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EMOTION IN HUMAN–COMPUTER INTERACTION

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Emotion is a fundamental component of being human. Joy, hate, anger, and pride, among the plethora of other emotions, motivate action and add meaning and richness to virtually all human experience. Traditionally, human–computer interaction (HCI) has been viewed as the ultimate exception: Users must discard their emotional selves to work efficiently and rationally with computers, the quintessentially unemotional artifact. Emotion seemed at best marginally relevant to HCI and at worst oxymoronic.

Recent research in psychology and technology suggests a very different view of the relationship between humans, computers, and emotion. After a long period of dormancy and confusion, there has been an explosion of research on the psychology of emotion (Gross, 1999). Emotion is no longer seen as limited to the occasional outburst of fury when a computer crashes inexplicably, excitement when a videogame character leaps past an obstacle, or frustration at an incomprehensible error message. It is now understood that a wide range of emotions plays a critical role in every computer-related, goal-directed activity, from developing a three-dimensional computer-aided design (CAD) model and running calculations on a spreadsheet, to searching the Web and sending an e-mail, to making an online purchase and playing solitare. Indeed, many psychologists now argue that it is impossible for a person to have a thought or perform an action without engaging, at least unconsciously, his or her emotional systems (Picard, 1997b).

The literature on emotions and computers has also grown dramatically in the past few years, driven primarily by advances in technology. Inexpensive and effective technologies that enable computers to assess the physiological correlates of emotion, combined with dramatic improvements in the speed and quality of signal processing, now allow even personal computers to make judgments about the user's emotional state in real time (Picard, 1997a). Multimodal interfaces that include voices, faces, and bodies can now manifest a much wider and more nuanced range of emotions than was possible in purely textual interfaces (Cassell, Sullivan, Prevost, & Churchill, 2000). Indeed, any interface that ignores a user's emotional state or fails to manifest the appropriate emotion can dramatically impede performance and risks being perceived as cold, socially inept, untrustworthy, and incompetent.

This chapter reviews the psychology and technology of emotion, with an eye toward identifying those discoveries and concepts that are most relevant to the design and assessment of interactive systems. The goal is to provide the reader with a more critical understanding of the role and influence of emotion, as well as the basic tools needed to create emotion-conscious and consciously emotional interface designs.

The seat of emotion is the brain; hence, we begin with a description of the psychophysiological systems that lie at the core of how emotion emerges from interaction with the environment. By understanding the fundamental basis of emotional responses, we can identify those emotions that are most readily manipulable and measurable. We then distinguish emotions from moods (longer term affective states that bias users' responses to any interface) and other related constructs. The following section discusses the cognitive, behavioral, and attitudinal effects of emotion and mood, focusing on attention and memory, performance, and user assessments of the interface. Designing interfaces that elicit desired affective states requires knowledge of the causes of emotions and mood; we turn to that issue in the following section. Finally, we discuss methods for measuring affect, ranging from neurological correlates to questionnaires, and describe how these indicators can be used both to assess users and to manifest emotion in interfaces.

UNDERSTANDING EMOTION

What is emotion? Although the research literature offers a plethora of definitions (Kleinginna & Kleinginna, 1981), two generally agreed-on aspects of emotion stand out: (1) emotion is a reaction to events deemed relevant to the needs, goals, or concerns of an individual; and (2) emotion encompasses physiological, affective, behavioral, and cognitive components. Fear, for example, is a reaction to a situation that threatens (or seems to threaten, as in a frightening picture) an individual's physical well-being, resulting in a strong negative affective state, as well as physiological and cognitive preparation for action. Joy, on the other hand, is a reaction to goals being fulfilled and gives rise to a more positive, approach-oriented state.

A useful model for understanding emotion, based on a simplified view of LeDoux's (1996) work in neuropsychology, is shown in Fig. 4.1. There are three key regions of the brain in this model: the thalamus, the limbic system, and the cortex. All sensory input from the external environment is first received by the thalamus, which functions as a basic signal processor. The thalamus then sends information simultaneously both to the cortex, for higher level processing, and directly to the limbic system (LeDoux, 1995). The limbic system,[1] often called the "seat of emotion," constantly evaluates the need/goal relevance of its inputs. If relevance is determined, the limbic system sends appropriate signals both to the body, coordinating the physiological response, and also to the cortex, biasing attention and other cognitive processes.

The direct thalamic-limbic pathway is the mechanism that accounts for the more primitive emotions, such as startle-based

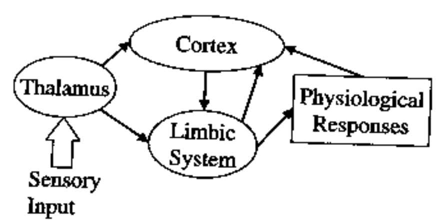

FIGURE 4.1. Neurological structure of emotion.

[1]The limbic system is often considered to include the hypothalamus, the hippocampus, and the amygdala. According to LeDoux, the amygdala is the only critical area (LeDoux & Phelps, 2000).

fear, as well as innate aversions and attractions. Damasio (1994) calls these the primary emotions. In an HCI context, onscreen objects and events have the potential to activate such primitive emotional responses (Reeves & Nass, 1996). For example, objects that appear or move unexpectedly (e.g., pop-up windows, sudden animations) and loud or sharp noises are likely to trigger startle-based fear. Visual stimuli that tend to be particularly arousing include images that fill a large fraction of the visual field either because the image or screen is large or because the eyes are close to the screen (Detenber & Reeves, 1996; Voelker, 1994), images that seem to approach the user (e.g., a rapidly expanding image on the screen, an image that appears to be flying out from the screen, or a character that walks toward the user), and images that move in peripheral vision (i.e., on the side of the screen; Reeves & Nass, 1996). Finally, certain images and sounds may be innately disturbing or pleasing due to their evolutionary significance (e.g., screeching or crying noises or explicit sexual or violent imagery; see, e.g., Lang, 1995; Malamuth, 1996).

Most of the emotions that we are concerned with in the design of human-computer interfaces—and the ones we will focus on in the remainder of this chapter—require more extensive cognitive (i.e., knowledge-based) processing. These secondary emotions, such as frustration, pride, and satisfaction, result from activation of the limbic system by processing in the cortex. Such cortical processing can occur at various levels of complexity, from simple object recognition (e.g., seeing the Microsoft Office Paperclip) to intricate rational deliberation (e.g., evaluating the consequences of erasing a seldom-used file), and may or may not be conscious. The cortex can even trigger emotion in reaction to internally generated stimuli (e.g., thinking about how difficult it will be to configure a newly purchased application). Finally, an emotion can result from a combination of both the thalamic-limbic and the cortico-limbic mechanisms. For example, an event causing an initial startle/fear reaction can be later [illegible]nized as harmless by more extensive, rational evaluation [illegible] when you realize that the flash of your screen suddenly [illegible] blank is just the initiation of the screen saver). In other [illegible]ions, higher level processing can reinforce an initial evalua[illegible]. Whatever the activation mechanism—thalamic or cortical, [illegible]ous or nonconscious—the cortex receives input from an [illegible]ed limbic system, as well as feedback from the body, both [illegible]ting to the conscious experience of emotion.

