Multicosts of Multitasking

By Kevin P. Madore, Ph.D., and Anthony D. Wagner, Ph.D.

Editor's Note: What happens to your brain when you multitask? Does your brain slow down? Do you feel increased levels of stress? Why are some people better at it than others? Our authors supply the answers to some of these questions and provide the latest on what happens to the brain when you try to handle more than one task at a time.

As you go about your day, you may barely notice that you are frequently multitasking. It may be driving to work while listening to a radio program or talking to a loved one on the phone (putting yourself and others at risk), or perusing Facebook while texting a friend, or switching back and forth between a high-level project like compiling a report and a routine chore like scheduling an appointment. Multitasking means trying to perform two or more tasks concurrently, which typically leads to repeatedly switching between tasks (i.e., task switching) or leaving one task unfinished in order to do another.

The scientific study of multitasking over the past few decades has revealed important principles about the operations, and processing limitations, of our minds and brains. One critical finding to emerge is that we inflate our perceived ability to multitask: there is little correlation with our actual ability. In fact, multitasking is almost always a misnomer, as the human mind and brain lack the architecture to perform two or more tasks simultaneously. By architecture, we mean the cognitive and neural building blocks and systems that give rise to mental functioning. We have a hard time multitasking because of the ways that our building blocks of attention and executive control inherently work. To this end, when we attempt to multitask, we are usually switching between one task and another. The human brain has evolved to single task.

Together with studies of patients who have suffered focal neural injuries, functional neuroimaging studies indicate that key brain systems involved in executive control and sustained attention determine our ability to multitask. These include the frontoparietal control network, dorsal attention network, and ventral attention network.

The first of these networks is thought to support the coding of a task goal and the selection of task-relevant information. This means identifying a task goal, selecting relevant information, and disregarding irrelevant information that does not help us to achieve the goal. In the context of multitasking, we know that the brain has a hard time processing and completing two or more tasks at once: the inherent ways the dorsal and ventral attention systems interact with the frontoparietal control network makes this so. When we approach a task, a goal representation in the frontoparietal control network is thought to guide top-down attentional allocation, mediated by the dorsal attention network, to select information that is relevant to achieve the task goal. This information can include external sensory information or internal thoughts.

For this reason, having multiple task goals places greater demands on the frontoparietal control and dorsal attention networks, which are limited in their capacities. At the same time, the ventral attention network is believed to support more automatic attention reorienting, which can include the capture of attention by distracting information. Importantly, when we multitask, the ventral attention network is more prone to be captured by competing streams of information, including information that is relevant to one task but irrelevant to—and thus disruptive of performance of—another task. Because on-task behavior emerges from interactions among the three brain networks, when we multitask, there are multiple competing sources of what constitutes relevant and irrelevant goals and information. This can cause interference and complex interactions between attention and control brain networks.

Switch Costs in Mind and Brain

One way we can examine the effects of multitasking on behavior and the demands it places on relevant brain networks is by analyzing "task switch costs." A switch cost is a reduction in performance accuracy or speed that results from shifting between tasks. A rich body of research in psychological science has documented that the behavioral costs of task switching are typically unavoidable: individuals almost always take longer to complete a task and do so with more errors when switching between tasks than when they stay with one task. Neuroimaging work from our lab and others has helped to highlight the effects of task switching in the brain.

In one functional magnetic resonance imaging (fMRI) study, we had subjects classify stimuli on one of three dimensions (color, shape, or pattern). In terms of behavior, one finding was that subjects took longer to classify stimuli in switch trials (i.e., where the task had changed from the previous trial) compared to stay trials (i.e., where the task stayed the same). In terms of the brain, we found that frontoparietal regions—including those of the frontoparietal control and dorsal attention networks—were more responsive during switch than stay trials. In fact, consistent with the view that multitasking creates heightened neurocognitive demands, the strength of task representation in the control network was greater when subjects switched to a new task than when they stayed with the same task. This means that when we switch from one task to another, it requires more neural processing because we have to bring back to mind the new task's representation and then use it to allocate attention to information that is relevant to perform the new task. As a consequence, when we switch between tasks, we lose the benefits of automaticity and efficiency that come from staying focused on a single task.

