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A REVIEW ON PSYCHOPHYSIOLOGICAL MEASURES OF HUMAN COGNITIVE STATES APPLIED IN HUMAN COMPUTER INTERACTION

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ABSTRACT

This article examines psychophysiological measurements used in Human Computer Interaction (HCI), with a particular emphasis on research involving human cognitive states. Psychophysiological measurements, despite their drawbacks, provide a potential method of user understanding in fields such as HCI that seek a "sixth sense" for user psychological shifts. First, we'll go through the relevant research and the most common cognitive state assessments. The basics of psychophysiological measurements are next examined in more depth. In the form of a table, we offer comprehensive information on their diagnostic ability and sensitivity to human cognitive processes. Finally, the article examines the most recent applications and suggests future possibilities.

KEYWORDS: *Psychophysiology, Cognitive, Evaluation, Review, Adaptive Interfaces, Mental Workload, Affective, Brain-Computer Interfaces.*

1. INTRODUCTION

Humans are surrounded by various computing systems such as computers, numerous interactive gadgets, and embedded computing technologies in this age of ubiquitous computing. Aside from the many benefits, such a life poses additional challenges for people. This may be due to the fact that conventional design methods no longer satisfy the needs of contemporary information-hungry gadgets, and controlling information sent via these devices has become more difficult [1]. Thankfully, humans have sophisticated cognitive skills that allow us to deal with these issues. However, in practice, these skills function poorly, thus they must be properly exploited and even encouraged if at all feasible.

Human Computer Interaction (HCI) researchers concentrate on creating computer systems that are:

1) More useable in order to alleviate these issues (cause lower mental workload and stress),
2) Acceptable (provide a pleasant user experience) and
3) Adaptable (acts in accordance with the requirements and circumstances of the user).

However, attaining these goals requires a comprehensive and multidimensional knowledge of the user. Psychophysiological measurements, despite their limits and flaws, have the ability to satisfy such a user comprehension, according to research [2].Psychophysiological measurements are an unobtrusive and implicit method of determining a user's emotional or cognitive state based on

mind-body relationships. They are, in fact, physical signals produced by the human body in reaction to psychological changes and recorded in real time by specific equipment. Electroencephalogram (EEG), Heart Rate Variability (HRV), and Electro Dermal Activity are some of the psychophysiological measurements used in the literature (EDA).

2. LITERATURE REVIEW

B. Cowley presented that simple cognitive states like arousal, attention, and mental strain may be detected using the psychophysiological approach. When cognition serves a useful function, such as in knowledge work, and is linked to human-computer interaction, this method may be very intriguing (HCI). Acts of synchronized high-level cognition, on the other hand, are more useful for practical reasons [3]. Decision-making, problem-solving, and executive control of cognition and behavior are all common examples of high-level (or higher-order) cognition (HLC). In addition, measuring someone's performance on a recognized task is an easy way to determine whether they are engaged in HLC. As a result, it's acceptable to describe high-performance cognition (HPC) as HLC with some performance constraint, such as real-time pressure or expert skill level. Such states are equally intriguing for HCI at work, and detecting them using the psychophysiological technique is a lofty goal. A survey of the literature on the subject is presented in this paper[1].

E. van Konijnenburg et al. discussed STEM education is presently receiving a lot of attention as a way to inspire young people in the United States to pursue careers in science, technology, engineering, and math. Gifted kids are a natural source of future innovators for various areas, yet gifted programs are often neglected when it comes to program funding. Since 1973, the Virginia Department of Education has supported the Virginia Governor's Schools, a unique model of regional magnet schools for exceptional and talented children. Often in the STEM disciplines, these institutions provide accelerated and customized curriculum. The researcher looked at the assessment reports of five STEM-focused Virginia Governor's Schools since evaluation is an important part of obtaining additional financing to fulfill the scientific and technical needs of these programs [4]. The goal of the research was to gather evidence on the effectiveness of an untested rubric instrument used in the assessments. A descriptive analysis of the instrument's criterion ratings was performed, as well as a content analysis of assessment reports and a theme analysis of eight evaluator interviews. The five Governor's Schools all met (n= 80.0 percent) or surpassed (n= 13.87 percent) assessment measure requirements, and they all had comparable strengths and areas of need for development. The claim that the instrument targets gifted students as autonomous learners, teachers as educational innovators, and develops STEM-capable citizens via scientific research and civic service was validated by triangulated data. The data gathered throughout the research was meant to help assessment designers determine the effectiveness of rubrics and provide suggestions for future changes[2].