[illegible] previous discussion provides a useful framework for con[illegible] one of the classic debates in emotion theory: Are emo[illegible] innate or learned? At one extreme, evolutionary theorists [illegible] all emotions (including complex emotions such as [illegible] relief) are innate, each evolved to address a specific [illegible]ntal concern of our ancestors (Darwin, 1872/1998; [illegible]0; Tooby & Cosmides, 1990; see also Ekman, 1994; [illegible]). These theories are consistent with a hypothesis [illegible]erentiation within the limbic system, corresponding [illegible] the biologically determined emotions. From this per[illegible] is also reasonable to speculate that each emotion [illegible] with a unique set of physiological and cognition[illegible]nses.

[illegible]her extreme, many emotion theorists argue that, [illegible]eption of startle and innate affinity/disgust (which [illegible] consider pre-emotional), emotions are almost entirely learned social constructs (Averill, 1980; Ortony & Turner, 1990; Shweder, 1994; Wierzbicka, 1992). Such theories emphasize the role of higher cortical processes in differentiating emotions and concede minimal, if any, specificity within the limbic system (and, consequently, within physiological responses). For example, the limbic system may operate in simply an on/off manner, or at most be differentiated along the dimensions of valence (positive/negative or approach/avoidance) and arousal (low/high) (Barrett & Russell, 1999; Lang, 1995). From this perspective, emotions are likely to vary considerably across cultures, with any consistency being based in common social structure, not biology.

Between these two extremes lie those who believe that there are basic emotions. Citing both cross-cultural universals and primate studies, these theorists contend that there is a small set of innate, basic emotions shared by all humans (Ekman, 1992; Oatley & Johnson-Laird, 1987; Panksepp, 1992). Which emotions qualify as basic is yet another debate, but the list typically includes fear, anger, sadness, joy, disgust, and sometimes also interest and surprise. Other emotions are seen either as combinations of these basic emotions or as socially learned differentiations within the basic categories (e.g., agony, grief, guilt, and loneliness are various constructions of sadness; Bower, 1992). In this view, the limbic system is prewired to recognize the basic categories of emotion, but social learning and higher cortical processes still play a significant role in differentiation.

If the basic emotions view is correct, a number of implications for interaction design and evaluation emerge. First, the basic categories would likely be the most distinguishable, and therefore measurable, emotional states (both in emotion recognition systems as well as in postinteraction evaluations). Furthermore, the basic emotions would be less likely to vary significantly from culture to culture, facilitating the accurate translation and generalizability of questionnaires intended to assess such emotions. Lower variability also enables more reliable prediction of emotional reactions to interface content, both across cultures and across individuals. Finally, for users interacting with onscreen characters, depictions of the basic emotions would presumably be most immediately recognizable. If the social construction view of emotions is valid, then emotion measurement and assessment, prediction, and depictions are more challenging and nuanced.

DISTINGUISHING EMOTION FROM RELATED CONSTRUCTS

Mood

It is useful to distinguish among several terms often used ambiguously: emotion, mood, and sentiment. Emotion can be distinguished from mood by its object-directedness. As Frijda (1994) explains, emotions are *intentional*: They "imply and involve relationships with a particular object." We get scared *of* something, angry *at* someone, and excited *about* some event. Moods, on the other hand, although they may be indirectly caused by a particular object, are nonintentional; they are not directed at any object in particular and are thus experienced as more diffuse, global, and general. A person can be sad about something (an emotion) or generally depressed (a mood). Unfortunately, the English language often allows the same term to describe both emotion and mood (e.g., happy).

Another distinction between emotion and mood emerges from a functional perspective. As a reaction to a particular situation, emotions bias action—they prepare the body and the mind for an appropriate, immediate response. As such, emotions also tend to be relatively short-lived. Moods, in contrast, tend to bias cognitive strategies and processing over a longer term (Davidson, 1994). More generally, moods can be seen to serve as a background affective filter through which both internal and external events are appraised. A person in a good mood tends to view everything in a positive light, whereas a person in a bad mood does the opposite. The interaction between emotions and moods is also important. Moods tend to bias which emotions are experienced, lowering the activation thresholds for mood-related emotions. Emotions, on the other hand, often cause or contribute to moods.

When assessing user response to an interface, it is important to consider the biasing effects of user mood. Users entering a usability or experimental study in a good mood, for instance, are more likely to experience positive emotion during an interaction than users in a bad mood. Pretesting for mood and including it as a variable in analysis can, therefore, reduce noise and increase interpretive power. If pretesting users immediately before an interaction is inappropriate, there is a second noise-reducing option: assessment of temperament. Temperament reflects the tendency of certain individuals to exhibit particular moods with great frequency. Participants can be pretested for temperament at any point prior to the study, enabling the exclusion of extreme cases of depressive or excitable individuals (e.g., Bishop, Jacks, & Tandy, 1993). Finally, if user testing involves multiple stimuli, the order of presentation can also influence the results. For example, earlier stimuli may establish a mood that biases emotional reactions to subsequent stimuli. To combat this problem, the order of stimuli should be varied from participant to participant, when feasible.

Sentiment

Sentiment is also often confused with emotion. Unlike emotions (and moods), sentiments are not states of an individual, but assigned properties of an object. When a person says that they like an interface or find an interface to be frustrating, what they really mean is that that they associate the interface with a positive or frustrating emotional state; they expect interaction with the interface to lead to positive or frustrating emotions. The basis for this judgment often comes from direct experience and subsequent generalization, but may also arise from social learning (Frijda, 1994).

One reason for the confusion between emotions and sentiment is that many languages use the same words for both. For example, the word "like" can be used both to indicate prediction or opinion (sentiment), as well as a current emotional state (e.g., "I like receiving e-mail" vs. "I like the e-mail that just arrived"). Clore (1994, p. 108) offers an interesting explanation for this ambiguity, theorizing that sentiments are judged by bringing the object to mind and observing the affective reaction. But, whereas emotions and moods are fleeting—emotions lasting only seconds and moods lasting for hours or even days—sentiments can persist indefinitely and are thus responsible for guiding our propensities to seek out or avoid particular objects and situations. In this sense, sentiments are of critical importance for HCI because they motivate users to return to particular software products or web sites.

Although direct interaction with an object is the most accurate way for a user to create a sentiment—consider the colloquial phrase, "How do you know you don't like it unless you try it?"—sentiments can also be caused by assumptions based on the communicated properties of an object. A person may, for example, base a sentiment on someone else's description of their interaction with the object, or even immediately adopt the sentiment of someone they know or respect (e.g., consider the presumed influence of celebrities in software advertisements).

