Exploring Technological Opportunities for Cognitive Impairment Screening

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Abstract
In this paper, I present continuous research on developing a novel computerized screening tool for people with cognitive impairment. With the quickly growing aging population, more effectively accessible screening tools need to be developed. In order to gain an in-depth understanding of the possible technological opportunities, I conducted clinical practice observations, surveys, and interviews with older adults, as well as medical practitioners, such as neurologists and neuropsychologists. Based on the analysis results, I identify several issues in the current practice. I then present an ongoing progression of the development in order to solve the issues with future directions.

Keywords
Sketch-based System, Computerized Screening, Dementia, Cognitive Impairments, Senior-friendly Design

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms
Human factors, Design, Experimentation.
Introduction

In 2003, the Alzheimer’s Foundation of America proclaimed the third Tuesday of November as National Memory Screening Day [1]. The goal of this initiative is to promote the early detection of Alzheimer’s disease and related disorders (ADRD), and to encourage timely intervention and treatment of them.

The senior population has been dramatically increasing. A prominent public health challenge caused by aging is cognitive dysfunction, which is poor mental functioning associated with confusion, forgetfulness, and difficulty concentrating. Alzheimer’s disease is one of the representative disorders. Unlike other diseases that are physically visible, early detection of cognitive dysfunction is rarely easy. In fact, fewer than 50% of Alzheimer’s cases are diagnosed, and only approximately 25% are treated, even after several years of progressive cognitive decline [1]. Unfortunately, there are no known treatments for curing Alzheimer’s disease [6]. Therefore, in order to properly treat cognitive dysfunction, it is critical to identify the early process of cognitive impairment.

Problem Statements and Motivation

The current practice administering the most cognitive impairment screening tests, such as the Saint Louis University Mental Status (SLUMS), Mini-Mental State Examination (MISE), and Montreal Cognitive Assessment (MoCA), is based on traditional analog media, such as paper-and-pencil tests in hospital environments by clinicians [6].

Most tests consist of verbal interactions complemented by drawing or written interactions. For an example of a drawing interaction, each patient is asked to either draw a clock and some complex figures with a pencil on a given sheet of paper. Then, clinicians such as neuropsychologists or neurologists need to spend hours analyzing and scoring the tests. The process is long and tedious. In addition, sometimes different administrators of the test may have different scoring criteria [2].

Patients often believe that talking over their potential health problems with neurologists is considerably expensive and time consuming. Thus, patients do not consult doctors until their symptoms are all too apparent, at which point they may be too late to treat successfully. Furthermore, most primary care doctors do not conduct any kind of neuropsychological examination [3]. However, primary care doctors may be best positioned to detect cognitive impairment in its early stages since older adults are more likely to have regular visits for physical check-ups [3].

In brief, it is often difficult to detect the early stages of cognitive impairment because (1) it is hard to differentiate cognitive impairment from normal cognitive degeneration due to aging; (2) there is limited opportunity for seniors to meet with specialists, such as neurologists or neuropsychologists, unless they have serious observable symptoms; and (3) the disease usually develops progressively; thus, capturing it at the appropriate moment is challenging, as it normally requires continuous monitoring through everyday activities.

Due to the reasons listed above, an alternative way to support patients and neurologists is needed, one which must be more accessible and effective. The significant amount of research currently being conducted regarding phone- or computer-based dementia
screening indicates that dementia screening should no longer be limited to clinicians’ offices [3]. Therefore, I explore possible technological opportunities to develop a neuropsychological screening tool for detecting and monitoring cognitive impairment.

**Related Work**

With the advent of personal computers in the early eighties, studies on developing computerized neuropsychological assessments have been actively conducted [2]. Luciana and Nelson performed an assessment of neuropsychological functioning through the use of a computer-automated battery with 4- to 12-year-old healthy children [9]. Gualtieri and Johnson conducted a study on the reliability and validity of CNS Vital Signs (CNSVS), which is a computerized neurocognitive test battery [7]. Their study shows that CNSVS is appropriate for a screening tool, but it cannot be good enough for replacing formal neuropsychological testing [7]. Research from De Luca et al. also addressed issues using the computer-based Cambridge Neuropsychological Test Automated Battery (CANTAB) [4]. Despite many trials, until now there have been no accomplished great successes in terms of clinical utilization [4].

The potentials of the computerized assessments that many studies support lie in the precision of measurement, shorter assessment time, standardization, automatic scoring, minimization of subjectivity, and the impact that the examiners may have on the participants [4, 5]. However, some researchers in studies have concerns about participants’ unfamiliarity with computers [5]. Iverson et al. conducted research on the relationship between self-reported computer familiarity and performance on computerized neurocognitive testing [8]. Their studies show that frequent computer users performed better than people with less computer experience. In particular, both rapid visual scanning and accurate keyboard use can significantly influence testing results [13]. In order to solve these issues, some studies suggest using a touchscreen rather than using a keyboard and mouse [2].

On the contrary, two recent studies contend that computer familiarity does not affect the outcomes of cognitive testing [5]. Fredrickson et al. conducted a usability study of a brief computerized cognitive screening test in older people. They argue that computerized testing can be completed successfully by older adults with less-experienced computer use if some supervision or practice is provided [8]. Moreover, Wagner and Trentini conducted a comparison study between the manual and computer-based versions of the Wisconsin Card Sorting Test [2]. With the results showing no difference between the two versions of the tasks, there is strong evidence to support that the two different versions of the test are equivalent [2].

