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Affect-Sensitive Computer Systems

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INTRODUCTION

Affective computing is the broad domain encompassing all of the hardware, software and underlying theoretical models underpinning the development of affect sensitive computer systems. Such systems facilitate more intuitive, natural computer interfaces by enabling the communication of the user's emotional state. Despite rapid growth in recent years, affective computing is still an under-explored field, which holds promise to be a valuable direction for future software development. Human-computer interaction has traditionally been dominated by the information processing metaphor and as a result, interaction between the computer and the user is generally unidirectional and asymmetric. The next generation of computer interfaces aim to address this gap in communication and create interaction environments that support the motivational and affective goals of the user.

This chapter will introduce and elaborate on the field of affective computing. First the background and origins of the field will be discussed. Next the elements of affective computing and affective human-computer interaction will be discussed along with associated concerns and issues. Next, examples of the diverse range of affective computing applications in current and recent development will be provided. Finally, the chapter will present a discussion of future directions for this promising technology, followed by some concluding remarks.

BACKGROUND

Computer usage has traditionally been regarded as a rational activity in which emotions are not involved. This view, however, has been changing as the importance of emotions in all aspects of human thinking, activity and interaction is becoming more apparent. Human interactions do not just include those with other people, but also with their surroundings, including inanimate objects. One such object that has a big role in the day to day life of many people is the computer.

It is not uncommon for a person to spend more hours in a day interacting with a computer than face to face with other people. For this reason it is important to design computers that are user-friendly and easy to use (Preece et al., 1994). One important aspect of this drive towards user-friendliness is that the user should be able to use his or her natural way of interacting rather than having to learn new ways of working (Norman, 1988). The goal of improving the interaction between users and computers requires that emotions be taken into account in this interaction.

The field of HCI has greatly matured over the last several decades since the first conference on human factors in computing systems was held in the early 1980's. Since this time the emphasis within HCI has shifted from a focus on trained systems operators, to analyzing how technology influences the general user. To this end, there has been a substantial amount of attention devoted to

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the concept of usability, as well as the role of the user in the development of successful interfaces. Usability is simply defined as "the extent to which a product can be used by specified users to achieve specific goals with effectiveness, efficiency, and satisfaction in a specified context of use" (International Organization for Standardization, 2010). This broad definition sets the stage for the fact that usability is a complex construct that can be influenced by a large number of external factors including context or environment.

In the early 80s, the role of a HCI specialist would be to evaluate interface components such as menus or terminology. As the field progressed, and the specialists came to realize the broader applicability of their work, new directions and specializations were created. The term "user-centered" is extensively used in the field of HCI (Karat & Karat, 2003) when describing approaches to building usable systems. For user-centered design, the main focus is that the needs of the user are used as a way to inform design (Vredenburg, Isensee, & Righi, 2001). This perspective is also sometimes referred to as human-centered design, or human centered computing (HCC). HCC broadly describes the methodology that would be applied to any field that uses computers in any form where users directly interact with them (Jaimes, Sebe, & Gatica-Perez, 2006). Thus HCC aims to integrate human sciences (such as cognitive and affective) into the existing body of computer science and HCI knowledge with a human focus throughout the lifecycle. HCC is said to incorporate social and cognitive sciences more closely than traditional HCI (Foley, 2006).

The recognition that interaction is not limited to simple interface modalities gives support to the development of new technologies. The ISO 9241 standard encapsulates this view in the following high level goal for user-centered design: "the design addresses the whole user experience" (International Organization for Standardization, 2010). This acknowledges that the HCC principles of cognitive and affective design are important when developing usable software and systems. To this end, a successful user interface would have an understanding of what emotions are, how they can be identified and what the implications of various emotional patterns are for a given interaction situation.

The term "affective computing" was coined as long ago as 1997 by Rosalind Picard, who defined it as "computing that relates to, arises from, or deliberately influences emotions" (Picard, 1997a, p. x). This is the most comprehensive and widely used definition and is often cited. Picard, a pioneer in this field, reports that the initial response to the very concept of emotion-sensitive machines was somewhat lackluster (Picard, 2010), and it is interesting to observe the dramatic rise in interest from both developers and the research community in recent years.

Affective computer interfaces improve human-computer interaction by enabling the communication of the user's emotional state. The growing interest in affective computing arises from findings in psychology and physiology which demonstrate the importance of emotional state in human behaviour (Partala & Surakka, 2004).

