COGNITIVE BARRIERS TO MAINSTREAM MOBILE COMPUTING DEVICES IN NEUROREHABILITATION

Duncan R. Babbage
School of Psychology, Massey University, Wellington, New Zealand

INTRODUCTION

Mobile computing provides potential to compensate for disability and increase participation for people with cognitive impairment (Gartland, 2004). A series of trials have found technological aids to be useful in neurorehabilitation (e.g. Culley & Evans, 2010; Kim, Burke, Dowds, Robinson Boone & Park, 2000; Mackie, Leathem & Babbage, 2008; van den Broek, Downes, Johnson, Dayus & Hilton, 2000; Wade & Troy, 2001; Wilkomm & LoPresti, 1997; Wilson, Emslie, Quirk, Evans & Watson, 2005; Wright et al., 2001). However, with advancing mobile computing technology societal expectations for ubiquitous instantaneous access to information are growing, which could expand disability for people with brain injuries into areas of functioning that did not previously exist. Developing mobile computing devices that adapt to the cognitive and physical capacities of the user will assist people with neurodisability. I argue a cognition-aware universal design approach to devices intended for mainstream distribution is desirable for all. When people with neurodisability use off-the-shelf products they will be positioned to benefit from future technological developments. Meanwhile, cognition-aware design is likely to produce products more intuitive and accessible for people without disabilities.

This paper juxtaposes a neuropsychological construction of cognitive functioning with concepts of mobile computing interface design. Operating mobile computing devices draws on virtually every domain of cognitive functioning. Cognitive impairment thus impacts on the use of this technology, but these impacts could be ameliorated. A device sophisticated enough to carry significant processing load could adaptively provide a less complex user interface by drawing on contextual cues (e.g. time, geolocation, pre-programmed tasks, recent user actions) and information about user capabilities to assist users to achieve functional outcomes. There are a range of accommodations necessary to make a mobile computing platform suitable for the diversity of cognitive needs of people with brain injuries. Barriers to accessing current mobile computing technology are outlined across the domains typically impaired in brain injury, with proposed design mitigations. For a detailed historical review, see Lopresti, Mihailidis and Kirsch (2004). The current paper lays out hypotheses, discussing solutions that could enable greater mobile computing access and thus independence for people with neurodisability. These would benefit from a programme of empirical scrutiny and practical application, examining whether such adaptations increase device access, task completion, and functional outcomes.

COGNITIVE BARRIERS TO MOBILE COMPUTING

Language functioning

Mobile computing devices frequently present information in only one modality (e.g. written text). For people with disrupted language functioning, this presents a problem. Solutions may include using multiple modalities; present information audibly, providing icon representations of all key functions, and intentionally using simple language wherever possible.

Visuoperception

Interpreting graphical representations of functions (e.g. icons) relies on intact visuoperceptual functioning. Using simple and distinctive concrete representations of functions will assist recognition, as may icons that can be customised to the user. Providing an option to present fewer icons of larger size will reduce stimulus complexity, and assist with reduced acuity. Providing cross-modal cues such as audio prompts may direct attention to functions and assist with accessing content.

Attention and Concentration

When using a mobile computing device, a user with brain injury may miss important information due to attention and concentration difficulties. There may also be confusion due to the complexity of decision-making tasks required. A solution might be a setting that controlled the complexity of interface presented to a user. For instance, some users with significant impairment might be able to consider only a forced choice between two alternatives. Applications could degrade gracefully when limited to a reduced stimulus set, in some cases re-designing workflows so a series of simple choices build to complex outcomes. In other cases it may prove necessary to hide complex functionality that cannot operate below a particular level of simplification.

Information Processing Speed

Speeded presentation or limited response times may outpace the absorption capacity of a person with brain injury. A slow rate of speech on auditory prompts (e.g. voicemail) will assist. Non-linear formats such as visual voicemail are preferable, however, as they are less dependent on impaired functioning. For visual information, a reduced scroll speed may increase efficiency, by remaining within the user's window of effective processing capacity. Users should not be required to respond to prompts within time limits; the option should also be offered to defer response until in a distraction-free situation.

Memory

The diverse capabilities of mobile computing devices potentially result in a steep and long learning curve for users. Ideally, mobile computing devices would be designed with interfaces that are so intuitive that healthy users require no training to use them correctly (see Wright et al., 2001). A person with brain injury could potentially use such a device correctly, even if they cannot recall training in the use of the device from explicit memory. Correct intuitive use would maximise opportunities for errorless learning and train implicit memory. (Formal training should also employ errorless techniques.) Devices could also be programmed to train users using errorless learning techniques, only allowing users to follow successful "pathways" through the interface and initially greying out alternatives, with additional pathways only being opened up when the user has consistently demonstrated mastery in the use of initial functions.

Executive Functioning

Executive functions involve taking the building blocks of cognitive functioning and putting them together to achieve intelligent outcomes—seen in initiation, self-organisation, self-monitoring and self-correction. The flexibility presented in mobile computing applications often demands a high level of self-organisation to achieve useful outcomes. A solution to this for people with cognitive impairment could be providing pre-built workflows focussed on achieving specific functional outcomes. Along the lines of the memory pathways described above, workflows would be designed to guide users through logical sequences without having to plan, sequence or monitor progress. They would provide prompts to complete tasks left incomplete, such as if distracted or interrupted. Meanwhile, content would be auto-saved—so the user does not need to monitor choices about information to retain.

