration.

Interaction 2. Smart home security camera companion apps

In the design scenario, a resident of Potrero Hill frequently engaged with his SHSC companion app became convinced that he knew who was stealing his packages and mistakenly admonished the wrong person for the crimes: Ganave's sister, Kai. This mistake is in line with experience of bias and racial profiling, a documented problem (e.g., Goodnough, 2009) recognized by Nextdoor (Smiley, 2019), and with particularly worrying implications for AI when systems do not recognize faces of people of color as accurately as white faces (Buolamwini, 2018).

I imagine Kai walking through the neighborhood, handing out flyers for a community event, her activity watched over by people instead of SHSCs. Kai lives in the same housing development as her sister, but is employed and likes her job with a local organization. Perhaps some neighbors do not acknowledge her, while others smile and wave from their porches. I imagine Kai happy, relaxed, and focused on her work; her posture, gait, facial expression, and physiological signals aligned with her subjective experience. While many neighbors may intuit Kai's affect fairly accurately, others may not, as the aphorism, "we don't see things as they are; we see them as we are" (attributed to Anaïs Nin) articulates, pointing to the difficulty of lack of ground truth and to the interactional nature of affect.

The scenario describes how a neighbor frustrated with repeat thefts and whose experience is framed by use of a SHSC companion app mistakenly accuses Kai of the thefts. I now imagine a person in place of the companion app deciding whether to alert this neighbor of the presence of someone walking by his porch. While the companion app alerts users to *all* motion within range of the SHSC, a human may make a more nuanced decision about whether to raise an alarm. I like to imagine that a person watching Kai move from porch to porch and positively engaging with neighbors would not raise an alarm. However, bias may not easily be overcome by increased awareness of affect and context (even when detected by humans), and I cannot conclusively determine whether Kai would endure any more or less racial profiling with humans in place of SHSCs.

In the design scenario, the SHSC companion app user engaged in a proximal process with the app that impacted his development in such a way that he mistook Kai for Ganave, but there was no proximal process between the user and Kai or Ganave directly. In this counterfactual, I imagine possible proximal process unfolding between Kai and the residents of Potrero Hill, where she lives and sometimes works. If encounters with neighbors are characterized by mostly positive affect, it is likely that Kai will return there, intensifying the process and potential for development of new opportunities and relationships.

Interaction 3. Social network sites

In the design scenario, Ganave is unaware of the growing concern about package theft in the community and is excluded from the debate about how to respond to it because it happened primarily on a social network app that she did not use. On this app, photos and video footage of her stealing packages was posted for all to see. When Ganave finally went to court, it seemed that the residents of Potrero Hill knew her personally from their collection of video footage just as well as she knew them from the contents of their packages (Smiley, 2019). In this counterfactual, I imagine residents sharing information about their package thefts at a community meeting. In this public forum, residents who have not had packages stolen become aware of the possibility that their packages might be stolen, and perhaps make some behavioral changes in response, such as having them delivered elsewhere. Others decide to form a neighborhood watch committee. If Potrero Hill is similar to other gentrifying neighborhoods, I might assume that Ganave's public housing complex has its own community meetings and that Ganave does not attend the other Potrero Hill neighborhood meetings. Therefore, as in the original design scenario, she may not know that residents were beginning to discuss her activities.

There are important differences between sharing video footage and stills on SNS and sharing information and stories verbally at an in-person community meeting. Social network sites often have different social norms (both from each other and from other forms of communication, such as face-to-face), and provide an opportunity for people to cultivate identity (boyd & Ellison, 2007). This presents an opportunity for different kinds of speech, such as hate speech, to emerge (Mondal, Silva, & Benevenuto, 2017). While hate speech is beyond social acceptance, less extreme expressions of racism and bias are common, as Nextdoor acknowledged in explaining a redesign aimed at preventing it (Smiley, 2019). Furthermore, community SNS activity has impacts offline. Online conversations about crime have been found to increase fear and anxiety and lead to stereotyping with reported influence on real-life interactions (Erete, 2015).

The nature of the impact of hypothetical community meetings on Ganave and her activities cannot be pre-determined. However, community members would have an opportunity to act without the invisible influence of algorithms, and their decisions would likely have an impact on Ganave.

Counterfactual 3. Technology Augmented by Affective Computing

Finally, I consider three versions of a third counterfactual, technology augmented with affective computing (Table 3).

Interaction	Version A	Version B	Version C
1. Smart home security camera (SHSC)	The doorbell detects the emotion of the remote owner speaking through the doorbell and changes color to communicate that feeling to the passerby.	The doorbell has a humanoid form (e.g., face). The system synthesizes the emotion of the remote owner (learned their affect/behavior), portrayed through the doorbell.	The doorbell detects the passerby's affect and uses this information to start an emotionally intelligent dialogue.

Interaction	Version A	Version B	Version C
2. SHSC companion app	The detected affect of the passerby is used to determine whether to alert the SHSC owner of the remote interaction.	The detected affect of the user/owner is used to determine whether to send alerts and/or which clips to highlight at the end of the day.	The detected affect of the passerby is included on the user interface as the video is live streamed or viewed after the fact.
3. Social network sites (SNS)	The system evaluates the affect present in the video or photo before upload to SNS, informing the user of the affective tone and ensuring they want to post it.	The detected affect of the passerby is included on the user interface after being posted.	Content is served to the community of SNS users based on affective tone (and other characteristics).

Table 3. Counterfactual 3: Technology augmented with affective computing

Counterfactual 2 (“humans in place of technology”) begins to uncover areas for additional consideration at the nexus of affect and impact on users from an ecological perspective. The remainder of this chapter focuses on three variations of affective computing interaction design applied to the three technology interactions defined. While there are many variations of affective computing that could be considered, these were chosen to highlight some of the most common applications of affective computing in research and development. These counterfactuals are speculative and may not be equally technically feasible at the moment. However, they are grounded in current research and theoretical possibility, as work on affective intelligent user interfaces explores (Conati, Marsella, & Paiva, 2005). Examples of similar affective computing systems are provided where possible.

