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The Design of Computer Interfaces Adaptive to Human Emotion: Current Issues and Research Directions

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Abstract

Despite the rapid advancement of computer technology, computers remain incapable of understanding human emotion. As a result, users have often been unaided for their aversive emotion that may take place during their computer tasks. This may be detrimental to positive and productive interactions between users and computers. This paper reviews some empirical studies regarding the effect of emotion on computer work and conceptualizes what constitutes an emotional computer. It is proposed that the emotional computer be designed to understand human emotion and adapt its interface accordingly. This paper raises a number of research questions in relation to such issues as measurement (e.g., automatic detection of human emotion, time delay), signal processing (e.g., accuracy) and user interfaces (e.g., ways to alleviate the intensity of negative emotion). Considering that there has been very little research on the design and aftermath of emotional computers, further studies are urgently needed.

Introduction

There has been much remarkable development in computer technology that shapes user interfaces considerably different from that of a few decades ago (Preece et al., 1994; Schneiderman, 1998). In the past, computer interfaces were the black and white screen where users keyed in their commands in an unfriendly computing environment. As software technology advances, user interfaces have undergone many changes. Now, users enjoy friendlier graphical interfaces where they are allowed to manipulate screen objects with a mouse as they feel like doing it in real life (i.e., direct manipulation, Schneiderman, 1998). Help systems may also be called upon whenever the users are in need of more information about their tasks.

Despite such noteworthy development, computer interfaces have been much condemned about their inflexibility and thus, users may not be fully satisfied with the current interfaces. An important aspect that has been lacking of proper attention would certainly be the consideration of human emotion in the design of computer interfaces. Computers are capable of processing users' demand merely based on what has been given to and stored in them. As a result, they are still far beyond being sympathetic as human beings do. It is without a question that one would feel friendlier with those who could be sympathetic with one's feelings. Although the role of users has been highlighted in the design process of computer interfaces, their emotion has been inproperly taken care of at the interaction stage with computers. The negligence of human emotion would certainly be detrimental to productive relationships and possibly users may not wish to use the computers.

Emotional computers are designed to be equipped with some devices that can understand the emotion of computer users and trigger appropriate actions adaptively depending upon the changes of emotion. In this context, the physiological data of users are read into the signal processor of emotional computers to assess the state of users' emotion. This paper shall briefly review literature on the effect of emotion on simple and complex cognitive tasks. As a way of overcoming the problems of the current interfaces, this paper proposes the functional components of emotional computer required to mitigate the negative effect of emotion on computer tasks. Then, this paper concludes with a number of research questions that are raised in relation to emotional computers. This paper would be valuable to provide insights into the notion of emotional computers and research directions in the future.

Emotion and Judgement

What Is Emotion?

Emotion can be best understood as what we have in our mind. We often feel happy from conversing with acquaintances. We may also feel sad from losing valuables. Emotion is so commonplace that we hold in our mind and experience every day. It is one of the traits that can

distinguish human beings from computers (Oatley, 1998). Despite considerable efforts over the past decades, computers are far from understanding the delicacy of human emotion and this would certainly lead users to perceive computers being challenging and inhumane. The term emotion is often used interchangeably with mood. (Forgas, 1995). Whilst mood appears to be a broader, longer term, emotion denotes the opposite nature of being "more intense, short-lived" and usually has "a definite cause and clear cognitive content (anger, fear)" (Forgas, 1995: p.41; Lazarus, 1990). There are two contrasting views as to what emotion is (Mandler, 1990). Fundamentalists argue that emotion can be constructed from a number of basic emotions. Although there has been little consensus that what constitutes the basic emotion, it may include anger, fear, happiness and sadness among others. On the other hand, constructionists highlight the role of cognition in emotional experience (Ortony & Turner, 1990; Mandler, 1990).