Studies from other labs have reached similar conclusions. One fMRI study examined the effects of switching between tasks: subjects performed a single task repeatedly or two tasks intermixed in a block of trials. Response times were slower during task-switch blocks, and brain patterns reflected this effect. Nodes of the frontoparietal control network and dorsal attention network were more active during switch blocks, revealing increased neurocognitive demands associated with switching. From developmental studies, we have learned that older individuals often exhibit reduced abilities to selectively attend to and engage cognitive control in support of goal-directed behavior. Age-related fMRI studies provide initial hints as to what neural changes make multitasking (or task switching) particularly challenging for older adults. In one, older adults' diminished multitasking ability was associated with reduced connectivity between brain networks of attention, control, and memory, compared to young adults.

Psychological science and neuroscience indicate that our minds are taxed by multitasking. When we attempt it, we must engage in task switching, placing increased demands on neurocognitive systems that support control and sustained attention. While engaging these systems can partially mitigate its behavioral costs, multitasking is not free—we pay a price in increased demands on these systems and some performance deficit typically occurs.

A Spotlight on Media Multitasking

With the explosion of digital media and the commodification of our attention (referred to as the "attention economy"), "media multitasking" has become ubiquitous. Have you ever opened your laptop to check your email or complete a work assignment, and put on Spotify or Netflix in the background? This kind of multitasking—engaging with or switching between multiple media streams—has attracted considerable interest given behavioral trends. We know that American youth spend an average of 7.5 hours a day with various media and at least 29 percent of that time involves media multitasking. Data from other countries show a similar pattern, and the phenomenon extends to adults.

In 2009, Cliff Nass's lab at Stanford developed what has become a widely used index—the Media Multitasking Inventory (MMI)—to quantify the extent to which an individual engages in this practice. The original MMI asked individuals to report their hours of media consumption for each of 12 different media categories (television, music, text messaging, and so forth), along with the extent to which when engaged with one medium they were also engaged with each of the others. Test-retest reliability of MMI is high over a week (r = .93) and moderate over a one-year period (r = .52), and shorter versions and different variants have been developed.

The MMI score from the Nass lab represents the mean number of media with which an individual multitasks during a typical consumption hour. A high MMI score means an individual engages in a lot of media multitasking (e.g., checking email while also perusing Facebook and watching Netflix), and a low score means he or she does not (e.g., checking email without any secondary media). In the 2009 study, heavier and lighter media multitaskers were asked to perform a set of cognitive tasks that place demands on attention, control, and memory. This study initiated a rapidly evolving literature that seeks to answer the fundamental question: does media multitasking in everyday life impact our minds and brains, affecting performance even when we are single tasking?

One might expect a heavier media multitasker (HMM) to perform better on other tasks that require multitasking. While this inference seems reasonable, empirical studies are pretty mixed: some suggest that HMMs perform worse—i.e., exhibit larger switch costs—in task switching paradigms than do lighter media multitaskers (LMMs), while in others HMMs apparently perform as well as or better than LMMs.

Another finding that has emerged is that HMMs sometimes perform worse than LMMs even when *single* tasking, and this is most consistently seen on tasks that require sustained attention, working memory, long-term memory, and various forms of impulsivity and inhibitory control. That is, even when performing only a single task that requires them to maintain top-down attention or to keep information active in working memory, HMMs do more poorly—whether their performance is assayed by accuracy rates, response times, or related metrics—than LMMs. Some evidence suggests that this relationship holds even when controlling for the total number of media consumption hours, which means that the total number of hours spent with media is less predictive than the extent to which multitasking with media occurs during those hours.