This counterfactual presents a number of possible ethical quandaries calling out for deeper consideration. I present the counterfactual with a range of versions and discuss the ethical implications in detail in Chapter 5.

Interaction 1. Smart home security cameras

Recall that when Ganave encountered the SHSC in the actual scenario as a telepresence device, it did not have the intended effect on her behavior (i.e., she continued stealing). In Counterfactual 1 ("without technology"), the absence of SHSCs with presence of frequent package delivery was considered likely to lead to alternative package acceptance methods, such as at a more secure address or by placement in a locker, potentially leading to evaporation of Ganave's enterprise. Counterfactual 2 ("humans in place of technology") suggests that Ganave's behavior with a human near the package may depend on the affective character of that interaction in relation to Ganave's personal characteristics.

Three versions of an interaction with a SHSC system augmented with affective computing are presented in Table 3. Versions A and B both involve detecting and then communicating the emotions of the SHSC owner. Version C detects and responds to the passive user's (i.e., Ganave's) affect.

Version A uses changes in color to express the emotions of the remote user. While there are no universal connotations, there are some general associations between color and emotion. For example, red could be associated with anger, yellow with happiness, blue with calm, green-yellow with disgust, gray with sadness, red-purple with love, and black with fear (Kaya & Epps, 2004). These colors could be mixed and constantly changing based on input from the remote user or activated at the point of telecommunication. Because of the ambiguity of color-to-emotion association, this kind of interface could be developed in a similar fashion as Affector, an emotion communication prototype (Boehner, DePaula, Dourish, & Sengers, 2005).

Version B is similar to Version A, but is intended to communicate the remote user's emotion more concretely through humanoid features, however this too may depend on the passive user's own emotional state and ability to interpret co-constructed emotional cues (Barrett, 2012). Here, I imagine a system similar to the affective robot Kismet in form (Breazeal & Scassellati, 1999). Unlike Kismet, which synthesizes emotion in response to a partner, this system would convey emotion on behalf of the remote SHSC owner using the system as an automated pseudo-telepresence device.

Version C of the affective SHSC would sense the passive user's affect and respond appropriately. An example of a similar system is a virtual patient system used for training medical professionals designed to elicit empathetic response (Kleinsmith, Rivera-Gutierrez, Finney, Cendan, & Lok, 2015). In addition to conveying synthesized emotion in order to elicit empathy, the SHSC might also recognize Ganave's emotional state and respond appropriately. For example, if it sensed fear, it might respond with reassurance and offer resources. A strength of Version C is the possibility of engaging the passerby (i.e., Ganave) and eliciting empathy, however if the kind elderly woman in Counterfactual 2 was unable to do this, would we want to design a SHSC that could?

Interaction 2. Smart home security camera companion apps

The design scenario introduced a SHSC owner reliant on the companion app for real-time alerts about his property and for a stream of recorded video to be reviewed at a later time. In Counterfactual 1 ("without technology"), I considered what existing structures might be called upon to fill the perceived need for constant monitoring of private homes and property during the day. In Counterfactual 2 ("humans in place of technology"), I imagined a block of neighbors on their porches watching passersby with curiosity, able to react in real time and share information with others later, taking in an array of contextual information.

Three versions of an affective SHSC companion app are summarized in Table 3. Versions A uses affect detection to determine whether to alert the SHSC owner of remote activity, Version B does this in a different way and can also customize an end-of-day review, and Version C includes information about affect on the user interface.

Version A describes a system that tries to interpret the affect of the SHSC subject and based on that information, determines whether to alert the SHSC owner of the activity. This could be implemented in various ways. For example, the system could be designed (or set) to not alert the owner to activity with neutral affect, reducing the number of alerts. Or, it could filter subjects' affect by valence or intensity, alerting the owner only to (for example) high intensity, negative emotional states.

Version B is the inverse of Version A. Version B detects the affect of the owner and determines whether to send alerts based on this information. This is similar to desktop computer systems designed to not interrupt users in certain emotional or cognitive states. For example, if the owner is feeling anxious, the system might delay informing them of activity on their property. The system could also aggregate the owner's mood throughout the day and curate an end-of-day review designed to convey the information they missed in a way that is mindful of their emotional needs (not merely chronologically), such as sandwiching recordings of disturbing activity between recordings of delightful activity.

Version C takes a different approach, displaying on the user interface information about the emotional state of the video subject. This might be used during a synchronous telecommunication interaction as well as for reviewing older recordings, as a type of metadata. This kind of system is the inverse of Versions A and B for interactions with SHSCs: it offers an additional modality for interpreting affect that supplements the natural human ability (or inability) to detect affect through voice, facial expression, and/or posture.

Interaction 3. Social network sites

Last, I consider three versions of SNS or social media apps augmented with affective computing technology (Table 3). Recall that, in the design scenario presented in Table 1, Ganave was unaware that images of her stealing packages were being posted online and that she was the subject of discussion there. Counterfactual 1 ("without humans") involved using other forms of computer-mediated communication to address the package theft problem, and Counterfactual 2 ("humans in place of technology") brought the discussion into face-to-face conversation at community meetings.

Here, I offer for consideration three versions of SNS or social media apps augmented with affective computing capabilities. Version A is a system that will evaluate a video, image, or text entry prior to posting and inform the user of the affective characteristics of that content. Version B does the same, but instead of alerting the user, appends this information to the post for other users to access and consider. Finally, Version C suggests a SNS that curates the content feed based on the affective qualities of available content.

Version A is designed to assist the user in making sense of the content they are considering sharing. If the detected emotional tone of the content comes as a surprise to the user, I imagine that it might encourage the user to reflect more on the meaning of the content and reconsider sharing it. An example of a prototype that does this is Tweet

Moodifier, a system that analyses the affective tone of tweets during composition, which was found to shift users away from extreme emotions toward more neutral content (Saldías F. & Picard, 2019).

