Applying Psychophysiological Methods for Measuring User Experience: Possibilities, Challenges and Feasibility

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ABSTRACT
Traditional methods to access the experience of a user such as subjective reports have certain disadvantages. Participants have to be asked for their experiences and emotions which interrupts the process of experience and flow. Psychophysiological methods offer data throughout the process of experience, which unfolds new possibilities for user experience (UX) evaluation. In this paper we provide a short overview of psychophysiological methods for human computer interaction (HCI) and the findings of our examinations. Our outcomes will be discussed considering the possibilities, challenges and feasibility of these methods in the area of interaction with systems and emotions. Based on our experience we think that psychophysiological measurements provide important possibilities in product development and can help to deepen and expand the insights gathered by traditional methods.

Keywords
User Experience, Psychophysiology, Emotion, Human Computer Interaction, Evaluation;

INTRODUCTION
Over the past years there has been increasing interest in emotional aspects of customer behaviour. Pleasurable products have to offer more than functionality and usability, they address other aspects such as aesthetics, beauty, or playability, which enrich our experience with interactive systems. In recent years the field of HCI and industry acknowledged the design and architecture knowledge that stimulating experience of a product plays an essential role in customer satisfaction as well. Evaluation methods aim to support the process of designing pleasurable experience for products. However trying to "measure the experience" is a nontrivial task even by definition. UX is embedded in a situational, temporal, individual and product context and difficult to comprehend [13]. Experience with technology as characterized by McCarthy and Wright consists of a sensual, an emotional, a compositional and a spatio-temporal thread [17]. Hence, accessing the emotional state of users is crucial for developing satisfying products that are rich in experience. The application of UX evaluation methods help to increase the possibility that the end-products go beyond functional development and end users can enjoy their use.

Methods to Assess Emotions
Traditional methods include questionnaires, interviews, narrative techniques and contextual inquiry. In general, these methods are based on self-reporting and record a user's perception, such as sensual evaluation [11]. The added value of these methods is the possibility of an insight into the person's feelings and preferences. Other possibilities are observational techniques and video analysis, where the evaluation of the material is a very long and laborious process. Moreover, the intersubjectivity and validity of this approach is hard to guarantee. Beside the described techniques, there are approaches to automate expression recognition of speech, faces or gestures [7]. Combinations of these automatic expression recognition methods result in a broader spectrum of emotions that can be detected [5, 8]. To support the development of pleasurable products, these methods can be applied on prototypes of the product or through wizard of ozing. The application of UX evaluation methods increases the possibility for products end users can enjoy.

Psychophysiological Methods in HCI
Psychophysiological recordings have been shown to be valuable approaches for measuring valence (a quality for positive and negative emotions) and arousal throughout the process of an experience. Asking a participant about its emotional state is crucial, but interrupting the flow of interaction and experience, which is not necessary when psychophysiological methods are employed. Additionally, psychophysiological measurements can help uncovering social masking, which means people often say positive things about a product because they hesitate to be negative. Furthermore, it's possible to analyse data for special situations during the evaluation, e.g. the moment when a participant won a game.

Unfortunately, psychophysiological methods have some disadvantages as well. They are still costly and complex to apply and people are fitted up with cables and electrodes and therefore restricted in moving and acting freely and without restrictions. Making it more difficult, the setting in a lab may cause arousal or different emotions in people and therefore alter the results. Nevertheless, the possibility of obtaining data throughout the whole test is very advantageous. To give more insight into the world of psychophysiology, the following section shall give a short overview of methods considered for the UX evaluation of interactive systems:

Electroencephalography (EEG) measures electrical activity of the brain. Though very interesting in principle, EEG is very difficult to implement considered for a practical implementation. Even the movement of the eyes causes noise that has to be filtered out. Regarding that interaction with systems naturally involves movement and activity, EEG is not very suitable for UX research.