Emotion and cognition are linked and there is evidence of emotion influencing aspects of cognitive performance and decision making (Cytowic 1989; Eysenck et al. 2007). The interaction between affect and cognition is bi-directional, thus the underlying affective state of the individual will also influence the outcome of various cognitive processes. This, predictably, has far ranging implications. There is evidence that emotion has an impact on the speed at which information is processed (Öhman, 2001) and whether it is attended to (Anderson, 2001; Vuilleumier, 2001). Emotion also has a relation to motivation in that evaluations or feelings regarding the current situation will largely determine the action that is taken in response. Therefore, emotions are often precursors of motivations (Oatley, 1992). Memory is also impacted by emotional state, and again there are many mechanisms by which this can occur (Reisberg & Hertel, 2003). Thus there are substantial potential benefits to be had from the development of user interfaces that support users' emotional, as well as cognitive processes, in their day to day work or life.

Currently, affective computing research is conducted in a large number of areas including education, autonomous agents, games and healthcare. There is also a rapidly growing body of published literature on the subject with 2010 marking the launch of the *IEEE Transactions on Affective Computing*. This is the first cross-disciplinary, international journal dedicated toward disseminating the results of research in areas such as theories of affective human-computer interaction systems, algorithms to detect and respond to emotions, and applications of affective computing.

AFFECTIVE HUMAN-COMPUTER INTERACTION

Although a computer will not actually experience emotions in the same way that a human would, the quality of interaction has been shown to improve even if the system *appears* to do so. Klein, Moon and Picard (2002) conducted a study in which users interacted with a computer system that was designed to deliberately elicit negative feelings of frustration. It did this by inserting random delays or periods of unresponsiveness to hinder the users from carrying out the goals of the study. The results demonstrated that if the computer system provided users with the ability to vent their frustrations (as a form of affect-support), users continued to interact with the frustrating system significantly longer than if no affect-support was provided. Empathic agents have also been successfully used in software to improve usability. Prendinger, Mayer, Mori and Ishizuka (2003) utilized an on-screen animated agent to provide empathic support to users who had been carrying out a frustrating computer interface task. Findings indicated that a character demonstrating empathy may decrease users' levels of experienced stress. For these findings to be applicable for real-world affective interfaces, a key aspect of software functionality is the ability to detect the emotional state of the user.

Detection of Affective State

Mehrabian (1981) is often cited for his 7%-38%-55% rule of non-verbal communication which simply states that in human communication, 7% of the message is communicated by the words, 38% by tone of voice and the remaining 55% by body language. This is particularly relevant when we consider the expression of emotional content, or affect, which is largely non-verbal in nature. The use of subtle non-verbal communication methods is not only desirable but almost a necessity for a successful affect detection system to operate. Methods for inferring affective state are numerous but may be broadly categorized into a few areas, which are described below.

Self-Report Measures

A number of self-report measures of affect have been developed and used in research on mood and emotion; many of these share similar features but also have differences in the way that the responses are formatted and the way in which tests are conducted. Many of the most prominent self-report affective measures involve presenting lists of adjectives to the subjects, and obtaining a rating as to how appropriate or strong these particular emotions are (e.g. POMS (McNair, 1971) or PANAS (Watson, Clark, & Tellegan, 1988)). Self-report measures are a valuable instrument in the development and assessment of affective computer interfaces. However, as their use often requires the user to be interrupted or to recall a memory of an event, these have limited applicability for end-user applications which generally aim to produce the most natural interaction environment possible.

Observable Traits

The use of observations to infer the emotional state of an individual stems largely from the work of Ekman and Friesen (1978) who theorized a relationship between particular facial configurations and the underlying "basic" emotions present and later derived lists of facial expressions that would be used as markers for particular emotions. More recent work has called for other "non-basic" emotions to be considered within affect sensing systems, as different application domains may bring different emotional states into relevance (D'Mello & Calvo, 2013). Similar techniques may be applied to the observation of other features, such as the user's posture or gestures. Observable traits have the benefit that an affective application may utilize this source of information with little or no user intervention. Subtle changes in facial expressions and posture occur without conscious effort on the part of the individual and may also reveal a deeper insight into the underlying affective state. One disadvantage of these methods is that the technical and implementation environment is often quite "noisy" and the success rate of automatically detecting affective state from natural expressions or gestures may be impaired.