As a predictive construct, sentiments are often generalizations about a class of objects with a given recognizable property, i.e., stereotypes. Although some of these generalizations may be logical and accurate, others may not—in fact, they may not even be conscious. Negative experiences with a particular computer character, for example, may lead users to conclude that they dislike all character-based interfaces. However, using a character that people know and like already—Mickey Mouse, for example—may be able to leverage sentiment to an interface's advantage. Similarly, many people have well-established sentiments regarding certain types of applications, e.g., "I hate spreadsheet applications." For such users, interfaces that avoid triggering their negative stereotypes have the advantage. Positive stereotypes, on the other hand, should be encouraged whenever possible, such as when learning applications are framed as entertainment.

EFFECTS OF AFFECT

Attention

One of the most important effects of emotion lies in its ability to capture attention. Emotions have a way of being completely absorbing. Functionally, they direct and focus our attention on those objects and situations that have been appraised as important to our needs and goals so that we can deal with them appropriately. Emotion-relevant thoughts then tend to dominate conscious processing—the more important the situation, the higher the arousal, and the more forceful the focus (Clore & Gasper, 2000). In an HCI context, this attention-getting function can be used advantageously, as when a sudden beep is used to alert the user, or can be distracting, as when a struggling user is frustrated and can only think about his/her inability.

Emotion can further influence attention through a secondary process of emotion regulation (Gross, 1998). Once an emotion is triggered, higher cognitive processes may determine that the emotion is undesirable. In such cases, attention is often directed away from the emotion-eliciting stimulus for the purpose of distraction. For example, becoming angry with an onscreen agent may be seen as ineffectual (e.g., because it does not recognize your anger) or simply unreasonable. An angered user may then actively try to ignore the agent, focusing instead on other on- or offscreen stimuli, or even take the next step and completely remove the agent from the interaction (which could mean leaving an application or web site entirely). Positive emotions may likewise require regulation at times, such as when amusing stimuli lead to inappropriate laughter in a work environment. If the emotionally relevant stimulus is too arousing, however, regulation through selective attention is bound to fail (Wegner, 1994), because users will be unable to ignore the stimulus.

Mood can have a less profound but more enduring effect on attention. At the most basic level, people tend to pay more attention to thoughts and stimuli that have some relevance to their current mood state (Bower & Forgas, 2000). However, people also often consciously regulate mood, selecting and attending to stimuli that sustain desired moods or, alternatively, counteract undesired moods. An interface capable of detecting—or at least predicting—a user's emotional or mood state could similarly assume an affect regulation role, helping to guide attention away from negative and toward more positive stimuli. For example, a frustrated user could be encouraged to work on a different task, focus on a different aspect of the problem at hand, or simply take a break (perhaps by visiting a suggested online entertainment site).

Memory

Emotion's effect on attention also has implications for memory. Because emotion focuses thought on the evoking stimulus, emotional stimuli are generally remembered better than unemotional events (Thorson & Friestad, 1985). Negative events, which tend to be highly arousing, are typically remembered better than positive events (Newhagen & Reeves, 1991, 1992; Reeves & Nass, 1996, chap. 10; Reeves, Newhagen, Maibach, Basil, & Kurz, 1991). In addition, emotionality improves memory for central details while undermining memory for background details (see Heuer & Reisberg, 1992; Parrott & Spackman, 2000).

Mood also comes into play both in memory encoding and retrieval. Research has shown that people will remember "mood-congruent" emotional stimuli better than incongruent stimuli. Bower, Gilligan, and Monteiro (1981), for example, hypnotized subjects into either a happy or sad mood before having them read stories about various characters. The next day, subjects were found to remember more facts about characters whose mood had agreed with their own than about other characters. Similarly, on the retrieval end, people tend better to recall memories consistent with their current mood (Ellis & Moore, 1999). However, the reverse effect has also been shown to occur in certain situations: People will sometimes better recall mood-incongruent memories (e.g., happy memories while in a sad mood). Parrott and Spackman (2000) hypothesize that mood regulation is responsible for this inverse effect: When a given mood is seen as inappropriate or distracting, people will often actively try to evoke memories or thoughts to modify that mood (see Forgas' (1995) Affect Infusion Model for insight into these contradictory findings (also see Erber & Erber, 2001). Finally, there is some evidence for mood-dependent recall: Memories encoded while in a particular mood are better recalled when in that same mood. This effect is independent of the emotional content of the memory itself (Ucros, 1989). It should be noted, however, that the effects of mood on memory are often unreliable and therefore remain controversial.

Performance

Mood has also been found to affect cognitive style and performance. The most striking finding is that even mildly positive affective states profoundly affect the flexibility and efficiency of thinking and problem solving (Hirt, Melton, McDonald, & Harackiewicz, 1996; Isen, 2000; Murray, Sujan, Hirt, & Sujan, 1990). In one of the best-known experiments, subjects were induced into a good or bad mood and then asked to solve Duncker's (1945) candle task. Given only a box of thumbtacks, the goal of this problem is to attach a lighted candle to the wall, such that no wax drips on the floor. The solution requires the creative insight to thumbtack the box itself to the wall and then tack the candle to the box. Subjects who were first put into a good mood were significantly more successful at solving this problem (Isen, Daubman, & Nowicki, 1987). In another study, medical students were asked to diagnose patients based on X-rays after first being put into a positive, negative, or neutral mood. Subjects in the positive-affect condition reached the correct conclusion faster than did subjects in other conditions (Isen, Rosenzweig, & Young, 1991). Positive affect has also been shown to increase heuristic processing, such as reliance on scripts and stereotypes. Although some have argued that such reliance is at the expense of systematic processing (Schwartz & Bless, 1991), more recent evidence suggest that heuristic processing and systematic processing are not mutually exclusive (Isen, 2000). Keeping a user happy may, therefore, not only affect satisfaction, but may also lead to efficiency and creativity.

Assessment

Mood has also been shown to influence judgment and decision making. As described earlier, mood tends to bias thoughts in a mood-consistent direction, while also lowering the thresholds of mood-consistent emotions. One important consequence of this is that stimuli—even those unrelated to the current affective state—are judged through the filter of mood (Clore et al., 2001; Erber & Erber, 2001; Niedenthal, Setterlund, & Jones, 1994). This suggests that a user in a good mood will likely judge both the interface and their work more positively, regardless of any direct emotional effects. It also suggests that a happy user at an e-commerce site would be more likely to evaluate the products or services positively.

Positive mood also decreases risk-taking, likely in an effort to preserve the positive mood. That is, although people in a positive mood are more risk-prone when making hypothetical decisions, when presented with an actual risk situation, they tend to be more cautious (Isen, 2000). In an e-commerce purchasing situation, then, one can predict that a low-risk purchase is more likely during a good mood, due to a biased judgment in favor of the product, whereas a high-risk purchase may be more likely in a less cautious, neutral, or negative mood (consistent with the adage that desperate people resort to desperate measures).