Version B could be combined with Version A, however the unique aspect is sharing the system's determination of affect with the SNS audience as a kind of metadata appended to the post, for example along with time and location. The intent would be to invite viewers to think more critically about the content of the post.

Version C offers means to consider the affective metadata of published content as it determines which posts to give greater or lesser exposure. This is a kind of "invisible influence" of ML/AI algorithms (Susser, 2019). One can imagine posts with greater degrees of anger or fear gaining more exposure under certain ecological imperatives (such as to sell more home security ads), or an effort to create the impression that distress (as a latent indicator of a crime-related post) is in fact low or non-existent.

Discussion

Considering the affective computing design alternatives presented in Counterfactual 3 using the PPCT model reveals similarities to Counterfactual 2 ("humans in place of technology"). While it is not possible to know how a user in Ganave's position would respond to each without conducting user studies or observations (for example), I surmise the strengths and weaknesses of each based on the existing prototypes they are compared to, where available. One strength of many of the design ideas presented is multimodality. In addition, users may prefer affective information conveyed through different modes, such as through the voice, color, or facial expression.

One area this analysis does not explore in detail is individual characteristics. This is an important part of the PPCT model and is reflected in the first two paragraphs of the constructed design scenario presented in Table 1. A deep and realistic understanding of the individual can help designers make more informed decisions, as foregrounded by user-centered design (Abras, Maloney-Krichmar, & Preece, 2004). However, it is not clear that user-centered design is suitable for considering the range of ethical challenges around design with affective computing. If we consider every interaction an opportunity for development, interactions that are not enriching are missed opportunities. In fact, as Bronfenbrenner & Morris (1998) stated strongly, reciprocal interactions with people, objects, and symbols that *do not* invite, "attention, exploration, manipulation, elaboration, and imagination" (p. 997) can in fact undermine development. If designers acknowledge that persons have innate dispositions, resources, and demands, they can be alert to uses of technology that interact with those qualities. The PPCT model illustrates how technologies in the environment—not only those owned by an individual—can influence transformations toward or away from values.

Nextdoor CEO Sarah Friar said that difficulty identifying people correctly is a human problem, not one Nextdoor invented. Nevertheless, the company has formed an anti-racial-profiling task force and continues to update the platform to encourage users to " '…get out of your bird brain—that immediate response—and into your cognitive brain, to pause and ultimately make a better decision'" (Smiley, 2019). This kind of problem is perhaps best illustrated in the design scenario (Table 1) by the interaction between a SHSC owner and his companion app, which leads to the unjustified abuse of Ganave's sister, Kai. This mistake is a tragedy that may present an opportunity for affective computing not because it would more accurately identify any particular passerby, but because it could use data about affect to intelligently direct alerts and present information. However, individual and contextual variables are many: while affective computing may benefit Kai in this scenario, it could harm another person in another scenario. A framework for navigating the ethical challenges of applying affective computing to design problems such as those described in Counterfactual 3 is presented in the next chapter.

Chapter 5. Toward a Framework for Ethical Affective Computing

Improving awareness of the political influences involved in technologies marketed to us, taken up by our neighbors, and promoted by local authorities has the potential to mitigate future harm. For example, it can help computing professionals abide by section 3.7 of the ACM Code of Ethics and Professional Conduct, “Recognize and take special care of systems that become integrated into the infrastructure of society” (Association for Computing Machinery, 2018). Uncovering the considerations specific to affective systems can support interpretation of ethical codes such as the ACM and other computing and engineering professional associations, thus guiding policy about affective systems and helping those involved in design and implementation. Additionally, increasing awareness about ecological systems theory also has the potential to empower end users and other stakeholders impacted by computing systems, helping them understand how they work and providing language to enable them to think about and demand alternatives.

There are a number of paths forward regarding areas affective computing researchers might focus attention in the consideration of ethical design, described in Chapter 2. To add to this important discussion, the following directions toward a framework for thinking about the ethical issues important to the design and implementation of affective systems in private and public settings considers this topic from a development-focused ecological systems theory using the PPCT model.

Applying the Process-Person-Context-Time Model

I propose an ecological framework for thinking about the ethics of affective computing systems consisting of four elements, each connected to an element of the PPCT model. Each element is supported by a set of guiding questions, discussed in terms of the counterfactuals introduced in Chapter 4. There are any number of possible counterfactuals, and this study looks at three that each focus on three kinds of interaction. While it is possible that this framework many not apply to all affective computing systems or affective interactions, the PPCT model was designed to help organize thought about human life in context, with explicit attention paid to affect and other human and social variables. Attempts to identify areas of interaction design that do not relate to ecological systems theory may prove insightful, however outside the scope of my thesis. The intention here is to focus on ethical issues unique to affective computing and to supplement frameworks for ethical design of other aspects of these systems, such as ML/AI. An ecological framework for ethical decision-making is by definition relevant to a wide range of stakeholders. While it may be refined for specific audiences, the proposed framework in its present iteration is intentionally general and aspires to be a starting point accessible to researchers, designers, policy makers, and everyday users and other non-traditional user stakeholders.

While each element of the proposed framework emphasizes a different consideration, at this point in the development of the framework, they are not entirely separated from one another. While this may pose limitations in usefulness, and future iterations may seek to refine each element (and/or reframe them entirely), this limitation points to an assumption central to ecological systems theory: interdependence. Figure 5 illustrates how the four elements of the framework may overlap. With this in mind, questions suggested by each element of the framework will be discussed with attention to both independence and interdependence from other ethical concerns.