Electromyography (EMG) measures muscle activity by detecting surface voltages that occur when a muscle is contracted. To find out about positive emotions the activation of the *zygomaticus major* muscle, which is activated while laughing, is recorded. Simultaneously, negative emotions are measured by the *currogator supercilii* muscle, which is activated while frowning. EMG was used in a lot of studies to access the valence of emotions [16, 14, 9, 3]. On the one hand, EMG is more accurate than facial expression recognition with video analysis, because low evocative emotions are difficult to recognize visually. On the other hand, sensors with cables are attached in the face, which is obtrusive for participants.

Electrodermal activity (EDA) measures the activity of the eccrine sweat glands and is said to be a linear correlate to arousal [4]. Although room temperature, humidity, participants activities and the correct attachment of the electrodes has to be carefully considered, tonic EDA is a well researched and valid method to record arousal and was used for measuring emotions for interaction with systems [21, 16].

The cardiovascular system offers several measuring options to determine valence or arousal: Blood Volume Pressure (BVP) indicates a correlation between greater dilation in the blood vessels with less arousal [21]. The heart rate (HR) is correlated with arousal as well and variability of the heart rate (HRV) is used as a metric for assessing the positive or negative valence of an experience [1]. HRV is also used as a measure for mental workload. Nevertheless, measuring HR can raise privacy and intimacy issues, as traditional electrocardiography requires the attachment of electrodes in the chest area.

The magnitude of pupillary dilation appears to be a correlation to arousal and mental workload. Pupillometry is hard to apply in a practical context, because the eye reacts to different light conditions which are almost impossible to anticipate and difficult to calculate outside of controlled conditions.

Respiration can be used as measurement for negative valence and arousal [6]. More important, changes in respiration rate affect other psychophysiological metrics such as EDA or cardiovascular functions.

Measuring hand movement and pressure can be used to detect emotions as well. A keyboard [15, 20] or gamepad [19] that is sensitive in pressure can be utilized to measure certain aspects of emotional behaviour. This method is perfect for normal desktop applications because it is non-invasive.

It's important to mention that most methods should not be applied unimodal, which means applying only one method. A multimodal approach is more accurate and results in a broader spectrum of emotions, but has the disadvantage that multiple channels have to be combined, analysed and finally interpreted. Every method has its strengths and weaknesses, also strongly depending on the evaluation context.

All these described methods seem to have great potential to be used in UX research, but the question remains whether they can be used in praxis. With the following report we try to shed some light on the world of psychophysiology for UX research.

AN EXPERIENCE REPORT

Implementing psychophysiological methods has to be done very carefully and with great care due to the many variables that can alter the result. Temperature, humidity, attachment of electrodes, individual differences, differences concerning gender (women even differ depending on the menstrual cycle), age, time of the day, consumed stimulants such as coffee or energy drinks, medicaments, drugs, etc can cause different reactions in sensors and in people. Therefore the former consumption of stimulants from test participants has to be clarified. Care has to be taken for sensor attachment as well: the skin should be shaven if very hairy and not have stains of makeup and skin creme.

In order to access the practicability of such approaches we tried several methods, including EMG, EDA, Respiration, BVP and HR using the ProComp Infiniti System from Thought Technology. Generally, it's a simple task to attach the electrodes and recording the signals. The difficulty lies more in the psychophysiological signal processing and finally interpreting the signals. After data acquisition trials and delving into signal processing, psychophysiological methods can become more coherent and clear to the researcher. Last but not least, not only the signals have to be interpreted but also why participants reacted the way they did in certain situations. That means reflecting on the technology and how people interact with it.

Our findings and examination of methods suggest that facial EMG is a viable and reliable method to measure positive or negative emotional states. Analysis of the signals clarifies explicitly when certain muscles are activated or not. Fortunately talking doesn't activate the muscle responsible for laughing. Other methods are demanding in signal processing and more accessible to movement artefacts, but will be further explored for UX research.

Generally it's more accurate to implement methods in parallel for either valence or arousal, to be able to correlate two methods with each other for more valid results. From our point of view, psychophysiological methods should be supplemented by subjective reports. We used EmoCards, which represent eight faces distributed over the valence arousal space, asked participants about discrete emotions such as happiness and anger, and conducted qualitative interviews.

