Dynamic Online Computerized Neuropsychological Testing System

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Abstract
Traditional cognitive testing for detecting cognitive impairment (CI) can be inaccessible, expensive, and time consuming. This dissertation aims to develop an automated online computerized neuropsychological testing system for rapidly tracking an individual's cognitive performance throughout the user's daily or weekly schedule in an unobtrusive way. By utilizing embedded microsensors within tablet devices, the proposed context-aware system will capture ambient and behavioral data pertinent to the real-world contexts and times of testing to compliment psychometric results, by providing insight into the contextual factors relevant to the user's testing efficacy and performance.

Author Keywords
Assistive technology; mobile sensors; context-aware; cognitive test; older persons.

ACM Classification Keywords
H.5.2. Information Interfaces and Presentation (e.g., HCI): User Interface; K.4.2 [Computers and Society]: Social Issues.

Introduction
The 21st century will continue to see huge demographic movements and cultural shifts caused by the aging world population. This age gap lends itself to health

service disparities, such as a possible increase in health issues related to aging, including cognitive impairment (CI). Computerized neuropsychological tests (CNTs) offer many new avenues for early detection and treatment of CI. The emergence of smart and wearable technology [1] has given both technical and non-technical professionals new tools for exploring novel cognitive testing strategies, including self-administered CNTs. With self-administered CNTs, however, comes the possibility of missing important contextual and behavioral information of the user, such as displays of emotion and perceived user engagement [2]. Therefore, there is a need for understanding the role context has on the user's testing efficacy and performance. With embedded ambient sensors and carefully designed accessible user interfaces, mobile devices offer an undeniable plausibility for real-world, context-aware systems, as defined by Dey and Abowd [3].

Related Work

Canini et al. [4] investigated the relationship of age and different testing interface modalities with user efficacy and ecological validity. They set out to test the efficacy of CNTs for attention and memory with respect to two different interface (visual vs. verbal) and input (keyboard vs. touch) modalities. They concluded that both input and interface modalities are feasible and valid options for neuropsychological testing. However, the fact that the authors solely used healthy participants, excluding those with CI and low cognitive performance scores, warrants further investigation into the accessibility and efficacy issues faced by a broader range of older adults.

Advances in microsensors and embedded chips has opened the door for intelligent forms of sensing and computation. In 2010, Ganti et al. utilized Nokia smartphones to assess daily living patterns of users via microphones, accelerometers, GPS, and GSM [5]. They show the feasibility of using micro sensors on consumer smartphones for context identification. They also point out the potential use of such technology for medical monitoring of older adults.

Thesis Proposal

The ability for smart devices to make use of machine learning algorithms to learn individual user behaviors and interaction patterns allows for the development of adaptable CNT interfaces. I argue that modern tablet devices with embedded ambient sensors can enhance CNT administration by providing richer data that is contextually pertinent to the user's performance and testing efficacy. It is with this argument that I propose to develop a context-aware online CNT system.

The primary research questions for the project are:

RQ1: What role do contextual factors (i.e., environmental sound, location, time-of-day) have on user testing efficacy and performance? How can tablet devices be used to accurately detect such factors during testing?

RQ2: What is the interplay of interaction modality and user testing efficacy and performance during CNTs? How can automated CNTs accurately assess and display temporal variations in a user's testing efficacy and performance?

With these research questions in mind, I intend to:

RO1: Develop an accessible, dynamic, online CNT system capable of capturing contextual data during testing and tracking temporal variations in the user's test performance.

RO2: Develop an information fusion system capable of capturing and analyzing ambient data during testing.

Pilot Work

My colleague and I researched the feasibility of using web-based brain-training software to help stroke survivors [6]. The work consisted of observing and interviewing stroke survivors at Cabrillo College Stroke and Disability Learning Center (CCSDLC) to get a better understanding of the technologies that they felt were helpful, as well as examining the effectiveness and limitations of such technologies. The result was an improved set of guidelines for software that aims to improve the cognitive skills of stroke survivors and individuals with CI.

In the summer of 2014, I worked as an accessibility research intern at IBM Research – Tokyo. I aided in the design and development of a smartphone-based indoor navigation system for blind individuals. As a result, we learned effective sampling strategies given the characteristics of the sensors that aided in indoor localization and postulated its use for more context-aware applications.

User Study

For this project, I will conduct a user study with healthy aging older adults age 60 or older and older individuals with some form of CI. A sample of 15 healthy aging older adults will be aggregated from the residential participant pool. Additionally, 15 older individuals with CI will be pooled through Kindred Santa Cruz, a nursing and transitional care center, and CCSDLC. These individuals will be screened by cognitive status (MMSE scores), age, and education level. Participants will be required to have a tablet device with embedded sensors, i.e., microphone and GPS. If the user does not have access to a tablet device, one will be provided on a temporary basis to the user. Training and usage tutorial sessions on the device and system capabilities and features will be administered to all users.

I will conduct a combination of individual interviews, focus groups and home visits. Observational results of user studies will further reveal insight into user needs and system design requirements. Following participatory design methodologies, I will develop a low- and high-fidelity prototype of the system based on user feedback. I will develop the prototypes through the web interface using HTML5 and will make use of the accumulated user data to adapt the system for specific use. The system will then be evaluated over the course of 1-2 weeks per user in natural setting.

Status of Research

I am recruiting users and developing the initial wireframe of the system. We are setting up user recruitment through CCSDLC and Kindred Santa Cruz. Our initial visits involved collecting observational information on activities and resources available to residents at the facilities, particularly older adults. Initial observational data and interviews with staff suggest that tablet devices pose as a viable activity solution for residents.

I have also been working on developing the system's foundational framework. Conceptual wireframes of the

system and interface have been designed and discussed with HCI researchers. Presently, PHP and Sencha Touch have been interactively explored as potential system framework solutions.

Challenges

One foreseeable challenge is the possibility of users who are completely unfamiliar with devices. To make sure all users are at the same level of competence with the device, training will be conducted with the users to get them familiar and ready to use the proposed system. It will also be important to maintain the user's attention and keep the user engaged throughout the assessment to elicit accurate and meaningful user responses. By using familiar graphics and interfaces (e.g., touching virtual playing cards), we can utilize a game-like interface to engage the user [7].

Expected Contributions

The technical and societal contributions of the proposed project include practical knowledge and applications that will aid in future accessibility and usability research techniques for intuitive web and mobile interface designs that can aid older adults. The emphasis on online and mobile applications will introduce important scientific concepts devised for human centered application design and implementation. Future work could incorporate wearable technology as well as improved intelligent features, such as affect detection and prediction of user performance.

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