A mood's effect on judgment, combined with its effect on memory, can also influence the formation of sentiments. Sentiments are not necessarily determined during interaction with an object; they often are grounded in reflection. This is important to consider when conducting user tests, as the mood set by the interaction immediately prior to a questionnaire may bias like/dislike assessments of earlier interactions. Thus, varying order of presentation ensures both that later stimuli do not influence the *assessment* of earlier stimuli and that earlier stimuli do not influence the *experience* of later stimuli (as discussed earlier).

CAUSES OF EMOTION

What causes emotions? The answer to this question is critical for HCI because an understanding of emotions' antecedents will better enable us to design interfaces that encourage desired emotional states and understand interfaces that do not.

Needs and Goals

As we saw in the first section, emotions are reactions to situations deemed relevant to the needs and goals of the individual. Clearly, a user comes to a computer hoping to achieve certain application-specific goals—composing a document, sending an e-mail, finding a piece of information, etc. The degree to which an interface facilitates or hampers those goals has a direct effect on the emotional state of the user. An interface capable of detecting emotion could, therefore, use such information as feedback regarding whether the user's goals are being met, modifying its behavior as necessary. In an information-seeking context, for example, emotional reactions to displayed content could be used to improve the goal relevance of future retrievals. Similarly, if an interface detects frustration, desperation, or anger in a user, goals may be facilitated by trying a new approach or offering assistance (Klein, Moon, & Picard, 1999; Picard, 1997a). (If the particular goals implicated by an emotion are not clear, there can be advantages to an interface that empathizes with the user; Klein et al., 1999). More generally, user preferences can be automatically determined based on a user's emotional reactions to interface elements (Picard, 1997a).

There are also a host of more abstract needs underlying, and often adjacent to, application-specific goals. A user may have a strong need to feel capable and competent, maintain control, learn, or be entertained. A new user typically needs to feel comfortable and supported, whereas an expert is more focused on aesthetic concerns of efficiency and elegance. Acknowledging these more abstract goals in interface design can be as instrumental in determining a user's affective state as meeting or obstructing application-specific goals. Maslow's hierarchy (Maslow, 1968) presents a useful starting place for considering the structure of these more abstract user needs. In his later work, Maslow (1968) grouped an individual's basic needs into eight categories:

Physiological: hunger, thirst, bodily comforts, etc.
Safety/security: being out of danger
Social: affiliate with others, be accepted
Esteem: to achieve, be competent, gain approval and recognition
Cognitive: to know, to understand, and explore
Aesthetic: symmetry, order, and beauty
Self-actualization: to find self-fulfillment and realize one's potential
Transcendence: to help others find self-fulfillment and realize their potential.

When a particular situation or event is deemed as promoting these needs, positive emotion results. When someone or something hampers these needs, negative emotion results. The specific emotion experienced is due in part to the category of need implicated by the event. Fright, for example, is typically associated with threatened safety/security needs; love and embarrassment with social needs; pride with esteem needs; and curiosity with cognitive needs.

Within Maslow's (1968) framework, application-specific goals of a user can be seen as instruments ultimately serving these more basic needs. For example, a user who successfully enhances a digital family photograph may simultaneously be contributing to the fulfillment of social, esteem, cognitive, and aesthetic needs. However, interfaces can also directly address a user's basic needs. For example, a spell-checker interface that praises a user on his or her spelling ability, regardless of their actual performance, is a somewhat humorous, although illustrative, approach to acknowledging a user's esteem needs. Such interfaces, by enhancing the user's affective state, have been shown also to be viewed as more intelligent and likable (Reeves & Nass, 1996, chap. 4). As another example, an interface that takes care to establish a trusting and safe relationship with users may ultimately lead to more effective and cooperative interactions (Fogg, 1998). Educational software should address users' emotional needs, not only teaching the relevant content, but also ensuring users believe that they are learning. Optimized learning further requires a careful balance of esteem and self-actualization needs, offering appropriate levels of encouragement and challenge, as well as praise and criticism. Finally, one of the key arguments for social interfaces is that they meet the social needs of users (Reeves & Nass, 1996).

Although the type of need relevant in a situation offers some insight into emotional reaction, need category alone is not sufficient to differentiate fully among all emotions. Distinguishing frustration and anger, for example, cannot be achieved based solely on knowing the users' need; it also requires some notion of agency.

Appraisal Theories

"Appraisal" theories provide much greater predictive power than category or hierarchy-based schemes by specifying the critical properties of antecedent events that lead to particular emotions (Lazarus, 1991; Ortony, Clore, & Collins, 1988; Roseman, Antoniou, & Jose, 1996; Scherer, 1988). Ellsworth (1994), for example, describes a set of abstract elicitors of emotion. In addition to *novelty* and *valence*, Ellsworth contends that the level of *certainty/uncertainty* in an event has a significant impact on the emotion experienced. For instance, "uncertainty about probably positive events leads to interest and curiosity, or to hope," whereas "uncertainty about probably negative events leads to anxiety and fear" (Ellsworth, 1994, p. 152). Certainty, on the other hand, can lead to relief in the positive case and despair in the negative case.

Because slow, unclear, or unusual responses from an interface generally reflect a problem, one of the most common interface design mistakes—from an affective standpoint—is to leave the user in a state of uncertainty. Users tend to fear the worst when, for example, an application is at a standstill, the hourglass remains up longer than usual, or the hard drive simply starts grinding away unexpectedly. Such uncertainty leads to a state of anxiety that can be easily avoided with a well-placed, informative message or state indicator. Providing users with immediate feedback on their actions reduces uncertainty, promoting a more positive affective state (see Norman, 1990, on visibility and feedback). When an error has actually occurred, the best approach is to make the user aware of the problem and its possible consequences, but frame the uncertainty in as positive a light as possible (e.g., "this application has experienced a problem, but the document should be recoverable").

According to Ellsworth (1994), *obstacles and control* also play an important role in eliciting emotion. High control can lead to a sense of challenge in positive situations, but stress in negative situations. Lack of control, on the other hand, often results in frustration, which if sustained can lead to desperation and resignation. In an HCI context, providing an appropriate level of controllability, given a user's abilities and the task at hand, is thus critical for avoiding negative affective consequences. Control need not only be perceived to exist (Skinner, 1995; Wegner & Bargh, 1998), but must be understandable and visible, otherwise the interface itself is an obstacle (Norman, 1990).