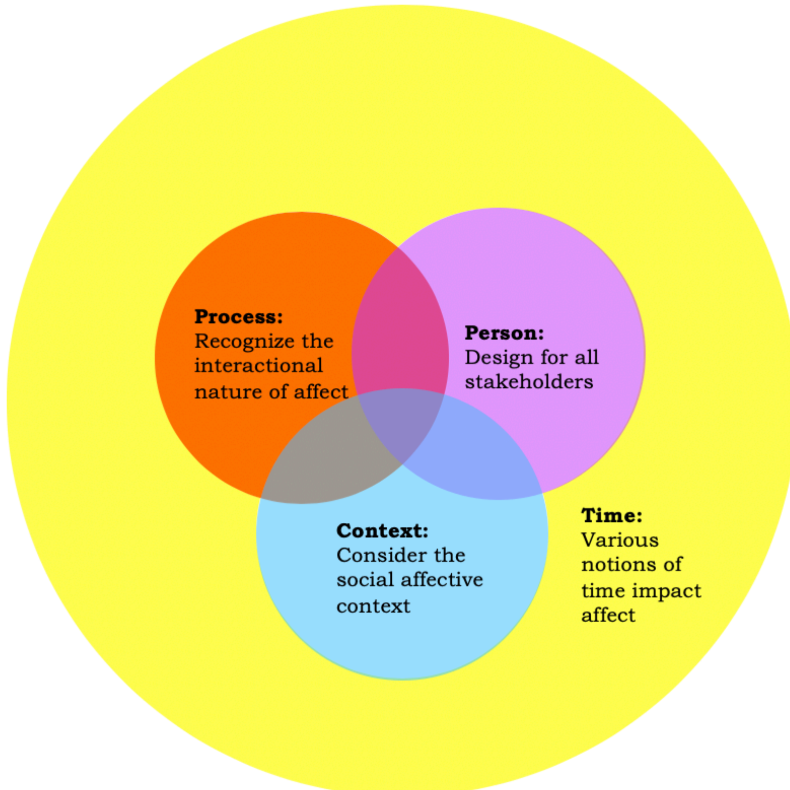

Figure 5. Elements of the proposed ecological framework for ethical affective computing

1. Process: Recognize the interactive nature of affect

Because emotion and affect are person, context, time, and sometimes perceiver dependent, determining ground truth is one of the most challenging aspects of affective computing (Afzal & Robinson, 2015). While computers can identify affect approximately, and can be designed to categorize that such data for intelligent interaction or human interpretation, these systems, "…in most cases disregard the influence of culture and personality in the experience and expression of emotion," and so the broader meaning of affective-related data is not well understood (Afzal & Robinson, 2015, p. 362).

Appraisal theory is based on the interpretation of an outside event by an individual, thus is dependent on the context and the individual experiencing the emotion. With respect to ground truth, the appraisal theory approach to affective computing challenges the idea that emotion can be interpreted consistently or accurately. While affective computing models based on appraisal theory can be used in social contexts, ecological systems theory urges either an interactional (e.g., Boehner et al., 2005, 2007) or cultural and critical theory (Fritsch, 2018; Fritsch et al., 2019) approach, compared with an informational one (e.g., Rosalind W. Picard, 1995; Rosalind W. Picard, 1997).

It may seem obvious that a person appearing happy might accurately be labeled as happy, and there are databases that can be used to reliably detect a simple emotion such as happiness. The duly labelled person might agree with this categorization. However, the absence of ground truth raises two issues: first, the person may not, in fact "be" happy, and second, the emotion the person is experiencing—even if it is happiness—is not merely an attribute of that person, but rather the consequence of the interaction of events and personal characteristics. Given this analysis, this ecological framework generally supports the interactional approach to affective computing (Boehner et al., 2005, 2007; Höök et al., 2008).

Analysis of the story of Ganave and her neighbors demonstrates the interdependence of developmental outcomes. Because affect arises within an interdependent ecological system, “ground truth” affect cannot be established. This fact has implications for “classification error,” (i.e., the subject looks happy and is classified as happy, but is actually nervous), as well as for data relationships and ownership. Guiding questions and reflection about the nature of ground truth are suggested in Table 4.

Guiding Questions by Interaction Type Process: Recognize the Interactive Nature of Affect	
1. Smart home security camera (SHSC)	How is affect data about passersby stored?
2. SHSC companion app	How is affect information connected to passersby conveyed at the user interface?
3. Social network site (SNS)	How might algorithms be designed using collective data about affect?

Table 4. Guiding questions for the "Process" framework element

Interaction 1. Smart home security cameras

Questioning individual ownership of affect invites new ways of thinking about data relationships and ownership with the potential to reduce hyper-individualization, an idea gaining traction in the privacy community and highlighted in the Feminist Data Manifest-No (Cifor et al., 2019). An affective SHSC system that accounts for the absence of ground truth and the collective ownership of affect might not, for example, store data about affect as an attribute of an individual person. Such a design would have implications for privacy, should the video footage and connected data be subpoenaed for use by law enforcement.

Interaction 2. Smart home security camera companion apps

In addition to data relationships, mentally decoupling affect as an attribute of an individual has consequences for the design of the user interface. If affect data about an individual cannot be determined with certainty, and is not merely an attribute of that person, to begin with, is it appropriate to label an individual with an emotion? For example, consider with the kind of information displayed by the companion app in Figure 4, such as "Your camera spotted someone it doesn't recognize." If the absence of ground truth and the shared interactional nature of affect are accepted, a similar notification, such as, "Your camera spotted someone angry" would signal an inappropriate and potentially unethical interface design decision.

Interaction 3. Social network sites

While systems that aim to detect and work with discrete emotions have many beneficial applications, it could be used to "hyper-individualize" and may not be appropriate for all applications. A SNS taking an interactive approach to affect to the design of some features could potentially cultivate a more realistic experience of a social space, a possibility inviting further exploration.

Consensus is emerging that when it comes to social computing systems for crime prevention, it is preferable to design for interaction among users, rather than simply providing information (Kadar, Te, Rosés Brüngger, & Cvijikj, 2016). With this in mind, designs that do not merely display or make use of data about affect as information about individuals, but rather encourage meaning-making interaction among users, may be preferable in this context.