Psychophysiology

Researchers have become increasingly aware that a critical component of emotion is physiological activity. According to some theories, if there is no physiological reaction there is no emotion (e.g. Schachter & Singer, 1962). It is theorized that every psychological event or affective state has some physiological referent (Cacioppo & Tassinary, 1990), therefore the issue is not so much of whether or not a physiological signal is present, but rather which aspects of emotion may be inferred from this signal. There are many advantages to this approach. Physiological signals are unconscious and do not carry any of the subjectivity of self-report measures, furthermore they bring about the potential for real time measurement with no need to interrupt or otherwise distract the user. Finally, as technology advances, physiological sensors may be suitable for incorporating into existing physical interfaces to ensure a more natural interface which the user need not be constantly aware of. Recent developments have permitted the integration of physiological sensing into wearable form factors (e.g. Lanatà, Valenza, & Scilingo, 2012) and even enabled physiological sensing from existing commodity devices such as smartphones (Hernandez, McDuff, & Picard, 2015).

APPLICATIONS OF AFFECTIVE COMPUTING

Affective computing applications have potential uses in practically any situation where a human-computer interaction is taking place. Technology that can recognize and even express affect can provide insights into human-computer (and in some cases human-human) interactions. Measuring the stress or difficulty caused by a system may also allow developers to pinpoint problems, or simply allow the system to be improved by being able to respond in a more natural and realistic way. Such technologies have been successfully implemented in very diverse environments. These include robotic personas (Breazeal, 2003), learning companions (D'Mello, Lehman, & Graesser, 2011; Sarrafzadeh, Alexander, Dadgostar, Fan, & Bigdeli, 2008), games (Gilleade, Dix, & Allanson, 2005) or wearable computers (Picard, 1997b)..

Sociable humanoid robots present a novel and under explored area of human-machine interaction. Traditionally robots have been utilized for functional roles such as automation or inspections, in roles that require autonomy and minimization of human interaction. However, as robots may be used for any number of applications, including domestic use, the requirement for natural and usable human-machine (in this case robot) interaction, presents itself.

Humanoid robots may express affective states in a number of ways. Robotic characters, if human like in appearance, are well suited to affective expression as they can communicate in ways which emulate the natural communication modalities of humans. This can include non-verbal communication such as gestures, facial expression or body positioning. One example is Kismet: a socially expressive anthropomorphic robot. Kismet perceives a variety of cues from visual and auditory channels and delivers affective information back to the human through gaze direction, facial expression, body posture, and vocalization (Breazeal, 2002). The robot possesses a computation model of emotion, in which affective state is sensed, used as part of the internal decision (action) making strategy, and communicated to the human.

As mentioned, animated agents may also be used in a similar way to communicate affective content and to put the user in a positive and constructive affective state to maximize enjoyment, entertainment, learning or productivity. Education is an area in which affective computing applications have shown promise, partly due to the increasing reliance on online and computer mediated learning and teaching strategies. Goleman (1995) reported that expert teachers are able to recognize emotional states of students, and respond appropriately to positively impact learning. Whilst the way in which this is accomplished is not well documented a key element involves the recognition of negative affect or states that are detrimental to learning and guiding the learner into a more positive and constructive state. Intelligent tutoring systems incorporating an emotional or affective model are known as affective tutoring systems. An affective tutoring system is thus any tutoring system that can adapt to perceived emotion. This may be to respond to any negative emotions being experienced by the learner, or to interact in a manner that is more natural and engaging for the learner.

A number of such affective tutoring systems exist, that respond to different types of input. For example, AutoTutor is an intelligent tutoring system that interacts with learners using natural language and helps them to construct explanations in simulation environments (Graesser, McDaniel, & Jackson, 2007). It detects the learner's affective state using physiological and facial expression analysis and conversational cues. Easy with Eve (Alexander, Sarrafzadeh, & Hill, 2006; Sarrafzadeh, et al., 2008) is an affect sensitive mathematics tutor. Affect recognition is performed by video analysis to capture facial expression and gesture information from the user. These systems have also been shown to be effective and result in increased learning, however are still not as effective as a one-to-one human tutor.