Agency is yet another crucial factor determining emotional response (Ellsworth, 1994; Friedman & Kahn, 1997). When oneself is the cause of the situation, shame (negative) and pride (positive) are likely emotions. When another person or entity is the cause, anger (negative) and love (positive) are more likely. But, if fate is the agent, one is more likely to experience sorrow (negative) and joy (positive). An interface often has the opportunity to direct a user's perception of agency. In any anomalous situation, for example—be it an error in reading a file, inability to recognize speech input, or simply a crash—if the user is put in a position encouraging blame of oneself or fate, the negative emotional repercussions may be more difficult to diffuse than if the computer explicitly assumes blame (and is apologetic). For example, a voice interface encountering a recognition error can say, "This system failed to understand your command" (blaming itself), "The command was not understood" (blaming no one), or "You did not speak clearly enough for your command to be understood" (blaming the user).

Appraisal theories of emotion, such as Ellsworth's (1994), are useful not only in understanding the potential affective impacts of design decisions, but also in creating computer agents that exhibit emotion. Although in some cases scripted emotional responses are sufficient, in more dynamic or interactive contexts, an agent's affective state must be simulated to be believable. Ortony, Clore, and Collins' (1988) cognitive theory of emotion is currently the most commonly applied appraisal theory for such purposes (Bates, Loyall, & Reilly, 1994; Elliott & Brzezinski, 1998; for alternate approaches, see Ball & Breese, 2000; Bozinovski & Bozinovska, 2001; Scheutz, Sloman, & Logan, 2000). Appraisal theories can also be used to help model and predict a user's emotional state in real-time (Elliott & Brezezinski, 1998).

Contagion

Another cause of emotion that does not fit cleanly into the structure described previously is contagion (Hatfield, Cacioppo, & Rapson, 1994). People often catch other's emotions. Sometimes, this social phenomenon seems logical, such as when a person becomes afraid upon seeing another experience fear. At other times contagion seems illogical, such as when another person's laughter induces immediate, unexplainable amusement. Anticipatory excitement is another emotion that transfers readily from person to person.

Emotions *in* interfaces can also be contagious. For example, a character that exhibits excitement when an online product appears can make users feel more excited. Similarly, an attempt at light humor in a textual interface, even if unsuccessful, may increase positive affect (Morkes, Kernal, & Nass, 2000).

Moods and Sentiments

Mood and sentiment can also bias emotion. One of the fundamental properties of mood is that it lowers the activation threshold for mood-consistent emotions. Sentiment can act in a similar way. For example, interaction with an object, to which a sentiment is already attached, can evoke emotion either in memory of past interaction or in anticipation of the current interaction. Thus, an interface that proved frustrating in the past may elicit frustration before the user even begins working. In addition, sentiment can bias perception of an object, increasing the probability of eliciting sentiment-consistent emotions. For example, an application that users *like* can do no wrong, whereas one that users *dislike* does everything to anger them, regardless of the application's actual behavior. Of critical importance here is that sentiments need not be derived from direct experience; they may also be inferred from stereotypes or other generalizations.

Previous Emotional State

Finally, a user's previous emotional state can affect the experience of subsequent emotions. This occurs not only through the mechanism of mood—emotions can cause moods and moods then bias the activation thresholds of emotions—but also through the mechanisms of excitation transfer and habituation. Excitation transfer (Zillmann, 1991) is based on the fact that after an emotion-causing stimulus has come and gone, an activated autonomic nervous system takes some time to return to its deactivated state. If another emotion is triggered before that decay is complete, the residual activation (excitement) will be added to the current activation and be perceived as part of the current emotion. As Zillmann (1991) explains, "residues of excitation from a previous affective reaction will *combine* with excitation produced by subsequent affective stimulation and thereby cause an *overly intense* affective reaction to subsequent stimuli. . . . Residual arousal from anger, then, may intensify fear; residues from fear may intensify sexual behaviors; residual sexual arousal may intensify aggressive responses; and so forth" (p. 116). Thus, people who have just hit the purchase button associated with their Web shopping cart can become particularly angry when they are presented with multiple pages before they can complete their transaction: The arousal of buying increases the intensity of their frustration with the postpurchase process. Similarly, Reeves and Nass (1996) have argued that pictorial characters raise the volume knob on both positive and negative feelings about an interaction, because explicitly social interactions are more arousing than their nonsocial counterparts.

Habituation is, in some sense, the converse of excitation transfer. It posits that the intensity of an emotion decreases over time if the emotion is experienced repeatedly. One explanation for this effect relates back to appraisal theory: "Emotions are elicited not so much by the presence of favorable or unfavorable conditions, but by actual or expected changes in favorable or unfavorable conditions" (Frijda, 1988, p. 39). Repeated pleasurable affective states, therefore, become expected and thus gradually lose intensity. The same is true for negative affect; however, particularly extreme negative emotional states may never habituate (Frijda, 1988). This may be why negative experiences with frequently used interfaces (e.g., operating systems) are remembered more vividly than positive experiences.

CAUSES OF MOOD

Mood has a number of potential causes. The most obvious is emotion itself. Intense or repetitive emotional experiences tend to prolong themselves into moods. A user who is continually frustrated will likely be put in a frustrated mood, whereas a user who is repeatedly made happy will likely be put in a positive mood. Mood can also be influenced, however, by anticipated emotion, based on sentiment. For example, if users know that they must interact with an application that they dislike (i.e., they associate with negative emotion), they may be in a bad mood from the start.

Contagion

Similar to emotion, moods also exhibit a contagion effect (Neumann & Strack, 2000). For example, a depressed person will often make others feel depressed, and a happy person will often make others feel happy. Murphy and Zajonc (1993) have shown that even a mere smiling or frowning face, shown so quickly that the subject is not conscious of seeing the image, can affect a person's mood and subsequently bias judgment. From an interface standpoint, the implications for character-based agents are clear: Moods exhibited by onscreen characters may directly transfer to the user's mood. On-screen mood can also lead to perceived contagion effects: One smiling or frowning face on the screen can influence users' perceptions of other faces that they subsequently see on the screen, perhaps as a result of priming (Reeves, Biocca, Pan, Oshagan, & Richards, 1989; Reeves & Nass, 1996, chap. 22).

Color

Color can clearly be designed into an interface with its mood-influencing properties in mind. Warm colors, for example, generally provoke "active feelings," whereas cool colors are "much less likely to cause extreme reactions" (Levy, 1984). Gerard (1957, 1958), for example, found that red light projected onto a diffusing screen produces increased arousal in subjects, using a number of physiological measures (including cortical activation, blood pressure, and respiration), whereas blue light has essentially the opposite calming effect (see Walters, Apter, & Svebak, 1982). Subjective ratings of the correlations between specific colors and moods can be more complicated. As Gardano (1986) summarizes, "yellow (a warm color) has been found to be associated with both sadness (Peretti, 1974) and with cheerfulness (Wexner, 1954). Similarly, red (another warm color) is related to anger and violence (Schachtel, 1943) as well as to passionate love (Henry & Jacobs, 1978; Pecjak, 1970); and blue (a cool color), to tenderness (Schachtel, 1943) and sadness (Peretti, 1974). . . ." Nevertheless, as any artist will attest, carefully designed color schemes (combined with other design elements) can produce reliable and specific influences on mood.