Effect of Emotion

Although human emotion plays an important role in every aspect of daily activities, it is over the last decade that research has been conducted on its effect on judgement and decision making (Forgas, 1995). Mandler (1990) pointed out that "much contemporary cognitive theory seems to leave human beings unable to feel. Until recently, conventional wisdom in cognitive science has painted people without passion – thinking and acting rationally and coolly… There is now a burgeoning body of evidence that emotional states interact in important ways with traditional 'cognitive' functions." (Mandler, 1990: p. 22). Lazarus (1990) also argued that emotion is inseparable from cognition and thus, appraisal is an essential part of emotion experience (Cacioppo et al., 1993). Emotion has been of much interest to the schools of personality and psychology that extensively investigated its effect on social behavior (Isen, 1990). Not only does emotion play a critical role in social context, it also influences the process of individual decision making (Lazarus, 1990; Isen, 1990). Empirical evidence appears to exist that emotion may influence the way people process information and make decisions. Goldberg and Gorn (1987) found that commercials performed better with happy programs than with sad programs. However, when viewers were willing to like watching the negative programs, advertisements embedded in negative-emotion programs performed as well as the ones embedded in positive-emotion programs (Murry & Dacin, 1996). A number of studies also suggest the effect of emotion on decision making styles which would certainly affect decision outcomes. Schwarz (1990) reported that people tended to be intuitive in happy mood, whereas more analytical judgment was evident when people were in sad mood. Indeed, increasing task-related negative affect appeared to lead people to use scanning strategies, which increased choice accuracy in easy tasks but impaired it in hard tasks (Stone & Kadous, 1997). More directly addressing the role of emotion in the selection of decision strategies, Isen and Means (1983) argued that when induced to happy mood, people tended to simplify the problem space (Payne, 1976) and employ shortcuts in their decision making (i.e., Elimination-By-Aspects). Given the effect of emotion on decision making, there is empirical evidence as to its effect on problem-solving (Kaufmann & Vosburg, 1997). In general, empirical results appear to uphold the notion of beneficial effects of negative emotion on task performance. To summarize, emotion plays a critical role in decision making and many of judgmental biases appear to be related to the cognitive efforts of people to maintain their mood/ emotion positive. That is, in positive emotion, people tend to be intuitive and protect their positive emotion. On the other hand, people in negative emotion appear to be analytical and avoid their negative emotion to turn it into positive one. Although this tendency may influence decision accuracy, there has been very limited evidence that addresses this issue.

Emotion and Computer Interfaces

The State of the Art of Computer Interfaces

Computer technologies have been advancing very rapidly and their progress accelerates over time. Over the past decades, the computer has become smaller, faster and more importantly, much cheaper. It has now become a commodity. Along with the technological progress of computer hardware, computer interfaces have also evolved to a friendlier shape, which contributes substantially to the widespread use of computers. Some of the noteworthy trends are discussed hereafter. Firstly, a remarkable change may be observed in relation to the surface of computer interfaces. In the 1970s, host computers were overwhelmingly adopted with the dumb terminals hard-wired to them and thus, computer interfaces were quite primitive. As the host computers were in complete control of the way computer interfaces operate, quite limited features were allowed (Preece et al., 1994). As an example, the amount of information that can be transferred to the terminal is limited to as many as 1920 characters (80 x 24). This circumscribed the implementation of graphical interfaces which requires to get much more data ready in memory. As the host computers renounce their control over interfaces, a significant transition has been introduced into computer interfaces by the adoption of graphical objects that enabled users to do their computer tasks much easier. Secondly, it is worth noting that over the decades, a focus has shifted from the standpoint of developers to that of users in the design of computer interfaces. Under the principles of user-centered design, users are trusted to take part more heavily in the development process of friendlier interfaces with computers. Thirdly, recent technical advancement has introduced new input and output devices into the domain of user interfaces. Over the past decade, the

keyboard was a dominant medium in interacting with computers. With the advances in hardware technology, a number of alternative input and output devices have been adopted into computer work. Some of the devices that can be easily found at practice include a mouse, touch screens, light pens, etc (Preece et al., 1994). A line of research is now underway to reshape the way we are currently interacting with the computers. In the near future, computers may become wearable and a number of unusual and interesting devices have been under development (e.g., twiddler, private eyes, http://wearables.www.media.mit.edu). Taken together, a theme underlying the aforementioned changes highlights the importance of users and the considerable efforts being driven to shape user interfaces as closely as possible to the way human-beings interact with each other.