2. Person: Design for all stakeholders

An intractable challenge in designing affective computing systems for all is presented by a lack of ground truth about the nature of any one person's (or any collective's) affective experience. Recall Kai's experience of being misidentified as her sister, Ganave, and the uncertainty of whether affective computing could ameliorate such a problem. Could an affective system be counted on to correctly infer Kai's positive, calm demeanor and reflect that to SHSC users? Not necessarily. Designers must consider how to use and convey information related to affect in the absence of ground truth.

One of the motivations of this thesis addresses the question of the impact of design on diverse societies. The PPCT model demands attention to the multiplicity of actors involved in interactions with technology, demonstrated by the experiences of Ganave and her neighbors with SHSCs and related artifacts. Baumer (2015) suggests the term "usees" to describe persons such as Ganave with SHSCs. However, this form is suggestive of the French grammatical convention signifying a person who is e.g., "used;" and thus may not be entirely accurate, in this case. Satchell and Dourish (2009) identify six types of non-use demanding the attention of HCI researchers, one of which is disenfranchisement, about which, they write, “A narrow focus on use—typically a focus on consumption, and consumption of high-end digital systems and services—inherently renders significant populations analytically invisible” (p. 12). Ecological systems thinking can help address this blind spot.

What does it mean to “design for”? Light et al. (2017) wrote, “The user is us;” we are designing for our future selves: “…for our own fear, hope, sadness, joy and need for purpose” (p. 7). Thus, to “design for” may mean to design in the best interest of. Light et al. implore designers to consider the developmental outcomes of design decisions:

> Some people will never be curious or alive to possibilities around them. Many people’s circumstances do not allow for a full use of their creative faculties. While worth observing, this is no reason to design only to the lowest common denominator. If we become what our interactions make us, we risk the atrophy of the muscles we neglect, and the real range of our potential humanity is lost to us. (p. 8)

When we think of ourselves as users and stakeholders, the possibility of alternate futures becomes palpable. Considering the range of users and stakeholders and the interactions among them and with technology can lead us to demand and create systems that are more open ended, protect fiercely agency and privacy, and promote wellbeing and positive development.

In order to illustrate the application of inquiring into the experience of all users, I consider the three interactions introduced in Tables 2 and 3 with the mandate of designing for all stakeholders. Guiding questions and opportunities for reflection based on the application of the PPCT model are presented in Table 5 and discussed in relation to each of the three key interaction types.

Guiding Questions by Interaction Type Person: Design for All Stakeholders	
1. Smart home security camera (SHSC)	Can passersby consent to or opt out of interaction with the system? How might emotion communicated by SHSC owners via telepresence impact the wellbeing of passersby?
2. SHSC companion app	Does the user have the ability to customize or turn off system responses to affect detection, or turn off affect detection entirely? Is information about affect detected and/or conveyed by the SHSC presented in a meaningful way?
3. Social network site (SNS)	Does the user posting content have the ability to override affect-driven system suggestions? Does the user viewing content posted by others have the ability to customize or turn off system responses to affect detection? Does content serving based on affect promote positive development for all stakeholders?

Table 5. Guiding questions for the "Person" framework element

Interaction 1. Smart home security cameras

By applying the PPCT model to the experience of passersby encountering SHSCs, I predict that repeated interaction over time may result in a proximal process with SHSCs and thus influencing development, highlighting the importance of designing ethical interactions. As Figure 4 shows, their affective “image” (and data) may be captured by the SHSC system and transmitted to the SHSC owner entirely without the subject’s knowledge. This comes into conflict with Picard and Klein’s (2002) call for transparency in affective systems, as well as with the demands of the Feminist Data Manifest-NO (Cifor et al., 2019).

For Picard, consent is a requirement in the design of affective devices. She points to simple ways to ensure user agency, such as by removing an affective wearable device (like a watch): the opposite of the ankle monitor (which is also a kind of “wearable” (Iliadis & Pedersen, 2018)) that Ganave is forced by the state to wear following her conviction. It also compares sharply with each version of Counterfactual 3, where Ganave encounters affect-aware SHSCs during her package stealing activities. In these encounters, Ganave does not have the option of non-interaction.

Furthermore, an affective interaction can have a profoundly harmful impact on a stakeholder. In Counterfactual 2, I show how Ganave is emotionally triggered by a high arousal, negative, strongly dominant affective posture, re-experiencing a traumatic memory and interrupting her behavior. While in this scenario Ganave could be described as a public nuisance whose behavior *should* be interrupted, designers need also to consider higher priorities, such as fairness and wellbeing. Ganave’s story is complex, and it would be very challenging to design an affective system able to differentiate between a public nuisance and a violent criminal, whose behavior ought to invoke responses with different priorities.

Interaction 2. Smart home security camera companion apps

Augmentations of SHSC companion apps using affective computing suggested in Chapter 4 involved tailoring the experience to the owners' affect or displaying information about passerby affect on the user interface. Designing for all stakeholders invites consideration of the autonomy of the SHSC user. For example, while it might be beneficial to design notifications around the affect of the passerby and/or the companion app user, the user must have the opportunity to provide feedback on the quality of the notifications they receive and the recordings they review, in part because people are skeptical about affective computing (Loi, 2018) and because direct manipulation, when feasible, provides greater control (Shneiderman & Maes, 1997).

It is also important to be considerate of the way passerby affect is represented on the companion app user interface. This can be operationalized in a variety of ways. For example, if a passerby's posture is indicative of a low mood (e.g., sad), is that necessary and meaningful information for the SHSC owner? Probably not. If a contextually relevant affect is detected in a passerby (e.g., fear or anger), care must be taken in representation at the interface to ensure that it is useful and accurate.

Interaction 3. Social network sites

One concern with augmenting SNS and apps with affect detection bears similarities to that of SHSC companion apps: enabling user control. A system might make suggestions based on affect detected in content, but the decision about whether to post or view such content ought to be in the hands of the user. However, that does not mean that a well-designed system cannot promote interactions that lead to demonstrably better outcomes for a variety of stakeholders. The example of Ganave and the fearmongering generated on SNS illustrates the urgent need for well-designed systems that encourage empathy and reflection, and there is emerging evidence that this approach can work (Saldías F. & Picard, 2019).