A number of affective games have been developed to encourage the user to express their affective states and to dynamically respond and adapt to this form of input. For example, in SenToy, the user interacts with a doll to communicate one of six emotions through gestures (Paiva, 2003). Other games utilize biofeedback to guide the user into certain affective states, for example in the game "The Wild Divine" (2012) the player needs to achieve a state of relaxation to interact and progress within the game environment. Affective interaction and expression has been identified as a valuable direction of research to develop more engaging and realistic games (Hudlicka, 2009).

Wearable computers provide a rich and diverse ground for evaluating and implementing affective technologies. The close contact with the user enables easy communication of subtle non-verbal cues that may be valuable indicators of affective state. In some cases, the affect detection capabilities may even be used to improve the users' own abilities to perceive emotions in others, and thus improve human-human communication. For example "expression glasses", developed at MIT provide the wearer with feedback about the emotional expressions of others (Scheirer, Fernandez, & Picard, 1999). This technology may improve the quality of life for those with autism or other disorders that impair human-human communication (el Kaliouby, Picard, & Baron-Cohen, 2006). Existing devices that are in close contact with the user may also have potential to be used as affect sensing devices, for example a mouse may sense the user's stress levels (Kirsch, 1997), or a car steering wheel may sense when the user is falling asleep or identify lapses in attention (Gusikhin, Filev, & Rychtyckyj, 2008).

ISSUES

The diverse nature of affective computing applications described in the previous section highlights that this technology is successful and adaptable to a wide range of situations with positive outcomes. However, as many of the implementations are disparate and "one-off" in nature, it is potentially difficult to transfer findings from one particular domain to a new application. Furthermore, as this is a new and emerging field, there is little evidence of "shared best practice" aside from the high level principles that have been established regarding inference of affective state.

Affective computing applications are often built in the same way as more traditional applications, with the affective functionality inserted into the program architecture wherever the developer considers it appropriate. Consequently, the current trend for ad-hoc development in affective computing is hampering progress. Allanson and Fairclough (2004) noted that research in the area was disparate and uneven, and it seems that little progress has been made since then. One goal that has been identified in the literature is that of "device-independence" – any successful solution to the issue must be capable of abstracting over multiple implementation environments which may have different outputs, manufacturers and operating requirements.

Due to the diverse nature of implementation, and the many methods by which affective information may be gathered, affective computer interface components often need to deal with many different types of data (all with different characteristics and requirements for processing). This often presents a complex signal processing task, which involves a number of stages from extraction of the raw signal to analysis and transformation of the data into a computer input with well understood parameters. For this reason it may be necessary to add a layer of signal processing between the intelligent sensors and the interface to limit the complexity of the interaction techniques (Allanson, 2000).

It becomes apparent that the one commonality amongst affective computing applications is the extent to which developments are unique and tied to a particular implementation. Hamming (1969) stated that "a central problem in all of computer science is how we are able to get to the situation where we build on top of the work of others rather than redoing much of it in a trivially different way" (p.10) – an observation that is valid to this day. As affective applications are highly specialized and complex, there has to date been no discussion regarding the concept of reusing existing affective applications in new problem domains and situations. Furthermore, the potential for adding affect support as an additional layer above existing software has not been investigated thoroughly to date. Aist, Kort, Reilly, Mostow and Picard (2002) demonstrated the utility of adding emotional support to an existing tutoring system, and noted that this approach may be useful for future developments. Certainly, the ability to augment existing software with affect sensing capabilities could for the most part turn the entire operating system and all its application software and tools into an affective computing application. This would be a breakthrough for those who envision affective computing as being a part of the entire computing experience rather than the domain of a few isolated applications

FUTURE TRENDS

In a relatively new field such as affective computing, theories regarding emotion, tools, methods and software are constantly evolving and improving as our knowledge grows. The rapidly developing body of research in the field of affective computing gives a clear indication that affective computing is going to play a major role in the future of human-computer interaction.

The domain of affect sensing technologies is one which will directly be improved as advances in computer technology take place. The increased processing power and portability of modern computing devices makes advanced signal processing and affective pattern recognition, more feasible. Furthermore, as computers become ubiquitous and become integrated into vehicles, clothing and our surroundings, the opportunity for greater physical contact between user and machine increases and makes new input paradigms increasingly viable.

