DEVELOPMENT OF PHYSIOLOGICAL SIGNAL BASED AFFECTIVE MARKERS FOR UX TESTING OF HCI PRODUCTS

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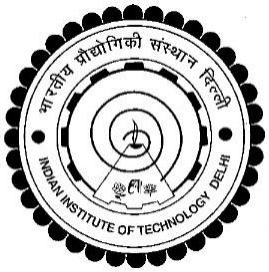

DEPARTMENT OF DESIGN

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Development of Physiological Signal Based Affective Markers for UX Testing of HCI products

by

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DEPARTMENT OF DESIGN

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Dedicated to my beloved mother 

CERTIFICATE

This is to certify that the thesis titled, "**Development of Physiological Signal Based Affective Markers for UX Testing of HCI products**", being submitted by **Mr. Jyotish Kumar** to the Indian Institute of Technology Delhi for the award of the degree of **Doctor of Philosophy** has been carried out under my supervision.

The research work contained in this thesis has not been submitted in part or full to any other university or institute for the award of any degree or diploma.

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Date: Mr. Jyotish Kumar

ABSTRACT

Advances in technology and rise in use of the internet has expedited growth of Human Computer Interaction (HCI) as a discipline. Many HCI products are now being used in different types of domains for different kinds of purposes on different kinds of technological platforms. From a business perspective, User Experience (UX) in HCI products has become an important factor in the success of the HCI products. Usability tests and User experience tests are two formal methods of tests used at various stages of designing HCI products. While usability tests capture ease of use, efficiency and effectiveness (ISO, 2000), UX tests have been used in a broader sense of measuring affective engagements that users undergo while interacting with HCI products. While usability tests attempt to measure the cognitive aspects of HCI, UX tests include measures of affective responses of users as well. The affective responses elicited by the human in human computer interaction, particularly plays a greater role in HCI systems where decisions have to be made. As more and more online HCI systems are facilitating decisions, hence, there has been an increased focus on the UX testing methods of late.

Behavioral observations and self-reported measures have been used in the past for both usability tests and UX tests. The behavioral observations and self-reported measures have their limitations; hence this research has investigated the possible use of physiological measures in UX testing. Physiological measurement tools like Electroencephalography (EEG), Eye Tracker (ET) and Galvanic Skin Response (GSR) are more easily available now, have better technology for increased accuracy, have become easier to use and have become increasingly more economically affordable. On the other hand, the cost of poor UX has drastically increased and hence measurement of UX in HCI systems have become more important in HCI design process. This thesis looks at the context of easy availability of physiological measurement tools and increased value of UX testing as an opportunity to argue for the use of physiological tools in UX testing and hence has explored the usefulness of these physiological tools namely EEG, Eye Tracker and GSR in the UX testing process.

Total of seven experiments have been conducted to ascertain the feasibility of different aspects of UX testing using physiological tools. The overall purpose of conducting seven experiments was

to understand the various features of data obtained from the three physiological tools, namely, EEG, GSR and eye tracker, which can be used to understand the affective states of users during UX testing. First three experiments were conducted to extract the physiological features of EEG and GSR for measurement of human emotions. Next two experiments were conducted to identify eye tracker and GSR features useful for UX testing. The sixth experiment was conducted to develop a combined measure of all the three physiological tools together for a UX testing context. The seventh experiment was conducted with HCI designers to ascertain the usefulness of the UX markers in an HCI design context.

It was found that physiological markers can dig deeper into users' affective states and provide better UX testing data than observation-based data. Further, it was also found that such physiological markers are more useful in UX testing setup. This thesis, in light of the observations, therefore recommends the use of physiological markers as developed and tested in this thesis for use during the UX testing for a better understanding of the emotional response of the users which often do not surface out during the behavioural observations or self-reported felt emotions during UX testing.