While informational affective systems may capture and communicate data about affect much like other kinds of data, such as date, time, and location; data about affect is not so straightforward. In this way, affect recognition systems bear similarity to automatic gender recognition systems, and call for equal care in determination of appropriate implementation and representation (Hamidi, Scheuerman, & Branham, 2018).

Finally, algorithms that take into account affect detected in content (for example) may be designed to influence site or app users' behavior, including, for example, time spent on the site and propensity to engage with advertisements. This is already possible and happening (Kramer et al., 2014), and decisions must be made about how and why algorithms are manipulated when direct manipulation it is no longer feasible due to volume (Shneiderman & Maes, 1997). Algorithms of social and collaborative platforms influence behavior (e.g., Salehi & Bernstein, 2018), and design decisions must account for the developmental needs of a range of stakeholders.

3. Context: Consider the social affective context

Affect is an important area of research and design in sustainable HCI (Fritsch, 2018; Fritsch et al., 2019). Recent scholarship in environmental sustainability and climate change also calls on computing and information systems researchers and designers to address the challenge presented by affect in this context. From the perspective of sustainability leadership and management, Bendell (2019) proposes five ways technology can assist with adaptation in the face of the climate crisis, including with respect to emotion:

> [T]echnology needs to be made more available where it is desperately needed to reduce suffering and deepen adaptation. … One area where such opening-up is urgent is to support mass psychological adaptation to our climate tragedy. Awareness of our situation is provoking many difficult emotions. We will continue living with loss, grief, sadness, confusion, fear and anger. (p. 7)

Designing in an “end times” milieu of negative affect may prove challenging for designers, themselves affected.[8]

Designing for context awareness is notoriously difficult (Dourish, 2004a). Multimodal sensory input can help contextualize affective phenomenon, which, though challenging, can be selected as appropriate for applications (Pantic & Rothkrantz, 2003). Multimodal systems tested under realistic assumptions about the social and personal emotional tendencies could aid in liberating stakeholders’ ingrained patterns of thought, feeling, and behavior compounded by negative emotion. Otherwise, the system may contribute to the potentially devastating problem of “bovine design” (Light et al., 2017).

Starting with the time element, designing with consideration of the emotional or affective context in mind requires awareness of our place in time. For example, what pressure might the post-industrial (or industrial) economy exert on the environment at this time? From an appraisal theory standpoint, how do people evaluate events initiated by those pressures in context of their goals? Contextually, this element of

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[8] An example of the connection between individual and collective affect and crisis events can be seen in a recent blog post by UMBC Writing Center intern Ilsa Mir (2020). Mir begins, “In the wake of a global pandemic that has halted the world, all of my emotions are heightened. Feelings of fear, anger, sadness, and concern have occupied every single second of existence as I move through life at a languid pace.” She also wrote, “It may help to dedicate a few minutes of your day to understanding and appreciating the complexity of thoughts and emotions you are experiencing. … If you are angry, perhaps at the way institutions are handling this pandemic, write a letter. Maybe you can even send it in the morning. If you feel lonesome, revel in the idea that thousands of people are understanding of your circumstance because they too are living it.”

the framework is perhaps most informed by the more distal aspects of the environment with respect to the individual, that is, the social structures mediating life in the exosystem and the cultural beliefs and social norms in the macrosystem. Each of these impacts and is impacted by developmental processes occurring at the meso- and microsystem levels. For example, if the goals of actors in these more distal system levels conflict with those in the microsystem level, an affective tension may arise. Affective computing could be used to manipulate this tension.

Considering the social affective context of our current situation means advocating for design that supports empathy and enhances coping and other positive affect-motivated behaviors that might aid in advancing an agenda focused on justice and survival (Knowles, Bates, & Håkansson, 2018). Guiding questions and reflection about social emotional or affective context are suggested in Table 6.

Guiding Questions by Interaction Type Context: Consider the Social Affective Context	
1. Smart home security camera (SHSC)	Does the system consider the emotional needs of all stakeholders?
2. SHSC companion app	In what ways do design decisions manipulate users' emotions?
3. Social network site (SNS)	Does the system include and empower marginalized voices?

Table 6. Guiding questions for the "Context" framework element

Interaction 1. Smart home security cameras

Times of crisis can produce heightened awareness of what we as individuals and as a society have to lose. Crisis "…directly impacts our ability to affect (what can we do?) and to be affected (what matters?)" (Fritsch et al., 2019). In the analysis of Ganave's interaction with SHSCs in the original scenario and related counterfactuals, I demonstrated how Ganave appeared at times *unaffected* by encounters at the point of the SHSC, by, for example, ignoring angry requests for her to return the stolen package made via telepresence through the SHSC. While certain interventions might change her behavior (as in, for example, Counterfactual 2), it may be that Ganave has greater concerns, that the affect and opinion of the SHSC and package owner do not matter to her in this context. If an affective system cannot fairly *affect* a passerby or other person such as Ganave in a morally acceptable manner, the designer might question whether it is possible to build a reciprocal system that balances and distributes power among stakeholders justly.

Interaction 2. Smart home security camera companion apps

Manipulation is not limited to SNS, where its power has already been discussed; it can also apply to the design of SHSC companion apps and similar personalized interfaces. Here, I consider ways the system might capitalize on opportunities to reduce negative emotions associated with, for example, the climate crisis and the detrimental social and cultural systems driving it.

It is difficult to imagine such a perspective applied to the design of SHSC companion apps, which are designed to exacerbate fear for the purpose of achieving specific profit targets (c.f., Smiley, 2019). Design decisions already manipulate users' emotions and affect detection technology could amplify this strategy. Ethical decision-making in this respect calls for an analysis of the power structures involved and any conflicts of interest between corporate entities and other exosystem-level actors (such as politicians and state agencies) and microsystem-level stakeholders, such as individual active and passive users.

