A Tale of Two Studies: Investigating the Impact of Interruptions on Task Performance in Older Adults

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ABSTRACT
We present two ongoing studies that are part of a larger multi-disciplinary research project which aims to design, develop, and implement a web-based computerized screening test for cognitive impairment, called Cognitive Testing on a Computer. A laboratory study is conducted to investigate the impact of interruptions on task performance among three different age groups. A qualitative field study is undertaken in older adults' homes to examine potential interruptions and distractions that may be present as barriers to their performance when taking the assessment tool from home. Our initial findings indicate that technological interventions may help detect and mitigate interruptions for older adults.

Author Keywords
Interruption, experimental study, task resumption, task performance, field study, contextual inquiry, observation.

ACM Classification Keywords
H.m. Information Systems: Miscellaneous.

INTRODUCTION

This paper presents two ongoing studies that are part of a larger multi-disciplinary research project. The goal is to design, develop, and implement a web-based computerized screening test for cognitive impairment, called Cognitive Testing on a Computer (C-TOC), that older adults will be able to take independently from the comfort of home.

With ongoing advances in modern medicine, people are living longer, resulting in an aging population. This is particularly prevalent in developed countries including Canada. An aging population however is often associated with an increase of older individuals experiencing cognitive decline and presenting concerns regarding cognitive health. Currently, the screening for cognitive impairments such as Alzheimer's disease and related dementias are conducted using paper-based tests and are administered by healthcare professionals in clinical settings. The average wait time for an in-depth diagnosis and consultation regarding cognitive concerns ranges between 6 and 24 months. Thus innovation in cognitive testing is an urgent yet unmet need because of the growing demand for diagnostic services. The goal of our research is therefore to make such diagnostic services more readily available than they currently are so that patients exhibiting symptoms associated with dementia could be diagnosed and treated sooner. With the concerted efforts from multidisciplinary researchers and clinicians including neurologists, cognitive psychologists, and computer scientists specializing in human-computer interaction, C-TOC has been iteratively designed and prototyped as a novel testing tool with high sensitivity to mild levels of cognitive impairments. The current C-TOC prototype, implemented in PowerPoint, is comprised of a battery of 15 short tests, assessing several cognitive faculties, including memory, language, and spatial reasoning. The battery is designed to be completed in approximately 30 minutes. We expect C-TOC to be a cost-efficient screening tool for cognitive impairment, which will be taken in a clinic office or online from home. Meanwhile, C-TOC should support the streamlining of clinical assessment for cognitive impairment and constitute a decisive improvement over current paper-based tools.

Given the goal that C-TOC is to be taken at home, it is therefore important to address the issue of interruptions and distractions that are pervasively present in home environments. Such barriers may hinder older adults from completing the test at ease, which will in turn affect the test results. The two studies presented in this paper aim to address this issue. A laboratory study is designed to investigate the impact of interruptions on task performances among three different age groups. A field study employs a qualitative approach and is conducted in older adults' homes to examine potential interruptions and distractions that may be present as barriers to their performance on a computerized assessment tool. The findings from these two studies are expected to help inform technological designs for detecting and mitigating interruptions, specifically in C-TOC, and more generally in other applications designed for the aging population.

Relevant work will be presented in the next section, followed by the methodology employed for the two studies.

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Next, some preliminary results from the ongoing studies will be presented. Lastly, our current status and next steps will be briefly described together with possible extended work from our current studies.

RELATED WORK

A body of research on interruptions and distractions in HCI is well established, yet is disjoint from research pertaining to the design of technology for older adults. Our current research thus attempts to unify research areas in interruptions, universal usability and cognitive aging.

Previous research relating to the cost of interruptions in HCI focuses predominantly on younger adults, but nevertheless informs the design of our current studies. Interruptions similar to one's main task are known to be more detrimental to performance than dissimilar interruptions [4]. Our current work examines the similarity, modality, and complexity of interruptions and how they interact with different main tasks. Additionally, the length of the interruption lag, the time before responding to an interrupting task, also interacts with main task type [1]. In our current work, we are interested in how age affects the use of the interruption lag.

Older adults are increasingly open to new technology, especially technology having obvious practical purpose [5]. As such, it is our hope that our development of an online cognitive assessment tool will motivate older adults from a range of backgrounds to become involved at an early stage in our research. This provides us with an opportunity to refine methodologies for conducting HCI research with older adults [3].

A decline in higher cognitive functioning in adults after 55 and again at 70 has been well documented in the cognitive psychology literature [2]. This decline can be attributed to a number of factors, including a decrease in the size and duration of working memory, and also to a reduced capacity to inhibit responses to distracting stimuli and to enhance responses to attended stimuli [6], as well as a drop in processing speed [7]. As a result, it is hypothesized that the effects of interruptions interact with the age of a C-TOC test-taker and the type of task being interrupted. It is our aim to determine the nature of this interaction and how the validity of C-TOC test results can be preserved despite the presence of interruptions.