सार

प्रौद्योगिकी में प्रगति और इंटरनेट के उपयोग में वृद्धि ने एक विषय के रूप में मानव कंप्यूटर इंटरेक्शन (एचसीआई) के विकास में तेजी लाई है। कई एचसीआई उत्पाद अब विभिन्न प्रकार के डोमेन में विभिन्न प्रकार के तकनीकी प्लेटफॉर्म पर विभिन्न प्रकार के उद्देश्यों के लिए उपयोग किए जा रहे हैं। व्यावसायिक दृष्टिकोण से, एचसीआई उत्पादों में उपयोगकर्ता अनुभव (यूएक्स) एचसीआई उत्पादों की सफलता का एक महत्वपूर्ण कारक बन गया है। उपयोगिता परीक्षण और उपयोगकर्ता अनुभव परीक्षण, एचसीआई उत्पादों के परीक्षण के दो औपचारिक तरीके हैं जिनका उपयोग एचसीआई उत्पादों को डिजाइन करने के विभिन्न चरणों में किया जाता है। जहाँ प्रयोज्य परीक्षण उपयोग, दक्षता और प्रभावशीलता में आसानी को मापते हैं (आईएसओ, 2000), वहीं यूएक्स परीक्षणों का उपयोग एचसीआई उत्पादों के उपयोग करते समय उपयोगकर्ताओं को प्रभावित करने वाले जुड़ाव को मापने के व्यापक अर्थ में किया जाता है। जहाँ प्रयोज्य परीक्षण एचसीआई के संज्ञानात्मक पहलुओं को मापने का प्रयास करते हैं, वहीँ यूएक्स परीक्षणों में उपयोगकर्ताओं के भावनात्मक प्रतिक्रियाओं के मापने के उपाय भी शामिल हैं। मानव कंप्यूटर इंटरैक्शन में मानव द्वारा प्राप्त दी गई भावनात्मक प्रतिक्रियाएं, एचसीआई सिस्टम में एक बड़ी भूमिका निभाती हैं विशेष रूप से जहां निर्णय लेने होते हैं। चूंकि अधिक से अधिक ऑनलाइन एचसीआई सिस्टम निर्णय लेने में प्रभावित करते हैं, इसलिए, पिछले कुछ समय से यूएक्स परीक्षण विधियों पर अधिक ध्यान केंद्रित किया गया है।

व्यवहारिक अवलोकन और स्व-रिपोर्ट किए गए उपायों का उपयोग अतीत में प्रयोज्य परीक्षणों और यूएक्स परीक्षणों दोनों के लिए किया गया है। व्यवहार संबंधी टिप्पणियों और स्व-रिपोर्ट किए गए उपायों की अपनी सीमाएं हैं; इसलिए इस शोध ने यूएक्स परीक्षण में शारीरिक उपकरणों के संभावित उपयोग की जांच की है। इलेक्ट्रोएन्सेफलोग्राफी (ईईजी), आई ट्रैकर (ईटी) और गैल्वेनिक स्किन रिस्पांस (जीएसआर) जैसे शारीरिक माप उपकरण अब अधिक आसानी से उपलब्ध हैं, बढ़ी हुई सटीकता के लिए बेहतर तकनीक है, उपयोग करना आसान हो गया है और आर्थिक रूप से अधिक किफायती हो गए हैं। दूसरी ओर, खराब यूएक्स के कारन लागत में भारी वृद्धि हुई है और इसलिए एचसीआई सिस्टम में यूएक्स का मापन एचसीआई डिजाइन प्रक्रिया में अधिक महत्वपूर्ण हो गया है। यह थीसिस शारीरिक माप उपकरणों की आसान उपलब्धता और यूएक्स परीक्षण के बढ़े हुए मूल्य के संदर्भ में यूएक्स परीक्षण में शारीरिक उपकरणों के उपयोग के लिए बहस करने के अवसर के रूप में देखता है और इसलिए यूएक्स परीक्षण प्रक्रिया में इन शारीरिक उपकरणों जैसे ईईजी, आई ट्रैकर और जीएसआर की उपयोगिता का पता लगाया है।

शारीरिक उपकरणों का उपयोग करके यूएक्स परीक्षण के विभिन्न पहलुओं की व्यवहार्यता का पता लगाने के लिए कुल सात प्रयोग किए गए हैं। सात प्रयोग करने का समग्र उद्देश्य तीन शारीरिक उपकरणों, अर्थात्