Interaction 3. Social network sites

One way of interpreting the scenario described in Table 1 is that Ganave is significantly influenced by her lack of presence on the SNS popular in Potrero Hill. A counterfactual in which she is present on these platforms might explore alternate outcomes. However, the platforms do not at present lift up marginalized voices, as the description of Nextdoor as "upper-middle-class Facebook" (Smiley, 2019) reminds us. Social network sites augmented with ethical affective computing must use that technology to combat this imbalance.

4. Time: Various notions of time impact affect

Looking at different ways of considering time may seem alien to many today, but in fact, diverse concepts about time are common throughout the world, past and present. For example, the ancient Greeks had words for various kinds of time, including khronos (linear time), aion (unbounded or historical time), and kairos (the "right" moment in time).

The last element of Bronfenbrenner's PPCT model is time. This element is often overlooked and was absent from Bronfenbrenner's original theory. However, since its introduction, Bronfenbrenner and colleagues have only emphasized its importance to understanding developmental outcomes, and have differentiated several kinds of time, each with a different impact. The impact of different kinds of time can be seen in Ganave and the residents of Potrero Hill's interactions with SHSCs, companion apps, and SNS, and the ethical implications explored here.

Guiding Questions by Interaction Type Time: Various Notions of Time Impact Affect	
1. Smart home security camera (SHSC)	How frequently do active (or primary) users interact with the device? How frequently long to passive (or secondary) users interact with the device?
2. SHSC companion app	How frequently and for how long do users interact with the system? What are the needs and priorities of the company that owns the system at this moment in time, and how do they support or conflict with users' needs and priorities?
3. Social network site (SNS)	How frequently and for how long do users interact with the system? What are the needs and priorities of the company that owns the system at this moment in time, and how do they support or conflict with users' needs and priorities? How does time in one's life (for example, age) impact use of the system?

Table 7. Guiding questions for the "Time" framework element

<u>Interaction 1. Smart home security cameras</u>

In the course of analysis for this thesis, it at first appeared that Ganave did not spend enough time interacting with SHSCs to rise to the level of engaging in proximal process with them. Indeed, she is described as moving quickly from porch to porch, ignoring the devices. However, due to the frequency of her interactions with SHSCs, a proximal process unfolds, nevertheless. This means that even if Ganave is unaware of the impact of her repeated interaction with SHSCs (or that it is even happening, if she does not recognize them for what they are, or if they are hidden), these interactions impact her development as they amass video footage of her, leading to increased awareness about her activities online and fueling heated conversation about her, as well as providing evidence to help neighbors and law enforcement bring her to court—whether used in court, or not. Add affective computing to these interactions, and the power of time in these designs could be amplified.

Persons interested in evaluating the ethics of affective systems should consider the frequency of interaction with sensing devices, such as SHSCs. These interactions should be considered from the perspective of passive users, like Ganave, as well as more traditional users, like the person or family that purchased and installed the device. The impact of SHSCs on owners was not studied in depth herein, but is certainly of interest.

<u>Interaction 2. Smart home security camera companion apps</u>

User interactions with SHSC companion apps involve frequency of use, as well. Frequency of use can be modulated by the kind and number of notifications pushed to the user, and the potential for affective computing to influence these design decisions was discussed above. Affective computing could also be used to effectively hijack the user's attention and cause them to spend more time in the app than they would otherwise choose to.

Duration and frequency of use is a driver of proximal processes impacting developmental outcomes, and so decisions about how to interrupt and seize control of people's time using affective interactions or affective computing is a decision about ethics. Researchers, designers, policy makers, and users might better understand how time is manipulated by considering the moment in time that the system exists in, what the needs and priorities of companies promoting these systems are in that time, and how those needs and priorities support or conflict with those of end users and other stakeholders. This macrotime scale is closely related to the contextual macrosystem that includes social norms and cultural beliefs. For example, a company with a SHSC companion app, such as Ring's Neighbors app, may have an interest at this time in scaling their reach by gaining popular support for public programs that would subsidize the product for individuals but lead to powerful connections between the company and law enforcement (e.g., Richman, 2020).

Interaction 3. Social network sites

Concerns raised regarding time and SNS include those outlined above for SHSC companion apps. As above, those concerned with how time is manipulated can consider the moment in time that the system exists in, what the needs and priorities of companies promoting these systems are in that time, and how those needs and priorities support or conflict with those of end users and other stakeholders. For example, due to their financial structure at this time, Nextdoor has a need to increase revenue via ad sales. Thus, the designers of the app are incentivized to manipulate users' emotions in order to drive engagement with advertisements for home security systems, as described by Smiley (2019).

In addition, this framework advocates consideration of other elements of time in the context of SNS, such as time in one's life. Designers should think about whether some people may be systematically excluded from engaging with the product or system due to their age (e.g., too young or too old) or due to other lifetime-related factors, such as being too busy due to other obligations, or alternatively having a lot of free time to spend with the product or system. Adding to this, Bronfenbrenner invites us to consider mesotime. Mesotime describes how an individual is impacted by the impact of time on others in their ecosystem. For example, attending to the characteristic needs of a young child or elderly parent.

It is possible that affective computing and design could be used to reinforce these divisions, or to heal them. For example, attention to the role of affect at various points in stakeholders' lifetimes may help people otherwise excluded from involvement with products or systems access them, if other constraints—such as access to the Internet and hardware such as personal computers or mobile devices—are considered.

Summary

This chapter outlines how a framework based on Bronfenbrenner's PPCT model could guide ethical design and decision-making for affective computing systems. The four elements of the PPCT model are related to findings from the counterfactual analysis of the story of Ganave Fairley, as described in Table 1 and more extensively in Smiley (2019). To demonstrate how each element might be applied, the story is considered through three isolated types of interaction (with SHSCs, with SHSC companion apps, and with SNS) that could be augmented with affective computing technology.

