By Michael L. Waterston

The **Techno-Brain**

How does the human mind respond physiologically to our interruption-rich world?

Distraction is now a constant feature of our personal surroundings. The proliferation of mobile devices supporting multiple types of media delivery means there are always multiple types of information you could be attending to. The human brain, which has a remarkable ability to adapt to its environment, is changing to accommodate this reality. It wasn't always the case that we could see an e-mail from our spouse while we were checking our Facebook feed while there was a lull in the conversation, but our brains are adjusting to this task-shifting reality.

With the assistance of psychological testing and neuroimaging, researchers recently have begun to understand the ways in which people may be thinking differently because of new, ubiquitous technology. Interestingly, some of the differences in brain function in the presence of continuous incoming streams of information are akin to changes that occur with aging. Likewise, some of the techniques—even technologies—that are helpful for normal cognitive aging could also help us cope with our interruption-rich world.

Interactive Technology Affects How We Think

We know experiences leave their impression on us by altering our brains in some way. The brain continues to add neurons through adulthood, particularly in the hippocampus (Eriksson et al., 1998); this is necessary to consolidate new experiences into memories. When we encounter technologies and adapt our behavior to rely upon them, the brain also adapts. This neural adaptation may have unintended consequences on how we think and behave, even when the technology is not present.

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Both the positive and negative effects of today's computer-based technologies are of growing popular interest: organizations such as Mothers Against Video Game Addiction and Violence and the Video Game Voters Network lobby against each other over the restriction of video game content. Social games like World of Warcraft or Farmville are particularly noteworthy for the amount of time users will spend doing apparently repetitive, uninteresting tasks like harvesting resources or tending fields to raise their profile in the virtual world. Software companies are beginning to leverage neuroplasticity to develop brain games specifically designed to improve cognitive function.

Video gaming

The effect of video game technology on the brains of game players has been of interest to researchers partially because of its similarity to traditional training. Practicing most tasks will lead to performance improvement—up to a limit. If this performance improvement is carried over to similar tasks, it is an instance of near transfer. If performance on a less related task (such as a problem-solving test) is affected, then it is an example of far transfer. For repeated video game playing, improvements in visual attention would be expected near transfer. Indeed, video game players demonstrate an increased useful field of view and are able to attend to more objects at once than nonplayers (Green and Bavelier, 2003).

Some games also facilitate far transfer to skills that are less like the ones being trained. Early studies on jet fighter pilots found that training on simple games requiring balancing multiple skills simultaneously led to increased proficiency with the complex task of flying a plane (Gopher, Weil, and Bareket, 1994). Later studies showed that games requiring self-initiated switching between multiple sub-goals led to improved speed in task switching as well as increases in working memory and intelligence measures (Basak et al., 2008).

Online searching

The advent of online searching has changed the way we find and interact with information. We have more control over what we read, and the quantity of information available to be searched and filtered is unprecedented. Experienced Web searchers show significantly different brain activity patterns when engaged in search than those who are new to searching (Small et al., 2009). When both experienced and naive participants were scanned with functional magnetic resonance imaging (fMRI) while performing a Web search, there was significantly more activation of frontal areas in experienced participants. Whether through self-selection or adaptation, the experienced searchers were engaging more of the brain associated with executive function, or the control of cognitive processes, than were those unfamiliar with online searching.

Executive function can be thought to contain three interconnected but anatomically separable sub-processes: energization, task-setting, and monitoring (Stuss and Alexander, 2007). By analyzing the behavioral deficits of patients with frontal lobe lesions, Stuss and Alexander associated the executive sub-processes with particular sub-regions within the frontal cortex. Energization, in particular, is associated with the superior medial cortex and this region was preferentially activated by experienced Web users engaged in online searching.

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Mobile multitasking

Mobile devices enable new modes of communication in situations where communication previously was not possible. Texting, Twitter, and Facebook are all available on mobile devices and able to interrupt activities. Internet browsing presents a constant source of information, both relevant and irrelevant, and is deeply integrated into our workplace environments. With each new media platform that is introduced, people are more likely to be interacting with multiple media sources at a time. Fifty-seven percent of college students who instant message while studying report a detrimental effect on their academic performance (Junco and Cotton, 2011). Studies of cell phone use in subjects operating driving simulators find driver safety compromised more profoundly than driving at the 0.8 percent weight/volume alcohol limit (Strayer, Drews, and Crouch, 2011).

Psychological testing by Ophir et al. (2009) demonstrated that media multitasking is strongly related to difficulty in focusing on relevant information. The researchers classified people as high media multitaskers or low media multitaskers based upon subjects' self-reporting of using more than one media type at a time. The high media multitaskers were less successful at excluding distracting information from psychological tests and took longer to switch between tasks when directed. Distraction level was measured by asking participants to remember the orientation of a particular bar surrounded by irrelevant bars. In this task, the performance of high media multitaskers became significantly worse as the number of distracting bars increased.

Participants were also presented with a series of letters, one at a time, and were asked to indicate whether the current letter was a repetition of the letter shown two or three presentations earlier. High media multitaskers were less accurate at this task, and they were also more likely to falsely indicate a repetition if the presented letter had been repeated, but much earlier in the task.