Other Effects

A number of other factors can affect mood. For example, in music, minor scales are typically associated with negative emotion and mood, whereas major scales have more positive/happy connotations (Gregory, Worrall, & Sarge, 1996). Other possible influences on mood include weather, temperature, hormonal cycles, genetic temperament, sleep, food, medication, and lighting (Thayer, 1989).

MEASURING AFFECT

Measuring user affect can be valuable both as a component of usability testing and as an interface technique. When evaluating interfaces, affective information provides insight into what a user is feeling—the fundamental basis of liking and other sentiments. Within an interface, knowledge of a user's affect provides useful feedback regarding the degree to which a user's goals are being met, enabling dynamic and intelligent adaptation. In particular, social interfaces (including character-based interfaces) must have the ability to recognize and respond to emotion in users to execute effectively real-world interpersonal interaction strategies (Picard, 1997a).

Neurological Responses

The brain is the most fundamental source of emotion. The most common way to measure neurological changes is the electroencephalogram (EEG). In a relaxed state, the human brain exhibits an alpha rhythm, which can be detected by EEG recordings taken through sensors attached to the scalp. Disruption of this signal (alpha blocking) occurs in response to novelty, complexity, and unexpectedness, as well as during emotional excitement and anxiety (Frijda, 1986). EEG studies have further shown that positive/approach-related emotions lead to greater activation of the left anterior region of the brain, whereas negative/avoidance-related emotions lead to greater activation of the right anterior region (Davidson, 1992; see also Heller, 1990). Indeed, when one flashes a picture to either the left or the right of where a person is looking, the viewer can identify a smiling face more quickly when it is flashed to the left hemisphere, and a frowning face more quickly when it is flashed to the right hemisphere (Reuter-Lorenz & Davidson, 1981). Current EEG devices, however, are fairly clumsy and obstructive, rendering them impractical for most HCI applications. Recent advances in magnetoresonance imaging offer great promise for emotion monitoring, but are currently unrealistic for HCI because of their expense, complexity, and form factor.

Autonomic Activity

Autonomic activity has received considerable attention in studies of emotion, in part due to the relative ease in measuring certain components of the autonomic nervous system, including heart rate, blood pressure, blood pulse volume, respiration, temperature, pupil dilation, skin conductivity, and more recently, muscle tension (as measured by electromyography). However, the extent to which emotions can be distinguished on the basis of autonomic activity alone remains a hotly debated issue (see Ekman & Davidson, 1994, chap. 6; Levenson, 1988). On the one end are those, following in the Jamesian tradition (James, 1884), who believe that each emotion has a unique autonomic signature—technology is simply not advanced enough yet to fully detect these differentiators. On the other extreme, there are those, following Cannon (1927), who contend that all emotions are accompanied by the same state of nonspecific autonomic (sympathetic) arousal, which varies only in magnitude—most commonly measured by galvanic skin response, a measure of skin conductivity (Schachter & Singer, 1962). This controversy has clear connections to the nature-nurture debate in emotion, described earlier, because autonomic specificity seems more probable if each emotion has a distinct biological basis, whereas nonspecific autonomic (sympathetic) arousal seems more likely if differentiation among emotions is based mostly on cognition and social learning.

Although the debate is far from resolved, certain measures have proven fairly reliable at distinguishing among "basic emotions." Heart rate, for example, increases most during fear, followed by anger, sadness, happiness, surprise, and finally disgust, which shows almost no change in heart rate (Cacioppo, Bernston, Klein, & Poehlmann, 1997; Ekman, Levenson, & Friesen, 1983; Levenson, Ekman, & Friesen, 1990). Heart rate also generally increases during excitement, mental concentration, and "upon the presentation of intense sensory stimuli" (Frijda, 1986). Decreases in heart rate typically accompany relaxation, attentive visual and audio observation, and the processing of pleasant stimuli (Frijda, 1986). As is now common knowledge, blood pressure increases during stress and decreases during relaxation. Cacioppo et al. (2000) further observe that anger increases diastolic blood pressure to the greatest degree, followed by fear, sadness, and happiness. Anger is further distinguished from fear by larger increases in blood pulse volume, more nonspecific skin conductance responses, smaller increases in cardiac output, and other measures, indicating that "anger appears to act more on the vasculature and less on the heart than does fear" (Cacioppo et al., 1997). Results using other autonomic measures are less reliable.

Combined measures of multiple autonomic signals show promise as components of an emotion recognition system. Picard, Vyzas, and Healey (2001), for example, achieved 81% recognition accuracy on eight emotions through combined measures of respiration, blood pressure volume, and skin conductance, as well as facial muscle tension (to be discussed in the next subsection). Many autonomic signals can also be measured in reasonably nonobstructive ways (e.g., through user contact with mice and keyboards; Picard, 1997a).

However, even assuming that we could distinguish among all emotions through autonomic measures, it is not clear that we should. In real-world social interactions, humans have at least partial control over what others can observe of their emotions. If another person, or a computer, is given direct access to users' internal states, they may feel overly vulnerable, leading to stress and distraction. Such personal access could also be seen as invasive, compromising trust. It may, therefore, be more appropriate to rely on measurement of the external signals of emotion (discussed below).

Facial Expression

Facial expression provides a fundamental means by which humans detect emotion. Table 4.1 describes characteristic facial features of six basic emotions (Ekman & Friesen, 1975; Rosenfeld, 1997). Endowing computers with the ability to recognize facial expressions, through pattern recognition of captured images, has proven to be a fertile area of research (Essa & Pentland, 1997; Lyons, Akamatsu, Kamachi, & Gyoba, 1998; Martinez, 2000; Yacoob & Davis, 1996); for recent reviews, see Cowie et al., 2001; Lisetti & Schiano, 2000; Tian, Kanade, & Cohn, 2001). Ekman and Friesen's (1977) Facial Action Coding System, which identifies a highly specific set of muscular