CONCLUSIONS

Based on our first hand experience we think that psychophysiological methods are very well applicable in gaming and entertainment industry, as during gameplay or watching a movie intense emotion and their dramaturgy are a crucial element. This fact makes it easier to analyse and interpret the emotional scope. Psychophysiological measurements of the user's emotions and experiences can help to finetune gameplay and plot composition in the process of product development. However, psychophysiological measuring techniques are not appropriate for all contexts and the decision of which methods to choose has to be adapted in accordance to the system or product that has to be evaluated. Most important of all is to consider the setting, the product and the context before choosing which psychophysiological methods to apply. Not every method is suitable for evaluation of a certain type of interactive system, as invasiveness, privacy and other aspects of psychophysiological methods should be taken under consideration.

Psychophysiological methods support the analysis of certain crucial situations of an experience that are essential to product development, but also provide summative analyses over time [10]. Subjective reports are prone to the fact that emotions are not always easy to put into concrete words and small but important details are sometimes forgotten.

A lot of studies aim at assigning discrete emotions from psychophysiological recordings. From our point of view emotions are so complex themselves and vary individually and culturally, so that it's vague to create discrete models. Moreover, discrete emotions are not clear to differentiate on a psychophysiological level, and an experience consists of more than one emotion. For those reasons we think that psychophysiological methods are inappropriate for measuring discrete emotions.

Sooner or later psychophysiology will hopefully work non-invasively (advanced video analysis, speech recognition and other refined future technologies) and hence offer great opportunities for UX evaluation. Though, also other areas of interest such as affective computing would benefit from such technical solutions as well. During an interaction with an affective system the emotional state of users could be determined and the system will react to it appropriately. This could help to enhance technology acceptance for human robot interaction, increase the UX or even a learning process with a system. An example for non-invasive measuring is Anttonen's EMFi chair (a chair equipped with electromagnetical film), where attachment of an electrode is reduced to the ear to record the heart rate [1]. Regarding product development, it's crucial to provide methods that don't restrict users in moving, feeling and interacting freely.

Common sense and results from UX research suggests that the interaction with products, tools, and artefacts can be enriched by allowing people to move naturally and unrestrictedly [18, 2]. If people express themselves with their whole body, they immerse into another world more naturally and easily. Because of those reasons we are planning further research on the relation between movement and emotions [12]. Psychophysiological methods are not ideally applicable for such contexts because movement of participants alters the signals such as increased heart rate and electrodermal activity. Furthermore, almost all electrodes and sensors are sensitive to movement. This makes it a very difficult task to implement psychophysiological methods in a movement context. Our findings suggest that facial EMG is a viable and reliable method to measure positive or negative emotional states, even when a participant is in movement. We are working on the implementation of other methods such as EDA as well, if possible to get viable results even for moving participants.

Psychophysiology in the field of UX is in its infancy and further research is necessary to meet future challenges. We think that EMG is ready to be implemented in certain areas such as the entertainment and gaming industry. At the moment we consider other psychophysiological methods as a valuable complement to qualitative and quantitative subjective reports and observational analyses, but further research has to be done to improve these methods and develop non-invasive technologies.

REFERENCES

1. Anttonen, J. & Surakka, V. (2005), Emotions and heart rate while sitting on a chair, *in* 'CHI '05: Proceedings of the SIGCHI conference on Human factors in computing systems', ACM, New York, NY, USA, pp. 491--499.
2. Berthouze, N. B. (2008), 'Body movement as a means to modulate engagement in computer games', .
3. Cacioppo, J. T.; Petty, R. E.; Losch, M. E. & Kim, H. S. (1986), 'Electromyographic activity over facial muscle regions can differentiate the valence and intensity of affective reactions.', *Journal of personality and social psychology* 50(2), 260--268.

