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Affective computing in the era of contemporary neurophysiology and health informatics

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Abstract

This commentary is a response to Interacting with Computers (Vol 14)—[Interacting Comput. 14 (2002) 119], [Interacting with Comput. 14 (2002) 141], [Interacting Comput. 14 (2002) 93]. Its aim is to discuss the role that neurophysiological measurements, such as EEG and MEG, may play in affective computing. The discussion is drawn upon the light of current experience and practice, as well as, advances envisaged in the fields of health informatics, telecommunications and biomedical engineering. It is explained why HCI research into interface evaluation and affective computing may be greatly enhanced by exploiting the underlying information of neurophysiological recordings.

Keywords: Neurophysiology; Magnetoencephalography (MEG); Electroencephalography (EEG); Neuroimaging; Brain; Physiological measures; Microdevices; E-health

1. Introduction

Work on affective computing as conducted by the MIT group is not only fine research, but an exciting prospect for the HCI field as a whole, that consolidates previous knowledge, and also opens up new avenues for the foreseeable future. The authors of the three articles and the editors of the special issue deserve our generous congratulations for

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touching upon these very sensitive and important issues of research, but also for providing the opportunity for this lively follow up discussion (Cockton, 2002).

All three papers of the special issue are equally important. Scheirer et al. (2002) demonstrate that interaction with technology does indeed induce emotions (frustration in this case), which are psychophysiologically detectable and meaningful. Picard and Klein (2002) suggest 'computer' ways of supporting some human emotional needs. Klein et al. (2002) demonstrate that, after task obstructions, subsequent computer usage is affected by the way computer feedback is provided to the users.

With the increasing availability of information and communication technologies in all facets of human activity, users are faced with an amazing diversity and complexity of content, functionality, and interaction media and methods. Despite the progress, expansion and development of comprehensive interface design strategies, the actions of accessing, retrieving, or processing of information, as well as, the handling of devices and interfaces still suffers from the occurrence of often serious usability problems that impose barriers in the efficient and productive usage of new technologies (Bullinger et al., 2002). As the digital *era* progresses, more and more 'normal/usual people' with ever increasingly wide backgrounds, literacies and skills will need to interact with various end-expressions of the new technology, thereby lifting the importance of the HCI field of research as a whole, as well as, boosting the interest of the current timely discussion of this special issue.

This commentary discusses aspects of the MIT work that relate to the measurement of emotion (frustration), and contrasts them with proposed methodologies that stem from developments in the field of neurophysiology and health informatics in general.

2. Physiological sensing and the MIT experiments

In the MIT experiments, physiological signals such as skin conductivity (GSR) and blood volume pressure (BVP) were measured in an effort to determine and discriminate between different regimes of likely frustration. The authors (Scheirer et al., 2002) pinpoint very properly indeed the pros and cons of the measurements conducted and correctly comment that the two physiological metrics chosen, i.e. GSR and BVP are not claimed to be optimal for measuring frustration. The set of parameters identified to affect the validity of the results, such as transparency of measurements, multiple sensing for cross checking, participant sample, and finally analysis methodology (use of HMM), together with the careful and wide literature review provided, account for a methodical and rigorous approach.

Since the classic works by Gray (1978); Kimsey et al. (1974), where it was shown that emotions may be physically revealed by measuring their associated electric potentials on the scalp (by means of Electroencephalography—EEG) or intracranially (by means of stereo EEG—SEEG), numerous papers have appeared that attempt to link measurements with direct expressions of emotional states and behaviour. The richness of neurophysiological data accounts for the major part of that, as one is capable of studying specific spectral bands of data, e.g. delta and beta or narrower sub regions, and exploring their different emotion contents (Marosi et al., 2001; Marosi et al., 2002). Moreover, tomographic estimates of brain activity that is due to emotional stimuli may also be calculated from magnetoencephalogram (MEG) (Ioannides et al., 2000) or EEG/ERP measurements (Pizzagalli et al., 2002), coupling the involved emotions to specific brain regions.

Emotions may be manifested in terms of autonomic activation of the nervous system and behaviour. Visceral manifestations are indeed picked up via changes in physiological signals. If a person interacts with a device, this situation can certainly induce positive or negative emotions. However, frustration cannot unquestionably be considered exactly as a basic emotion; the basic emotions include anger, happiness, and sadness. Frustration is most likely linked with how the participant psychologically interprets negative emotions based on expectations or other factors. This limitation may affect the way frustration may be measured.

Thus, the signals chosen in the above paper may be indirect in measuring/signalling frustration. GSR and BVP can only be secondary effects of any changes induced as a result of user frustration (if someone is experiencing fear, anxiety, anger and so on, with these physiological measures one cannot discriminate among specific emotions). Neurophysiological correlates such as the EEG or even better MEG may provide more direct measurements (Bamidis et al., 1995), as they record outputs of neuronal regions, which occur at real reaction time and are in turn responsible for changing local blood flow and, therefore, GSR and BVP. The arguments that one can put forward here, could draw profitably on similar discussions taking place in publications of the brain function research community, where the relevant merits of different neuroimaging techniques, such as EEG/MEG, and their blood flow recording counterparts such as functional Magnetic Resonance Imaging (fMRI), and Positron Emission Tomography (PET), are discussed (Ioannides, 2001).

However, it is also true that even with these measurements one could look at correlates of emotions/frustration, but may not be measuring frustration as such. That is, one would need to have a psychological measure of frustration (most likely a questionnaire about positive and negative emotions). Then levels of frustrations may be linked with specific patterns or areas of activation.