Research in Relation to Emotional Interfaces

Despite rapid progress in computer hardware and software, computers are still far from understanding human emotion. It is quite contrary to the empirical evidence that emotion is such an influential factor in cognition. (Lazarus, 1990) The disregard of human emotion in ordinary computers leads to a number of issues. Firstly, although having been much friendlier than those of the past decades, computer interfaces are still hard for the novices to work with. Novices often get lost and feel angry at their computer work. Secondly, computers are designed to be subject to human orders and we are meant to be their master. Despite this claim, it is quite puzzling that computers do nothing when their master feels unhappy about their work. Indeed, the emotion of users is neglected in the design and development of computer interfaces. That is, users need to deal with any emotion that may arise over the performance of computer work. There are a number of coping strategies under aversive emotion - (1) problem solving, (2) support-seeking (including seeking help, comfort, and social approval), (3) distancing or avoidance, (4) internalization (e.g., hopelessness, self-deprecation) and (5) externalization (e.g., aggressive acting out). Users may opt for the distancing/ avoidance strategy against emotionless computers (Saarni, 1997; Lazarus, 1990: p.5).

Unfortunately, however, empirical studies have been very scant on this issue. A noticeable research is now underway at MIT. Picard (1997) at the MIT Multimedia Lab is challenging the issue of emotional computers (affective computing) to which emotion can be fed as a factor of adjusting computing environment. The rationale of her research is based on the empirical evidence that human emotion plays an essential role in rational decision making, perception, learning, and a variety of other cognitive functions (Isen, 1990; Lazarus, 1990). Affective computers aim to be able to comfort people by allowing such affective capability of computers as understanding users' emotion and passing this information in communicating with computers. It should be, however, noted that the accurate evaluation of human emotion is essential and the technique has not reached the level of maturity (e.g., physiological detection of human emotion). The issue of using physiological data to control external devices such as computers has been explored by a number of researchers (Kalcher et al., 1996; Keirn & Aunon, 1990; Pfurtscheller et al., 1996; Wolpaw et al., 1991; Wolpow & Mcfarland, 1994). In their research, subjects were asked to imagine cursor movement to the directions they want it to move and their brain waves were automatically transformed to cursor movement on the computer screen. The accuracy of cursor movement through brain waves appears to be far from practicality of such efforts.

Research Issues of Emotional Computers

There has been very scarce research as to the development of computer interfaces being adaptive to human emotion. Furthermore, little is known about what emotional experience people would have in the course of using computers and its effect on task performance. It may be due to the fact that the notion of emotional computers is at the very initial stage and requires interdisciplinary efforts from computer science, psychophysiology, cognitive science, biomedical engineering and decision science. Considering that as discussed earlier, emotion is inseparable from cognition (Lazarus, 1990), research on emotional computers is now urgently required. Given the empirical evidence that suggests the effect of emotion on cognitive tasks, a fundamental and crucial research question would be 'what aids should be provided for people to deal better with emotion without affecting task efficiency.' We discuss the notion of emotional computers and a number of research questions are raised in this section.

What Are Emotional Computers?

Emotional computers are designed to behave somewhat differently from the way ordinary computers do. They continuously examine the emotional state of the users and appropriately trigger some actions that can mitigate the negativity of emotion and restore it to a good one. Such adaptability of emotional computers would necessitate automatic detection of emotional changes and this certainly requires constant monitoring of biological data. It is expected that emotional computers with such adaptability would possibly contribute to more comfortable engagement in computer tasks over a prolonged session and thus, to improved task productivity. For this, it is proposed that the emotional computer be equipped with some additional functional components. Firstly, in contrast to ordinary computers that we are currently using, emotional computers require some apparatus to measure physiological data from which human emotion is assessed. Depending upon the types of human emotion, various physiological data may be employed. For example, the EEG may be useful in determining the intensity of negativity of human emotion