Moreover, recent research in Human Computer Interaction indicates that Tablet-PCs can provide an appealing platform for older adults [10]. Unlike WIMP (Windows, Icons, Menus, and Pointers)-based interaction, a pen can provide the elderly with more direct interaction in using the system. Users can put the stylus in the exact place where the cursor is, unlike a relative pointing device such as a mouse, which requires hand-eye coordination (moving the mouse on the desktop while looking at the screen to find the cursor location). Besides providing a familiar form of interaction, as well as the full advantage of hand-eye
coordination skills, pen-based interaction can truly provide authentic traditional neuropsychological assessments, but it would be empowered with computational benefits. For example, most neuropsychological testing heavily relies on drawing tasks, which are based on a paper-and-pencil interaction.

Understanding Technology Design Space
In order to understand the technological potentials to support screening for cognitive impairment, my unique approach started from gaining contextual knowledge, such as understanding the screening process, interactions between clinicians and patients in the screening process, and interactions with materials.

I performed several research activities: (1) observations of 24-session cognitive screening clinical practices; (2) computer-familiarity surveys of the session participants, together with their biographical surveys; (3) a preliminary usability comparison test between paper-and-pencil and tablet-pc based drawings; and (4) two focus group meetings with medical practitioners in Neurology and Neuropsychology.

Twenty-four older adult volunteers (average age = 75-year-olds) participated in the study from April to July in 2010. The participants consisted of 11 females and 13 males. Even though their average-age was 75, the groups included 10 individuals who were older than 78. The oldest participant was a 98-year-old, and the youngest participant was a 59-year-old. Their educational levels were diverse. Six participants had high school diplomas. Nine participants were college graduates. The last nine participants had a graduate-level education.

The participants were recruited from the HONOR Research Registry in Clinical Research in Neurology (CRIN) at Emory Alzheimer’s Disease Research Center in Atlanta. In order to enroll in HONOR, they must be either people over 70 with no memory problems or people of any age with mild cognitive impairment, with very mild memory or thinking problems, or with mild to moderate Alzheimer’s disease.

For the usability comparison test, in order to understand the computational potentials for the drawing test, I used the Clock Drawing Test [6] as an example module. The CDT is one of the simplest and most popular dementia screening tests. By simply asking people to draw a clock, it easily identifies people with dementia because clock drawings from people with cognitive impairment frequently show missing or extra numbers, or misplaced clock hands [6].

Considering the participants’ ages, it is not surprising to see the results of the computer familiarity survey. Most of them considered themselves as having low literacy, with limited or no computer experience. However, unlike their self-reported computer usage, the preliminary usability study results are very positive. Figure 2 indicates that the drawings using a stylus are almost identical to the drawings with a pencil. Furthermore, an 85-year-old adult expressed that it was fun to draw using a stylus and much easier than drawing with a pencil. None of the participants had problems with using a stylus. Through running the two focus group meetings with clinicians, I identified three issues that can be supported by technologies.
First, the drawings are predominantly analyzed at the end of the tests as a final product. Second, clinicians are required to do many things at once, such as measure the time and observe the patient. As a result, some critical moments can be easily missed. Third, the way data are collected and stored is not appropriate for monitoring any changes of cognitive condition.

In order to fully utilize the patient’s drawings, I propose that the user interface should integrate all of the data that will support the clinician’s decision, shown in Figure 3. For example, clinicians cannot examine or analyze the process of how the drawings were constructed because of the difficulty in data collection. Providing the automated capturing process as an animation would be helpful. Considering that the clock drawing is a mental processing and reasoning task, tracing the process can be a very useful approach in understanding patients’ cognitive status.

Therefore, the overarching goal of the clinician’s UI is to support the medical practitioner’s decision-making through performing several different analyses of the automated data collection. The bottom panel in Figure 3 shows a patient’s multiple clock drawings collected over time (e.g., weeks, months or multiple years) for easy comparison. With the longitudinal data available, a particular progress or trend of the patient’s cognitive condition can be easily visualized through an automatic system generated, as well as clinician-driven analysis. As shown Figure 4, a medical practitioner can interact with the top left window for a video playback to examine any moment in the process of a recorded clock drawing test.

Lastly, due to the complex features of brain-behavior relationships, data interpretation by clinicians may exhibit some disagreements. For example, some neurologists follow Freedman’s 15 evaluation criteria, while others use Mendez’s 20-item qualitative criteria [6]. Therefore, they may derive different diagnoses and treatments. The UI will incorporate different evaluation algorithms for medical practitioners to choose and compare results calculated from the different scoring criteria. Providing an analysis with multiple criteria will enable medical practitioners to critically analyze the current situation with diverse perspectives and to advance knowledge of early cognitive impairment detection never before possible.

**Conclusion and Future Directions**

In this paper, I presented several research activities to gain insights into developing a computerized screening system. I also proposed that the goal of the clinician’s UI should offer a well-organized data collection device, as well as an automated analysis of the results. I am
currently building the system, implementing other more computational functionalities that may provide novel biomarkers of cognitive status, such as measuring pressure while drawing, and the time of pausing while drawing. Then, I will start to design a patient’s UI, which can also be conducted as iterative design processes. From the preliminary surveys and interviews, I gained the insight that if a computing environment is similar to the familiar paper-and-pen interaction, then older adults seem to be able to handle it well. Once I meet the development goal, I plan to deploy it with real users in a hospital to determine its effectiveness.

This study can significantly contribute to the efficacy of a computer-based cognitive screening test. I believe that technology can offer more effective and efficient cognitive impairment screening. Furthermore, it also empowers medical practitioners to make evidence-based decision-making, and can ultimately enable transformative research in the field of neurological assessment.

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