Software tends to assume users make good choices that reflect their goals. This is not necessarily true after brain injury, such as for someone with poor impulse control. Applications should provide multiple levels of undo, using version control rather than over-writing data, and storing history up to the storage capacity so regretted decisions can be rolled back. Alongside this, "parental control" features may usefully protect the user from editing core settings or deleting large swathes of data, without a password held by a trusted support person. Clearly such relationships need clear communication about the rationale, to maximise the likelihood a user feels supported rather than controlled.

Motor dexterity

Fine and gross motor control are commonly impaired in brain injury. Fine motor control difficulties make precise interaction difficult. Having the option to display fewer targets of a larger size would assist; the recent predominance of touch screen interfaces now provides the possibility of this on standard hardware. Per-user calibration of required responses would also assist people with motor control difficulties. (For example, only record a response when the user presses and holds the button for a minimum period.) Confirmation dialogs are common for tasks like file deletion; requesting confirmation for all significant functions may be easier for someone with motor control difficulties than needing to target a less prominent control to undo mistakes. Providing audio and verbal interfaces will also be a useful alternative for many people with motor control difficulties.

Mobile computing devices are typically small and light; history and the general desirability of this suggests they are likely to become more so over time. Such designs assume capacity to holding and stabilise the device during use. However, difficulties with this can be ameliorated by accessories that attach to the person, a surface or wheelchair, or to furniture.

<u>Visuoconstruction</u>

Mobile computing interfaces that require users to create interactions between content on the device, such as dragging and dropping icons or text, may be difficult for people with impairment in this area. This could be ameliorated by enabling the creation of pre-specified data-function interactions (e.g. macros) that are specific to a user's needs. These would provide a way to specify relationships between content and functions, that do not rely on manipulating spatial relationships.

A WHOLE-PLATFORM APPROACH TO COGNITIVE ACCOMMODATIONS

Individual applications can make design accommodations for the cognitive capacity of users. However, truly universal design would be served by platform-level preferences that specified the capabilities of the user along a number of dimensions, such as their fine motor control abilities, capacity to handle cognitive complexity, and the pace that information should be presented. These kinds of preferences would complement and extend existing options such as voice-over announcements of active items, screen contrast controls, providing application developers with (optional) additional information they could use to scale their applications to the capabilities of the user. For instance, if a sliding scale for cognitive complexity was set to its lowest level, an application might scale down to present just one large button for a single application item at a time (e.g. review tasks, or create task, or show next task) with a smaller button that would advance to the next item in the list. This reduces a range of simultaneous choices down to a single Yes-No decision of "Is this the option I want?"

UNIVERSAL DESIGN

I recommend a universal design approach when considering use of mobile computing technology in brain injury rehabilitation. Such an approach aims to improve and build upon standard hardware and software platforms, rather than custom-developing from scratch a device. With the rapid advances in smartphone technology there is now—arguably for the first time—the potential to develop flexible cognitive prostheses based on mainstream hardware and software platforms. (See LoPresti, Bodine & Lewis, 2008, for examples of research examining this.) Inglis et al. (2004) reported one of their participants who carried a bulky lever-arch file around with him expressed a desire to keep a record of all his information entered into an electronic memory device, as well as having a hard copy as a backup. Inglis et al. described this as "ultimately unrealistic". A scant seven years later, his request should simply be routine; my own phone holds in local storage a full copy of the contents of a cloud-based database (via Evernote) that supports a paperless workflow, while a decade worth of files synched from my desktop and laptop computers is accessible wirelessly through another application (Dropbox). There is no reason why people with brain injuries cannot access such services, if they are properly presented. A cognition-aware universal design approach incorporating neurodisability-aware functionality into applications and devices like these that are intended for mainstream distribution is desirable for all parties. People with neurodisability will benefit most when they can use off-the-shelf products and so benefit immediately from technological developments. Meanwhile, cognition-aware design is likely to lead to products more intuitive and accessible for people without disabilities. Such an approach would require commitment from software and operating system developers and hardware platform manufacturers to extend the range of accessibility options they provide. This would be beneficial for developers and manufacturers, as adopting a neurodisability-aware development approach is likely to lead to products that are also more intuitive and accessible for people without disabilities.

UNIVERSAL USE BY REHABILITATION PROFESSIONALS

Gartland (2004) notes the significant commitment of time and effort necessary for rehabilitation professionals to keep abreast of the latest developments in technology, in order to utilise it with their clients. I suggest that rehabilitation professionals are only going to achieve this at all if they "eat their own dog food"—to employ an expression used in the software development industry. Only by personally using mobile computing aids themselves will rehabilitation professionals have the intimate familiarity with the technology necessary to train a person with neurodisability to use them successfully. If a rehabilitation professional cannot use a smartphone to record information about their own contacts, organise their own appointments, and record important information they encounter in their day, what hope would they have of training their clients with brain injuries to do so?

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