For example, one recent study from our lab measured media multitasking, working memory, and long-term memory in undergraduate students at Stanford University. In one part of the study, subjects were asked to keep simple visual objects in memory over a brief (one second) delay and to make a memory-dependent decision after the delay. This is a standard task to measure working memory capacity (that is, the amount of information that can be held active in mind). After this came a long-term memory test: the subjects were shown the same objects they had seen during the working memory task along with novel ones and had to indicate which were seen earlier and which were new. We found that heavier media multitasking (as measured by the MMI) was associated with worse performance on both the working memory and long-term memory tasks. This was the case whether using an *extreme groups approach* (comparing the top 25 percent of individuals who were HMMs to the bottom 25 percent as LMMs) or a *continuous approach* (using data from all subjects, including light, intermediate, and heavy media multitaskers).

These results add to a growing body of work documenting the relationship between media multitasking and cognitive operations linked to sustained attention and working memory. To build on our prior work, one approach we have recently taken is to measure attention lapses at the trial and subject level while individuals of varying media multitasking habits perform single cognitive tasks. By trial level, we mean moment-to-moment (i.e., state-level) attention lapses during a task that could help predict why an individual performed well at one moment and less well at another; by subject level, we mean individual (i.e., trait-level) differences in attention lapsing that could help to predict differences in task performance across people. Previous work has shown that fluctuations in pupil diameter from eye tracking data and fluctuations in alpha and theta oscillatory power from electroencephalographic (EEG) data reliably track attention lapses during various single tasks.

In this ongoing project, we are measuring moment-to-moment changes in pupillary response and alpha and theta oscillatory power to quantify attention lapsing, with the aim of testing the relationship between lapsing, task performance, and MMI status. We are also learning more about which indices of sustained attention may relate to MMI status. (Here, we should note that while we and others have identified sustained attention as a potential mechanism behind performance differences between HMMs and LMMs, not all studies come to this conclusion. As we review in a recent publication, the discrepancy between studies could be due to differences in: (a) multitasking and performance measurement methodology, (b) demographics of the measured samples, (c) statistical power, and/or (d) analytic approach, among other reasons.)

There are a number of potential practical consequences of media multitasking in everyday life, one being academic outcomes. While we have primarily examined the relationship of MMI status and single tasking and multitasking performance in the lab, new translational studies offer a complementary perspective. For example, recent work has shown that students learn less when texting or using social media while attending lectures. Reading proficiency and homework accuracy have also been shown to decrease as individuals multitask with instant messaging and various computer programs.

In modern society, we are often pulled in different directions by competing sources of information, and how we react can affect our performance and quality of life, as highlighted by work on the "attention economy." A take-away from this body of research is that individuals should be thoughtful about the degree to which they engage in media and other forms of multitasking. As consumers of knowledge (and media), we should be cognizant of the potential relationships between task-switching, brain, and behavior, whether we are trying to complete a single task or to multitask. When we multitask, the context may matter. For example, recent data suggest that there are certain domains—like creative problem solving—that may benefit from task switching by reducing fixation on a problem. Weighing the costs and benefits of multitasking is important.

Critical challenges for the future include addressing the central question of causality, as well as determining the brain mechanisms that may underlie relationships between levels of media multitasking and cognition. For example, do pre-existing trait differences in attention or impulsivity lead to differences in media use and multitasking, or do media use and multitasking increase inattention and impulsivity? Are there tasks where heavier media multitaskers might outperform lighter media multitaskers? How do brain networks of attention and control differ between heavier and lighter media multitaskers, and how do these neural profiles relate to task performance? These are questions that researchers are just beginning to tackle—in the lab and in the field—highlighting how psychological science and neuroscience are living and breathing disciplines whose discoveries can inform fundamental issues faced by modern society.

Bios

Kevin P. Madore, Ph.D., is a Postdoctoral Fellow in psychology and neuroscience at Stanford University. He is interested in neurocognitive interactions among cognitive control, attention, and memory in young and older adults, as well as functions of memory like imagination and creativity. He uses a combination of behavioral, eye tracking, and neural methods, and focuses on state- and trait-level effects. He received his Ph.D. at Harvard University and his Bachelor of Arts degree at Middlebury College.

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