As it is also correctly mentioned in Scheirer et al. (2002), 'much of the work into this area has focused on mental workload rather than components of the emotional response system (such as frustration), but is still relevant to the experiment'. Indeed, most of the researchers of the neuropsychological community do use measurements such as arousal as an indication of mental workload and then try to link it to emotion. Some of the work recently conducted by our group is also along these lines (Papadelis et al., 2002), but goes a bit further, and tests the effect of caffeine on cognitive performance, blood pressure and catecholamines under resting conditions and under mental workload (i.e. while subjects were performing a multitask performance test). Mental workload in this case is again linked to arousal.

3. Prerequisites of physiological sensing

Upon attempting to clarify issues inherent in the complex notion of affect and emotion several authors from the psychology community make distinctions about the relative temporal scales involved in the manifestation of emotion. This is well given by another author of this series of commentaries (Lindgaard, 2004), but is also clearly noted by Scheirer et al. (2002). It is worth pinpointing the importance of this issue in such experiments, and introduce the terminology of 'temporal resolution/evolution' of emotion.

In order for affect and emotion to be well studied, one needs to accommodate both their macro and micro temporal scale effects. As far as the micro scale is concerned, EEG and MEG are the only techniques available that allow millisecond by millisecond studies of the changes in the emotional state, even in single epoch recordings (Ioannides et al., 1995). In addition, long-term effects may also be analysed especially if one has the appropriate set of processing tools. Such tools may include trivial EEG pattern classifiers based on quadratic metrics such as the Mahalanobis distance (Cincotti et al., 2002), but also more sophisticated MEG methodologies that allow one to obtain summaries of brain activation over longer periods of time (Bamidis et al., 1995).

We, therefore, stress that this battery of neurophysiological measurements could resolve problems associated with the temporal resolution of emotion elicitation, and enable the switching from micro resolution (ms by ms; detailed study) to macro resolution (min/hours/days; gross measures). An important barrier to overcome, however, is associated with the availability of techniques capable of efficient processing of the truly enormous volume of recorded data. Newly developed intelligent methodologies like independent component analysis (Bamidis et al., 2002), data mining (Stilou et al., 2001), single trial associations (Liu et al., 1998) and other, that enable quick data overviews, as well as, powerful feature extractions are necessary players in this game (Bamidis and Zisis, 2002). However, there is still a long way to reach the point of practically useable, real-time processing of such measurements.

However, the design of such a battery of experiments should pay proper attention to 'user-transparency' issues already identified and well accounted for by the MIT researchers. It is advantageous for the elicitation of emotions, to use recording devices that are as transparent as possible to the participants. However, EEG electrodes attached to the participant's scalp may generally affect human performance, in probably the same way wearing a hat may affect a football player's performance. This is not a terrible restriction, however, in the sense that subjects will still be able perform mentally even when they wear a hat with electrodes. It is a problem, though, that should be taken into account when analysing and interpreting the EEG data. MEG is better on this aspect, as completely non-contact measurements are conducted. The drawback involved in MEG though, is related to the devices/tools that may be used in the experiments. Non-magnetic material needs to be involved in all peripheral equipment used, and when participants are placed in a magnetically shielded, room fibre optics technology needs to be employed for screens, joysticks, mice, finger tapping devices, etc., which are technologically available today.

Finally, the most severe limitation that needs to be overcome in both of these cases is concerned with inability to allow participants freedom of movement, and be measured in natural settings and not in pre-set rooms/labs.

4. Advances in health informatics and their effects in HCI

User-machine interaction will be much increased with the use of new interactive media such as Interactive Television (iTV), which is established as a popular and widespread communication medium. People may want to find out about a news broadcaster's nice clothes or nice furniture in a TV film or series. This is not currently possible, where millions of web sites are competing for a limited number of users and trying to convince them to perform certain actions (Light, 2004). If interaction with the iTV sets becomes simple enough, then the total number and age span of users will be enlarged too. However, this raises the issue of how to evaluate usability for such technologies. Novel technologies and methodologies are required to assess the usability of such systems; tele-evaluation or remote usability testing (McFadden et al., 2002) should be allowed.

Under these circumstances, microdevices used in the area of health informatics and home monitoring of chronic disease patients may offer themselves in the interface evaluation methodology research. Knowledge drawn from the wide application of home care technologies could possibly be extended to meet the above types of needs, and allow for more flexible EEG/MEG devices[1] that will in turn be used in the interface evaluation, but more importantly will open new avenues for affective computing and HCI. In the future, such two-way communication systems (Dillon et al., 2004) would mean that user feedback could be not only be collected unobtrusively, as suggested by Scheirer et al. (2002), but also directly linked with user emotions, and also synchronised with information about system failures and associated viewer behaviours.

5. Conclusions

The research in Interacting with Computers, 14(2) has indicated possibilities to create novel, *objective*, and more importantly, evolving real world experiences concerning multi-modal and multi-sensory information about human emotion as a result of human computer interaction. Subjective and physiological readings are not always fully correlated, as well pointed out by Wilson and Sasse (2004), and this may mean that physiological measures could provide information about responses that cannot be detected otherwise. Thus, our proposal is that use of neurophysiological methods would enhance such HCI studies even further. Technological advances from sister fields such as health informatics, biomedical engineering and telecommunications science could enable more HCI researchers to start collecting such data and applying the underlying latent information into traditional HCI study topics such as interface evaluation. Sophisticated analysis techniques, careful consideration of all the involved parameters (as it is done in the case of the three MIT papers), and finally newly developed processing methodologies will harness the HCI

[1] Portable EEG devices are technologically feasible currently. However, the flexibility of MEG instruments has only reached the point of utilising high temperature (i.e. non-cryogenic) sensors and measurements outside a magnetically shielded room, but there are still far away from being portable.

research activities on the whole, but more importantly will enable us to understand how to make computer machinery respond more closely to real human needs.

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