METHODOLOGY

Two separate but interrelated studies, a laboratory study and a field study, are being conducted to investigate different aspects of interruptions that may play a role in the validity of the assessment results of C-TOC.

Laboratory Study

The laboratory study examines how different levels of interruption demand interacts with the age of the test-taker and the type of task being interrupted.

Participants. We are recruiting 12 healthy, English-speaking participants from three age groups, for a total of 36 participants: 19 - 54, 55 - 69 and 70+.

Tasks. To gain a better understanding of how interruption demand and age interact with task type, two main tasks were used in this study, adapted from C-TOC tests: Sentence Comprehension and Square Puzzles.

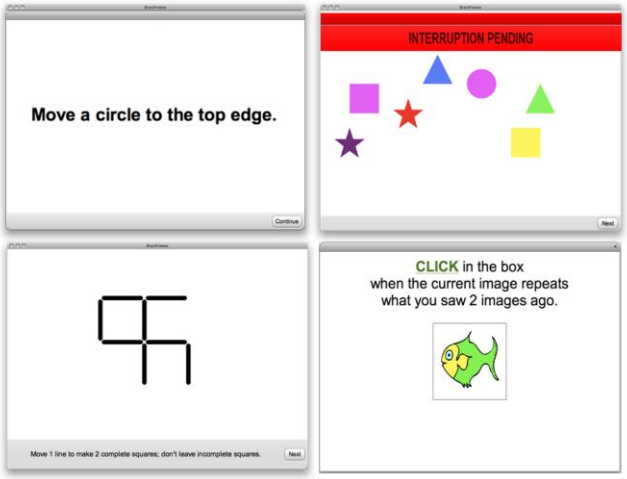

Figure 1. Experimental software used in the laboratory study. Sentence comprehension task (top left & right); Square puzzles task (bottom left); Interruption pending notification (top right); High-demand interruption (bottom right).

Sentence Comprehension (Figure 1, top) tests verbal memory, wherein each trial the user moves geometric figures, and is comprised of an instruction step and an execution step. Square Puzzles (Figure 1, bottom left) tests non-verbal spatial reasoning, wherein each trial the user is to move lines to create complete squares. Two interrupting tasks were used in this study, corresponding to low and high levels of interruption demand. The interruptions occlude the main task, and are preceded by an interruption lag lasting 2s (Figure 1, top right). Both interruption tasks display an automated and randomized sequence of cartoon images for approximately 20s. A low-demand interruption asks the user to watch the sequence of images passively. A high-demand interruption (Figure 1, bottom right) asks the user to click on an image that repeats what was shown two images prior in the sequence, placing a high load on working memory. At the end of an interrupting task, the user returns to the interrupted main task at the point where it was interrupted.

Design. The experiment used a 3 x 3 x 2 mixed design with three age groups, three counterbalanced levels of interruption demand, and two counterbalanced main tasks. Age was the only between-subjects factor. Each participant completed 30 trials in the Sentence Comprehension task, and 24 trials in the Square Puzzles task. In both main tasks, three isomorphic trial blocks were used for the three levels of interruption demand (no interruption, low-demand, and high-demand), and each participant was randomly assigned one of the six possible trial block permutations. Each trial

block in the low and high interruption demand conditions contained a subset of trials which were interrupted. The same subset of trials received interruptions in low and high interruption demand conditions. Interruption onsets were fixed in that they would occur shortly after beginning the execution phase of a trial.

Procedure. The experiment was designed to fit into a single 120 minute session. Participants completed 3 blocks of trials of the first task (either Sentence Comprehension or Square Puzzles). After each block, participants completed a short workload survey. They repeated this process for the second task. Upon completion of the experimental trials, participants were interviewed regarding their perceptions of task difficulty and their strategies for task resumption following an interruption.

Measures. We measured trial time as the total uninterrupted time elapsed during the execution step of a trial. We measured trial accuracy according to clinical scoring schemes for C-TOC tasks. Performance accuracy on the high-demand interrupting task was also recorded.

Hypotheses. We had the following hypotheses for this study. *H1*: older adults will perform proportionally worse on interrupted trials than on corresponding uninterrupted trials. *H2***:** older adults will perform proportionally worse on trials interrupted with a high-demand interrupting task than on corresponding trials interrupted with a low-demand interrupting task. *H3***:** Interruptions will incur worse performance on the memory-dependent Sentence Comprehension task than on the spatial reasoning-dependent Square Puzzles task.

Field Study

The field study employs mixed qualitative methods.

Participants. Our participants are healthy adults aged 50 and above, free from cognitive impairment and motor impairment in their hands. They are required to own and use a computer at home. Participants are first asked to fill in an online screening survey. The purpose of the survey is to screen participants for their computer experience in terms of the types of communication applications that they use, whether email or message alerts are employed, and the frequency and amount of computer usage.

Setting. The field study takes place in participants' home. Each study session lasted between 1.5 and 3 hours.