Task switching, or interruption, is measured by presenting a cue before tests that instructs subjects to either accomplish a letter-discrimination task (vowel or consonant) or a number discrimination task (even or odd), and then measures reaction time to respond. The two tests are each relatively simple. It is not difficult to distinguish vowels from consonants or to distinguish even from odd numbers, but the amount of time it takes to respond can indicate even small changes in difficulty. Participants performed the reaction-time test either by repeatedly performing the same test, or periodically switching between the letter and number test. "Global switch cost" is the difference in reaction times when subjects are completing groups of repeated similar tests and when subjects are switching between types of tests. "Local switch cost" is the difference in reaction time to the first new test when they are periodically alternating.

Although high media multitaskers have the same response times when measured on the same repeated tests, they

had higher global and local switch costs. This implies that it is both more difficult for high media multitaskers to change to a new test and that performance was impaired even by the possibility that the test might switch.

Cognitive Effects of Media Multitasking Similar to Effects of Aging

As adults age, some of their cognitive abilities continue to improve, while others show a decline. Vocabulary continues to increase over the lifespan (Park et al., 2002) and decision making based upon experience also improves (Kovalchik et al., 2005; Tentori, 2001). In contrast, memory for events in the past, memory of tasks in the future (Grady and Craik, 2000), and behavioral inhibition (Wecker et al., 2000) show reduced performance with the onset of aging. The declines in executive function have been attributed to an underlying slowing of processing times (Salthouse, 1996), or an increased susceptibility to interruption and distraction while completing tasks (Hasher, Zacks, and May, 1999).

Like high media multitaskers, older adults are known to be less able to ignore irrelevant information (Healey, Campbell, and Hasher, 2008). Increased distractions lead older adults to take more time to respond and be less accurate on cognitively demanding tasks when compared to younger subjects. Noisy environments and interruptions while working pose a larger problem for older workers. The time of day is also an important influence on test participants' ability to ignore the presence of distractions; younger adults typically have peak performance in the afternoon while older adults' peak performance is in the morning. These behavioral measures are corroborated by neuroimaging, with both fMRI and EEG data showing evidence of reduced inhibition of irrelevant information for older adults (Gazzaley et al., 2005; Gazzaley et al., 2008).

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Task switching ability also shows significant decline with age (Wasylyshyn, Verhaegen, and Sliwinski, 2011). Global task switching, or the overall cost associated with maintaining more than one active task, shows a particular deficit with age. The specific challenge with interruptions for older adults stems from difficulty with returning to the original task (Clapp et al., 2011). Analysis of fMRI data identified areas of strong correlation during an interrupted-scene interpretation task. Before interruption, activation in the right mid-frontal gyrus (associated with task monitoring) and activation in the parahippicampal place area (associated with scene interpretation) fluctuated together. After interruption, older adults do not re-establish this correlation as effectively when they should be returning to the first task.

Technology Can Serve as a Cognitive Aid

The same mobile tools that cause our current levels of distraction can also—ironically—mitigate some adverse effects of multitasking. Heavily used applications for mobile phones such as calendars, task lists, and contact managers are designed to complement cognitive processes that are complex and challenging to begin with. When coupled with an understanding of the cognitive processes they are meant to support, these tools can be particularly effective.

Focusing on the small items in your task list during the time of day when you are more likely to re-engage after interruption may be most effective. Placing items in your calendar is a cue to yourself to remember the commitment in the future. The technological cue to remember something can be made more effective by coupling it with a cognitive strategy for remembering future commitments. Research shows that by visualizing how and when you plan to implement a commitment you can double the likelihood that you will follow through on your intention (Gollwitzer, 1999). Software that guides users through the optimal thought processes to complete their tasks successfully will be a more effective productivity aid. This will require software developers to be aware of cognitive strategies and provide support for the appropriate strategies at the right time.

The similarity in switching difficulty reported in high media multitaskers and aging adults suggests that our media-rich environment introduces some deficits of aging earlier in life. Older adults may be more impaired by distracting environments, but so are younger multitaskers. The increase in both global and local switch costs during multitasking in high media multitaskers is particularly unexpected. High media multitaskers are in some ways training to be better at switching between tasks, but their performance in these situations is not improving. Instead, multitaskers may be cultivating the habit of being drawn to distractions rather than improving their ability to return to their original goal. Being aware of the importance of returning to task and taking steps to mitigate interruptions may be important for people of all ages to do in our increasingly distraction-saturated environments.

Summary

The brain adapts constantly to its environment, and recent evidence indicates that the brain changes its function as individuals interact with new technologies and media platforms. Video games psychologically motivate players and, through repeated play, can change behaviors that are only abstractly related to the games. People who often search online recruit more of the brain areas associated with task energization than those new to searching, indicating similar neural adaptation from casual Internet use. Media multitasking clearly interferes with current task performance but also leads to higher distractibility and difficulty with task switching overall. Older adults are naturally more attentive to distractions, so the effect of our media-rich environment may be of particular importance to them.

While current technology may be impairing our ability to focus, our interface with digital media is constantly evolving. As the increased costs of distractions become better understood, consumers may seek technical solutions that support, rather than interfere, with attaining goals. Devices or services that can take advantage of the strong psychological drives fueling online distraction and orient them toward achieving personal goals will hopefully become more common. At the same time, social norms of behavior may adjust to acknowledge the consequences of distractions and constant attention switching: this sea change is already reflected in the increased prevalence of laws prohibiting types of multitasking while driving. Ultimately, our changing environment will always require us to learn and appreciate the limits of our brain's adaptive ability.

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