Education is an area in which applications of affective computing are highly applicable and substantial research has been carried out in this area. The fact that interaction with computers is a fundamental part of study in most disciplines renders this a prime candidate for affective computing developments. Endowing a computer with the ability to respond to affective state should enhance learning outcomes and have a positive impact on the user experience of e-learning. Furthermore with the increased dependence on online learning, such technology may be in even more demand as teachers no longer have access to students' non-verbal cues in classrooms (Crosby, Brent, Aschwanden, & Ikehara, 2001). Interest in the educational implications of affective computing is not limited to the academic research community. In 2012, industry analysts Gartner Research discussed how the field is on the rise in education. Whilst most of the affective tutoring systems are in the proof of concept stage, the advice given to education institutions is to track the progress and developments in the field and that those with a large online presence should immediately get involved. Affective computing is described as having "the potential to bring back a bit of the lost pedagogical aspect of in-classroom learning and increase the personalization of online learning" (Lowendahl, 2012, p. 15).

CONCLUSION

Affective computing facilitates more intuitive, natural computer interfaces by taking into account the emotional state of the user. As such, affective computing holds great promise for improving human-computer interaction. This chapter has provided an insight into the field of affective computing: covering the origins of the field, the underlying elements of affective computing, and highlighting issues in the field. Detailed examples of a diverse range of affective computing applications are provided and future directions have been identified.

REFERENCES

Aist, G., Kort, B., Reilly, R., Mostow, J., & Picard, R. (2002). Experimentally augmenting an intelligent tutoring system with human-supplied capabilities: Adding human-provided emotional scaffolding to an automated reading tutor that listens. *Proceedings of the 4th IEEE International Conference on Multimodal Interfaces*, 483-490. doi:10.1109/ICMI.2002.1167044

Alexander, S., Sarrafzadeh, A., & Hill, S. (2006). Easy with Eve: A functional affective tutoring system. In G. Rebolledo-Mendez & E. Martinez-Miron (Eds.), *Proceedings of Workshop on Motivational and Affective Issues in ITS. 8th International Conference on ITS* (pp. 38-45). Academic Press.

Allanson, J. (2000). *Supporting the development of electrophysiologically interactive computer systems* (Unpublished doctoral dissertation). Lancaster University, Lancaster, UK.

Allanson, J., & Fairclough, S. H. (2004). A research agenda for physiological computing. *Interacting with Computers*, *16*(5), 857–878. doi:10.1016/j.intcom.2004.08.001

Anderson, A. K., & Phelps, E. A. (2001). Lesions of the human amygdala impair enhanced perception of emotionally salient events. *Nature*, *411*(6835), 305–309. doi:10.1038/35077083 PMID:11357132

Breazeal, C. (2002). *Designing sociable robots*. Cambridge, MA: MIT Press.

Breazeal, C. (2003). Emotion and sociable humanoid robots. *International Journal of Human-Computer Studies*, *59*(1-2), 119–155. doi:10.1016/S1071-5819(03)00018-1

Cacioppo, J. T., & Tassinary, L. G. (1990). Inferring psychological significance from physiological signals. *The American Psychologist*, *45*(1), 16–28. doi:10.1037/0003-066X.45.1.16 PMID:2297166

Crosby, M. E., Brent, A., Aschwanden, C., & Ikehara, C. (2001). Physiological data feedback for application in distance education. *Proceedings of the 2001 Workshop on Perceptive User Interfaces*, 1-5. doi:10.1145/971478.971496

D'Mello, S., & Calvo, R. A. (2013). *Beyond the basic emotions: what should affective computing compute?* Paper presented at the CHI '13 Extended Abstracts on Human Factors in Computing Systems. doi:10.1145/2468356.2468751

D'Mello, S., Lehman, B., & Graesser, A. (2011). A motivationally supportive affect-sensitive AutoTutor. In R. A. Calvo & S. K. D'Mello (Eds.), *New perspectives on affect and learning technologies* (Vol. 3, pp. 113–126). New York: Springer. doi:10.1007/978-1-4419-9625-1_9

Ekman, P., & Friesen, W. (1978). *Facial action coding system: A technique for the measurement of facial movement*. Palo Alto, CA: Consulting Psychologists Press.

el Kaliouby, R., Picard, R. W., & Baron-Cohen, S. (2006). Affective computing and autism. *Annals of the New York Academy of Sciences*, *1093*(1), 228–248. doi:10.1196/annals.1382.016 PMID:17312261

Foley, J. (2006). *HCC Education Digital Library*. Retrieved 5th June, 2013, from http://hccedl.cc.gatech.edu/

Gilleade, K., Dix, A., & Allanson, J. (2005). Affective videogames and modes of affective gaming: Assist me, challenge me, emote me. *Proceedings of the DIGRA*.