Methods. All participants are first administered with the Montreal Cognitive Assessment (MoCA) [7] for screening out those with mild cognitive impairment. Contextual interviews are then conducted to explore the computer applications that participants use in their computer and the potential interruptions and distractions in their home.

Participants are then observed using the latest C-TOC prototype running on the researchers' notebook computer while the participant's computer is running in the state where it is normally running. For example, if communication applications such as emails, chat tools, and calendars are usually running when they use their computer, we would ask them to leave them up and running before they start working on the C-TOC. Ideally we would have had C-TOC running on the participant's own computer. However, due to limitations of the current C-TOC prototype, we chose a dual-computer set up for our study (Figure 2). This set up allows us to capture all the activities taking place on participant's computer during the study while minimizing the intrusiveness to participants' computer, as the prototype did not need to be installed on their computer. Yet, to compensate for the reduced realism, we ask the participants to use the notebook computer together with their own computer as if they were one big computer. That is, if there are things that they would normally attend to in their own computer, they should feel free to behave in their usual way during the study.

Finally, participants are interviewed for their experiences working on the prototype. They are also asked about the interruptions and distractions that have occurred while they were using the prototype. The purpose is to better understand their perception and their mental state such as anxiety level when interruptions or distractions occurred. We also inquire into their strategies of task resumption after interruptions.

Participants' home settings, particularly where sources of distractions such as telephone and TV are present, are captured with a digital camera. Data are collected by note-taking and video-recording throughout the study session except when the MoCA was administered.

Interview and observation data are analyzed using open coding to identify and group common themes.

Figure 2. C-TOC running on a notebook computer placed on the right of the participant's computer; participant use the two computers as "one big computer".

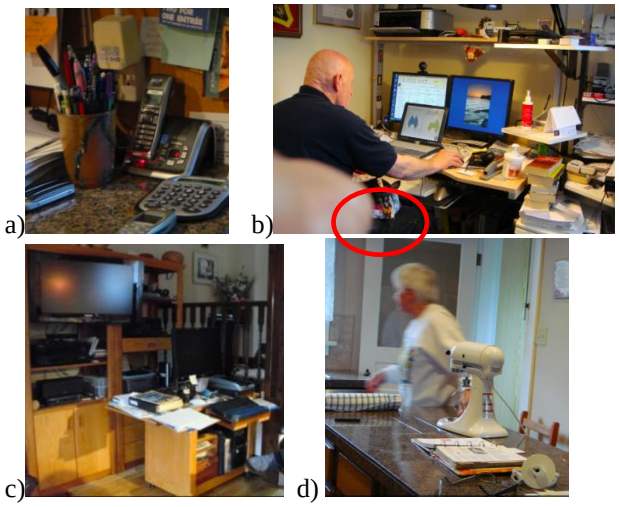

Figure 3. Interruptions in home environment: a) phone calls, b) pets needing attention (puppy circled), c) TV and radio, d) noises from kitchen and general ambient noise

PRELIMINARY FINDINGS

Preliminary findings of the laboratory study with 24 participants to-date do not yet provide any indication as to how the level of interruption demand interacts with age. Research participants have reported that interruptions are more disruptive to their performance during a verbal Sentence Comprehension task than during the non-verbal Square Puzzles task. We are currently faced with the challenge of recruiting healthy participants from the 70+ age group.

The initial findings from the field study with 9 participants to-date indicate a wide range of computer experience among adults aged 50 and above and a variety of barriers present in home environments. The range in computer experience seems to point to the need for interface designs that are suitable for older adults with varying computer experiences. As such, C-TOC interface components must be familiar to those with a range of computer experience; a low level of experience should not impact task performance. On the other hand, the barriers identified in the homes may be initiated by computers (e.g., pop-ups ad audio alerts), in the environment (phone calls, noises from TV, radio, and home appliances), from people and pets (e.g., family members or pets needing attention), and within the person who is taking the test (e.g., hunger, fatigue, anxiety and health problems) (Figure 3). Such interruptions and distractions can potentially affect a person's performance on a time-sensitive online assessment program such as C-TOC. Our findings thus far appear to suggest that technological interventions for mitigating the impact of interruptions and for ensuring the validity of the test scores could be developed for the C-TOC test battery. For example, a time-dependent pop-up prompt may be used to confirm if the test-taker is working on the test when a certain period of inactivity is detected.

CURRENT STATUS AND NEXT STEPS

Data collection is actively ongoing for both the laboratory and the field studies. In-depth data analyses are expected to take place when all the participants are run in the lab study and data saturation is obtained in the field study. Our current plan for extended work from these two studies includes an examination of other interruption factors and their potential interaction with age and main task. These factors have been examined in related work, and include interruption length [4], interruption similarity and modality, and the presence, perceptual salience, and length of interruption lag preceding an interruption [1]. Interruption frequency is also of interest, as well as the source of an interruption. As well, how these factors interact with task instruction is an important question, implying a potential speed-accuracy tradeoff.

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