4. Dawson, M. E. (2007), 'The Electrodermal System' in Cacioppo, J. T.; Tassinary, L. G. & Berntson, G., ed. (2007), *Handbook of Psychophysiology*, Cambridge University Press.
5. De Silva, L. (2004), 'Audiovisual emotion recognition', *Systems, Man and Cybernetics, 2004 IEEE International Conference on* 1, 649-654 vol.1.
6. Glowinski, D.; Camurri, A.; Volpe, G.; Dael, N. & Scherer, K. (2008), 'Technique for automatic emotion recognition by body gesture analysis', *Computer Vision and Pattern Recognition Workshops, 2008. CVPRW '08. IEEE Computer Society Conference on*, 1-6.
7. Gomez, P.; Stahel, W. A. & Danuser, B. (2004), 'Respiratory responses during affective picture viewing', *Biological Psychology* 67(3), 359 - 373.
8. Gunes, H. & Piccardi, M. (2006), 'A Bimodal Face and Body Gesture Database for Automatic Analysis of Human Nonverbal Affective Behavior', *Pattern Recognition, 2006. ICPR 2006. 18th International Conference on* 1, 1148-1153.
9. Hassenzahl, M. & Sandweg, N. (2004), From mental effort to perceived usability: transforming experiences into summary assessments, *in* 'CHI '04: CHI '04 extended abstracts on Human factors in computing systems', ACM, New York, NY, USA, pp. 1283--1286.
10. Hazlett, R. L. & Benedek, J. (2007), 'Measuring emotional valence to understand the user's experience of software', *Int. J. Hum.-Comput. Stud.* 65(4), 306--314.
11. Isbister, K.; Hццk, K.; Sharp, M. & Laaksolahti, J. (2006), The sensual evaluation instrument: developing an affective evaluation tool, *in* 'CHI '06: Proceedings of the SIGCHI conference on Human Factors in computing systems', ACM, New York, NY, USA, pp. 1163--1172.
12. Izard, C. E. (1993), 'Four systems for emotion activation: cognitive and noncognitive processes', *Psychological review* 100(1), 68-90.
13. Karapanos, E.; Hassenzahl, M. & Martens, J.-B. (2008), 'User experience over time', , 3561--3566.
14. Lv, H.-R.; Lin, Z.-L.; Yin, W.-J. & Dong, J. (2008), 'Emotion recognition based on pressure sensor keyboards', *Multimedia and Expo, 2008 IEEE International Conference on*, 1089-1092.
15. Mandryk, R. L.; Inkpen, K. M. & Calvert, T. W. (2006), 'Using psychophysiological techniques to measure user experience with entertainment technologies', *Behaviour & Information Technology* 25(2), 141-158.
16. McCarthy, J. & Wright, P. (2004), 'Technology as experience', *interactions* 11(5), 42--43.
17. Moen, J. (2007), From hand-held to body-worn: embodied experiences of the design and use of a wearable movement-based interaction concept, *in* 'TEI '07: Proceedings of the 1st international conference on Tangible and embedded interaction', ACM, New York, NY, USA, pp. 251--258.
18. Partala, T.; Surakka, V. & Vanhala, T. (2005), Person-independent estimation of emotional experiences from facial expressions, *in* 'IUI '05: Proceedings of the 10th international conference on Intelligent user interfaces', ACM, New York, NY, USA, pp. 246--248.
19. Sykes, J. & Brown, S. (2003), Affective gaming: measuring emotion through the gamepad, *in* 'CHI '03: CHI '03 extended abstracts on Human factors in computing systems', ACM, New York, NY, USA, pp. 732--733.
20. Tsihrintzis, G.; Virvou, M.; Alepis, E. & Stathopoulou, I.-O. (2008), 'Towards Improving Visual-Facial Emotion Recognition through Use of Complementary Keyboard-Stroke Pattern Information', *Information Technology: New Generations, 2008. ITNG 2008. Fifth International Conference on*, 32-37.
21. Ward, R. D. & Marsden, P. H. (2003), 'Physiological responses to different WEB page designs', *Int. J. Hum.-Comput. Stud.* 59(1-2), 199--212.