Goleman, D. (1995). *Emotional intelligence*. New York: Bantam Books.

Graesser, A. C., McDaniel, B., & Jackson, G. T. (2007). Autotutor holds conversations with learners that are responsive to their cognitive and emotional states. *Educational Technology*, *47*, 19–22.

Gusikhin, O., Filev, D., & Rychtyckyj, N. (2008). Intelligent vehicle systems: Applications and new trends in control automation and robotics. In J. A. Cetto, J.-L. Ferrier, J. M. Costa dias Pereira & J. Filipe (Eds.), Lecture Notes in Electrical Engineering (Vol. 15, pp. 3-14). Berlin: Springer Heidelberg.

Hamming, R. W. (1969). One mans view of computer science. *Journal of the ACM*, *16*(1), 3–12. doi:10.1145/321495.321497

Hernandez, J., McDuff, D. J., & Picard, R. W. (2015). Biophone: Physiology monitoring from peripheral smartphone motions. *Proceedings of the Engineering in Medicine and Biology Society (EMBC), 2015 37th Annual International Conference of the IEEE*, 7180-7183.

Hudlicka, E. (2009). Affective game engines motivation and requirements. *Proceedings of the 4th International Conference on Foundations of Digital Games*, 299-306.

International Organization for Standardization. (2010). *ISO 9241-210:2010 Ergonomics of human-system interaction -- Part 210: Human-centred design for interactive systems*. Retrieved 2nd June 2012, from http://www.iso.org/iso/catalogue_detail.htm?csnumber=52075

Jaimes, A., Sebe, N., & Gatica-Perez, D. (2006). Human-centered computing: a multimedia perspective. *Proceedings of the 14th annual ACM international conference on Multimedia*, 855-864. doi:10.1145/1180639.1180829

Karat, J., & Karat, C. M. (2003). The evolution of user-centered focus in the human-computer interaction field. *IBM Systems Journal*, *42*(4), 532–541. doi:10.1147/sj.424.0532

Kirsch, D. (1997). *The Sentic Mouse: Developing a tool for measuring emotional valence*. Retrieved Nov 5th, 2012, from http://affect.media.mit.edu/projectpages/archived/projects/sentic_mouse.html

Klein, J., Moon, Y., & Picard, R. W. (2002). This computer responds to user frustration: Theory, design and results. *Interacting with Computers*, *14*(2), 119–140. doi:10.1016/S0953-5438(01)00053-4

Lanatà, A., Valenza, G., & Scilingo, E. P. (2012). A novel EDA glove based on textile-integrated electrodes for affective computing. *Medical & Biological Engineering & Computing*, *50*(11), 1163–1172. doi:10.1007/s11517-012-0921-9 PMID:22711069

Lowendahl, J.-M. (2012). *Hype Cycle for Education*. Retrieved 1st September, 2012, from http://www.gartner.com/DisplayDocument?doc_cd=233974&ref=g_sitelink

McNair, D., Lorr, M., & Dropplemen, L. (1971). Edits manual: Profile of mood states. San Diego, CA: Educational and Industrial Testing Services.

Mehrabian, A. (1981). *Silent Messages: Implicit communication of emotions and attitudes*. Belmont, CA: Wadsworth.

Norman, D. (1988). *The design of everyday things*. New York: Doubleday.

Oatley, K. (1992). *Best laid schemes: The psychology of emotions*. Cambridge, UK: Cambridge University Press.

