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Keio University

Thesis Abstract

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Thesis Title

Cognitive State Assessments through Monitoring Physiological Signals on the Face.

Thesis Summary

This dissertation is comprised of 7 chapters, divided into a number of sections and subsections. The two last chapters contain the bibliography and the appendices, thus will not be introduced in detail. The thesis is structured reflecting the layered character of this research. After motivating the work, we specify the contributions in the field of context-aware computing. Subsequently, we detail the theoretical foundations that form the basis for the conducted research and help to locate this work into the domain. We then explain the conducted studies that laid the groundwork for and resulted in the prototype development and application case scenarios presented in Part III. In this chapter we detail the development of a prototypical feedback loop and describe an application case for alertness tracking in everyday settings to validate our approach. Chapter 7.3.1 gives an outlook on a currently tested system that is grounded in the all the works presented earlier. It describes a first attempt for a holistic cognition-aware system integrated into a responsive feedback-loop to support learners and teachers. The final part will conclude the thesis by summarizing the overall research contribution and discussing limitations and future works.

Part I: Introduction and Background

Chapter 1 - Introduction

The first chapter introduces the context within
which the work is located, and motivates the author’s vision for cognition-aware
systems. Throughout the sections of this chapter, the RQs building
the scaffold of this research are stated, challenges the author faced throughout the work, and the contributions to the field of ubicomp are described.

Chapter 2 - Foundations

The second chapter lays the theoretical groundwork for the conducted studies and applied methodologies, and gives an
overview of relevant related works and key concepts of cognitive psychology
and physiological computing that constitute preconditions for the presented

work.

Part II: Physiological Sensing

Chapter 3 - Eye Blink

Eye blink has been shown to be directly related to cognitive functions, such as sustained attention. On this account, chapter 3 establishes the foundation for how eye blink can be sensed and in which way it can be influenced. We present a lab study which investigated the impact of frame rates human eye blink, because content delivery systems, such as computer displays are constantly gaining importance in educational domains.

Chapter 4 - Facial Thermography

In this chapter we concentrate on a study that examined facial regions for their thermal characteristics under different levels of cognitive engagement. We identify a set of regions qualified for measuring temperature pattern changes that allow for inferring cognitive demand levels.

Part III: Implementation

Chapter 5 - Eye Blink in Feedback Loops

Attention is crucial for effective knowledge acquisition. Sustained attention enables us to focus on a task for a prolonged period of time. In order to non-invasively alter eye blink features related to sustained attention, we developed an application that uses eye blink frequencies as input modalities. This chapter contains the detailed description of this prototypical responsive feedback loop that enables display setting changes (Frame rate (FR)) in response to varying blink frequencies.

Chapter 6 - Alertness Assessment In-The-Wild

As our alertness levels fluctuate throughout the day, our cognitive performance also underlies constant variations. We therefore, investigated ways to infer changes in alertness in everyday settings through an in-the-wild study. Chapter 6 presents

the results and introduced a model for continuously eliciting alertness levels through eye blink frequency measurements obtained with off-the-shelf hardware.

Part IV: Conclusion and Future Work

Chapter 7: Conclusion and Future Work This chapter summarizes the results of the presented work with regard to the RQs stated in the beginning and affirms the contributions made throughout this work. The thesis is concluded by indicating future works and discussing limitations and implications for cognition-aware systems.
Section 7.3.1 - Outlook Based on the theoretical foundations and presented results, section 7.3.1 gives an insight into future works, such as a project that introduces a new prototype based on the major findings and models presented in this body of work. The suggested system contains of a device that contains IR sensors for continuous temperature readings on the face, and EOG sensors for inferring eye movement features.

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Living in a knowledge society, we are facing an abundance of new information every day. Technology pervasively surrounds us and enables the virtually uninterrupted information retrieval and distribution, resulting in a constant communication between people and computers. One of the key functions of a computer is to support its user and react to input with the response expected or desired by the users, creating an understanding of context. By using explicit and implicit input modalities we can increase the information density and allow computers to better interpret the user's context, making them context-aware. Recent developments in cognitive psychology and computer science have extended the context-awareness of computers by a cognitive layer, i.e. systems can infer user states of changing cognitive performance measures. Even though, most of the research focuses on constrained settings and utilizes cumbersome, often stationary machinery, recent developments in the ubiquitous and wearable computing domain have presented us with the potential for less invasive, mobile solutions. The research presented in this dissertation investigates the development of unobtrusive sensing solutions, that allow for uninterrupted sensing in laboratory and everyday life settings. We present a series of studies based on psychophysical principles utilizing off-the-shelf hardware for measuring eye motion features and changing facial temperature. These measurements allow

us to infer variations in states of alertness, fatigue, and cognitive workload. We introduce three research probes that investigate the feasibility of consumer-grade sensing solutions and correlate changes in physiological signals with cognitive state variations. Furthermore, we present a prototypical feedback loop that utilizes blink frequency variations as an input modality, and give an outlook on a sensing device that combines infrared and electrooculography sensors in regular frames. The concepts, results, and tools detailed in this thesis enable researchers, product and application designers, and potentially teachers and students to gain insights into the capacities of context-aware systems, here in particular cognition-aware systems. Awareness of fluctuating levels of cognitive performance measures will support better management of tasks, allow for the development of new adaptable user interfaces informed by cognitive states, and will eventually support maintaining short- and long-term health of users by better in-situ matching of task-load and available cognitive resources.