(Davidson & Fox, 1982), whereas the GSR and the ECG data may be used as an indicator that informs of the arousal level of emotion. Secondly, the adaptive nature of emotional computers entails the automatic detection of any changes in human emotion. It is crucial and imperative for emotional computers to be equipped with a pool of algorithms that could extract the patterns and signals contained in the physiological data. Lastly, emotional computers should provide more intelligent user interfaces that are adaptive to the changes of human emotion. Surely the adaptive nature of user interfaces would bring in such technical complexities as knowledge base, data base, object-oriented interface and intelligent agents among others.

Accuracy

The most prevailing factor to be considered in the design of emotional computers would be how accurately human emotion can be assessed and user interfaces would react to it. There may be a number of factors that could contribute to the accuracy of emotion evaluation. Accuracy may be greatly related, among others, to data measurement and preprocessing of measured data and mathematical models to classify the state of human emotion. Over the decades, considerable research has been conducted on the robustness of mathematical models for the classification of human emotion. The Fourier model has often been employed to analyze the power spectrum of physiological data (McFarland et al., 1993). The recent development of mathematics highlights the importance of such models as neural networks, Chaos and Wavelet that could recognize any changes in patterns contained in physiological data (Pfurtscheller et al., 1996). In consideration of the dynamic nature of human emotion, however, it may be practically impossible to achieve the perfect level of accuracy. Some empirical studies showed accuracy only a little higher than a pure guess at the task of predicting 2-dimensional computer cursor paths and limb movements through brain waves (Pfurtscheller et al., 1996; Wolpow & Mcfarland, 1994). Thus, research should be directed to under what contexts the mathematical models would perform well. To ensure that the adaptive behavior of emotional computers based on physiological data truly reflects the subjective state of emotion, models are to be evaluated to minimize false negativity and positivity.

Time Lag

Time lag refers to the amount of elapsed time for mathematical models to pick up any emotional changes. It may be represented as the time interval between the emotional changes of human emotion and its detection. Depending upon the characteristics of mathematical models used, some level of time lag may be imperative. It is due to the fact that most models require some training sessions of data, which leads to a certain period of time delay. For example, neural networks require a set of training data in order to tune their layered mathematical architecture. Slow reaction to the changes of human emotion should result in longer time lag, which in turn would certainly lead to the awkward behavior of emotional computers. As the performance of mathematical models hinge, to a considerable extent, on the training, research is needed to shorten the time lag and pseudo-level of time lag should be ensured for the practicality of emotional computers.

Obtrusiveness

Whereas the aforementioned issues of accuracy and time lag are related to the operational efficiency of emotional computers, obtrusiveness refers to the ease of use and it is rather a behavioral issue. A number of issues may determine the level of obtrusiveness. Firstly, the size and number of sensors required for the collection of physiological data may be obtrusive. Secondly, the time and chemicals to affix sensors onto human body may be cumbersome. Some wiring that is required to transmit measured data to remote signal processors may also worsen the usability of emotional computers. A number of empirical studies showed that the valence of human emotion could possibly be assessed from the small number of channels that is read from the frontal regions of human brain (Lim et al., 1998). Research is needed to find out the appropriate regions of data measurement and the role of wireless technology (e.g., wireless sensors) to minimize the level of obtrusiveness people may experience in using emotional computers.

Individual Differences

Individual differences should be taken into account in the design of emotional computers in that emotion may not be necessarily consistent over individuals. For example, linguistic representation of one's emotion (e.g., happiness, anger) should differ from person to person (e.g., fuzzy logic). As earlier discussed, this may be the reason why mathematical models should be trained to accommodate the individual differences of human emotion. It should also be noted that an individual may show different encoding of emotional changes. The former is referred to as inter-individual differences, whereas the latter, as intra-individual differences. Intra-individual differences suggest the importance of resting prior to data measurement and its timing. Variance would be larger for the intra-individual differences than for the inter-individual ones (Gasser et al., 1985) and thus, research may be needed to typify some homogenous groups of individuals who exhibit similar patterns in the intensity of emotional changes.