Öhman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: Detecting the snake in the grass. *Journal of Experimental Psychology*, *130*(3), 466–478. doi:10.1037/0096-3445.130.3.466 PMID:11561921

Paiva, A., Costa, M., Chaves, R., Piedade, M., Mourão, D., Sobral, D., & Bullock, A. et al. (2003). SenToy: An affective sympathetic interface. *International Journal of Human-Computer Studies*, *59*(1-2), 227–235. doi:10.1016/S1071-5819(03)00048-X

Partala, T., & Surakka, V. (2004). The effects of affective interventions in human–computer interaction. *Interacting with Computers*, *16*(2), 295–309. doi:10.1016/j.intcom.2003.12.001

Picard, R. W. (1997a). *Affective computing*. MIT Press. doi:10.1037/e526112012-054

Picard, R. W. (2010). Affective Computing: From laughter to IEEE. *IEEE Transactions on Affective Computing*, *1*(1), 11–17. doi:10.1109/T-AFFC.2010.10

Picard, R. W., & Healey, J. (1997b). Affective wearables. *Personal Technologies*, *1*(4), 231–240. doi:10.1007/BF01682026

Preece, J., Rogers, Y., Sharp, H., Benyon, D., Holland, S., & Carey, T. (1994). *Human-computer interaction*. Addison-Wesley.

Prendinger, H., Mayer, S., Mori, J., & Ishizuka, M. (2003). Persona effect revisited. Using bio-signals to measure and reflect the impact of character-based interfaces. *Proceedings of the Fourth International Working Conference on Intelligent Virtual Agents (IVA-03)*, 283-291.

Reisberg, D., & Hertel, P. (2003). *Memory and emotion*. Oxford University Press.

Sarrafzadeh, A., Alexander, S., Dadgostar, F., Fan, C., & Bigdeli, A. (2008). How do you know that I dont understand? A look at the future of intelligent tutoring systems. *Computers in Human Behavior*, *24*(4), 1342–1363. doi:10.1016/j.chb.2007.07.008

Schachter, S., & Singer, J. (1962). Cognitive, social, and physiological determinants of emotional state. *Psychological Review*, *69*(5), 379–399. doi:10.1037/h0046234 PMID:14497895

Scheirer, J., Fernandez, R., & Picard, R. W. (1999). Expression glasses a wearable device for facial expression recognition. *Proceedings of the Computers in Human Interaction, CHI*, *99*, 262–264.

Vredenburg, K., Isensee, S., & Righi, C. (2001). *User centered design: An integrated approach*. Upper Saddle River, NJ: Prentice Hall.

Vuilleumier, P., & Schwartz, S. (2001). Beware and be aware: Capture of spatial attention by fear-related stimuli in neglect. *Neuroreport*, *12*(6), 1119–1122. doi:10.1097/00001756-200105080-00014 PMID:11338176

Watson, D., Clark, L. A., & Tellegan, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology*, *54*(6), 1063–1070. doi:10.1037/0022-3514.54.6.1063 PMID:3397865

Wild Divine. (2012). *The Journey to Wild Divine*. Retrieved 1 Nov 2012, from http://www.wilddivine.com

ADDITIONAL READING

Allanson, J., & Fairclough, S. H. (2004). A research agenda for physiological computing. *Interacting with Computers*, *16*(5), 857–878. doi:10.1016/j.intcom.2004.08.001

Ball, G., & Breeze, J. (2000). Emotion and personality in a conversational agent. In J. Cassel, J. Sullivan, S. Prevost, & E. Churchill (Eds.), *Embodied conversational agents* (pp. 189–219). Cambridge, MA: The MIT Press.

Baylor, A. L., & Rosenberg-Kima, R. B. (2006). Interface agents to alleviate online frustration. *Proceedings of the 7th International Conference of the Learning Sciences*, Bloomington, IN. 30-36

Beale, R., & Peter, C. (2008). The role of affect and emotion in HCI. In P. Christian & B. Russell (Eds.), *Affect and Emotion in Human-Computer Interaction* (pp. 1–11). Springer-Verlag. doi:10.1007/978-3-540-85099-1_1

Cacioppo, J. T., & Tassinary, L. G. (1990). Inferring psychological significance from physiological signals. *The American Psychologist*, *45*(1), 16–28. doi:10.1037/0003-066X.45.1.16 PMID:2297166

Cacioppo, J. T., Tassinary, L. G., & Berntson, G. G. (Eds.). (2007). *Handbook of psychophysiology* (3rd ed.). New York: Cambridge University Press. doi:10.1017/CBO9780511546396

Coan, J. A., & Allen, J. J. B. (Eds.). (2007). *Handbook of emotion elicitation and assessment*. New York: Oxford University Press.

Fulda, J. S. (1998). Giving computers emotions - Why and how. *ACM SIGCAS Computers and Society*, *28*(4), 30–31. doi:10.1145/308364.606115

Goleman, D. (1995). *Emotional intelligence*. New York: Bantam Books.