3. PSYCHOPHYSIOLOGICAL MEASURES AND COGNITIVE STATE ASSESSMENT

The basics of psychophysiological measurements and cognitive state evaluation are covered in this section. We begin by briefly describing various techniques for assessing cognitive status in the literature, followed by a discussion of the foundations of psychophysiological measurements, including definitions, benefits, drawbacks, and application recommendations. Performance measures, subjective measures, and psychophysiological measures are the three kinds of measurements utilized in cognitive state evaluation [5].In the literature, these measures are often associated with cognitive load or mental strain evaluation. Although they may be used in the same sense, their meanings may vary depending on the point of view. In cognitive load theory, for example, cognitive load is a notion related with working memory. Mental workload, on the other hand, is a more complicated and multifaceted term that lacks a universal definition. It is linked to both task needs and the user's skills, motivation, and condition. The word "cognitive state" is used

in this article to refer to the state of human cognitive processes and resources such perception, attention, cognitive effort, engagement, working memory, arousal, stress, and exhaustion.

3.1. Performance Measures:

Users' overt performance, such as error ratio and job completion time, is used to calculate performance. There are two kinds of measurements: primary-task measures and secondary-task measures [6]. These tests offer an objective and real-time evaluation of the user's cognitive status. They are, however, one-dimensional and should be tailored to the job. Although secondary-task measurements are frequently employed, they may be invasive and unpopular with users.

3.2. Subjective Measures (Rating Scales):

Subjective measurements are based on how a user perceives a task. They are directly affected by user factors such as responding style, social desirability, questionnaire interpretations, and memory limitations. Because they are typically captured after the action, they cannot be used in real time. One-dimensional or multi-dimensional subjective measurements are possible.

3.3. Psychophysiological Measures:

Physiological reactions of the human body to psychological interventions are known as psychophysiological measurements. These reactions are, in fact, physical signals that may be used to assess a person's psychological processes by observing their physiological changes. Thus, psychophysiological measurements offer a novel method of understanding users for research and practice fields like Human Computer Interaction that seek a "sixth sense" for users' (or operators') psychological state (affective or cognitive) (HCI).Psychophysiological tests are classified by the neurological system that controls them. The Central Nervous System (CNS) and the Peripheral Nervous System (PNS) are the two components of the human nervous system [7]. The brain, brain stem, and spinal cord make up the central nervous system. Electroencephalography (EEG), Event Related Brain Potentials (ERP), and Electrooculography are the most common CNS tests (EOG). The peripheral nervous system, on the other hand, includes all of the human nervous system's remaining components. Somatic and autonomic subsystems make up this system. While the somatic nervous system is in charge of voluntary muscle activation, the autonomic nervous system (ANS) is in charge of regulating involuntary muscles and internal organs. Heart Rate (HR), Heart Rate Variability (HRV), Pupil Dilation, Eye Movements, Galvanic Skin Response (Skin Conductance) and Electromyogram are the most used ANS measurements (EMG). Sympathetic (SNS) and parasympathetic nervous systems are two components of the autonomic nervous system (PNS). SNS is in charge of mobilizing the body in case of an emergency, whereas PNS is in charge of maintaining bodily resources.

4. DISCUSSION

Psychophysiological measurements have been used in a variety of HCI applications.

1) Evaluation applications,
2) Adaptive interface applications, and
3) Evaluation applications,

The use of psychophysiological measurements as direct input methods has been a significant focus of Brain-Computer Interfaces, particularly for physically handicapped individuals (BCIs). Much of the work in BCIs was done to help people with neuromuscular diseases live better lives. This scenario has lately begun to alter. The concept of directing computers with thought, as well as its potential applications for healthy humans, seems to be a promising field of future study.

Psychophysiological measurements are, in fact, hidden interaction channels that reveal a lot about the user's internal processes. Utilized this information in their fascinating research to propose a

"psychophysiological authentication" technique that allows users' identities to be verified constantly without interrupting them. They suggest that the amount of pressure given to a computer mouse be used as an authentication method. The initial authentication is authorized, as is customary, using one of the traditional authentication procedures (passwords or biometrics). Following that, users' identities were constantly confirmed using mouse pressure patterns. Only if abnormalities in these patterns are identified, are users prompted to input their password.

There are two kinds of psychophysiological measure assessment applications: usability evaluation and user experience evaluation. In-depth usability evaluation applications in the literature include mental workload assessment research. In addition, there are studies that look at the relationship between conventional usability indicators and psychophysiological measurements. On the other side, user experience assessment focuses on the emotional elements of user interfaces [8].Psychophysiological measurements have a wide range of applications in adaptive systems, including interruptibility estimates and notification regulation, adaptive avatars, adaptive learning systems, and so on. Notifications or interruptions that aren't scheduled correctly create tension, anxiety, and a loss of performance. As a result, they must be controlled in accordance with the user's communication availability or interruptibility. To control notifications, a mobile phone uses HRV (to measure mental strain) and EEG (to detect physical activity). Users may choose among four cognitive states and configure their cell phone, instant messenger, and email software appropriately.