ईईजी, जीएसआर और आई ट्रैकर से प्राप्त डेटा की विभिन्न विशेषताओं को समझना था, जिनका उपयोग यूएक्स परीक्षण के दौरान उपयोगकर्ताओं की भावनात्मक स्थिति को समझने के लिए किया जा सकता है। मानवीय भावनाओं के मापन के लिए ईईजी और जीएसआर की शारीरिक फीचर्स को निकालने के लिए पहले तीन प्रयोग किए गए। यूएक्स परीक्षण के लिए उपयोगी आई ट्रैकर और जीएसआर फीचर्स की पहचान के लिए अगले दो प्रयोग किए गए। छठा प्रयोग यूएक्स परीक्षण संदर्भ के लिए सभी तीन शारीरिक उपकरणों का एक संयुक्त माप द्वारा यूएक्स मार्करों को विकसित करने के लिए आयोजित किया गया। एचसीआई डिजाइन के संदर्भ में यूएक्स मार्करों की उपयोगिता का पता लगाने के लिए एचसीआई डिजाइनरों के साथ सातवां प्रयोग किया गया।

यह पाया गया कि शारीरिक यूएक्स मार्कर उपयोगकर्ताओं के भावनात्मक पहलुओं की गहराई से अध्ययन कर सकते हैं और अवलोकन-आधारित डेटा की तुलना में बेहतर यूएक्स परीक्षण डेटा प्रदान कर सकते हैं। इसके अलावा, यह भी पाया गया कि ऐसे शारीरिक मार्कर यूएक्स परीक्षण सेटअप में अधिक उपयोगी होते हैं। टिप्पणियों के आलोक में, यह थीसिस, उपयोगकर्ताओं की भावनात्मक प्रतिक्रिया की बेहतर समझ के लिए यूएक्स परीक्षण के दौरान इस थीसिस में विकसित और परीक्षण किए गए शारीरिक मार्करों के उपयोग की सिफारिश करता है जो अक्सर व्यवहार संबंधी टिप्पणियों या यूएक्स परीक्षण के दौरान स्वयं-रिपोर्ट की गई भावनाओं के दौरान सामने नहीं आते हैं।

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBRIVIATIONS AND TERMINOLOGIES

HCI	Human Computer Interaction. A multidisciplinary field that studies how humans interact with computers.
UX	User Experience. The overall experience felt by users while using a product.
UCD	User Centered Design. A design methodology which keeps users in focus while designing a product.
EEG	Electroencephalography. A method to measure electrical activity of brain functions over time which is often used to assess cognitive and affective state of human.
GSR	Galvanic Skin Response. Method to measure change in skin conductivity which gives direct assessment of arousal.
SCL	Skin Conductance Level. Slow varying galvanic skin conductance response which gives measure of arousal level.
SCR	Skin Conductance Response. Fast varying galvanic skin conductance response which measures event related arousal.
SUS	System Usability Scale. A widely used questionnaire based usability testing method for HCI products.
ANN	Artificial Neural Network. A machine learning classification model inspired from working of human brain which is widely used to classify human emotions through physiological features.

KNN	K-Nearest Neighbor. A distance based machine learning classification model which is widely used to classify human emotions through physiological features.
UI	User Interface. The means by which the user and a computer system interact, in particular the use of input devices and software.
FFT	Fourier Fast Transform. A method to transform time domain signals into frequency domain signals.
PSD	Power Spectral Density. It shows the strength of the variations (energy /power) as a function of frequency. The unit of PSD is energy per frequency.
ICA	Independent Component Analysis. Method to identify source of a signal.
PCA	Principal Component Analysis. A technique used to emphasize variation and bring out strong patterns in a dataset.
Entropy	The degree of randomness present in any system. Inspired from the concept of thermodynamics, calculation of entropy is also used for brain and other bio-signals which gives information about cognitive and affective states of users.
Eye Fixation	Momentary pauses of user's eye movements while using the HCI products. I gives direct assessment of visual attention.
Saccades	Ballistic Movement of the user's eye between two fixations.
Physiological feature for emotion	A characteristic of physiological signal which contains information about a given emotion and should be capable to map that particular emotion.
Physiological marker	Change in behavior of the physiological feature associated with a given emotion which can be used to map affective states of users