Klein, J., Moon, Y., & Picard, R. W. (2002). This computer responds to user frustration: Theory, design and results. *Interacting with Computers*, *14*(2), 119–140. doi:10.1016/S0953-5438(01)00053-4

Marcus, A. (2003). The emotion commotion. *Interaction*, *10*(6), 28–34. doi:10.1145/947226.947239

Mehrabian, A. (1981). *Silent Messages: Implicit communication of emotions and attitudes*. Belmont, CA: Wadsworth.

Norman, D. (1988). *The design of everyday things*. New York: Doubleday.

Partala, T., & Surakka, V. (2004). The effects of affective interventions in human–computer interaction. *Interacting with Computers*, *16*(2), 295–309. doi:10.1016/j.intcom.2003.12.001

Picard, R. W. (1997). *Affective computing*. MIT Press. doi:10.1037/e526112012-054

Picard, R. W. (2010). Affective Computing: From Laughter to IEEE. *IEEE Transactions on Affective Computing*, *1*(1), 11–17. doi:10.1109/T-AFFC.2010.10

Preece, J., Rogers, Y., Sharp, H., Benyon, D., Holland, S., & Carey, T. (1994). *Human-computer interaction*. Massachusetts: Addison-Wesley.

Reeves, B., & Nass, C. (1996). *The media equation: How people treat computers, television, and new media like real people and places*. New York: Cambridge University Press.

Riseberg, J., Klein, J., Fernandez, R., & Picard, R. W. (1998). Frustrating the user on purpose: using biosignals in a pilot study to detect the user's emotional state. *Proceedings of the CHI '98 Conference on Human Factors in Computing Systems*, Los Angeles, United States. 227-228 doi:10.1145/286498.286715

Sarrafzadeh, A., Alexander, S., Dadgostar, F., Fan, C., & Bigdeli, A. (2008). How do you know that I dont understand? A look at the future of intelligent tutoring systems. *Computers in Human Behavior*, *24*(4), 1342–1363. doi:10.1016/j.chb.2007.07.008

Scherer, K. R., Banziger, T., & Roesch, E. (Eds.). (2010). *A blueprint for affective computing*. Oxford: Oxford University Press.

Sears, A., & Jacko, J. (2008). *The Human-Computer Interaction handbook*. New York: Lawrence Erlbaum Associates.

Serbedzija, N. B., & Fairclough, S. H. (2009). Biocybernetic loop: From awareness to evolution. *Proceedings of the IEEE Congress on Evolutionary Computation, CEC '09*., 2063-2069. Trondheim, Norway.

Shneiderman, B. (2003). *Leonardo's laptop: Human needs and the new computing technologies*. Massachusetts: MIT Press.

Thompson, N., & McGill, T. (2012). Affective Tutoring Systems: Enhancing e-learning with the emotional awareness of a human tutor. *International Journal of Information and Communication Technology Education*, *8*(4), 75–89. doi:10.4018/jicte.2012100107

KEY TERMS AND DEFINITIONS

Affective Computing: Defined by Picard (1997a) as "computing that relates to, arises from, or deliberately influences emotions".

Affective Human-Computer Interaction: Affective HCI incorporates the communication of affective state information as an interface modality. This aims to enrich the quality of interaction and permit the user to employ more intuitive methods of communication.

Affective State: This term refers to the experience of feeling the underlying emotional state. The description often distinguishes between the more diffused longer term experiences (termed moods) and the more focused short term experiences (termed emotions).

Human-Computer Interaction (HCI): The study of how users interact with computer based devices. This includes techniques for assessing elements of the effectiveness or ease of use of an interface as well the development of more intuitive and natural interfaces.

Psychophysiology: Research suggests that all underlying affective states have some physiological manifestation that may be subtle, but potentially observable. The field of psychophysiology bridges the domains of psychology and physiology with the study of how these aspects of human experience interact.

User-Centered Design: A type of user interface and interaction design in which the main focus is that the needs of the user are used as a way to inform design. This often involves a participatory or cooperative design approach in which designers and users work collaboratively.

Wearable Computers: Any portable, miniature devices that are computer based and worn by the user as part of their clothing or accessories. Increasing miniaturization and widespread use of portable computers (including smartphones) makes this a viable and promising domain in which affective computer interfaces may be developed.