TABLE 4.1. Facial Cues and Emotion

Emotion	Observed Facial Cues
Surprise	Brows raised (curved and high)
	Skin below brow stretched
	Horizontal wrinkles across forehead
	Eyelids opened and more of the white of the eye is visible
	Jaw drops open without tension or stretching of the mouth
Fear	Brows raised and drawn together
	Forehead wrinkles drawn to the center
	Upper eyelid is raised and lower eyelid is drawn up
	Mouth is open
	Lips are slightly tense or stretched and drawn back
Disgust	Upper lip is raised
	Lower lip is raised and pushed up to upper lip or it is lowered
	Nose is wrinkled
	Cheeks are raised
	Lines below the lower lid, lid is pushed up but not tense
	Brows are lowered
Anger	Brows lowered and drawn together
	Vertical lines appear between brows
	Lower lid is tensed and may or may not be raised
	Upper lid is tense and may or may not be lowered due to brows' action
	Eyes have a hard stare and may have a bulging appearance
	Lips are either pressed firmlytogether with corners straight or down or open, tensed in a squarish shape
	Nostrils may be dilated (could occur in sadness too), unambiguous only if registered in all three facial areas
Happiness	Corners of lips are drawn back and up
	Mouth may or may not be parted with teeth exposed or not
	A wrinkle runs down from the nose to the outer edge beyond lip corners
	Cheeks are raised
	Lower eyelid shows wrinkles below it and may be raised but not tense
	Crow's-feet wrinkles go outward from the outer corners of the eyes
Sadness	Inner corners of eyebrows are drawn up
	Skin below the eyebrow is triangulated, with inner corner up
	Upper lid inner corner is raised
	Corners of the lips are drawn or lip is trembling

Based on Ekman & Friesen (1975). Adapted with permission.

movements for each emotion, is one of the most widely accepted foundations for facial recognition systems (Tian et al., 2001). In many systems, recognition accuracy can reach as high as 90–98% on a small set of basic emotions. However, current recognition systems are tested almost exclusively on produced expressions (i.e., subjects are asked to make specific facial movements or emotional expressions), rather than natural expressions resulting from actual emotions. The degree of accuracy that can be achieved on more natural expressions of emotion remains unclear. Further, "not all . . . emotions are accompanied by visually perceptible facial action" (Cacioppo et al., 1997).

An alternate method for facial expression recognition, capable of picking up both visible and extremely subtle movements of facial muscles, is facial elecromyography. Electromyography signals, recorded through small electrodes attached to the skin, have proven most successful at detecting positive vs. negative emotions, and show promise in distinguishing among basic emotions (Cacioppo, Bernston, Larsen, Poehlmann, & Ito, 2000). Although the universality (and biological basis) of facial expression is also debated, common experience tells us that, at least within a culture, facial expressions are reasonably consistent. Nonetheless, individual differences may also be important, requiring recognition systems to adapt to a specific user for greatest accuracy. Gestures can also be recognized with technologies similar to those for facial expression recognition, but the connection between gesture and emotional state is less distinct, in part due to the greater influence of personality (Cassell & Thorisson, 1999; Collier, 1985).

Voice

Voice presents yet another opportunity for emotion recognition (see Cowie et al., 2001, for an extensive review). Emotional arousal is the most readily discernible aspect of vocal communication, but voice can also provide indications of valence and specific emotions through acoustic properties such as pitch range, rhythm, and amplitude or duration changes (Ball & Breese, 2000; Scherer, 1989). A bored or sad user, for example, will typically exhibit slower, lower-pitched speech, with little high-frequency energy, whereas a user experiencing fear, anger, or joy will speak faster and louder, with strong high-frequency energy and more explicit enunciation (Picard, 1997a). Murray and Arnott (1993) provide a detailed account of the vocal effects associated with several basic emotions (see Table 4.2). Although few systems have been built for automatic emotion recognition through speech, Banse and Scherer (1996) have demonstrated the feasibility of such systems. Cowie and Douglas-Cowie's ACCESS system (Cowie & Douglas-Cowie, 1996) also presents promise (Cowie et al., 2001).

Self-Report Measures

A final method for measuring a user's affective state is to ask. Postinteraction questionnaires, in fact, currently serve as the primary method for ascertaining emotion, mood, and sentiment during an interaction. However, in addition to the standard complexities associated with self-report measures (such as the range of social desirability effects), measuring affect in this way presents added challenges. To begin with, questionnaires are capable of measuring only the conscious experience of emotion and mood. Much of affective processing, however, resides in

TABLE 4.2. Voice and Emotion

	Fear	Anger	Sadness	Happiness	Disgust
Speech rate	Much faster	Slightly faster	Slightly lower	Faster or slower	Very much slower
Pitch average	Very much higher	Very much higher	Slightly lower	Much higher	Very much lower
Pitch range	Much wider	Much wider	Slightly narrower	Much wider	Slightly wider
Intensity	Normal	Higher	Lower	Higher	Lower
Voice quality	Irregular voicing	Breathy chest tone	Resonant	Breathy blaring	Grumbled chest tone
Pitch changes	Normal	Abrupt on stressed syllables	Downward inflections	Smooth upward inflections	Wide downward terminal inflections
Articulation	Precise	Tense	Slurring	Normal	Normal

Based on Murray & Arnott (1993). Adapted with permission.

the limbic system and in nonconscious processes. Although it is debatable whether an emotion can exist without any conscious component at all, a mood surely can. Furthermore, questions about emotion, and often those about mood, refer to past affective states and thus rely on imperfect and potentially biased memory. Alternatively, asking a user to report on an emotion as it occurs requires interruption of the experience. In addition, emotions and moods are often difficult to describe in words. Finally, questions about sentiment, although the most straightforward given their predictive nature, are potentially affected by when they are asked (both because of current mood and memory degradation). Nevertheless, self-report measures are the most direct way to measure sentiment and a reasonable alternative to direct measures of emotion and mood (which currently remain in the early stages of development).

Several standard questionnaires exist for measuring affect (Plutchik & Kellerman, 1989, chaps. 1–3). The most common approach presents participants with a list of emotional adjectives and asks how well each describes their affective state. Izard's (1972) Differential Emotion Scale, for example, includes 24 emotional terms (such as delighted, scared, happy, and astonished) that participants rate on 7-point scales, indicating the degree to which they are feeling that emotion (from "not at all" to "extremely"). McNair, Lorr, and Droppleman's (1981) Profile of Mood States is a popular adjective-based measure of mood. Researchers have created numerous modifications of these standard scales (Desmet, Hekkert, & Jacobs, 2000, present a unique nonverbal adaptation), and many current usability questionnaires include at least some adjective-based affect assessment items (e.g., the Questionnaire for User Interface Satisfaction; Chin, Diehl, & Norman, 1988).

A second approach to questionnaire measurement of affect derives from dimensional theories of emotion and mood. Many researchers argue that two dimensions—arousal (activation) and valence (pleasant/unpleasant)—are nearly sufficient to describe the entire space of conscious emotional experience (Fledman Barrett & Russell, 1999). Lang (1995), for example, presents an interesting measurement scheme in which subjects rate the arousal and valence of their current affective state by selecting among pictorial representations (rather than the standard number/word representation of degree). Watson, Clark, and Tellegan's (1988) Positive and Negative Affect Schedule is a popular dimensional measure of mood. Finally, to measure emotion as it occurs, with minimum interruption, some researchers have asked subjects to push one of a small number of buttons indicating their current emotional reaction during presentation of a stimulus (e.g., one button each for positive, negative, and neutral response; Breckler & Berman, 1991).