Chapter 6: Conclusions

This thesis demonstrates how Bronfenbrenner's PPCT model can be used to better understand the implications of affective computing design decisions and affective system implementation by conducting a counterfactual analysis that seeks to isolate the effects of affective computing, were it implemented within an existing system. This analysis was used to describe how the PPCT model might serve as a framework for ethical design and implementation. My analysis is based on a narrow set of interactions drawn from a single design scenario focused on affective computing and thus may not be applicable as-is to other kinds of interactions and scenarios. However, the PPCT model was designed to be broadly applicable, and an ethical framework based on the model could potentially shed light on other complex human-human interactions mediated and facilitated by computing systems, such as doxing, cancelling, catfishing, and trolling.

In this chapter, I situate and summarize my analysis and findings, consider the limitations of this work, and suggest areas for future work.

Applications in HCI and Affective Computing

Bronfenbrenner's PPCT model was not made for application by interdisciplinary computing researchers, but this attempt to do so demonstrates the possible utility of more systematic ecological approaches to understanding HCI and related issues, especially in the context of longitudinal observational or experimental study.

At the time of writing, 21 publications in the ACM Digital Library mention Bronfenbrenner's ecological systems theory. While most of these investigate social aspects of interaction and use, none focus on affect or affective computing specifically. In order to prevent bias, a thorough review of this body of literature was conducted after analysis of the scenario derived from the story of Potrero Hill and corresponding counterfactuals. Results and suggestions based on these investigations vary. Interestingly, Murnane et al. (2018) applied Bronfenbrenner's ecological systems theory to personal informatics for mental health, concluding that designing for collective experience supported user priorities such as representation, privacy, sensemaking, knowledge production, and decision-making. This finding, supported by interviews and focus groups, is in line with the ecological framework suggested herein, specifically with respect to the interactive nature of affect and considering affect in social context.

In the PPCT model, affect most prominently features as an aspect of the first 'P'—process. There is a reason processes come first in the name of Bronfenbrenner's most mature ecological systems theory model: it is central to development (Shelton, 2019). As much as affective computing scholarship has given back to psychology, one hope is that the application of the PPCT model to affective computing might contribute new knowledge about the importance of affect in the PPCT model to psychology.

This thesis began with questions about usability and the affordances that might exist in affective computing. Using the PPCT model to explore applications of affective computing has in fact shed light on this question: it has become evident that Gibson's description of affordance is strikingly similar to Bronfenbrenner's description of proximal process. Research exploring the connection between proximal process and affordance, and the potential utility of affect in proximal process/affordance may prove interesting and useful.

The herein suggested framework for thinking about the ethical design of affective computing systems consists of four overlapping elements, each connected to an element of the PPCT model:

1. Process: Recognize the interactive nature of affect,
2. Person: Design for all stakeholders,
3. Context: Consider the social affective context, and
4. Time: Various notions of time impact affect.

Application of the framework to the three interaction types (with SHSCs, with SHSC companion apps, and with SNS) demonstrates how a holistic approach to ethical design of affective systems is necessary for any one part to be considered morally good. For example, if affective SHSC and SHSC companion app interactions are not designed with an ethical framework, then sharing content derived from those interactions on affective SNS will be ethically compromised, even if other measures are taken to design the site ethically.

Limitations

The methods used herein have limits, as all methods do. First, it must be acknowledged that while the ideas surrounding the present analysis were discussed with specialists in affective computing, privacy, and ethics, the analysis itself was conducted by a single researcher. Triangulation by other researchers following the documented methods could strengthen, weaken, or change the themes identified via the multiplicity of possibilities that counterfactual analysis affords.

Adelman (2018) describes the work of figuring affective scenarios for a humanistic analysis in terms related to the limitation of subjectivity encountered in this thesis. “Crucially,” she writes, “the actual voices of the beings on which these figures are patterned are absent, muted, or extensively mediated” (p. 4); so it is for Ganave and the other residents of Potrero Hill. Adelman adds that the purpose of the practice of figuring in her work is to challenge ingrained assumptions, to “denaturalize them by documenting their origins in various political, social, and cultural system” (p. 5). While the analysis of an isolated case by a single researcher is perhaps uncommon and of limited utility within the field of HCI, it is not without its own merits. My hope is that this thesis demonstrates both the limitations and merits of such a practice.

Directions for Future Work

This thesis and its limitations highlight an urgent need for designers to engage with individuals in the communities where systems are implemented. Community-engaged participation in design can help designers of affective and ubiquitous computing systems understand the needs of *all* stakeholders (not only primary stakeholders, often called "customers" or "users"), the second element of the ecological framework developed in this thesis.

Thus, to mitigate the limitations of the methods used in this thesis, immediate future work might seek to test the face validity of the counterfactual analysis and proposed framework. To accomplish this, community-based workshops with stakeholders such as those introduced in "The Porch Pirate of Potrero Hill" (Smiley, 2019) could provide feedback or even suggest design scenarios and counterfactuals reflective of their personal experiences with—and affects related to—SHSC systems. Such work would benefit from participatory design literature calling for explicit attention to the impact of affect in the design process (e.g., Frauenberger, Foth, & Fitzpatrick, 2018; Light & Akama, 2012), as well as examples of participatory design applied to affective computing systems (e.g., Grond et al., 2019; Mulvenna et al., 2017).

Community-based participatory design of affective systems may also help the research community better understand emerging notions of affect, such as promoted by Fritsch (2018). As the dialogue regarding informational and interactional approaches to affective computing has nearly come to a standstill, this alternate approach based in critical and cultural theory may prove fruitful. This approach to affect may also contribute to the design of truly context-aware applications (whether high- or low-tech) that support the needs of people experiencing the effects of unsustainable ways of life.

Additional work in this area must engage policy makers and members of communities impacted by proliferating sensing systems, such as SHSCs. The application of the PPCT model to a complex scenario involving a variety of affective human-human and human-computer interactions has, by my analysis, informed a framework for ethical decision-making capable of identifying unethically designed systems and products. The strength and proven record of the PPCT model in demonstrating causality in social and health applications should pique the attention of policy makers and advance the work of those seeking more just and sustainable futures.

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