Behavioral Issues

As earlier discussed, there have been a number of studies in social and judgmental psychology that investigate

into the effect of emotion on simple and complex tasks (Isen, 1990; Lazarus, 1990). Interestingly enough, however, very limited research has been conducted in the context where computers are necessarily involved to perform tasks. Considering that there have been an increasing number of computer users and they experience various types of emotions at the computer task, further studies are urged on this issue. It is quite common that an illiterate computer novice may get angry at the way computers behave as s/he learns them. Even an intermediate user often finds oneself at a loss with the complicated software. Current computer technology provides quite useful help systems, which would certainly require some level of expertise and familiarity with them. We need to know as to what emotion users would experience over the session of computer tasks and how they react to any negative emotions. A pertinent issue would be what emotional state is most contributing to productive and efficient computer work. There have been a number of empirical studies and their results are contradictory (Kaufmann & Vosburg, 1997). That is, some research showed the beneficial effect of negative emotion on task performance, whereas others did not (for review see Forgas, 1995). Behavioral issues must be appropriately taken care of in the design of emotional computers and thus, further research is required to clarify the effect of emotion on computer work.

User Interfaces

User interfaces refer to the totality of the surface users would see and interact with (Preece at al., 1994). Although it may include not only what appears on the screen but also all related documentation, the former is of more interest to the design of emotional computers. The essential issue would be concerned with what should be called upon to help people to deal with their aversive emotion. The types and complexities of aids are certainly related to the nature of task in which users are engaged. In the context of a simple task, simple aids may be provided with multimedia technology to ease the intensity of negative emotion. For example, either favorite colors or music may be activated to relax users' boredom with computer tasks. It is also possible to provide some wizards to let users know about what they do not know of according to their expertise level. It should be, however, noted that human emotion is inherently not stable over time, promptly swinging on a continuum from positivity to negativity. Users may be irritated with the user interfaces that would change very frequently upon the minute changes of emotion.

Conclusions

The distinctive feature of emotional computers is its adaptiveness of user interfaces, which plays a role to differentiate them from the ordinary computers. The development of adaptive user interfaces is far from simple and requires interdisciplinary efforts. First of all, we need to know what provokes uneasy feelings of users and their effect of emotion on computer work. Despite its importance, much research has focused on the technical aspects of user interfaces such as the customization of graphical interfaces and the design and behavior of interface objects (Preece et al., 1994; Schneiderman, 1998). Now is the time we challenge the behavioral issues of emotion in the context of computing work. Most pertinent questions would be 'what influences does human emotion bear on the performance of computer tasks? and what aids should be provided to let users stay with their comfortable feelings?' We proposed in this paper the theoretical framework of emotional computers. They may consist of three functional components of (1) physiological measurement, (2) pre-processing and (3) user interfaces. In relation to this theoretical framework, a number of research issues were raised. Firstly, the adaptive nature of emotional computers assumes their actions in good tune with the subjective emotion of users. Such adaptability is to a great extent trusted to the signal processors of emotional computers. Thus, research should be made to determine under what conditions mathematical models performs robustly. Secondly, the apparatus to be affixed to human body should be kept to a minimum and thus, unobtrusive to users. The device may include some sensors and transmission systems that are required to measure and transfer the physiological data. Lastly, user interfaces should also be designed to provide appropriate actions to alleviate the uncomfortable feelings of users that may occur in the course of using computers. It should be noted that too much care of unstable emotion may lead to irritation. Thus, in addition to constant monitoring of physiological emotion, the subjective and behavioral state of emotion should be collected to keep track of the appropriateness of the adaptive behavior of user interfaces. Given the growing interests in emotion and its application into computing environment (Picard, 1997) and the principle of user-centered design in user interfaces, appropriate attention should be paid to research on emotional computers.

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