Affect Recognition by Users

Computers are not the only (potential) affect recognizers in human-computer interactions. When confronted with an interface—particularly a social or character-based interface—users constantly monitor cues to the affective state of their interaction partner, the computer (although often nonconsciously; see Reeves & Nass, 1996). Creating natural and efficient interfaces requires not only recognizing emotion in users, but also expressing emotion. Traditional media creators have known for a long time that portrayal of emotion is a fundamental key to creating the illusion of life (Jones, 1990; Thomas & Johnson, 1981; for discussions of believable agents and emotion, see, e.g., Bates, 1994; Maldonado, Picard, & Hayes-Roth, 1998).

Facial expression and gesture are the two most common ways to manifest emotion in screen-based characters (Cassell et al., 2000; Kurlander, Skelly, & Salesin, 1996). Although animated expressions lack much of the intricacy found in human expressions, users are nonetheless capable of distinguishing emotions in animated characters (Cassell et al., 2000; Schiano, Ehrlich, Rahardja, & Sheridan, 2000). As with emotion recognition, Ekman and Friesen's (1977) Facial Action Coding System is a commonly used and well-developed method for constructing affective expressions. One common strategy for improving the accuracy of communication with animated characters is to exaggerate expressions, but whether this leads to corresponding exaggerated assumptions about the underlying emotion has not been studied.

Characters that talk can also use voice to communicate emotion (Nass & Gong, 2000). Prerecorded utterances are easily infused with affective tone, but are fixed and inflexible. Cahn (1990) has successfully synthesized affect-laden speech using a text-to-speech system coupled with content-sensitive rules regarding appropriate acoustic qualities (including pitch, timing, and voice quality; see also Nass, Foehr, & Somoza, 2000). Users were able to distinguish among six different emotions with about 50% accuracy, which is impressive considering that people are generally only 60% accurate in recognizing affect in human speech (Scherer, 1981).

Finally, characters can indicate affective state verbally through word and topic choice, as well as explicit statements of affect (e.g., "I'm happy"). Characters whose nonverbal and verbal expressions are distinctly mismatched, however, may be seen as awkward or even untrustworthy. In less extreme mismatched cases, recent evidence suggests that users will give precedence to nonverbal cues in judgments about affect (Nass et al., 2000). This finding is critical for applications in which characters/agents mediate interpersonal communication (e.g., in virtual worlds or when characters read email to a user), because the affective tone of a message may be inappropriately masked by the character's affective state. Ideally, in such computer-mediated communication contexts, emotion would be encoded into the message itself, either through explicit tagging of the message with affect, through natural language processing of the message, or through direct recognition of the sender's affective state during message composition (e.g., using autonomic nervous system or facial expression measures). Mediator characters could then display the appropriate nonverbal cues to match the verbal content of the message.

OPEN QUESTIONS

Beyond the obvious need for advancements in affect recognition and manifestation technology, it is our opinion that there are five important and remarkably unexplored areas for research in emotion and HCI:

1. With which emotion should HCI designers be most concerned?
   Which emotion(s) should interface designers address first? The basic emotions, to the extent that they exist and can be identified, have the advantage of similarity across cultures and easy discriminability. Thus, designs that attempt to act on or manipulate these dimensions may be the simplest to implement. However, within these basic emotions, little is known about their relative manipulability or manifestability—particularly within the HCI context—or their relative impact on individuals' attitudes and behaviors. Once one moves beyond the basic emotions, cultural and individual differences introduce further problems and opportunities.
2. When and how should interfaces attempt to directly address users' emotions and basic needs (vs. application-specific goals)?
   If one views a computer or an interface merely as a tool, then interface design should solely focus on application-specific goals, assessed by such metrics as efficiency, learnability, and accuracy. However, if computers and interfaces are understood as a medium, then it becomes important to think about both uses and gratifications (Katz, Blumler, & Gurevitch, 1974; Rosengren, 1974; Rubin, 1986), that is, the more general emotional and basic needs that users bring to any interaction. Notions of "infotainment" or "edutainment" indicate one category of attempts to balance task and affect. However, there is little understanding of how aspects of interfaces that directly manipulate users' emotions compliment, undermine, or are orthogonal to aspects of interfaces that specifically address users' task needs.
3. How accurate must emotion recognition be to be useful as an interface technique?
   Although humans are not highly accurate emotion detectors—the problem of receiving accuracy (Picard, 1997a, p. 120)—they nonetheless benefit from deducing other's emotions and acting on those deductions (Goleman, 1995). Clearly, however, a minimum threshold of accuracy is required before behavior based on emotion induction is appropriate. Very little is known about the level of confidence necessary before an interface can effectively act on a user's emotional state.
4. When and how should users be informed that their affective states are being monitored and adapted to?
   When two people interact, there is an implicit assumption that each person is monitoring the other's emotional state and responding based on that emotional state. However, an explicit statement of this fact would be highly disturbing: "To facilitate our interaction, I will carefully and constantly monitor everything you say and do to discern your emotional state and respond based on that emotional state" or "I have determined that you are sad; I will now perform actions that will make you happier." However, when machines acquire and act on information about users without making that acquisition and adaptation explicit, there is often a feeling of surreptitiousness or manipulation. Furthermore, if emotion monitoring and adapting software are desired by consumers, there are clearly incentives for announcing and marketing these abilities. Because normal humans only exhibit implicit monitoring, the psychological literature is silent on the psychological and performance implications for awareness of emotional monitoring and adaptation.
5. How does emotion play out in computer-mediated communication?
   This chapter has focused on the direct relationship between the user and the interface. However, computers also are used to mediate interactions between people. In face-to-face encounters, affect not only creates richer interaction, but also helps to disambiguate meaning, allowing for more effective communication. Little is known, however, about the psychological effects of mediated affect, or the optimal strategies for encoding and displaying affective messages (see Maldonado & Picard, 1999; Rivera, Cooke, & Bauhs, 1996).

CONCLUSION

Although much progress has been made in the domain of affective computing (Picard, 1997a), more work is clearly necessary before interfaces that incorporate emotion recognition and manifestation can reach their full potential. Nevertheless, careful consideration of affect in interaction design and testing can be instrumental in creating interfaces that are both efficient and effective, as well as enjoyable and satisfying. Designers and theorists, for even the simplest interfaces, are well advised to thoughtfully address the intimate and far-reaching linkages between emotion and HCI.

ACKNOWLEDGMENTS

James Gross, Heidy Maldonado, Roz Picard, and Don Roberts provided extremely detailed and valuable insights. Sanjoy Banerjee, Daniel Bochner, Dolores Canamero, Pieter Desmet, Ken Fabian, Michael J. Lyons, George Marcus, Laurel Margulis, Byron Reeves, and Aaron Sloman provided useful suggestions.

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