The Need for Assistants that Monitor Cognitive Abilities

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Introduction

Many modern occupations require workers to spend a significant portion of their time operating computers. Some may see this as a potential problem (e.g., Internet addiction or repetitive stress injuries) while others may see this as an opportunity (e.g., increased productivity). From both points of view, we can make a case for the need to monitor and analyze the interactions of people and the computers they use. The data gleaned from these interactions can be used to increase the productivity of the person/computer pair, to reduce the cost and number of errors resulting from the collaboration, to detect the ill-effects of extensive computer use, and to detect changes in other abilities that manifest themselves as changes in computer use.

A common viewpoint for personal assistants centers around the question of which tasks the assistant can perform for (or in partnership with) the user. This short paper argues that we need to expand this viewpoint to include personal assistants that monitor and report back on the user's performance. In support of this argument, we will enumerate specific uses and benefits of monitoring the cognitive abilities of computer users through human-computer-interaction and map these benefits to specific occupations and populations. We focus on one particular population: older adults experiencing or concerned about cognitive decline.

Particular uses for cognitive monitoring

Below, we list specific uses of a cognitive monitor and how its use will benefit particular populations.

Reducing errors

Using any tool for a significant length of time likely leads to fatigue and eventually to errors. For example, a person performing data entry for hours at a time may make more mistakes toward the end of a session than at the beginning; a tired air traffic controller is more likely to make a mistake than if he is fresh; and an increase in pressure or fatigue for a programmer will increase the number and degree of bugs.

In all these cases, it is preferable that the worker stop working (or be replaced) when a particular level of fatigue is reached. The cost of errors (in dollars or lives) far exceeds the cost of lost productivity due to the work stoppage. A work stoppage may not be necessary; switching to a new context that uses different mental abilities may be sufficient for recovery. But how is the level of fatigue chosen or even measured?

For the occupations mentioned, it is easy to conceive of measures that at least weakly correlate with fatigue: how often is the backspace key hit by the data entry clerk? What is the time lag between requests to the air traffic controller and her response? What is the number and nature of the compile errors experienced by the programmer? For all three, changes in mouse speed, time distance between keystrokes, or any other atomic activity may also weakly correlate as well with level of fatigue and other cognitive abilities.

Increasing productivity

In many cases, computing devices are intended as a labor saving or productivity enhancing tool. The productivity level of a human/computer team depends on many factors, including the familiarity of the person with the device and its applications, the degree of intelligence of the device, and the cognitive abilities of the person. Of the effort to increase the productivity of this pair, much has gone toward creating smart and easier to use devices or into training the person to better use the device. Less attention, however, has gone into supporting or increasing the cognitive abilities of the person using the device.

The typical office worker performs a wide array of different activities that require very different mental skills: writing a paper requires different skills than formatting a spreadsheet or conducting a meeting. Most of us have some sense of when we are best at a given activity. "No heavy thinking before 9am" or "cannot focus as well right after lunch" are examples. A context-sensitive cognitive monitor could give weight to these hunches or disprove them. Furthermore, they could give us real-time feedback via suggestions on what activity in our ToDo list best matches our current abilities.

Detecting cognitive decline

We began thinking about cognitive monitoring in the context of developing technologies that help older adults "age in place", which is to continue living in their homes rather than in a nursing home or assisted-living facility for as long as possible. We are studying ways to provide older adults and their caregivers feedback on the current cognitive abilities of the older adult. We believe that a (trusted) cognitive monitor will provide several benefits:

Reduced stress for the caregiver The worry that a loved one is declining physically or mentally is a cause of constant stress for a caregiver. A mechanism for constant feedback (beyond repeated phone calls) will help ease this stress.

Guided choice of interventions Knowing which cognitive abilities are declining or improving will help a system or caregiver choose an appropriate intervention. There is a growing focus on *cognitive games* (a.k.a. serious games), which are in some cases proven to increase particular cognitive abilities of their players.

Evaluation of interventions Older adults often suffer from multiple ailments and diseases, which require multiple drugs that interact in ways doctors cannot always predict. Monitoring the cognitive (and physical) performance of the person before and after medication changes will help quantify the total effect of the drug cocktail, and possibly detect sudden drops that could lead to physical injury.

Proposed Approach

Our specific approach to building a cognitive monitor for older adults involves instrumenting their personal computers and telephones (in a privacy-preserving way) to collect data; 32% of adults over 65 use the Internet, up from 22% in 2004 (Pew 2006), making computer use ripe for monitoring. A key aspect of our cognitive monitor is that it is unobtrusive, and requires little if any change in the user's computer habits. For the older adults population, we intend to perform three types of measurements.

Motor skills

Several neuropsychological tests, such as the Finger Tapping Test, measure neuro-motor abilities. This cognitive ability likely correlates with many human-computer interactions, including mouse speed, time between keystrokes, and the 'double-click' interval. Preliminary work suggests that time between keystrokes can be used to indicate mild cognitive impairment (Jimison, Pavel, & McKanna 2005). Other measures cut across several cognitive abilities. For example, the relative frequency of "backspace" may predict neuro-motor abilities (how often the intended key was missed) or language abilities (misspellings or cannot think of a word.)

Linguistic and speech analysis: written and oral

We are interested in language content as a clinical indicator of mental and even physical health. A body of prior research indicates that aspects of cognitive and emotional functioning can be predicted on the basis of a computer-based analysis of the words used in communication. Pennebaker et al. (Pennebaker, Mehl, & Niederhoffer 2003) and Bechtel et al. (Bechtel *et al.* 2002) describe how computer based lexical analysis can be applied to the problem of detecting cognitive impairment. Email is an obvious data source for this analysis. However, oral communication is an attractive source as well. By applying automatic speech recognition (ASR) technology to a consenting patient's telephone conversations, one will have an even larger and more ecologically-valid sample of the patient's linguistic patterns.

In addition to language content, oral fluency is an important diagnostic indicator. Cognitive impairment can be indicated by a general slowness in speech or by halting speech (Haley & Vanderploeg 2000). We believe ASR can be applied to the problem of detecting changes in oral fluency.

Performance on applications

If instrumented, certain applications can give valuable information about a user's executive functions, memory, and intelligence. Performance on a trivia game, crossword puzzle, or even a race car game has obvious connections to many cognitive abilities. The challenge in this case is to separate the user's natural improvement (learning) in the game from changes in the core cognitive abilities. One study has shown that performance on the game FreeCell can be used to predict mild cognitive impairment (Jimison *et al.* 2004).

Conclusion

In the near future, we intend to implement a longitudinal study in which we assess a set of older adults using both traditional, clinical neuropsychological tests and our computer measures. The data from the study should enable an analysis that leads to a predictive model linking the measures and levels of particular cognitive abilities.

We believe that in the quest for truly helpful personal assistants, we should not focus solely on what actions or decisions we can delegate to the assistants; we should also consider the potential role of AI in monitoring our own actions and decisions to help us maintain and improve our own performance. The potential benefits of developing this area of research include reduced errors, increased productivity, and detection of temporary of long-term cognitive decline.

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