Psychophysiological measurements may also be used in particular areas of HCI, such as game research and human-robot interaction. Game study focuses on a game's user experience or attempts to adjust the game to the user's shifting emotional or cognitive state. Human-robot interaction, on the other hand, aims to comprehend people' interactions with robots (their experiences and responses) or to provide various services tailored to human psychological states. Psychophysiology studies human mind-body relationships and offers a wealth of information on the physiological underpinnings of psychological processes. The majority of this literature's results have yet to be applied to Human Computer Interaction (HCI). We believe that evaluating these results from an HCI perspective and determining how to use them in HCI are both difficult and interesting research topics. Furthermore, there are many psychophysiological measurements in the literature. Another future research will look at their applicability for other HCI issues.

Unfortunately, psychophysiological measurements and human psychological processes do not have a one-to-one relationship. Each metric has the potential to reflect a variety of psychological processes, benefits, and drawbacks. Most of the time, psychophysiological measures must be coupled for accurate assessments and effective applications. This is especially essential in real-world scenarios. As a result, future research may focus on finding suitable measure combinations, solving implementation issues, and creating novel interaction techniques based on these combinations. The number of HCI applications that use psychophysiological measurements is constantly changing. They've been getting a lot of interest from particular areas of HCI including mobile interaction, gaming research, human robot interaction, and ambient intelligence, in addition to usability and user experience assessment. Naturally, each area has its own set of issues and offers future research focused on these issues. Psychophysiological measurements may be used to better understand the features of an issue, improve a product or software, and offer adaptive solutions in these areas [9].

4.1. Advantages:

Psychophysiological tests offer significant benefits. Objectivity, multidimensionality, unobtrusiveness, implicitness, continuity, and responsiveness are some of these qualities.

- Objectivity: Objectivity allows you to make evaluations that aren't influenced by the user's perspective. Objectivity is an essential characteristic that improves the measuring technique's dependability.
- Multidimensionality: Multidimensional measurements may show various aspects of a user's condition.
- Inconspicuousness: While psychophysiological measurements need the insertion of electrodes on the body, they do not interfere with user tasks in the same way as "secondary task measures" do. As a result, they are seen as non-obtrusive measures.
- Implicitness: Psychophysiological measurements do not need the assessment of overt performance since they compare the "main task measures." They implicitly give the required information (covertly).
- Responsiveness and Continuity: Because psychophysiological measurements are continuous signals, they may be utilized in real-time. They enable scientists to study both short-term (phasic) and long-term (tonic) physiological responses. As a result, it is feasible to see psychophysiological changes that occur in reaction to user manipulations.

4.2. Disadvantages:

Psychophysiological tests have a number of drawbacks. We divide them into three categories: specific equipment drawbacks, data quality and interpretation drawbacks, and unnaturalness drawbacks.

- Special Equipment Drawbacks: Psychophysiological signals are measured using specialized equipment, which may be expensive depending on the capabilities of the system bought. Furthermore, several electrodes connected to the body are utilized in these assessments. It's critical to choose the right ones and put them in the right places if you want to get data that's free of noise. As a result, staff training and equipment maintenance should receive adequate attention and time.
- Data Acquisition and Interpretation: Psychophysiological measurements are mainly faint electrical signals that may be easily influenced by noise. As a result, appropriate filtering methods should be chosen and applied to data. Aside from that, complicating variables such as ambient lightning (pupil dilation), power grid (ERP), and body mobility affect a number of them (ECG). These variables must not be overlooked; else, inaccurate results will occur. Another issue that researchers and engineers face is data interpretation. As a result, psychophysiological measurements generate a huge quantity of difficult-to-understand data [10].
- Unnaturalness Disadvantages: The surroundings is sufficiently artificial and unnatural, especially in labs. With recent technological advancements, portable and wireless solutions for certain measurements such as EEG, GRS, and HR are now available. If not, electrodes are connected to the user through wires, restricting their motions and breaking the naturalness of the connection.

5. CONCLUSION

This article provides an overview of psychophysiological measurements used in Human-Computer Interaction for assessing cognitive status (HCI). User experience assessment and adaptive user interfaces are examples of modern HCI applications that need unobtrusive, implicit, and real-time techniques that offer multidimensional information on the user's emotive or cognitive state. Psychophysiological measurements have the ability to fulfill these criteria, according to many research. They have the ability to portray many aspects of human psychological processes at

various levels. Psychophysiological measurements, on the other hand, must be properly applied. Data collection and interpretation issues, in particular, prohibit them from being used in real-world settings. We believe that, although these issues will not go away entirely, they will be eased with time, and psychophysiological measurements will become simpler to study and use.

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